MOBILIZING BIOTECHNOLOGY FOR DEVELOPING COUNTRY AGRICULTURE

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The paper briefly described modern agricultural biotechnology and its components: genomics, bioinformatics, transformation, molecular breeding, diagnostics, and vaccine technology. Among the components applied in agriculture, development of genetically modified (GM) crops with specific desirable traits is the most commercially advanced with 39.9 million hectares grown to such GM crops worldwide and sales estimated at US$2.1 – 2.3 billion in 1999. Based on the premise that modern biotechnology could be a powerful tool for improving productivity and sustainability of agriculture in developing countries, five major concerns and issues were discussed and recommended to be the foci for collective regional action. These are 1) managing risks associated with biotechnology; 2) promoting public sector investment in agricultural research; 3) private sector investments in biotechnolo9gy for agriculture in developing countries; 4) official development assistance (ODA) for agricultural biotechnology; and 5) managing intellectual property.

Introduction

Agriculture constitutes a very significant part of the economies of the countries in Southeast Asia and provides the livelihood of the greatest number of people. However, although the region as a whole has made significant progress in recent years in increasing average per capita incomes, rural communities, for the most part, remain poor (Lipton 1999). Thus, any means, any intervention that will further lift productivity in agriculture will be a positive step toward alleviating poverty.

Moreover, there is increasing realization that man, through his mere presence and increasing numbers, is putting intolerable pressure on the environment and the natural resources he is exploiting to meet his needs. The major sources of environment pressure are the rural industries of farming, fishing, and forestry. Thus, similarly, any technology that will save land, water, and forest resources, any technology which will diminish the need for environment-polluting farm inputs, will help conserve the environment and should be most welcome.

One such means, which has the potential to contribute to agricultural productivity and sustainability, and at the same time dramatically alter the course of agriculture, is modern biotechnology.

Biotechnology is defined as the use of biological processes for the development of products such as foods, enzymes, drugs, and vaccines. Biotechnology 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 narrowly refers to biological applications based on the new science of molecular biology. With the new knowledge in molecular sciences, it is now possible to identify specific genes; understand their function in the whole organism;

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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.

In classical or conventional plant breeding, gene transfers are limited to between varieties of the same species; occasionally, between species within the same genus; and rarely, between species belonging to different genera. Transferring novel genes between plant families, much less from bacteria to plants, were impossible. But now with modern biotechnology, these very wide genetic introgressions are possible.

In one sense, modern biotechnology is merely a 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 deployed in the past.

Status of Commercialization of Biotech-derived Products

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

- 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 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 at Tsukuba 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 in the characterization of the human genome. However, to be useful, these genomic maps should be accompanied by information indicating gene function (functional genomics). This will still take some time.

Marker-assisted breeding is in progress in many countries, including all the CGIAR crop centers. For example, the Asian Rice Biotechnology Network using molecular markers has succeeded in pyramiding bacterial blight resistance genes in a number of popular varieties. Many diagnostic kits have been developed to detect presence of specific races of plant pathogens. Recombinant DNA vaccine work is in progress for the control of East Coast fever in ruminants. Just to mention a few.

Among the modern biotechnology components applied in agriculture, the development of genetically modified crops with specific desirable traits (transgenic crops) has been the most commercially advanced. This has been going on for almost 20 years, although it was only in the past five years when commercial release and adoption of transgenic crops have 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 were 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 US and Canada accounting for 72 percent and 10 percent, 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 and insect (Bt) resistance.

The above observations are pivotal to the rest of this paper 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 Southeast Asia 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, among others, 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.

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 in 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 the United States who have adequate nutrition, these may still not be attractive enough. It would be better if the breeding objectives were low cholesterol, low sodium, high antioxidant, and “lite” farm produce.

One of the purposes of a keynote address is to prepare the stage for accomplishing the objectives of the conference. I have decided to depart from the topic assigned to me and instead dwell on how we mobilize biotechnology for agriculture in a developing country. I have selected five concerns/issues which, in my judgment, could very well be the foci for collective regional action.

I proceed from the basic premise that modern biotechnology could be a powerful tool for improving the 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 of intelligently deciding which aspects of change to accept and which to reject.

Managing Risks Associated with Biotechnology

We are all aware that there are strong, discordant voices against the desirability of genetically modified crops. Although there are some who absolutely reject modern science, by and large, those who have reservations do not necessarily object to modern biotechnology per se. Potential recombinant DNA vaccines against HIV, cancer, malaria and other serious human diseases are acceptable to all. The use of molecular markers to assist in plant breeding and for systematizing the management of biodiversity in plant genebanks are perceived as benign. In other words, of the six major components of modern biotechnology, opposition actually centers on the release and use of transgenic plants into which novel genes from unrelated species have been inserted.

