BIOTECHNOLOGY FOR THE 21ST CENTURY: OPPORTUNITIES IN AGRICULTURE

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ABSTRACT

Biotechnology has great potential to influence and benefit agriculture, forestry and fishery. In conjunction with conventional technologies, modern biotechnology holds promise of increased and sustained food production. On the global level, latest estimates indicate that 826 million people remained undernourished in 1996-98: 791 million people in the developing world and 34 million in the developed one. Under such food insecurity situation, when people live with hunger and fear starvation, agricultural biotechnology could play a major role in resolving the serious food gap the developing countries are already facing. In this regard, the science of developing biotechnological tools should not make any distinction between developing and developed countries. The current paths of research and development have given rise to concern that the disparity in harnessing biotechnology for agricultural and economic development may increase between industrialized developed countries and developing ones. The presence and persistence of such a situation will make it difficult for developing countries to secure that through agricultural biotechnology the steady increasing shortage in food production will find its solution. Therefore, to attain the major gains that biotechnology could provide to the agricultural sector and food production, the primary task is to ensure that such benefits be shared by people in the North and the South, in both large and small, rich and poor countries.

RÉSUMÉ

La biotechnologie peut grandement influencer l'agriculture, les forêts et la pêche et leur apporter des bénéfices. Conjointement avec les technologies traditionnelles, la biotechnologie moderne fait espérer une production alimentaire accrue et soutenue. Au niveau global, les dernières estimations indiquent que 826 millions de personnes étaient sous-alimentés en 1996-98: 792 millions de personnes dans les pays en développement et 34 millions dans les pays développés. Dans une telle situation d'insécurité où les gens souffrent la faim et craignent d'en mourir, la biotechnologie agricole pourrait jouer un rôle majeur pour combler le grave déficit alimentaire face auquel les pays en voie de développement se trouvent déjà. Les chemins actuels de la recherche et du développement ont suscité le souci que la disparité dans l'exploitation des biotechnologies pour le développement agricole et économique pourrait augmenter entre les pays industrialisés développés et les pays en développement. La présence et la persistance d'une telle situation, rendra encore plus ardue la tâche de réduire, à travers la biotechnologie, le déficit constamment croissant de la production alimentaire dans les pays en voie de développement. Pour réaliser les gains importants que la biotechnologie peut offrir au secteur agricole et à la production alimentaire, il faut tout d'abord assurer qu'ils soient partagés par les populations du Nord et du Sud, dans les pays plus petits et plus grands, dans les pays plus pauvres et les pays plus riches.

Due in large part to scientific advance in crop breeding and farming techniques, world food production has doubled since 1960 and productivity from agricultural land and water usage has tripled.

But on the global level a dilemma lies a head.

The world's population is expected to double by the year 2030 to 12 billions, and it is not clear whether current food production is keeping pace with population growth.

The question is how best to feed billions of additional people without destroying much of the planet in the process.

The situation seems to be much more complicated in the developing countries where more than 80% of the people are expected to live.

Such continuous population growth at an annual rate of 1.6% over the last 25 years and expected to grow at 1.03% rate over the next 25 years did, not lead to commensurate declines in the percentage of the population chronically undernourished.

The latter has fallen only modestly and still remains stubbornly high at some 800 million persons. In the quest for solutions to the problems of food security and undernutrition, concerns are often expressed about the capability of the world's agricultural resources, technology and human ingenuity to increase food supplies by as much as required to ensure to all people adequate access to food.

It seems certain that agricultural biotechnology could play a major role in resolving the food security problems.

Although major genetic improvements have been made in crops, progress in conventional breeding programmes has been slow.

The evolution of conventional plant breeding methods in conjunction with advances in other fields of science and knowledge helped to shape the current status of world agriculture.

However, the success of plant breeding were relatively limited and the increments in production advanced in small steps, not in great leaps and bounds. Since 1920, through breeding, the yields of most crops have increased by approximately 1 percent per year.

No doubt that the improvement of plant breeding techniques and the development of modern more productive cultivars brought great gains in the fight against world hunger. This clearly stresses that biotechnology is not a substitute for the latter and should be seen as complementary.

Indeed, the strengthening of traditional biological research is an essential prerequisite for establishing a

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biotechnological research capability in most developing countries.

