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Modern Biotechnology and Philippine Agriculture

The National Academy of Science and Technology (Philippines)

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Promoting and developing a national scientific culture and environment.

MODERN BIOTECHNOLOGY AND PHILIPPINE AGRICULTURE

PREFACE

This is the maiden issue of a monograph series, which will serve as a compilation of selected papers, presented during fora organized by the National Academy of Science and Technology (NAST). These papers present issues affecting the lives of the Filipino people.

Through modern biotechnology, scientists have developed health products to detect, prevent and/or combat ailments such as diabetes, hepatitis, AIDS, cancer, etc. which are now widely accepted. Within the past six years, applications of modern biotechnology in agriculture have gained headway in fulfilling its potentials to enhance agricultural productivity while protecting the environment. In the year 2000, 44 million hectares were grown to transgenic or genetically modified crops worldwide. Of these, almost 10 million hectares or 24% of total hectarages, were in developing countries including 500,000 ha of Bt cotton in China and 10,000 ha of Bt cotton in Indonesia. On the other hand, in the Philippines, as of this writing, only two field trials of 500 sq. m. each of Bt corn have been completed.

Recognizing the important role of modern biotechnology as a tool to improve a gricultural productivity to feed and improve the lives of the growing population and to address environmental degradation, the National Academy of Science and Technology (Philippines), the highest advisory and recognition body of the government on science and technology, has sponsored or co-sponsored fora and meetings to discuss issues and concerns of modern biotechnology with various sectors and stakeholders.

Based on several consultative studies, NAST has expressed its support to the use of modern biotechnology in the areas of food and agriculture, health and medicine, environmental protection and trade and industry. Further, NAST advocates science-based evaluation of all technologies, including biotechnology, and their products.

NAST lauds the recent approval of the Policy Statement on Modern Biotechnology by President Gloria Macapagal-Arroyo on July 16, 2001. This should give the proper momentum to exploring "the safe and responsible applications of modern biotechnology in science and technology, agriculture and food, health and medicine, environment and trade and industry—for the upliftment of the Filipino Nation."

In this volume, three Academicians of NAST discuss the different issues, concerns and applications of modern biotechnology and the need for developing national capabilities in this area. The NAST positions on modern biotechnology sent to the Philippine Congress in March and April 2000 and the Policy Statement on Modern Biotechnology approved by President Gloria Macapagal-Arroyo are also included.

PERLA D. SANTOS OCAMPO, MD
President
National Academy of Science and Technology

NAST POSITION ON BIOTECHNOLOGY

Our country strives to enhance its agricultural productivity, at the same time, protect its environment, to feed and improve the health and lives of its increasing population.

Modern biotechnology can potentially contribute to the country's efforts to attain food security and global competitiveness. Its benefits to developing countries in the areas of food and agriculture, health and medicine, environmental protection, trade and industry, are expected to be more than those for developed countries where food and feed overproduction exists.

As of January 21, 2000, the Office of the President approved as a ***national policy the use of biotechnology to increase productivity and accelerate national development.***

The National Committee on Biosafety of the Philippines, the inter-Departmental agency tasked to regulate R & D in modern biotechnologies has been cautious and stringent in the implementation of its regulations. On the other hand, the Department of Agriculture setting up the mechanism for the commercialization of modern biotechnology-derived food and feed products.

To realize the potential benefits of modern biotechnology to our people and country, let us promote the careful, unbiased, science-based evaluation of technologies and products of modern biotechnology. Thus, let us

- Allow the conduct of more controlled field trials to enable risk assessment studies on the possible effects of the new technology on the environment under local conditions;
- Promote science-based evaluation of the products of modern biotechnology to assess their food safety to humans and animals.

Let us exhort our Government to

- Strongly support R & D in and using modern biotechnology to develop our own local biotechnologies and their products; and
- Strengthen its regulatory agencies in enhancing and modernizing its manpower and logistics capabilities needed in the regulation of modern biotechnology-derived products.

Banning field trials of modern biotechnology-derived crops or the use of foods or feeds derived by these new technologies will deprive our farmers, consumers and industries of their potential benefits. It will also further stall our S & T efforts along this area.

Let us all work to ensure the safe and responsible applications of modern biotechnology in science and technology, agriculture and food, health and medicine, environment and trade and industry, for the upliftment of the Filipino Nation.

Presented to the Philippine Congress, March 2000.

FILIPINO SCIENTISTS IN SUPPORT OF BIOTECHNOLOGY

We, at the National Academy of Science and Technology - the advisory and recognition body of the government of the Republic of the Philippines on science and technology, and the scientists-undersigned, believe in and support the application of modern biotechnology as a tool to enhance agricultural productivity to feed and improve the lives of the fast-growing population and to address environmental degradation, hunger and poverty. We also strongly advocate using sound science as the basis for regulatory and political decisions pertaining to biotechnology. We promote the careful, unbiased and science-based evaluation of technologies and products of modern biotechnology.

Modern biotechnology has tremendous potential and offers remarkable innovations to support our country's efforts to attain food security and global competitiveness. Developing countries are expected to benefit more than developed countries from biotechnology in the areas of food and agriculture, health and medicine, environmental protection and trade and industry.

Products of modern biotechnology promise to reduce farmers' high input costs, increase their yields while helping conserve the ecosystem and enable crops to grow under normally unfavorable conditions. Biotechnology products can even provide greater benefits to consumers who are the ultimate beneficiaries of technological innovations. For instance, modern biotechnology can be used as a tool to attain greater nutritional security through enhanced product qualities such as higher vitamin contents, better protein quality and prolonged shelf life. Modern biotechnology can also produce healthier oils and develop vaccines to fight dreadful diseases like cholera and malaria.

We recognize that no technology is without risk. However, we have great confidence in the National Committee on Biosafety of the Philippines, the interdepartment agency tasked to regulate R&D in modern biotechnology which has been cautious and stringent in implementing its regulations. In addition, the Department of Agriculture is setting up mechanisms for commercializing modern biotechnology-derived food and feed products.

We, therefore, advocate and promote the safe and responsible applications of modern biotechnology in science and technology, agriculture and food, health and medicine, environment and trade and industry —for the upliftment of the Filipino Nation. Considering the tremendous potential of this technology, we urge policymakers to base their decisions on sound scientific evidence.

Presented to the Philippine Congress and Senate, April 2000

POLICY STATEMENT ON MODERN BIOTECHNOLOGY

"We shall promote the safe and responsible use of modern biotechnology and its products as one of several means to achieve and sustain food security, equitable access to health services, sustainable and safe environment, and industry development.

"We shall ensure that all technologies that we promote, including modern biotechnology, will provide farmers and fisherfolks the opportunity to increase their overall productivity and income; enhance the welfare of consumers; promote efficiency competitiveness and improved quality standards of local industries--all within the paramount objective of attaining safety and sustainable development, including its human, social and environmental aspects.

"The Departments of Agriculture, Science and Technology, Health, Environment and Natural Resources, Trade and Industry, and other concerned agencies are hereby directed to address the current issues associated with the local and global dimensions and trends of modern biotechnology, including its potential health, environmental and social impacts. Towards this end, they shall conduct public consultations with representative from civil society, government and business; formulate departmental directives and regulations on the access to and use of products of modern biotechnology, coordinate activities and programs on research, development and application; and allocate appropriate resources for the upgrading of capacities and capabilities to effectively regulate the technology and its products, including but not limited to product testing and labeling."

Approved by President Gloria Macapagal-Arroyo as per Memorandum signed by Executive Secretary Alberto G. Romulo dated July 16, 2001.

GENETICALLY MODIFIED CROPS: BIOSAFETY AND FOOD SAFETY ISSUES AND CONCERNS

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Introduction

NAST recognizes the potential benefits of modern biotechnology to mankind and to the Filipino people, in particular, as well as the issues and concerns that confront this new technology. As the leading science advisory body of the country, NAST adheres to a science-based evaluation of any technology, including modern biotechnology. Since the present controversy revolves around GM crops and not on biotechnology-derived medical products which seem to have been widely accepted, this evaluation will focus on GM crops.

Concerns regarding transgenic crops or genetically modified crops include the following: (1) possible risks to environment--(a) transfer of gene to other species, (b) effects of gene product on nontarget flora and fauna; (2) safety to human and animal health--(a) presence of toxic and/or allergenic substances in food crops brought about by the process; (b) effects of transgene product or antibiotic resistance gene product. This paper summarizes and evaluates the various scientific evidences regarding these concerns and issues.

Biotechnology and Its Products

Biotechnology is any biology-based technology, which uses living organisms or their parts to make or modify products, or to improve microorganisms, plants and animals. As early as the 16th century, Filipinos have practiced biotechnology in preparing basi, tuba and tapuy as well as patis, vinegar and bagoong.

The scope of biotechnology is wide--from classical techniques such as fermentation producing products as earlier mentioned and biological nitrogen fixation to more modern innovations such as tissue and cell culture, recombinant diagnostics and genetically engineered (or genetically modified or transgenic) microorganisms, animals and plants (Figure 1). Modern biotechnology is often equated to processes involving genetic engineering or recombinant DNA technology which started in the 1970s.