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 newly introduced genes escaping to other organisms by outcrossing thus creating superweeds: and, in the case of insect-repelling genes, the possibility of killing beneficial non-target pests. Moreover, antibiotic resistance has been used as a marker for selecting genetically modified plants. There is fear that the gene might be transferred to bacteria that cause disease in man.

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 that have the potential to generate allergenic substances.

The possibility of introduced genes "escaping" in the wild through outcrossing between the genetically manipulated transgenic plants with wild relatives cannot 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 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 surviving and flourishing over their competitors in the wild are extremely low 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 field management 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 pests 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 British 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 (Anon 1999). Indeed, a large number of bacteria present in the gut already carry resistance to several antibiotics, including kanamycin and ampicillin. Nevertheless, the 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 buildup is discouraged by, for example, creation of insect refuges amid 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 the 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 than 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 forestall and anticipate the debate on biotech products raging in the West.

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 and poor farmers within the same communities, and the further loss of biodiversity should the new transgenic varieties become too successful and displace 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 conference today because we have to aggressively address both concerns if we were to succeed in exploiting the potential of modern biotechnology to advance our respective national purposes now, and not much later.

Promoting Public Sector Investment in Agricultural Research

Although our topic in this conference is narrowly agricultural biotechnology, the broader issue of declining public support for agricultural research in general ought to be of greater concern to all of us. In both developed and developing countries, agriculture as a sector is increasingly being marginalized and its share of public expenditure progressively declining. Agricultural support services, including research, are being phased out with the expectation that the private sector will take over the slack.

This is not a very serious problem in the developed economies because they have well-developed agriculture-based private sectors with strong research base. In fact, in the US and Europe private sector investments in biotechnology already dwarf public sector investments.

But this is not the case in most developing countries where private sector research in agriculture is practically non-existent. Without the public research institutions, the small farmers are really left on their own.

For us in Southeast Asia, there could very well be a momentary surge of public support for agricultural biotechnology but this will not do us much good in the long run without a sustained effort for complimentary agricultural research in conventional plant breeding, integrated pest management, integrated natural resources management, postharvest handling and processing, in rural social sciences and rural policy research.

So even as we fight for our share of public funds for agricultural biotechnology, we have to keep pressing as well for support for the rest of the agricultural education and research system.

Private Sector Investments in Biotechnology for Agriculture in a Developing Country

Since modern biotechnology in all of its dimensions is still at its infancy, large investments are still needed to push the frontiers of knowledge. Given the urgency and the prospects for recovering investments, biotechnology for the understanding and control of debilitating human diseases and genetic disorders naturally attract the greater bulk of global investments, both public and private. Nevertheless, agricultural biotechnology has been receiving a healthy share of private sector investments.

However, with the effective lobby against genetically modified crops in Europe, the new life science companies are retreating from their commitments to agricultural biotechnology. There is a real danger that private sector investments in agricultural biotechnology will slow down.

Moreover, as shown by the data on release and adoption of transgenic crops, the private sector investments in agriculture had been exclusively on commodities and traits for commercial growers in developed countries.

Thus, the challenge is two-fold: 1) encouraging global private sector investment in agricultural biotechnology in general, and 2) diverting some of those investments to address commodities and traits of relevance to the needs of developing countries.

We should therefore, as a first measure, discard the notion that the private sector companies investing in agricultural biotechnology are enemies. All of us workers in agricultural science are allies and ought to work together to arrest the marginalization of agriculture in the priorities of the governments both in developed and developing countries.

Intellectual priority rights are necessary evils. Foreign and domestic companies will hesitate to invest in research and development without guarantee of recognition and protection of their IPR. We have to lobby to set into place the appropriate legislation on intellectual property rights in our respective countries. We must comply with the minimum requirements set by the international conventions but must, in doing so, safeguard the interests of the farmers, particularly the small subsistence farmers and local entrepreneurs.

The small unorganized subsistence farmers in developing countries are not an attractive target market for multinational biotech companies. They are dismissed as not worth the effort. However, if we disaggregate the activities private companies have to undertake to develop such markets and engage the public research agencies and the domestic private sector to take on some of these activities where they have competence, the attitude of these big biotech companies may change.