Agricultural biotechnology: concepts and definitions

Biotechnology is defined as any technique that uses living organisms to make or modify a product, to improve plants or animals, or to develop micro-organisms for specific uses.
Biotechnology is not new and many products are the results of a simple but effective use of traditional biotechnologies.
Biotechnology here refers to both traditional and modern biotechnology which is based on the use of new tissue culture methods and recombinant DNA ($_r$DNA) technology, often referred as "genetic engineering".
Tissue culture includes in vitro fertilization and embryo culture, protoplasts and the culture of isolated cells and microspores.
Such methods are used to produce pathogen-free plants and for germplasm storage.

> **BIOTECHNOLOGY**
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> ***Biotechnology is defined as a set of powerful tools that employ living organisms (or parts of organisms) to make or modify products, improve plants or animals, or develop microorganisms for specific uses. Examples of the "new biotechnology" include the industrial use of recombinant DNA, cell fusion, novel biocrossing techniques and bioremediation.***

Biotechnology has been employed by humans for millennia; traditional applications include production of beer, cheese and bread.
But the recent development in molecular biology has given biotechnology new meaning, new prominence and new potential. It is this "new biotechnology" that has captured the attention of scientists, financiers, policy-makers, journalists and the public even though the revenue it generates, is as yet only a fraction of that produced by traditional biotechnology.
Through the use of advanced tools such as genetic engineering, biotechnology is exposed to have a dramatic effect on the world economy over the next decade.

Genetic Biotechnology

It is a branch of the study of genes or genetic make-up. Geneticists have the ability to isolate genes and then discover what traits those genes hold.
Scientists can then use the information to implant or splice those genes and their traits into other things. For example, a scientist could discover and splice a photosynthetic gene from a plant and put it into an animal, so animals could use the sun to produce food.
So far, no such gene is known to exist but that is just an example of the imaginative thinking that comes from biotechnology.

Genetically engineered crops versus classically bred crops

Extended research programmes and helpful guide information are available on this subject concerning the pest resistant plants.
The question raised up is: *Does a transgenic plant pose a plant pest risk?*
The assessment of such risk requires finding the answers to the following two questions:
1) *What is known about the properties of the plant and the environment into which it will be introduced?*
2) *What are the probable effects of the plant on the environment?*
However, to answer the forementioned questions implies good knowledge about the following factors:
– The biology of the crop (the mating system, mode of pollination and compatibility with wild relatives).
– The introduced trait (the source of the resistance and how it was introduced).
– The receiving environment (the presence of sexually compatible wild relatives, pest populations, and the cultivation practices for that crop).
Knowledge and experience with any and all of these factors provide familiarity which plays an important role in assessments. This concept of familiarity has consistently been a prominent criterion for evaluating risks associated with transgenic organisms. This concept allows the decision-makers to draw upon past experience with introduction of plants into the environment, and to compare genetically engineered plants to their non-engineered counterparts.
Recently, the National Academy of Sciences (NAS) - USA reported the following two important conclusions:
– *The first* is that crops modified by genetic engineering should pose risks that are not different from those of crops modified by classical genetic methods (including bridging crosses, wide crosses, mutagenesis, etc.) for similar traits and grown in similar environment. Similar traits means traits that produce similar phenotypes in an engineered or a traditionally bred crop.
A similar environment means an environment similar to the one where the plant has always been grown.
One important point of this first conclusion to be highlighted is that it is more important to evaluate the phenotype produced, rather than the process/technique that was used to produce it, because what needs to be addressed and focused on are the effects of any pest resistance genes, traditionally bred or engineered, in

managed ecosystem. Accordingly, it could be stated that for genetically engineered crops, the "transgenic organisms should be evaluated and regulated according to their biological properties (phenotypes), rather than according to the genetic techniques used to produce them. The long-term experience derived from traditional breeding is essential as it provides useful information for the evaluation of genetic alternations similar to those that might have been produced by traditional means and such alternations are likely to pose few ecological problems.

– *The second* conclusion is that plants modified by classical breeding techniques have a history of safe use. This is not to say that traditional practices pose zero risk, but the level of risk has been accepted and manageable. Familiarity does not necessarily means safe, but that enough is known about the plant to determine the level of safety.