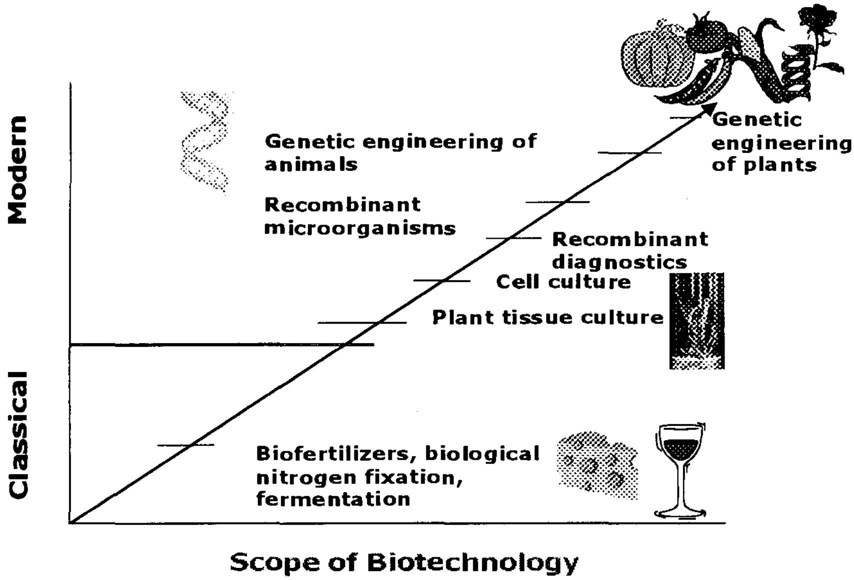

Figure 1. Scope of biotechnology

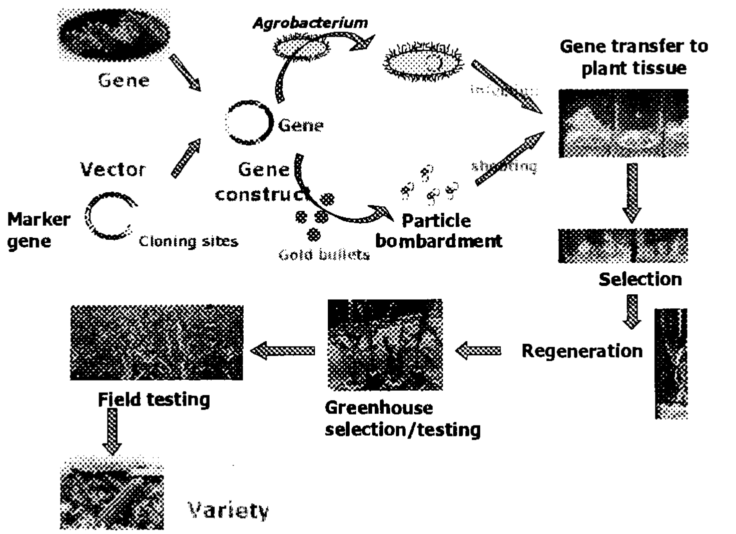

Figure 2. A simplified presentation of genetic engineering of plants (from Tecson-Mendoza, 1999)

Genetic engineering, simply put, is the transfer of specific gene(s) into an organism. A simplified presentation of genetic engineering is shown in Figure 2. The gene of interest is obtained (or cloned) from its source (which may be the same crop or different crop or even different species), and is inserted either in modified or unmodified form, into an appropriate transformation vector. This vector contains so-called regulatory elements such as promoter, a selectable marker which is oftentimes an antibiotic resistance gene (for example, kanamycin) and a reporter or marker gene (such as the GUS gene which provides evidence on the transfer and expression of the transgene by giving a blue color). The promoter can be a strong constitutive type which will direct expression of the gene in all tissues of the plant, or it can be a promoter for certain issues such as leaf, endosperm etc and/or at specific stages of development. The gene construct (gene-vector) is delivered to the plant cells by biolistic procedure or by the *Agrobacterium tumefaciens.* The cells are allowed to further multiply and differentiate into calli and are selected on medium containing the antibiotic. Thus, only those cells which are transformed (containing the transgene) will survive and will be regenerated into whole plants. From tubes and flasks, the plants are hardened and transferred to the greenhouse. The breeder will further select among the transgenic plants, the lines with the best desired traits.

Since the mid 1980s, several medical products produced through modern biotechnology have been approved for use by regulatory bodies and widely utilized. These include human insulin, interferon, interleukin, erythropoietin, hepatitis B vaccine etc. For various industries, recombinant (rec) enzymes have been utilized e.g., rec chymosin for the manufacture of cheese; rec enzymes for detergents, and ; xylose isomerase used in the industrial production of fructose from glucose.

In agriculture, more than 44 million hectares of genetically modified (GM) crops were grown in 2000 in 14 countries. Thus, about 50% of the maize, cotton or soybean planted in the USA in 1999 either possess resistance to herbicide or insect pest (with the *Bacillus thuringiensis* (Bt) endotoxin gene) or both. Other GM crops are insect-protected potato, virus-protected papaya and canola with higher lauric acid. Among the benefits that have been reported to accrue from the use of these GM crops are: for Bt cotton grown on 1 million ha in 1998, reduced chemical pesticide use by 450,000 kg and increased yields by 39 million kg worth US$92 million; for Bt corn, increased yield by 8%, no chemical pesticide used on 800,000 ha in 1998, better grain quality; for using herbicide tolerant crops, use of less hazardous herbicides, reduced need for farmer to till soil to remove weeds and thus reducing soil erosion.

However, inspite of the perceived benefits of agricultural biotechnology products, several environmental and health concerns have led to opposition to, wariness and lack of public acceptance of GM crops in many countries. This is quite unlike the general public acceptance of medical products that were derived by modern biotechnology.

Regulatory Agencies Involved

A. Regulation of R&D Including Field Testing and Commercialization

Countries which are undertaking research and development utilizing the modern tools of biotechnology have their mechanisms for regulating such activities. To be discussed below are those in the United States and in the Philippines.

In the United States. In the United States, three agencies are involved in the regulation of genetically modified organisms (GMOs)---the Department of Agriculture (USDA), the Environmental Protection Agency (EPA) and the Food and Drug Administration (FDA). The USDA's Animal and Plant Health Inspection Service (APHIS) regulates the interstate movement, importation into the US and field testing of organisms and products. During the field tests, buffer zones are set up around the test plots to keep the pollen of transgenic crops from reaching nontransgenic crops; all transgenic crops and tissues are also destroyed after the test. Before a crop is commercialized, the company has to show proof that the crop will not have significant effect on the environment such as crossing with or passing genes to weeds and making them more a ggressive. As of July 1997, there had been 4,700 field tests in the United States.

Starting in 1993, APHIS issued a notification system underwhich scheme, applicants need not to seek prior approval for field trials of certain crops of specific trait, but rather to only inform the agency. As of 1998, there were 36 nonregulated crops in the US. The EPA gets involved in the evaluation when the GM crops have traits that may affect the environment such as the BT-and herbicide tolerant crops.

In the Philippines. The National Committee on Biosafety of the Philippines (NCBP) deals with biosafety issues involved in research and development aspects including field testing.

The NCBP approved the application for field testing of transgenic maize (Bt corn) of Pioneer Hi-Bred and Monsanto Philippines in collaboration with the Institute of Plant Breeding in 1999. The first field testing of Bt corn was conducted in General Santos City on 500 sq m in the research station of Agroseed in cooperation with IPB from December 1999 to March 2000. The second Bt corn field testing was conducted by Pioneer Hi-Bred in cooperation with IPB in about 500 sqm in Polomolok, South Cotabato a year later.

Current efforts on the use of modern biotechnology techniques in crop improvement include the development of delayed ripening trait in papaya and mango and development of papaya and banana resistant to papaya ringspot virus and banana bunchytop virus, respectively, at the Institute of Plant Breeding. PhilRice is developing rice varieties with resistance to important diseases such as bacterial sheath blight and tungro by genetic engineering. BIOTECH, in collaboration with PhilRice, is engineering stem borer, brown planthopper, and green leafhopper resistance in rice. These activities are regulated and monitored by NCBP and the respective Institutional Biosafety Committees of these institutions.

B. Modern Food Safety Regulation

Safety assessment procedures for food products derived from modern biotechnology have been studied and evaluated carefully and lengthily since the early 1990s. The United Nations FAO and WHO and the OECD have held consultaltions on this issue and have recommended safety assessment strategies for food and food additives produced by modern biotechnology. Such strategies have been adopted by various countries including the United States, Canada, EEC countries, Japan, Australia, New Zealand. In general, the safety assessment procedures are based on the principle of substantial evidence, which provides that "if a new food or food component is substantially equivalent to an existing food and food component, it can be treated in the same manner with respect to safety (i.e., the food or food component can be concluded to be as safe as the conventional food component" (FAO-WHO 1996). These procedures require information on the composition and characteristics of the traditional or parental product or organism and those of the new product, including information on the technique and components used in the derivation of the product. Special considerations are given to possible allergenicity, transfer of gene from genetically modified plants to microorganisms in the gastrointestinal tract and possible toxic effects.