There are at least five sets of activities in the research, development, and marketing chain: basic research, strategic research, applied research, adaptive research, and marketing. The private companies have a great comparative advantage in strategic and applied research. On the other hand, national research institutions and domestic private companies have local expertise and have people deployed in the countryside and should be more effective in carrying the adaptive research and local marketing functions. Since the private seed companies will be exploiting principally the research spillovers from their major operations elsewhere, the marginal costs to them in strategic and applied research will be minimal. It should be possible to explore such co-development and similar partnership arrangements.

The International Service for the Acquisition of Agri-Biotech Applications (ISAAA) had been brokering such partnerships between private biotech companies and some developing countries. They have a number of very successful experiences, which demonstrate that such partnerships are possible. In the joint ventures they have brokered, the developing countries typically contribute adapted germplasm and the external private sector provide the proprietary gene that enhance the product (James and Krattiger 1999). For now, the private biotech companies provide their technology for free but as the partners gain experience and confidence their relationships can mature to a more business-like basis.

ODA Support for Agricultural Biotechnology

The network of international agricultural research centers (IARCs) of the Consultative Group for International Agricultural Research (CGIAR) has been the principal source of improved germplasm and biotechnology training, information, and materials for many developing countries. The IARCs rely heavily on official development assistance (ODA) funds provided by international bodies like the World Bank, FAO, and UNDP; the regional development banks like the Asian Development Bank, as well as by the OECD countries.

For the most part, the IARCs are not engaged in basic biotechnology research. They rely on the universities, advanced research laboratories, and the private sector for their information and material requirements and specialize in applying biotechnology information and techniques to meet the agriculture needs of developing countries.

They work on the three principal cereals – rice, maize, and wheat. However, they also work on pearl millet and sorghum; pigeon pea and beans; and roots and tubers like sweet potato, cassava, and yam which poor people in developing countries eat. The IARCs working closely with their national counterparts try to increase the yields of these crops as well as improve their nutritional quality.

Their target traits include resistance to pests and diseases as well as tolerance to drought and to adverse soil and climatic conditions, which are the common problems of marginal farmers in developing countries.

The CGIAR centers' budget for biotechnology is less than 10 percent of the total $340 million CG system research budget. They can use more if additional official development assistance (ODA) support were forthcoming. It will be a terrible loss to the developing countries should the IARCs be phased out for lack of political support.

Unfortunately, there are disturbing signs of flagging donor interest in international public agricultural research. We in the developing countries, who have been benefiting from CGIAR research, should demonstrate our solidarity and support for the IARCs so that the co-sponsors like the World Bank, FAO, UNDP, the regional banks and the OECD countries will maintain, if not raise, their support for public international agricultural research, including biotechnology. With the anti-biotechnology lobby groups attaining ascendancy in Europe, this demonstration of political support for the research activities of the CGIAR from the developing countries will be most timely.

Managing Intellectual Property

Agricultural research managers in developing countries are accustomed to managing people, funds, facilities, and infrastructure and even the political goodwill of their respective institutions. The management of intellectual capital is a relatively recent phenomenon brought about by the massive entry of the private sector in the hitherto public domain of agricultural science. Information and genetic materials that used to be freely received or shared now must be paid for, leased, exchanged, inventoried, and protected.

Cohen (1999) identified five management tasks at the institute level which require close attention from research managers:

1) Clarifying institutional roles – legal and regulatory frameworks; institutional policies for assembling intellectual property; rights and obligations of scientists, of research partners, of recipients
2) Identifying intellectual property – inventory of intellectual property used in the institution
3) Securing ownership – disclosure of intellectual property generated by researchers; registration of intellectual property rights
4) Managing intellectual property – liaison with suppliers, enforcement of IPR
5) Technology transfer and marketing – liaison with technology users, licenses and material transfer agreements, remuneration strategy

Managing the institution's intellectual property portfolio is a complex and demanding challenge for which most research managers are not prepared and properly trained. However, the appropriate institutional mechanisms need to be installed, staff need to be made aware of their obligations and rights under the new regime of intellectual ownership and the management must be able to deal with their various publics to gain access to other institutions' technology and to be compensated for their own. This is one subject area where our developing country agricultural research institutions can benefit from external assistance and a collective regional effort.

Conclusion

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 many manipulations of the factors of biological 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.

However, 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 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-transcending 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.

Technology-transcended 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.

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

The challenge therefore to developing countries is how to access and mobilize biotechnology for their national purposes. In addition to acquiring the actual capacity to conduct biotechnology research and development themselves, five areas of concern were highlighted as requiring national attention and possible foci for regional cooperation, namely:

- Managing risks associated with biotechnology;
- Promoting public sector investment in agricultural research;
- Private sector investments in biotechnology for developing country agriculture;
- ODA support for agriculture biotechnology; and
- Managing intellectual property.

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