Genetic Biotechnology in agriculture

Biotechnology already plays a major role in agriculture. In this part of the work major emphasis will be given the following:

- Biotechnology and water resources possible saving, water quality and wastewater treatment;
- Potential food production to solve the problem of chronic undernutrition for hundreds of millions of people.

General speaking, biotechnology offers a range of applications mainly for plant and animal production. Some are likely to have an increasing impact well before 2010 while others are of a longer term nature.

Many of these applications will contribute to more sustainable resource use, particularly by (a) gradually raising crop yields and reducing land requirements on marginal lands and natural forests; (b) complementing industrial with biological sources of nitrogen for plant growth; (c) raising production performance of plants and animals through growth manipulations and by producing improved vaccines and enhancing disease resistance and (d) lowering chemical inputs needs per unit of production.

In addition, biotechnology can make foods healthier and more nutritious by improving the seed quality, increasing protein levels in forage crops and levels of certain vitamins such as C and E and beta carotene in fruits and vegetables.

Moreover, the new knowledge gained through basic research into the nature of life and ecosystems at the molecular level can lead to improved farming practices and diagnostic tools for use in agriculture and thereby reduce the negative environmental impacts associated with traditional production methods.

However, in spite of innovations and progress already achieved, we are still very far from the opportunities biotechnology could offer in solving numerous problems heavily hitting both agricultural and environmental sustainability.

In our opinion and to attain the major expected benefits biotechnology could provide, for the development in the agriculture sector, further research is still needed and should be directed, particularly, to the following:

- Mapping and sequencing of animal/plant/microbial genomes to elucidate gene function and regulation and to facilitate new genes as a prelude to gene modification.
- Determining biochemical and genetic control mechanisms of metabolic pathways in animals, plants and microbes that may lead to products with novel food, pharmaceutical and industrial uses.
- Extending understanding of the biochemical and molecular basis of growth and development, including structural biology of plants and animals.
- Elucidating the molecular basis of interactions of plants and animals with their physical and biological environments, as basis for improving the organism's health and well being.
- Enhancing food safety assurance methodologies, such as rapid tests for identifying chemical biological contaminants in food and water.

Opportunities in environmental biotechnology

The quality of life on earth is linked inextricably to the overall quality of the environment. In response to growing pressures on air, water and land resources, global attention has been focused in recent years on finding new ways to sustain and manage the environment. Biotechnology is an essential tool in this endeavour because it can provide new approaches for understanding, managing, preserving and restoring the environment.

Biotechnology can be used to assess the well-being of ecosystems, transform pollutants into benign substances, generate biodegradable materials from renewable sources, and develop environmentally safe manufacturing and disposal processes.

Researchers are just beginning to explore biotechnological approaches to problem solving in many areas of environmental management and quality assurance, such as:

- restoration ecology which involves re-establishing the nutrient balance, structure and function of ecosystems;
- diagnosis, epidemiology and dispersal monitoring related to human diseases agents;
- disease, pest and weed control in agriculture;
- contaminant detection, monitoring and remediation;
- toxicity screening and
- conversion of waste to energy.

Environmental biotechnology is not a new field; composting and wastewater treatments technologies are familiar examples of "old" environmental biotechnologies. However, recent developments in molecular biol-

ogy, ecology and environmental engineering now offer opportunities to modify organisms so that their basic biological processes are more efficient and can degrade more complex chemicals and higher volumes of waste materials.
Regardless that some success has been achieved, the potential benefits of the new environmental biotechnology are far from being fully realized. As a matter of fact, advances in this area are delayed not only due to legal and social barriers, but also to a dearth of basic scientific knowledge about organisms that may be used in biotechnologies and the ecological systems in which these technologies are to be employed. New knowledge is still lacking and is acquired to provide the foundation of new environmental applications of biotechnology, facilitate the development of these technologies by the commercial sector, and ensure adequate evaluation and safe application of products without blocking innovation with regulatory requirements.
International cooperation will be needed to help generate new scientific knowledge in this area. The development in biotechnology will have a tremendous potential for use in developing nations (see the box below) seeking low cost solutions to environmental problems, such as municipal wastewater treatment and waste disposal both are main causes for the existing rapid degradation in the water quality. In addition, the adoptation of such low cost biotechnology technique will offer the possibility to convert agricultural wastes to energy sources and clean up polluted areas which are extremely increasing in developing countries.