In the United States, the US FDA regulates food and food components derived by modern technology by the same provisions which regulate other food products under the Food, Drug and Cosmetic Act. Based on the FDA policy guidelines on new plant varieties issued in 1992, developers of GM plant varieties are asked to submit summaries of nutritional and safety data on the new varieties for review by the agency. The FDA treats substances added to food products through recombinant DNA techniques as food additives if they are "significantly different in structure, function or amount than substances currently found in food." In this case, premarket approval is needed since federal law requires premarket approval for food additives, whether or not they are products of biotechnology. However, if a new food product derived by modern biotechnology does not contain substances that are significantly different from those already in the diet, then, it does not need premarket approval.

For the Monsanto herbicide-tolerant soybean and Ciba Geigy insect-resistant Bt corn, nutritional and safety data were reviewed by FDA biotechnology teams which included experts in chemistry, molecular biology, toxicology, human and animal nutrition, environmental science and regulation of food ingredients. Based on the data, the FDA "found no basis to disagree with the developers' determination that neither product was significantly altered from varieties of soy and corn with a history of safe use, and that both products are safe for introduction into the marketplace" (FDA Talk Paper, October 1996).

In the Philippines, two other agencies are involved in the food safety aspects of GM crops and foods: the Department of Health's Bureau of Food and Drugs (BFAD) and the Department of Agriculture's Bureau of Agriculture and Fisheries Product Standards (BAFPS).

Issues and Concerns

A. Antibiotic Resistance and Horizontal Gene Transfer

Most of the first generation GM crops have antibiotic resistance (like kanamycin) gene as selectable marker. It has been hypothesized that such antibiotic resistance genes could lead to the inactivation of oral doses of the antibiotic, or that these genes could be transferred to pathogenic microorganism in the gut or the soil which will render them resistant to such antibiotics. Various studies have revealed the following:

1. When plant DNA with beta-lactamase gene from insect-protected transgenic corn, either intact or nuclease-degraded, was incubated with competent *Escherichia coli,* transformation was 1 in 6.8×10^{19}; thus transfer of the resistance gene from plant chromosome to microbes in the gut or the soil would be most unlikely.
2. DNA when incubated with stomach fluids for 20 min is degraded to such extent that only 0.1% are > 1000 bp.
3 It was estimated that if all microorganisms in the gut were competent, transformation with kanamycin resistance gene would be very low, 3×10^{-15} compared with the frequency of natural mutation in bacteria of 10^{-9}.
4. Gene transfer to bacteria *(Acinetobacter* species) was observed in experiments in which purified DNA (5μg) from transgenic potato was used under conditions where transformation would be very high (De Vries and Wakernagel, 1998; Gebhard and Smalia, 1998).

5. The gene product of the kanamycin resistance gene, APH(3')II, an enzyme, is rapidly inactivated and broken down by stomach acid and digestive enzymes; it is also heat labile and does not have homology to any known allergen or toxin.
6. In *in vitro* studies, the APH(3')II does not significantly affect kanamycin.

Experts have concluded that "the chance of antibiotic-resistance genes getting into intestinal bacteria is miniscule" (Salyers, in Science, 26 Nov 1999). Syvanen (Nature Biotechnology, 17 September 1999) further stated that "no one has been able to show that native bacteria will take up antibiotic resistance genes when exposed to transgenic plant material under natural conditions." Many scientists are also unanimous in saying that even if they did get in, it would not matter since the same resistance genes are already widely present in many microorganisms. Kanamycin and neomycin are also not used any more in the clinics because they are toxic antibiotics. Nonetheless, the U.K. Royal Society (1999) has considered the presence of antibiotic resistance marker genes in GM crops unacceptable and has recommended the development and use of other marker genes.

Several strategies are now available to eliminate the use of antibiotic resistance gene markers from transgenic plants. These include: (1) co-transformation with two vectors, one containing the gene of interest and the other one the marker gene, which is selected out by traditional breeding methods; (2) use of green phosphorescent protein; (3) use of herbicide resistance genes; and (4) use of mannose isomerase which will allow selection on mannose-containing medium in which only the transgenic tissues will survive.

B. Question on the Creation of Superweeds

Escape of a foreign or transgene by pollen or seed dispersal which may create superweeds or cross with other nontransgenic crops is a common environmental concern. During field trials, such possibilities of crossing with wild relatives and distance by which pollen can be blown away are determined. Data on weedy wild relatives should thus be obtained for any transgenic crop to be field-tested.

Among the commercially released transgenic crops, rapeseed or canola has been shown to cross with weedy relatives thus additional tests are required by the USDA APHIS for such crops.

In general, even in outcrossing occurs, the resulting weed is not expected to persist in the field due to lack of selection pressure. Nonetheless, this property of possible crossing with weedy relatives has to be determined on a case-by-case basis.

C. Possible Faster Pest Adaptation

It is known that the resistance of crop varieties, either transgenic or conventionally-bred, against pest or disease breaks down in time and that insect populations eventually adapt to insecticides especially when these are not managed properly. This has led to the development of integrated pest management (IPM). Insect-protection of crops by modern biotechnology can be regarded as just a mode of pest management and is compatible with IPM strategies. Thus, for transgenic crops, several recommendations have been made to minimize pest adaptation. These are as follows:

- Expand knowledge of insect biology and ecology;
- Create refuges to support population of susceptible plants;
- Monitor for incidents of pesticide resistance and implementing a containment plan;
- Employing IPM practices that encourage ecosystem diversity and multiple tactics for insect control; and
- Developing products with different modes of action.

IPM strategies on using transgenic crops under local conditions should be developed and tested.

D. Effects on Nontarget Organisms and Persistence in Soil

Nontarget organisms. For GM crops with biological activities, their safety to nontarget organisms is a major concern. The non-detrimental effects of the Bt (*Bacillus thuringiensis*) toxin on nontarget organisms have been documented extensively. Table 1 summarizes the evaluation of Bt on several organisms.

A short paper (correspondence) published in Nature (Losey et al, 1999) reported a laboratory experiment showing the lethal effects of Monarch butterflies fed with milkweed dusted with Bt pollen. Although even the authors themselves noted that this was a preliminary study, the paper attracted considerable coverage in the media. The paper elicited rebuttals and criticisms as well as support from critics of biotechnology. Shelton (Nature Biotech, 9 September 1999) noted that an earlier more relevant paper was largely overlooked. In the study by Hansen and Obrycki (1999), the authors examined the Bt-corn pollen deposition on milkweed plants at different parts of the corn field and then assayed the leaves of the milkweed plants with the first instar larvae. Their results

Table 1. Effects of Bt toxin on different nontarget organisms.

Organism	No effect level
larvae honey bee	≥ 20 ppm
adult honey bee	≥ 20 ppm
green lacewing larvae	≥ 16.7 ppm
parasitic hymenoptera	≥ 20 ppm
Ladybird beetle	≥ 20 ppm
earthworms	≥ 20 mg/kg dry soil
Collembola	50.6 ug/g leaf tissue
Daphnia magma	100 mg pollen/liter

(From Sanders et al, 1998)

showed that pollen levels were highest within the field where the Monarch butterflies were scarce, but even there, the mortality of Monarch butterfly was only 16%. Other succeeding field studies showed (a) 20% mortality was seen on Monarch feeding on potted milkweed plants left at the edge of Bt cornfield; (b) milkweeds one meter away from Bt cornfields were not likely to be dusted with toxic levels of Bt toxin and (c) that the worst case scenario of a toxic pollen cloud saturating the Corn Belt and wiping out Lepidoptera would not occur (Science, 19 February 2000).

Persistence in soil. The Bt toxin present in transgenic corn and cotton plant tissues was observed to degrade relatively fast. Its bioactivity was reduced to 50% and 90% in 1.6 days and 15 days, respectively (Sims and Holden, 1996; Palm et al, 1994). This is comparable with mircrobial Bt products which degrade from 4 to 41 days, depending on soil composition and type of Bt protein (West et al, 1984; West, 1984; Pruett et al, 1980).

E. Questions on Food Safety

Requirements for evaluation. All of the GM crops/foods that have been released in the market in various countries have undegone rigorous analysis and evaluations for food safety. For instance, the European Union requires the following information on GM crops/foods for evaluation:

(a) specification of the novel food;
(b) effects of production process applied to the novel food;
(c) history of organism used on the source of the novel food;

(d) effect of genetic modification on the properties of host organism;
(e) genetic stability of the genetically modified organism;
(f) specificity of expression of novel genetic material;
(g) Transfer of genetic material from genetically modified microorganisms
(h) Ability to survive in and colonize the human gut
(i) Anticipated intake/extent of use of the novel food
(j) Information from previous human exposure to the novel food or its source
(k) Nutritional information on the novel food
(l) Microbiological information on the novel food
(m) Toxicological information on the novel food.

