Regional Development in Agricultural Biotechnology: Capacity Building in the 21st Century

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The paper briefly reviewed global trends in agricultural biotechnology research and applications, including commercialized products. Two major issues were cited to affect biotechnology in agriculture, food, medicine and natural resource management: intellectual property rights and biosafety. Almost all ASEAN countries, except Indochina, have their own biosafety guidelines which are in general, based on those from developed countries such as the USA, Japan and Australia. Field testing of genetically modified (GM) crops has been done in China, Japan, Thailand, Philippines and Indonesia. However, only China has allowed commercialization of GM crops. Further, two major problems in biotechnology R & D in the region were identified: shortage of skilled manpower in biotechnology (and other areas as well) and linkages between research and commercial sectors. Capacity building has been addressed in the region through various networks including the Asia-Pacific International Molecular Biology Network (IMBN), the Asian Rice Biotechnology Network, the Asian Maize Biotechnology Network and the Papaya Biotechnology Network. It was recommended that international and regional organizations in the region help developing countries in capacity building.

Green Revolution had saved the world food crisis during the late 1960s and early 1970s. During that period, the global population was about 3.7 billion. At present, world population is approximately 7 billion and it is anticipated to reach 10 billion by 2050 (Falvey 1996). The majority of this population will be in developing, resource poor countries. The increased demand for food will therefore come from these countries. While demand for food increases, the potential for meeting that demand decreases (Altman 1995). The adverse factors are ecological and socioeconomic. The per capita availability of land and water steadily goes down, while biotic and abiotic stresses limiting crop production are increasing. It is challenging how agriculturists and policymakers could make a more rapid growth in food production to cope with the rapid increase of world population.

Food security has become an important issue in the 21st century. Modern agriculture may not be able to guarantee for food sufficiency. During the period of the Green Revolution, traditional technologies had been used together with naturally rich resources in the production of food. With natural resource deterioration, it is necessary that advanced technologies such as biotechnology should be applied in order to improve productivity. Advanced biotechnology -- genetic engineering -- allows the transfer of a desirable gene from one distant species to another. It has become an effective means of genetic transformation that could not be realized through traditional breeding. It is a way to precisely engineer an organism to perform as one wishes to increase productivity and quality of the products.

Biotechnology is, in fact, not new but has been used for centuries. It involves any technique that uses living organisms, or parts thereof, to make or modify products, to improve plants or animals, or to develop microorganisms for specific uses. Fermentation

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and plant tissue culture are probably considered as old biotechnology that has helped produce foods and alcoholic beverages. These technologies are still useful, especially with the combination of modern science such as molecular biology, biochemistry, molecular genetics, and electronics. Genes in all living organisms could be discovered through the "Genome Research" and their functions known. At present, the "Human Genome" and "Rice Genome" are considered to be the largest operation, with the involvement of many national programs. It is anticipated that many applications could be made from knowledge coming out from genome research. This includes the application in agriculture through agricultural biotechnology.

This paper will give some background of the agricultural biotechnology development in the Southeast Asian region. Capacity building to cope with a rapid technology development, together with problems and issues such as biosafety and intellectual property, will be discussed.

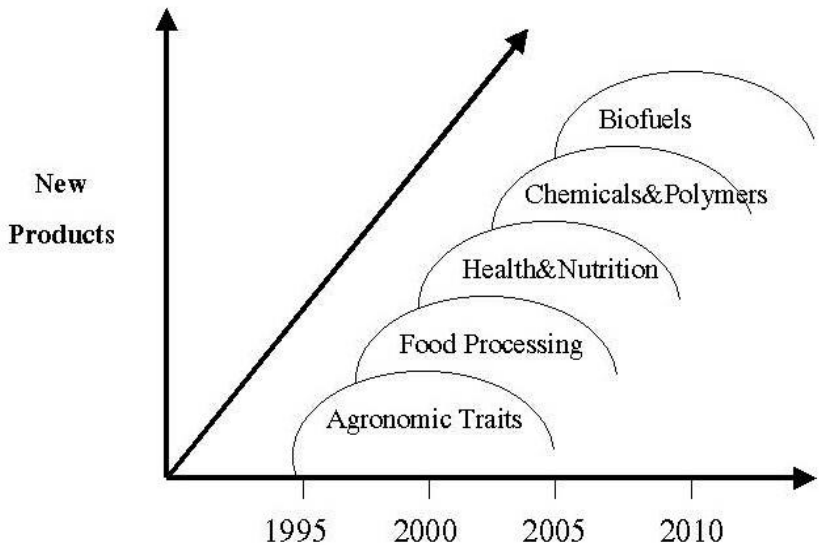
Agricultural Biotechnology

Biotechnology has been recognized as an important tool in improving a broad spectrum of industry, human health, and environment. Traditional biotechnology includes fermentation, tissue culture for plant propagation, vaccine production, bioinsecticides, and biofertilizers as well as other uses of microorganisms for various purposes. Modern or advanced biotechnology has been rapidly developed using DNA technology. It includes genotypic manipulation by using molecular aided selection and genotypic modification through genetic engineering.

Agricultural biotechnology covers broad areas of research and development leading to the improvement of microorganisms, plants and animals. Present fermentation industry uses improved strains of microorganisms, traditionally improved or genetically modified. The application in plant and animal improvement follows a similar process. DNA technology could be used in various ways, from the identification of individuals to the genotypic manipulation and modification.