PRIORITY RESEARCH NEEDS IN DEVELOPING COUNTRIES

Priority needs would be:

- *to know what is becoming available;*
- *to evaluate available technologies for technical suitability for removing or ameliorating problems of inefficiencies, or to size worthwhile opportunities;*
- *to make cost/benefit assessments or informed judgements on the consequences of introducing particular biotechnology in social, economic, environmental and institutional terms and in regard to sustainability and*
- *to acquire, to adapt and to bring to application in the fields of agriculture-forestry those biotechnologies which will improve the welfare of the country and its people.*

BIO-REMEDIATION

Bio-remediation is addressed as one example of environmental biotechnology.
The knowledge required for it is similar to that needed for the development of many other environmental biotechnologies.
Globally, many polluted sites contain mixtures of wastes of such chemical complexity that a suite of biochemical processes is required for degradation. Waste mixtures may contain sanitary (household) waste plus hazardous organic or inorganic materials. Hazardous wastes are those of toxic, corrosive, reactive and ignitable characteristics. Taking the case of the United States, a large number of polluted areas including land freshwater and marine sites are identified, that, by law, must be cleaned up. Estimates for the clean-up of Federal Lands alone may be $ 450 billions. The extent of contaminated non-Federal agricultural acreage, mining areas, industrial sites and aquifers and other water bodies is unknown, but the magnitude of the problem is undoubtedly large and clean-up expenses could be astronomical.
It has been estimated that clean-up of both Federal and non-Federal Lands could cost $ 1.7 trillions using conventional approaches, which would produce noxious waste by-products and thereby impose additional clean up or environmental costs.
Comparing the biotechnology clean-up techniques (bio-remediation) with the conventional ones, the former offers an attractive alternative and/or supplement to more conventional clean-up technologies due to its comparatively low cost and generally benign environmental impact. However, it is not always the technology of choice because efficacy and the rate of degradation at any particular site cannot be predicted reliably. Improved predictive and process validation capabilities would help stimulate wider use of this technology. This asks for further intensive international collaborative research characterized with a holistic strategy. Focussing on the degradation of mixtures of wastes by groups of organisms (primarily bacteria and fungi) is likely to be most realistic and efficacious.
The reason for this lies in the fact that the concentration of oxygen in soil and water environment is often highly variable in time and space and thereby biodegradation in nature probably is mediated by both anaerobic-aerobic micro-organisms. This phenomenon can be exploited through the development of anaerobic-aerobic technologies for controlled bio-remediation. In other words, the environment can be modified either spatial-

ly or temporally to allow the development of various types of bio-degradative microbial communities, thereby fostering the degradation of pollutants vulnerable to different agents. Anaerobic-aerobic processes can be developed to exploit the full range of microbial metabolic activity for clean-up of environments contaminated with multiple pollutants.
Therefore, biotechnologies research should continue to verify the bio-remediation potential of micro-organisms. Further exploration of microbial diversity is likely to lead to the discovery of many organisms with unique properties useful in bio-remediation.

BIOTECHNOLOGY OPPORTUNITIES IN FOOD PRODUCTION

Before discussing what we can expect from biotechnology for reducing the wide gap in food production and fighting the hunger problems more than one billion people are now suffering from, it is essential to illustrate briefly the projected world food demand (see the box below). In 1994, global food production of all types stood at 4.74 billion metric tons of gross tonnage and 2.45 billion tons of edible dry matter (**table 1**). Of this total, 99% was produced on the land, only about 1% came from oceans and inland waters, even though 70% of the earth's surface is covered with water. Plant products constituted 93% of the human diet, with about 30 crop species providing most of the world's calories and protein, including eight species of cereals, which collectively accounted for 66% of the world food supply. Animal products, constituting 7% of the world's diet, also come indirectly from plants.
At least in the foreseeable future, people will continue to rely on plants and especially the cereals to supply virtually all of our increased food demand. Even if current per capita food consumption stays constant, population growth would require that world food production increases by 2.6 billion gross tons or 57%, between 1990 and 2025.
However, if diets improve among the destitute who live in hunger, estimated to be 1 billion people living mainly in Asia and Africa, world food demand could increase by 100 percent to above 9 billion gross tons over this 35 year period.
Using the population growth rates mentioned above and expected changes in per capita cereal demand, we can come up with the following cereal production projections through the year 2025 (**table 2**), and the yield increases needed if we assume that virtually all of increased production will come from existing farmlands.