Japan, by 1999, has approved 21 different GM crops for food and/or feed use. Many other countries, including the European Union, have approved various GM crops such as soybean, corn, cotton, potato and oilseed for food/seed.

Allergenic potential. Potential health hazards of GM foods include the presence of antibiotic resistance genes and the presence of allergenic or toxic substances that critics contend may be produced by the genetic engineering process. Earlier, the safety of the antibiotic resistance genes used in the commercially approved GM crops has been discussed.

Based on the study by a panel of experts convened by the International Life Sciences Institute (ILSI) and the International Food Biotechnology Council, a decision tree has been developed for the assessment of allergic potential of foods derived by modern biotechnology (Metcalfe et al, 1996). Some of the general properties of proteins which do not have allergenic potential are: (a) those with no history of allergenicity; (b) no homology with known allergens; (c) those that are rapidly digested and (d) those that are expressed at low levels relative to the expression of major allergens (Lehrer, 2000).

The risks posed by the allergenic potential of GM foods, however, should be weighed against their potential benefits. It is known that many crop varieties which have been conventionally bred contain toxicants and allergens but their risks have been managed. Food crops like cassava, almonds, beans, soybean, peanut, other root crops and others have natural toxics and antinutritional factors which by processing have become edible to man and animal.

Labeling. Labeling policy for GM foods is similar for the United States, Canada, and the European Union. Labeling is mandatory only if a health or safety concern like allergenicity or changes in composition or nutrition are identified.

Voluntary positive or negative labeling are also permitted provided claims are factual and not misleading. The Philippines does not have an official policy yet on labeling of GM foods. Japan's Ministry of Agriculture, Forestry and Fisheries and Ministry of Health and Welfare have declared labeling requirements on foods that use genetically modified organisms by April 2002. The ministry, however, has confirmed the safety of GM crops such as corn, soybeans, rapeseed, potatoes and cotton (World Food Regulation Review, February 2000).

Benefits of Modern Biotechnology -- Actual and Potential

Benefits from the first generation transgenic crops have been documented. The use of insect-protected (Bt) crops such as corn, cotton and soybean has reduced the application of pesticides. Partial data show that on 1 million ha of Bt corn grown in 1998, chemical pesticide use was reduced by 450,000 kg, yield increased by 39 million kg worth US $92 million (Science, 26 November 1999). No chemical pesticide was used on 800,000 ha of corn plants. Yield increase in corn averaged 7-8% and grain quality was noted to be high since undamaged grains were not prone to microbial infections. The use of herbicide-tolerant crops allows farmers to use less hazardous chemicals as well reduce the need to till the soil to ward off grass, thus, reducing soil erosion.

The potential benefits of GM crops are:

1. Better nutritional qualities---rice with provitamin A and iron; corn with high lysine and tryptophan; vegetables with higher β-carotene and lycopene; legumes with higher sulfur containing amino acids; sweet potato with higher protein content.
2. Engineering pest or disease resistance in important crops such as rice and corn, various vegetables, sweet potato and others especially those important for developing countries.
3. Edible vaccines ---aimed at providing low cost immunization strategy for developing countries; banana with antigen of causal organism of diarrhea is now at clinical trial stage. Vaccine corn for gastroenteritis in hogs, hepatitis B in humans, etc.
4. Antibodies engineered and produced in plants---expressed antibodies in potato, tobacco and rapeseed were stable and active; need to increase expression level.
5. Crops which can extract and detoxify pollutants from the environment such as heavy metals---this research is hampered by the lack of basic knowledge on the molecular mechanism involved in the uptake and storage of inorganics in plants.
6. Crops which produce less toxic residues such as corn with low phytate.

Phytate complexes phosphorus and thus the latter becomes unavailable and cannot released by nonruminants. A large amount of phosphate is excreted and contributes to water pollution.

7. Production of alternative polymers which can replace o substitute plastics and other petrochemical products in plants and thus are renewable and biodegradable.

Conclusion

1. Regulatory mechanisms to ensure biosafety of GM crops are in place and operational in countries involved in R&D and commercialization; biosafety and food safety evaluation is done on a case-by-case basis.
2. Food safety assessment protocols have been established in countries that have approved the commercialization of GM crops as food or feed.
3. Presently available GM crops underwent voluntary and required risk assessment studies during field tests and were established to be safe to environment.
4. Presently available GM crops underwent voluntary and required food safety assessment and established to be safe to humans and animals.
5. In the Philippines, the regulatory mechanisms for biosafety aspects at the R&D level under the NCBP are established. Regulatory mechanisms for commercialization still have to be established.
6. Potential benefits of modern biotechnology in the areas of food, health, environment and industry are imperiled by strong opposition from anti-biotech sector.

Recommendation

1. Promote more balanced public discussions of the issues with increased participation of consumers, farmers, policy makers, scientists, and industry.
2. Government agencies concerned should fast track the establishment of regulations and mechanisms for the commercialization and food safety aspects of modern biotech-derived products.
3. More field trials of different commercially available transgenic crops should be undertaken to enable appropriate risk assessment studies on them under Philippine conditions.
4. The government should promote science-based evaluation of the products of modern biotechnology to assess their food safety to humans and animals.

5. The Philippine government should strengthen its regulatory agencies in enhancing and modernizing its manpower and logistics capabilities needed in the regulation of modern biotechnology-derived products.
6. The Philippine government should strongly support R & D in and using modern biotechnology to develop local biotechnologies and their products.
7. The potential benefits of any technology should be weighed against its risks and science-based protocols utilized in their evaluation.

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SUSTAINABLY PRODUCTIVE AGRICULTURE AND GENETICALLY MODIFIED CROPS

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Introduction

Sustainable agriculture and rural development has been defined by FAO **as the management and conservation of the natural resources base, and the orientation of technological and institutional change in such a manner as to ensure the attainment and continued satisfaction of human needs for present and future generations.**

The need for sustainably productive agriculture looms larger and larger in the horizon as we begin the 21st century. Between the years 2000 and 2025 the world population will increase by almost two billion people. To feed this additional population it has been calculated that the average yields of cereals must be 80% higher than the average yields in 1990.

In the Philippines, our population has been projected to increase from 77 million in 2000 to 108 million in 2020. For rice alone our requirement will escalate from 12.8 million tons to 17.9 million tons, an increase of 40% (Hossain and Sombilla, 1999).

However, because land and water are becoming increasingly scarce, these increases must come primarily from increasing biological yields, not from area expansion and more irrigation (Serageldin, 1999).

The Convention on Biological Diversity (CBD) defines biotechnology as **any technological application that uses biological systems, living organisms, or derivatives thereof, to make or modify products or processes for specific uses.** It is the new label for a process that humans have used for thousands of years to ferment foods such as beer, wine, bread and cheese (Vogt and Parish, 1999).

Modern biotechnology, in the narrow sense, refers to applications based on the new science of molecular biology. With the new knowledge in the molecular sciences, it is now possible to identify specific genes in the genomes of organisms; understand their functions in the whole organisms; modify, clone and transfer the genes across natural species barriers, and make the genes express their products in specific tissues, at specific growth stages at specific dosages in the recipient organisms.

In conventional plant breeding which is one form of biotechnology widely applied in agriculture, gene transfers are limited to between varieties of the same species; occasionally between species of the same genus, and rarely between species belonging to different genera. Transferring genes between plant families, much less from bacteria or animals to plants was impossible. But now with the capability of modern biotechnology to precisely manipulate, transfer and control gene expression, these very wide genetic introgressions are possible.

With modern biotechnology, man has at his disposal a new tool for dramatically increasing and stabilizing biological yields while protecting the natural resources base. Crops can be genetically modified to raise yield ceilings, improve resistance to pest and diseases, develop tolerance to drought, excessive temperatures, soil acidity and salinity and other abiotic stresses and to improve the nutritional, processing and keeping quality of farm produce.

The positive impact on the environment from modern biotechnology will come from (1) the more efficient use of land, mineral nutrients and water, (2) the less need for pesticides as more durable genetic resistances are built into crops, (3) the less need for cultivation with herbicide tolerant crops and more robust seedlings thus protecting the soil from erosion and (4) from the better conservation and management of biodiversity.

Objections to Modern Biotechnology

In one sense, modern biotechnology is simply a logical continuation of the old. The essential unity of the genetics of all living organisms had been there all along. We simply discovered the secrets of what the discrete units of inheritance are made of, how they function, and how we can manipulate them with more precision compared with the random statistical methods we have employed in the past.

Apart from agriculture, modern biotechnology has many other potential beneficial applications in health, industry and environment. It is used in producing recombinant DNA vaccines and in gene therapy to treat debilitating human diseases and genetic disorders. Microbial, animal and plant cells are now being genetically modified to produce enzymes, fine chemicals and biodegradable polymers to replace traditional agricultural and chemical factory processes. Microbial cells and genetically modified plants which have unique capability to selectively accumulate heavy metals are now being used to clean up the environment. DNA techniques are being employed to precisely characterize biodiversity to facilitate conservation.

