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SUSTAINABLY PRODUCTIVE AGRICULTURE AND GENETICALLY MODIFIED CROPS

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ABSTRACT

Sustainable agriculture is 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 author emphasizes the need for sustainably productive agriculture in the 21st century because of increasing world population for which food production must be improved by from 40 to 80% for cereals. Such crop yield increases must also come primarily from higher biological yields and not from area expansion and more irrigation.

The author proposes that through modern biotechnology, crops may be genetically modified (GM) to raise yield celings, 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. While applications of modern biotechnology in health and industry are widely accepted, there are objections to and unease in uses of GM crops in food and agriculture. The paper discusses the risks, both technological and technology-transcendent, associated with biotechnology, and proposes.

To address the question of unequal access to modern biotechnology by developing countries such as the Philippines, the author further proposes that (1) strengthening of national capacity to conduct agricultural biotechnology R&D, (2) put in place the proper intellectual property rights (IPR) to encourage private sector to invest on the problems of Philippine agriculture and (3) provide appropriate incentives so that the new technoologies can be accessed by poor farmers.

Key Words: sustainable agriculture, biotechnology, genetically modified (GM) crops

I. 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.

II. 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 constitute 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.

III. 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 the major crop commodities are 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 and insect pests were obvious priorities 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.

IV. 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.

V. 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 of 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 the 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.

VI. 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.

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.

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.

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