BIOTECHNOLOGY AND SUSTAINABLE PRODUCTION

Biotechnology provides opportunities to:

- *Develop genetically broad based varieties/breeds resistant/tolerant to biotic and abiotic systems;*
- *Increase efficiency in the conservation and enhanced use of natural resources, including genetic resource and systems;*
- *Reduce use off-farm inputs such as pesticides;*
- *Develop population adapted to marginal land and problematic soil conditions and*
- *Produce genetically engineered organisms for degradation of toxic wastes and detoxification of chemical residues on produce or land.*

WHAT CAN WE EXPECT FROM BIOTECHNOLOGY?

Over the past seven decades, conventional breeding has produced a vast number of varieties and hybrids that have contributed immensely to higher grain yield, stability of harvests, and farm income. Surprisingly, there has been no major increase in the maximum genetic yield potential of the high-yielding semi-dwarf wheat and rice varieties being grown commercially. There have been, however, important improvements in resistance to diseases and insects, and intolerance to a range of abiotic stresses, specially soil toxicities.
In any case, if we are to cope with the food production challenges before us, new and appropriate technology to raise genetic yield levels to higher levels is the other approach to be followed and the way to this is the biotechnology.
It is evident that what began as biotechnology 15 years ago has developed some new scientific methodologies and products which need active financial and organizational support to bring them to fruition in food and food and fiber production system. Today, there is a number of fascinating development that approaches commercial application in agriculture as well as animal production.
Some transgenic varieties and hybrides of cotton, maize and potatoes are now being successfully introduced commercially in the United States which effectively control a number of serious insect pests. The use of such varieties will greatly reduce the need for insecticide spray and dusts. Equally, considerable progress also has been made in development of transgenic plants of cotton, maize, oilseed rape, soyabean, sugar-beet and wheat with tolerance to a number of herbicides. This

Table 1 ***World Food Production.***

Commodity	Production (millions of metric tons)			
	Gross tonnages	Edible matter (1)	Dry protein (1)	Increase % 1980-90 (2)
CEREALS	1.950	1.623	162	22
Maize	570	501	52	19
Wheat	528	465	55	22
Rice	535	363	31	35
Barley	161	141	14	7
Sorghum/mil.	87	78	7	−7
ROOTS & TUBERS	583	156	10	9
Potato	265	58	6	3
Sweet potato	124	37	2	−7
Cassava	152	56	1	24
LEGUMES OIL SEEDS-OIL NUTS	387	263	88	48
SUGAR-CANE and SUGAR BEET (3)	133	13	0	21
VEGETABLES and MELON	486	57	5	32
FRUITS	388	53	2	28
ANIMAL PRODUCTS	858	170	75	25
MILK, MEAT, EGGS	760	143	57	21
FISH	98	25	8	24
ALL FOOD	4.743	2.456	343	24

(1) = at zero moisture content, excluding inedible hulls and shells.
(2) = 1979-81 and 1989-91 average use to calculate changes.
(3) = sugar content only.
Source: 1994 FAO production year book.

adding substances from other sources to the genetic make-up of the plants. If scientists succeed in making new drought resistance varieties for crops actually of highly consumptive water use, such as rice and other essential crops, then, they will succeed in increasing the net gain of farmers, saving huge quantities of water which are already very scarce in arid and semi-arid regions and may even increase the amount of rice and other crops grown and distributed world-wide.
The same will hold true for the soybean crop where several attempts are carried out to improve its genes to have new varieties of high quality and yield production.
Rice and soybean are just two examples of the many numerous options that scientists have with genetic biotechnology. But, genetic biotechnology is not just limited to creating more and better crops than can increase a farmer's income and help feed a growing world population. Biotechnology can also be used to prevent weeds from taking over crop fields which can also help to increase a farmer's income and feed a growing population.
Today, nearly half the soybean in the U.S., the stuff that is crushed and made into salad cooking oil and can lead to a reduction in herbicide use by much more specific dosages and interventions. Scientists are also trying to improve upon the natural resistant traits by that feeds most of the livestock we raise is produced from a variety that increases the plant's resistance to certain pesticides. Genetically, engineered corn with