Except for the small minority of people who object to all modern science, the health, industrial and environment applications of modern biotechnology are acceptable to most people. Most of the objections are directed to its applications to food and agriculture, particularly to genetically modified crops.

These detractors see peril in possible introduction of allergens and anti-nutrition factors in foods, in the accidental release of new but harmful organisms into the environment, the hegemony by a few multinational corporations who control the new technology over the world economy, and the replacement of traditional agriculture and the rural way of life by modern, corporate agriculture.

They perceive modern biotechnology as ethically objectionable as it is akin to playing God with nature. It is unnatural and therefore undesirable. They preach the virtues of organic farming (as opposed to modern chemical-based agriculture) to produce safe, healthy food and to conserve the environment.

They attack the Green Revolution as anti-poor unmindful of the fact that if you promote organic farming of the major food crops in the developing countries, this will result in low yields and therefore inadequate food supplies and ultimately high prices. Since food constitutes the bulk of the family expenses of the poor, high food prices will hurt the poor more than the rich who could always purchase their food from the market.

The yield inefficiency of organic farming has another very profound negative consequence to the environment of which people are generally unaware. To produce the amount of cereals the world consumes today with the average yields before the Green Revolution, Evenson (private communication), estimated that the world needs to put 200 million more hectares of land under the plow. Since practically all the arable lands are now under cultivation, those additional farmlands will have to come from cutting down tropical rainforests and plowing marginal, environmentally-vulnerable grazing lands.

Commercial Release of Genetically Modified Crops

Modern biotechnology in agriculture consists of at least six components (Persley and Doyle, 1999):

- genomics: the molecular characterization of species;
- bioinformatics: the assembly of data from genomic analysis into accessible forms;
- transformation: the introduction of novel genes into crops, forest, livestock and fish species;
- molecular breeding: identification and evaluation of desirable traits in breeding programs with the aid of molecular genetic markers;
- diagnostics: the use of molecular characterization to provide more accurate and quicker identification of pathogens; and
- vaccine technology: development of recombinant DNA vaccines for control of diseases.

Rapid scientific progress is being made on all these fronts. The mapping of the entire genome of the experimental plant *Arabidopsis thaliana* has been completed. The genomic characterization of major crop commodities is underway. The first that should be completely mapped will be rice, which has a relatively small-sized genome. A Japanese-led consortium is expected to complete the rice genomic map in a couple of years. This process has been greatly facilitated by the private sector initiatives using massive computing and high throughput DNA sequencing machines, in the characterization of the human genome. However to be useful, these genomic maps have to be accompanied by information indicating gene function (functional genomics) which will still take some time to complete.

Marker-assisted breeding is in progress in many countries. Bacterial blight is a devastating disease in rice which had been nearly impossible to control because of the occurrence of many races of the pathogen. Using molecular genetic markers, rice breeders have succeeded in pyramiding bacterial blight genes to develop much more durable resistance to the disease.

Among the modern biotechnology components applied in agriculture, the development of genetically modified crops with specific desirable traits (transgenic crops) had been the most commercially advanced. The first GM crop was the Flavr Savr tomato with long shelf life released in 1994. Since then commercial release and adoption of transgenic crops has dramatically increased. Between 1996 and 1999, the global area planted to transgenic crops increased from 1.7 million hectares to 39.9 million hectares (James, 1999). Sales are estimated to have risen from $75 million in 1995 to $2.1-$2.3 billion in 1999.

The following major observations characterize this initial phase of commercialization of biotechnology-derived crop varieties:

a) Most of the early technology adopters were commercial farms in developed countries with the USA and Canada accounting for 72% and 10% respectively of the area planted.

b) All the subject crops are crops widely grown in developed countries i.e., soybean, corn, cotton and canola.

c) The almost exclusive foci of trait improvement were herbicide tolerance[a] and insect (Bt) resistance[b].

The above observations are very significant because they call attention to and explain to a large extent the opposition and unease which genetically modified crops have elicited from significant sectors of society as well as highlight the challenges and opportunities for us in the Philippines and the rest of the developing world as far as exploiting the benefits of modern biotechnology for food and agriculture.

An essential feature of modern agricultural biotechnology is its increasing proprietary nature. Unlike the agricultural sciences in the past which have come out of publicly supported laboratories, the new biotechnologies are locked into patents, and other private intellectual property rights.

In order to recover their massive investments, the private companies must create value added for which there is effective demand – i.e., from farmers, consumers, food manufacturers and traders, etc. who are willing and have the capacity to pay. Thus it should not come as a surprise that their initial targets are commodities grown by commercial producers in developed countries.

Likewise, their objects of innovations are those characters of high value to commercial growers. Among the possible target traits, crop protection against weeds

[a] GM crops with high tolerance to heribicides like glyphosate and glufosinate ammonium.

[b] GM crops with a novel gene from *Bacillus thuringensis* (Bt). Bt is a known safe and widely used biopesticide which produces toxins which kill the larvae of insects belonging to the order Lepidoptera (i.e. butterflies)

and insect pests was an obvious priority in as much as commercial growers expend lots of money on herbicides and insecticides to control these pests. Moreover, these Western farmers are fully aware of the health hazard they expose themselves to and the pollution they cause their own environments with excessive use of pesticides.

Were the initial priorities high levels of essential vitamins and minerals in food crops, public perception would have been different although for people in Europe and USA who have adequate nutrition these may still not be attractive enough. Better if the breeding objectives were low cholesterol, low sodium, high antioxidant, and "lite" farm produce.

These statistics in the initial commercialization of genetically modified crops demonstrate clearly the bias in the application to developed country needs. With food surpluses and consumers with more than sufficient purchasing power to acquire adequate and balanced diets, the developed countries can very well do without agricultural biotechnology. It is really the developing countries who need biotechnology for agriculture. Should the anti-biotechnology lobbies in the West succeed in discouraging public and private investments in agricultural biotechnology, the poor developing countries will be the biggest losers.

It is therefore in the interests of the developing country themselves that the frontiers of agricultural biotechnology science be pushed to the limits through continuing investments by the private and public sectors globally. Additionally, it is in our national interest to develop capacity for biotechnology research ourselves to address those food, agricultural and environmental problems and opportunities which are uniquely ours.

Managing Risks Associated with Genetically Modified Crops

Modern biotechnology could be a powerful tool for improving productivity and sustainability of agriculture in developing countries. However, as with all other innovations and changes involving complex systems, there will always be trade-offs; there will always be unintended unwanted consequences that accompany the gains. It is a matter of weighing the risks against the benefits, of avoiding or mitigating the unwanted consequences and intelligently deciding which aspects of change to accept and which to reject.

It is useful at this point to recognize that the objections to the use of transgenic crops can be differentiated into two – those risks inherent to the technology and those that transcend it (Leisinger, 1999).

The risks inherent to genetically modified organisms include the danger of unintentionally introducing allergens and other anti-nutrition factors in our foods; the possibility of the new introduced genes escaping to other organisms by outcrossing thus creating superweeds, and in the case of insect-killing genes, the possibility of adversely affecting beneficial non-target arthropods. Moreover, antibiotic resistance has been used as a marker for selecting genetically modified plants. There is fear that the genes for antibiotic resistance might be transferred to bacteria that cause disease in man.

As far as the food risks are concerned, in the developed countries where legislation and regulatory institutions are in place, there are elaborate steps or protocols to precisely avoid or mitigate those dangers. There are standard tests for known specific allergens and anti-nutrition factors. At the molecular level, there are now DNA sequence tests which identify gene combinations which have the potential to generate allergenic substances.

On the matter of environmental risks, the possibility of introduced genes "escaping" to the wild through outcrossing between the genetically manipulated transgenic plants with wild relatives, can not be ruled out. Obviously if there are no known interfertile relatives as in the case of corn in most parts of the world, the risk is miniscule. Moreover, it depends on what genes may be "escaping" into the wild. A weedy rice plant which by chance acquired the novel beta carotene gene from daffodil (a GM rice plant developed in Switzerland) is clearly no threat to anybody including the insects who feed on them.

And even when such outcrossings do occur, the chances that these rare hybrid plants will survive and flourish over their competitors in the wild are extremely low not unless the gene confers a selection advantage for hybrid plants possessing the new gene. However, experience to date indicate that varieties bred and selected by man for specific purposes are less weedy and generally lose their ability to compete in the wild.

The so-called superweeds that may come out of outcrossing herbicide-resistant transgenic plants with weed relatives will be superweeds only in cultivated fields as long as the specific herbicide is used. In the wild where no herbicides are sprayed, there is no reason such rare hybrid plants should outcompete other plants which do not possess the herbicide-resistance gene. In any case, there is a ready agronomic expedient: switch to other modes of weed control such as cultivation and use of other herbicides.