Table 2 ***Current and projected world cereal production and demand (Millions of tons) and yield requirements.***

Cereal crop	Actual production	Projected demand		Yield (t/ha) Actual required		
	1990	2000	2025	1990	2000	2025
Wheat	600	740	1.200	2.4	2.8	4.4
Rice	520	640	1.030	2.4	3.1	5.3
Maize	480	620	1.070	3.7	4.1	5.8
Barley	180	220	350	2.3	2.7	4.1
Sorghum/mill.	85	110	180	1.5	1.8	2.6
All cereals	1.970	2.450	3.970	2.5	2.9	4.5

certain pest resistant characteristics is also rapidly displacing more traditional varieties.

Can agricultural biotechnology stay ahead of world population, will it solve the problem of world hunger?

While biotechnology may be able to increase yield outputs while lowering farmers' costs, it may not help to solve world hunger.
Though many people think that higher outputs of food will help to feed the growing population, the amount of food may not be the problem. As a matter of fact, if more food is made available to the people of the world, population might increase more rapidly. We are of the opinion that there can be no lasting solution to the world food/hunger/poverty problem until a more reasonable balance is struck between food production/distribution and human population growth. The efforts of those on food-production front are, at best, a holding operation which can permit others on the educational, medical, family planning, and political fronts to launch an effective, sustainable and human attack to tame the population monster.

ANTI-AGRICULTURAL BIOTECHNOLOGY APPROACH AND HOW TO STAND UP

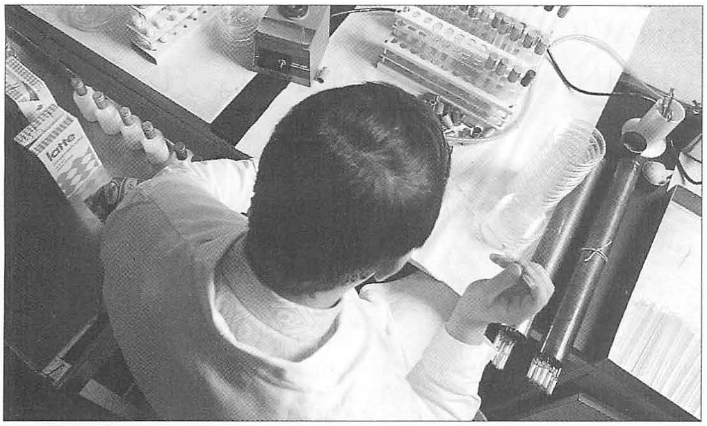
As previously discussed, agricultural biotechnology could have an enormous potential to help to combat hunger. Genetically modified plants have the potential to resist killer weeds that are, literally, starving people in Africa and other parts of the world.
Biotechnology can help to solve some of the most vexing environmental problems: it could reduce pesticide use, increase yields, improve nutritional content and use less water.
But, as with any technology, the road is not always smooth. Right now, in some parts of the world there is great consumer resistance and great cynicism toward biotechnology. In Europe protesters have turn up test plots of biotechnology-derived crops and some of the major companies in Europe have stopped using genetically-modified organisms (GMOs) in their products.
However, we are seeing that the G-8 agreed to a new review of food safety issues and that trade in GMOs is looming larger over US-EU trade relations.
The important question is not whether we accept the changes the biotechnology can bring, but today, we have to grapple and satisfy the numerous questions surrounding the biotechnology so that we can define the preconditions required for the application of such tools without any unforseen adverse effects after initial market approval.
We need to identify some certain principles to guide our approach to biotechnology towards the 21st century.
Among those principles, the following we would like to highlight:

- *Regulatory measures*

With all that biotechnology has to offer, it is nothing if it's not accepted. This boils down to a matter of trust in the science behind the process, but, particularly trust in the regulatory process that insures complete and open public involvement.
The regulatory process and the government regulators must stay completely independent from the companies developing and promoting biotechnological products as well as those who have a vested interest in the outcome.
We need to make sure that our regulatory system has the foresight to begin addressing issues before they arise so to keep pace with the accelerating growth of agricultural biotechnology, several additional obstacles should be fully analyzed and studied to ensure that we are fully prepared to meet the regulatory challenges of this new technology.
Finally, we need to ensure that our regulators just regulate and only regulate. The scientists who evaluate and approve biotechnological products for the market must be free of any hint of influence from trade support and distinct from any and all marketing functions to ensure that no commercial interests have even the appearance of influence on the decisions to be taken regarding food safety.

- *The biosafety aspects*

Those are primarily a matter of national decisions. The national governments and regional programmes should act to safeguard their own ecosystems, genetic resources and the health and well-being of their citizens from any possible risk associated with the release of GMOs and commercialization of genetically engineered food and other products. For this purpose, national governments should establish appropriate policies, laws, regulations and enforcement mechanisms for the control of potentially problematic introductions, either for testing, for export and import, or for releases on commercial scale.
Laws, regulations and guidelines on research, release, containment and monitoring of GMOs and food safety assessment and their effective implementation are available and feasible in most industrial countries.
Generally, such measures do not exist in most developing countries because of insufficient, scientific expertise and resources to assess the risks and implications adequately. However, national and international efforts are in progress to bridge this gap. International efforts are further needed to develop, harmonize and implement procedures and standards based on sound and comprehensive scientific assessment, so that all countries may follow internationally agreed biosafety and national decision-making processes.



• *Consumer Acceptance*

Consumer acceptance is fundamentally based on regulatory process, but, however strong the regulatory process is, it is of no use if consumer's confidence is low and if consumers cannot identify a direct benefit of them.

There clearly needs to be a strong public education effort to show consumers the benefits of these products and why they are safe. This should not only be the responsibility of private industry and government, but also the media could play a vital role.

• *Painess to farmers*

Like consumers, farmers need to have adequate choices made available to them. We need to ensure that biotechnology becomes a tool that results in greater not fewer options for farmers. Furthermore, it is needed to examine all of our law policies to ensure that, in the rush to bring biotech products to market, small and medium family farmers are not simply plowed under. Equally, it is also required to integrate issues like privatization of genetic resources, patent holders right and public research to find out if the approach we are following is helping or harming the public good and farmers' family.

Concluding remarks and recommendations

• Modern biotechnology is already giving important contributions to and poses great potential and challenges for agricultural development. Many international and national organizations and research institutes recognize that biotechnologies are a new group of powerful tools for research and ultimately for accelerating development and not an end in themselves. They perceive that modern biotechnologies should be used as adjuncts and not as substitutes to conventional technologies in solving problems, and that their application should be need – rather than technology – driven.

• The full value of products and technologies will be only realized when the necessary research and development infrastructures, guidelines and regulations, financing and public policies are in place. A technology will not succeed in an environment whose social and economic policies are not prepared to support it. Furthermore, the products and technologies should be accessible to farmers in both developed and developing countries.

• There exists a gradient of biotechnologies, depending on the degree of sophistication, complexity, stage of development and application. The lower side of the gradient comprises simpler but widely used techniques such as in vitro culture, rhizobium technology, fermentation. The upper-side of the gradient includes advanced techniques including genetic engineering. The gradient of biotechnology may be matched with gradient of national capabilities, economic investments and efforts to provide the possibility of choosing the appropriate techniques and approaches with the most positive impacts. The pattern of use and development of biotechnologies in developing and developed countries thus varies considerably.

• There is crying need today for creative pragmatism in research and extension organizations in many parts of the developing world.

In particular, we need more venturesome young scientists who are willing to dedicate their lives in helping to solve the production problems several billion small scale farmers are facing.

In seeking to push forward the frontiers of scientific knowledge, some researchers often lose sight of the most pressing concerns of farmers and ease to develop products that extension workers can promote successfully. For the developing countries, impact on farmers' fields should be the primary measure by which to judge the value of this research work, rather than by a flood of publications that often serve to enhance the position of the scientist but do little to alleviate hunger. ●

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