The risk of genetically modified insect-inhibiting plants affecting non-target organisms is no worse than the current practice of broad-spectrum insecticides decimating both harmful and beneficial insects. In fact, on the contrary, the transgenic plants like the Bt crops tend to be more specific and discriminating.

With regard to the concern about the use of antibiotic resistance genes, the U.K. Royal Society noted that the widespread use of antibiotics as feed additives for animals, and as over-the-counter and prescribed medicines for humans carry a greater risk of creating antibiotic resistant bacteria than transfer of marker genes from genetically modified plants (UK Royal Society, 1999a). Indeed, a large number of bacteria present in the gut already carry resistance to several antibiotics, including kanamycin and ampicillin. Nevertheless, the U.K. British Royal Society considers the presence of antibiotic resistance marker genes in genetically modified crops unacceptable and encourages the development and use of alternative marker systems.

However, what is more urgent is the real possibility that insects may quickly build up resistance to the new genes rendering the utility of the improved varieties very short-lived. It is clearly in the interest of the plant breeders and the private seed companies which developed the new varieties to manage the deployment of their genetically modified resistant varieties in such a way that insect-resistance build-up is discouraged by, for example, creation of insect refuges amidst fields sown to Bt crops.

These remarks were not meant to dismiss the concerns for food safety and biosafety inherent with biotech-derived foods and organisms. It is the obligation of the technology innovators, the producers and of government to assure the public of the safety of the novel food and drugs they offer as well as their benign effect on the environment. **However, hazard identification and risk assessment ought to be scientifically based and on a case-by-case basis i.e., regulating the end product rather that the process (Juma and Gupta, 1999). Risk assessment should consider the characteristics of the organism being assessed, intended use of the organism and features of the recipient environment.**

It is very important that we set in place the appropriate legislation and regulatory mechanisms to govern biotechnology not only as a matter of good science and sound governance but also to effectively respond to the genuine concerns for food safety and environmental safety of the general public.

On the other hand, technology-transcending risks as opposed to technology-inherent risks, emanate from the political and social context in which a technology is used (Leisinger, 1999). Included under this category are differential access to the new technology leading to a further widening of the economic gap between developed countries (technology users) versus the developing countries (non-users); further disparity in income between rich versus poor farmers within the same communities, and the further loss of biodiversity should the new transgenic varieties become too successful displacing other varieties.

However, in the case of technology-transcending risks relating to access, the solution is not to ban the use of the new technology by everybody, but by developing technologies tailor-made for the needs of the poor and by instituting measures so that the poor producers will likewise have ready, affordable access to the new technology.

As Leisinger (1999) contends, technology-transcending risks mostly materialize because a gap opens between human scientific technical ability and human willingness to shoulder moral and political responsibility.

This differentiation between technology-inherent risks and technology-transcending risks is very germane to our situation in the Philippines because we have to aggressively address both concerns if we were to succeed in exploiting the potential of modern biotechnology to advance our national purposes now, and not much later.

Labelling of GM Foods and Intellectual Property Rights

There are two other very important concerns related to the adoption of genetically modified crops – segregation and labelling of GM crops and GM derived foods and protection of intellectual property rights.

A debate is raging on in developed countries on the need to legally require the labelling of GM crops and foods derived from GM crops. The prevailing position in the United States is that if the GM crop or GM-derived food is substantially similar to the conventional product, there is no need for labelling. However, in Europe there is a powerful lobby to require labelling of all GM crops so that consumers can exercise the right of choice. The UK Royal Society (1999b) strongly supports the labelling of foods containing GM material but hedges its support by qualifying "... where the new food stuff is substantially changed (according to specific criteria) from that of its conventional counterpart".

Segregation of GM products and labelling will incur additional costs which ultimately will be passed on to the consumer. There is no point in legally requiring segregation and labelling when there are no demonstrated or anticipated risks. However if by labelling, the producers and the food processors expect to receive a premium for their products, they may do so voluntarily. The consumers can exercise their choice of paying a little more in exchange for the guarantee of the product being GM-free.

We import each year hundreds of thousands of metric tons of corn and soybean from the United States. Since easily half of these commodities grown in the US are from GM crops we can assume that we, as well as the American public and other importers, have been consuming GM-derived corn and soybean products for the last five years. So far there has not been a single report of food allergy and poisoning from GM corn and soybean.

However this may not be necessarily true for other GM crops that may follow.

In any case there is no rush for the Philippines to legislate the segregation and labelling of GM crops. If there is a real risk from GM corn and soybean, the US regulatory agencies and the consumer watchdog organizations will be the first to blow the whistle on the US GM corn and soybean crops.

However we should strengthen our capability to monitor, assess and regulate these new foods alongside the conventional ones. Should we in the future develop our own transgenics for our own unique crops like the coconut, we have to rely on our own capacity to test them. We can not expect help from the developed countries who produce soybean oil and rapeseed oil with which our coconut oil competes in the world market.

Much of the new agricultural biotechnology have been generated by the private sector. During 1997-1999, the transactions of the major bioscience companies in the seeds industry are reported to have reached about $18 billion (M. Kern in Persley, 1999). Thus the new knowledge and genetic materials are for the most part protected by intellectual property rights.

Since copying and infringement of patent rights can be easy with biological materials which can self-reproduce, the private sector is naturally reluctant to transfer their knowledge where there is no protection of intellectual property rights.

All countries who have joined the World Trade Organization (WTO) are bound to / implement the provisions of the Agreement on Trade Related Aspects of Intellectual Property Rights (TRIPS), which lay down the minimum levels of protection and ensures that enforcement procedures are available under national law.

Thus to facilitate transfer and dissemination of proprietary agricultural biotechnology and to promote technological innovation, the Philippines must comply with the minimum requirements under the TRIPS soon.

We must bring our business people, scientists and lawyers together to craft legislation which will satisfy the minimum requirements under the TRIPS while securing the freedom to operate of our national researchers and looking after the interests of our agribusiness sector and the small farmer sector.

However the new legal, regulatory and business arrangements could be very complex and very difficult for our national scientists to manage. We need to train our scientists and research administrators on how to assess, secure ownership and market intellectual property rights and how to enter into all kinds of licensing and material transfer agreements.

Conclusion

The need for sustainably productive agriculture looms larger and larger in the horizon as we begin the 21st century. During the next 20 years, the population of the Philippines is projected to increase from 77 million to 108 million. We will need 40% more rice by the year 2025 but we shall have less arable land and less water to produce it.

Modern biotechnology has great potential to contribute to agricultural productivity and sustainability. The biological processes which underpin the growth and development of crops, fish, forest trees, livestock and microorganisms can be manipulated through their genomes. With the new science of molecular biology, it is now possible to identify specific genes; understand their functions in the whole organism; clone, move and transfer the genes across natural species barriers, and make the genes express their products in specific tissues at specific growth stages in the recipient organisms. This new tool allows man to perform a lot of manipulations of the biological factors of production which were impossible before. In conjunction with other conventional tools of science, many essential operations can be performed with more precision, quicker and eventually cheaper.

A major application of modern biotechnology is the development and use of genetically modified or transgenic crops. Crops may be genetically modified to raise yield ceilings, improve resistance to pests and diseases, develop tolerance to drought, excessive temperatures, soil acidity and salinity and other abiotic stresses and improve the nutritional, processing and keeping quality of produce.

The applications of modern biotechnology in health, industry and on the environment are widely accepted. However there are objections and unease in their uses in food and agriculture, particularly in the use of genetically modified crops.

As with all other innovations and changes involving complex systems, there will always be trade-offs, there will always be unwanted consequences that come with the gains. It is a matter of weighing the risks against the benefits, of avoiding or mitigating the unwanted consequences and intelligently deciding which aspects of change to accept and which to reject.

There are risks associated with biotechnology – risks inherent to the technology and those that transcend it.

The risks inherent to biotechnology in particular to genetically modified crops include the danger of unintentionally introducing allergens and other anti-nutrition factors in our foods, introducing and/or creating novel genes which can in turn create and let loose in the environment unwanted and harmful organisms.

Technology-transcendent risks as opposed to technology-inherent risks emanate from the political and social context in which a technology is used. Differential access to biotechnology may engender serious economic gaps between users and non-users and further loss of diversity.

The transcendent risk of unequal access to biotechnology is a very real dilemma to developing countries like the Philippines. Much of the new biotechnology are proprietary and are not exactly relevant to the needs of the poor in developing countries.

We must do two things: We must strengthen our national capacity to conduct agricultural biotechnology research and development. We must also put in place the proper intellectual property rights environment to encourage the private sector to invest on the problems of Philippine agriculture as well as the appropriate incentives so the new technology will get into the hands of our poor farmers who need them most.

A clear distinction between these two sets of risks is important as they call for different responses.

Technology inherent risks are susceptible to scientific analyses and technological corrections. Protocols for assessing food safety and biosafety are in place for many organisms or products. If they are not yet available, further research can be conducted. There is no substitute to strengthening our national capacity to manage this type of risks.

What is important is that hazard identification and risk assessment are scientifically based and made on a case-to-case basis, regulating the end product rather the process. Risk assessment should consider the characteristics of the organisms being assessed, intended use of the organism, and features of the recipient environment.

Technology-transcendent risks on the other hand have their roots in social, economic and political inequalities or differences. Their solutions must for the most part be sought from the same realms of human activity e.g. agrarian reform, access to rural credit, more effective extension and rural institutions, better rural infrastructure and access to markets, and more agriculture-friendly policies.

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AGRICULTURAL BIOTECHNOLOGY: OPPORTUNITIES AND CHALLENGES FOR THE PHILIPPINES

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Developing countries, still heavily dependent on agriculture, must now harness biotechnology to modernize agricultural production and diversify product outputs. Agriculture is just the starting point of a large food industry that includes production, processing, transportation and marketing, including domestic storage and cooling. The dependence on traditional export crops must be reduced for the agricultural economy to progress and eventually eliminate poverty. Also, through research and development, new or alternative crops and high valued uses of the raw materials from the traditional export crops must be identified.

One of the ways by which these improvements could be introduced to the agriculture and fisheries sector is to use the tools of modern biotechnology. Traditional biotechnology has been practiced since man learned to prepare his food. Alcoholic beverages and other fermented foods have been produced through the traditional modes. Modern biotechnology, on the other hand, is a knowledge-intensive undertaking, based on the science of molecular biology. Modern biotechnology, using tools that are rapid and precise, has contributed to the understanding of many important processes of life both at the cellular and molecular level. The hallmark of modern biotechnology is the capacity to deliberately alter the genes of microorganisms, plants and animals. This is known as recombinant DNA technology or genetic engineering.

In summary, biotechnology can be used to denote the following (Schneiderman, 1987):

"1) Use of microorganisms, plant cells, animal cells or parts of cells such as enzymes to produce commercial quantities of useful substances;

2) Construction of microorganisms cells, plants or animals with useful traits by recombinant DNA techniques, cell fusion, and other methods besides traditional genetic breeding techniques;

3) The application of molecular biology to understanding how cells and organisms work, so that the activities of cells and organisms can be altered or repaired."

Although the task is difficult, there is a strong basis to strengthening national R&d capacity in agricultural biotechnology.

The Current Situation in the Philippines

The Philippines was one of the first Asian countries to establish a biotechnology research and development program. In 1980, the National Institutes of Biotechnology and Applied Microbiology (BIOTECH) was organized at UPLB. In 1997, the UP System formally organized three other biotechnology research institutes to promote various biotechnology-based research and development activities in UP campuses in Manila, Diliman and in Iloilo. This initiative brought to the fore the biotechnology research and development programs in medicine, fisheries and industry.

Also, many studies have been conducted to assess the prospects of using biotechnology in agricultural research in the Philippines (Krattiger, 1992; Hamada and Cruz, 1997; Halos, 1999; and Rola, 1999). All of them conclude that there are many areas in agricultural research and development where the new tools of biotechnology could be useful. They also noted that among the sciences, biology had the most number of doctoral and master's degree holders.

However, not much progress in harnessing the tools of biotechnology has been achieved, especially in the area of varietal improvement. Most of the initial activities in the biotechnology R&D program were in the field of applied microbiology. This is not surprising as the major biotechnology-based industries in the Philippines up till now are based on traditional fermentation technologies like beer, beverage ethanol, and vinegar and monosodium glutamate production. It is however noteworthy that there were a few significant discoveries in the use of microbial agents to enhance soil nutrient availability and as agents in biomass transformation.

Until the early 90's, not much activity was undertaken in molecular biology and genetic engineering. This indicates that although there was an early realization of the importance of biotechnology in national agricultural development, there was little political will to provide resources for these programs to move forward. Although budget difficulties are always cited as the limiting step in these endeavors, it seems that in this particular case, the non-existence of a critical mass of highly trained and updated researchers especially in molecular biology was a major contributing factor to the slow pace of development.

Furthermore, at that time the various biotechnology R&D proposals were being submitted for funding, the use of transgenic crops globally was not as extensive. Field tests were at an early stage and considered risky. Now, the situation has changed. In 1999, around 40 M hectares of land around the world are reported to have been planted to transgenic crops (James, 1999). Since 1996, when there was this big increase in hectarage, 80 million of hectare-years of experience had been accumulated and millions of people and animals had partaken of food containing ingredients from the major transgenic crops -- soybean, corn, and canola.

This wide acceptance of transgenic crops has triggered heightened interest in the tools of modern biotechnology, especially recombinant DNA technology. In response to these developments, many developing countries have increased their investments in molecular biology and plant biotechnology, the Philippines being no exception. To date, however, no new biotechnology-based industries have been established in the Philippines. This lack of a commercial base remains a big constraint for the development of agricultural biotechnology in the Philippines. Thus the renewed interest in agricultural biotechnology might just provide the opportunity for a big leap forward.

The Changing Environment

In addition to the tremendous advances in the application of modern-biotechnology to enhance agricultural productivity, there are some new developments that were not present when the Philippine biotechnology program was started in 1980.

First, is the change in the rules of global trade accompanying the establishment of the WTO. Each nation is now expected to trade freely with other nations and all trade barriers are expected to be dismantled. Goods are now expected to flow on the basis of competition and market forces will govern productivity.

Second, as part of the new global economic order, each country is committed to protect intellectual property rights. This is intended to enhance innovation even across national borders.

Third, the Convention on Biological Diversity has declared that genetic resources are owned by sovereign nations. This is having an impact on the multilateral system of access to genetic resources in food and agriculture.

Fourth, Biosafety and the Precautionary Principle have now been invoked in the control of the movement of goods across national borders. This was in response to the concerns raised about the safety of food derived from genetically modified organisms. These concerns are also being used to regulate the flow of agricultural products, especially transgenic crops, across nations.

Fifth, there is strong anti-science movement that is being promoted globally. This anti-science movement has picked up many issues in order to elicit public distrust of science and technology. These issues could be environmental, health, social and political.

Sixth, due to the enormous investments required to bring a biotechnology undertaking to its conclusion, private corporations have dominated the initiatives to generate new knowledge using the tools of modern biotechnology and molecular biology. These operational elements include well-equipped laboratories, highly trained staff to review compliance with biosafety protocols, a legal staff to handle IPR.

Lastly, the tremendous advances in information and communications technology have affected the knowledge traffic including those in modern biotechnology. Thus, the emergence of bioinformatics to handle the large amount of information related to the genetic makeup of several organisms. Furthermore, in a recent report attributed to the Goldman Sachs Group, agriculture is expected to account for 8% of the internet business-to-business market by 2004 (Lorek, 2000).

Implications of these Changes

The globalization of the market forces and the need for product competitiveness requires more rigorous reading of the market trends. This makes it necessary to have capacity in technology forecasting and assessment and a well-oiled machinery for technology scanning.

The introduction of new modes of transactions requires the revision of the legal and regulatory structures of countries. A competent and predictable legal environment within a country including policies and procedures for handling biosafety, bioprospecting, intellectual property rights can facilitate the flow of products and research materials. In view of the new experiences, the judicial systems will have to adjust in order to be able to adjudicate the issues affecting the conduct of biotechnology research and development with fairness and dispatch.

The information and communication technology infrastructure and governance will have to be updated in order to cope with new developments. The use of ICT in a farming operation is becoming more evident not only in the production activities but also in trade. Thus, all efforts must be exerted to allow farmers to access efficient and reliable communication facilities.

There is a need for a global effort to make the public aware of the benefits of scientific activity. The global research and development community, public and private must show utmost transparency in dealing with public concerns. They must be able to communicate their views in a comprehensible manner, devoid of technical language, which can be intimidating. This will stem the tide that is slowly moving to make certain scientific activities criminal.

Private sector must be considered partners in all of the efforts to adjust our habits of mind, perception, social processes, our modes of governance to fit the tremendous advances in new knowledge. The public image of private sector as an instrument of exploitation must be corrected. These efforts however must be undertaken mainly by the private sector itself, especially the multinationals.

The Prospects

Modern biotechnology is to be viewed as a tool to help us unlock some of nature's secrets so we can apply this knowledge to solve some of the problems in the agriculture and fisheries sector. However, modern biotechnology must not be viewed as a silver bullet that will provide the miracle solutions to all our problems, some of which are age-old. Modern biotechnology is simply an array of tools and must often be used in combination with the other time-tested techniques in agricultural research. As a tool, it must be mainstreamed with the major directions of our research programs in agriculture and fisheries and must not be considered or developed apart from the major needs of agricultural development. It will be a big mistake to establish a biotechnology lab simply as a showcase.

Varietal Improvement. The progress in genomics has reached a point where genetic manipulation has been made to work for many crop species. It is however of utmost importance that a priority list of Philippine crops to be improved using genetic engineering be drawn up. We simply cannot afford to produce transgenic lines for all crops, as the costs of manipulating all the crops will be prohibitive. Furthermore, close collaboration with the agronomist, the animal husbandman, and the fisheries experts should be required in order to assure that the experiments meet the criterion of doability and robustness.

Diagnosis and Prevention of Plant and Animal Diseases. It will probably take time before the pests and disease of plants and animals could be completely controlled, if ever. However, there are now new tools, based on molecular biology, which are more sensitive and specific in diagnosing certain diseases and controlling certain pests. New, cheaper and more effective vaccines for animal diseases have been produced due to progress in immunology.

Biomass and Waste Processing. The biomass of the by- products derived from agriculture are often wasted and left unused. The production of value-added products from agriculture and fisheries can be realized by using appropriate and economically viable processing technologies to the raw materials. Many of these processing technologies are biotechnology-based such as the use of enzymes and other fermentation techniques. The application of biotechnology to transform biomass and processing wastes into food, feed, energy, and chemicals can add value to these by-products. The harmful environmental effects of these by-products could also be minimized using these biological transformation technologies.

Biosecurity. The entry of large amounts of fresh, frozen or processed food products into the country makes it important that these are tested for the presence of harmful substances or organisms before they are sold to the consumers. The recent events in other countries involving BSE and infected chicken and goats is a wake-up call for the Philippines to make sure all its food products whether locally produced or imported are safe for human consumption. Again, there are now many tools available through biotechnology that will enable us to apply rapid, sensitive and accurate tests on these food materials to determine their safety.

Product Standards. Product standards are important to ensure free movement of goods in the world market. The scientific basis for monitoring compliance with product standards, especially for exportable goods, involves procedures for laboratory analysis in order to assess with precision and accuracy the quality and safety of the products. The progress in immunology and biochemistry has resulted into the development of a number of highly accurate, precise and high-throughput analytical procedures to assess the quality of the products and monitor compliance with global standards. These tools have been applied to both fresh and processed foods and are now widely used in many countries.

Concluding Statements

The initiatives to increase investments in modern biotechnology to improve agricultural productivity are steps in the right direction. While financial resources will enhance the development of agricultural biotechnology, there are other factors that will influence its growth and development in the Philippines.

Modern biotechnology must be regarded as one of the tools in modernizing Philippine agriculture. Its role in varietal improvement, biosecurity, product standards, pest and disease prevention and management must be enhanced.

A critical mass of highly trained human resources in the natural and social sciences that will undertake the research and development activities in agricultural biotechnology must be assured. A massive program to allow bright, young Filipinos to pursue advanced degrees must be implemented immediately. For their thesis, these scholars must be encouraged to select research problems which are of highly relevant to the needs and priorities of the agriculture and fisheries sector of the Philippines.

The competent legal and regulatory systems to facilitate the conduct of research in agricultural biotechnology must be installed without delay. This will not only assist the researchers in the work but also enhance public confidence in biotechnology including genetic engineering.

In order to save lead-time while we are increasing the ranks of the researchers, the government might explore the outsourcing of research projects to selected laboratories abroad. This should cover mission critical areas that need to be addressed without delay.

Private sector participation in the development of agricultural biotechnology must be encouraged. The sustainability of these research and development activities can only in assured if they are able to serve commercial purposes. This may form the beginnings of an agricultural biotechnology industry and the much-needed commercial base for modern biotechnology to take-off in the country.

These are strong indications that modern biotechnology offers tools that can enhance the quality of our food and improve the manner in which we grow crops in order to make food more affordable and also protect the environment. Let us not forget that aside from genetic engineering, agricultural biotechnology offers other tools that are useful for crop improvement and crop management. These tools should enable our researchers to generate technologies and information to make our farmers competitive.

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List of Fora and Conferences on Biotechnology Sponsored or Co-Sponsored by NAST

Title	:	Media Forum on Biotechnology
Date	:	07 September 2000
Venue	:	Dusit Hotel Nikko, Makati City
Co-Sponsor	:	International Service for the Acquisition of Agri-Biotech Applications (ISAA)

Title	:	Science Information Forum on Human Genome
Date	:	11 September 2000
Venue	:	Traders Hotel Manila

Title	:	Science and Technology Legislative Forum on Biotechnology
Date	:	11 October 2000
Venue	:	Via Mare Penthouse, Philippine Stock Exchange Center, Mandaluyong City
Co-Sponsor	:	Philippine Council for Advanced Science and Technology Research and Development (PCASTRD)

Title	:	Science Information Forum on Rice Genome
Date	:	27 October 2000
Venue	:	Manila Hotel

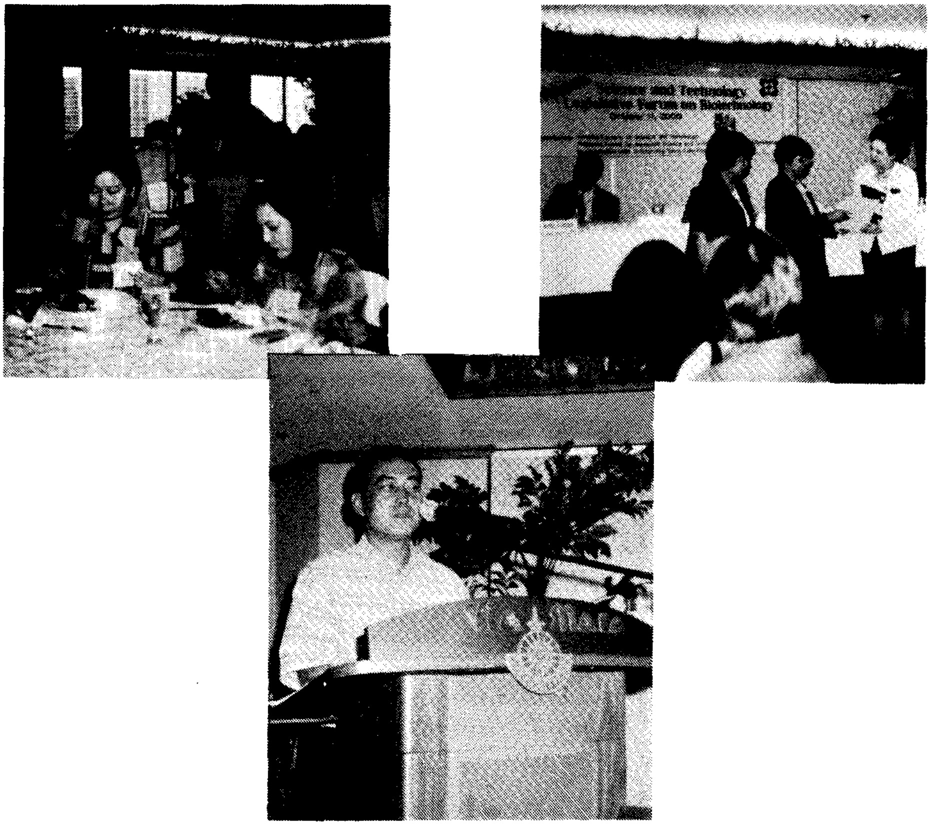
Title	:	Science Information on the National Committee on Biosafety of the Philippines (NCBP)
Date	:	10 May 2001
Venue	:	The Manila Hotel
Co-Sponsor	:	National Committee on Biosafety of the Philippines (NCBP)

Title	:	Philippine Society for Microbiology 30th Annual Convention and the 4th Asia-Pacific Biotechnology Congress
Date	:	16-18 May 2001
Venue	:	Waterfront Hotel, Cebu City
Co-Sponsor	:	Outstanding Young Scientist, Inc. (OYSI)

Title	:	Policy Forum on Genetically Modified Organisms (GMOs)
Date	:	16 July 2001
Venue	:	PHIVOLCS Auditorium , C.P. Garcia Street, Diliman, Quezon City
Co-Sponsor	:	Department of Science and Technology (DOST)

Media Forum

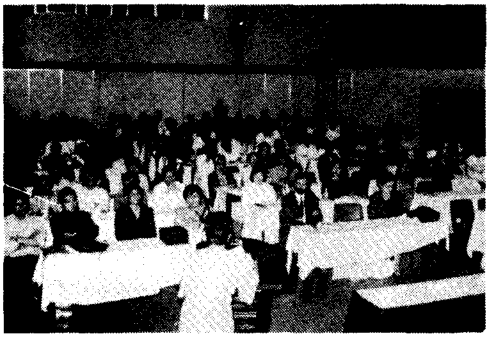
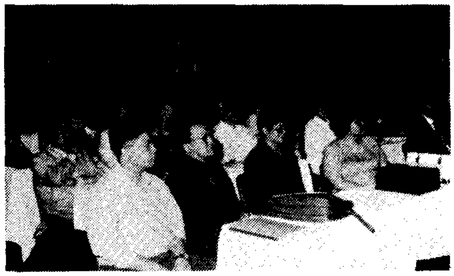
Human Genome



Legislative Forum

Rice Genome



Policy Forum on GMO's