Plant biotechnology promises to deliver new products and new industries (Fraley 1994). Figure 1 illustrates that many new products are expected to be developed in certain time periods. It is anticipated that biotechnology will lead to new opportunities to develop foods with different functional compositions as well as fruits and vegetables with better storage properties and flavor. We could expect to see plants as micro-factories producing some pharmaceutical products, biodegradable plastics, and biofuels. Through the application of genetic engineering technology, it could be possible to produce those target products.

Figure 1. Potential new products developed in certain periods (Fraley 1994)



Modern technologies in animal breeding represent a dramatic change that is, nuclear transfer, cloning, sexing, and transgenic biology may generate dramatic shifts in the phenotypes of animals (Powell 1995). These changes may bring new benefits to agricultural development regardless of potential problems they may pose. Recombinant DNA technology has been used in improving growth rate, meat and milk production, sanitation, feed quality, and others.

Genome Research

Advanced biotechnology allows the genetic study of life forms deep into the molecular level. At present, the US is the world leader in the Human Genome Project, which is projected to be completed in 2005 (Wilairat 1999). The International Rice Genome Sequencing Project (IRGSP) was launched in 1998 with 10 participating countries, namely: Japan, US, Canada, UK, France, Korea, China, Taiwan, India and Thailand (Vanavichit 1999). Brazil has decided to join the group in 2000 and that added up to 11 countries in the consortium. Besides rice genome, other crop species such as tomato, and animals such as shrimp, are under the early phase of genomic research. The information from genome research, when completed, could lead to the development of many valuable useful products such as pharmaceutical products, new treatments for diseases (human, plant and animal diseases), new plant varieties and animal breeds, as well as new food products.

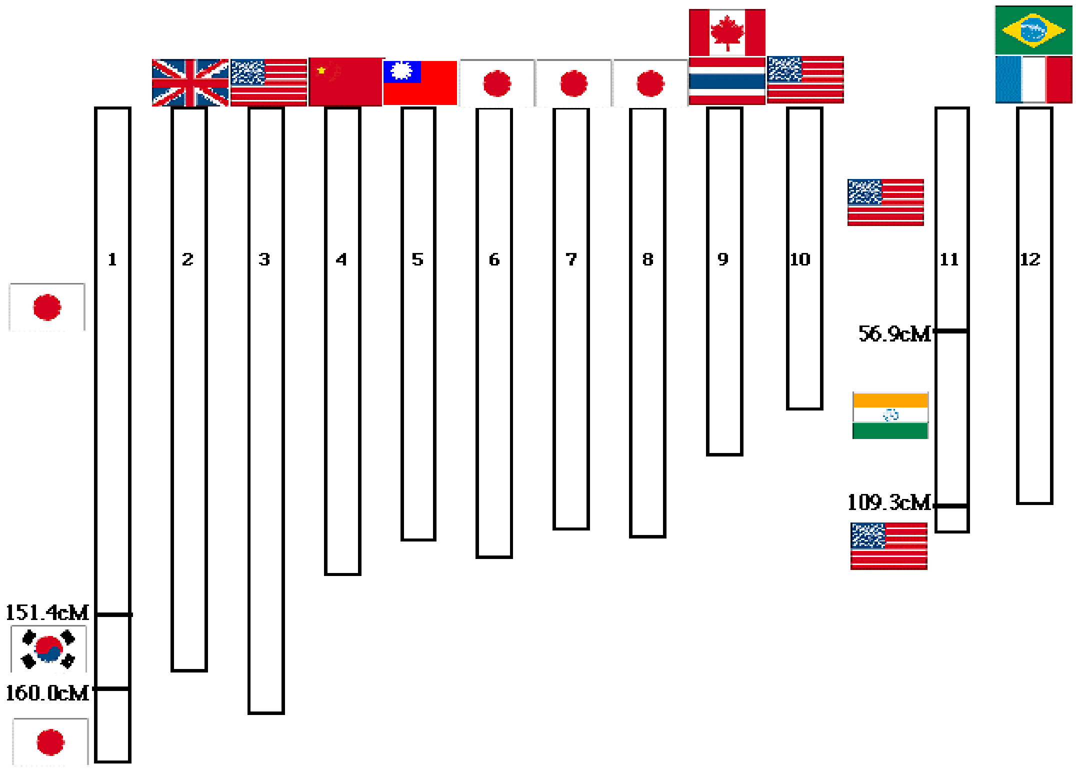


Figure 2. Rice Genome Research Consortium of 11 Participating Countries.

The Rice Genome Consortium has agreed to sequence the Japonica rice, Nipponbare. Each country has selected certain chromosome for sequencing as illustrated in Figure 2. It was also agreed that each country should contribute at least 1 kb annually (Vanavichit 1999). The Japanese Rice Genome Project (RGP) in Tsukuba has been working on genome mapping using this rice for quite some time (Sasaki 1996). Recently, Monsanto company announced that it has been engaged in rice genome sequencing for a number of years in a collaborative project with an US university. The first "working draft" of the rice genome will be delivered to the Ministry of Agriculture, Forestry and Fisheries (MAFF) of the Government of Japan on behalf of the IRGSP. Then IRGSP will make it available to its members. The sharing of the company's data will help advance the work of the IRGSP member by four to eight years (Monsanto Press Release 4 April 2000).

Recent work indicates that the grass genomes – wheat, rye, barley, maize, sorghum, millet, and rice -- have similar genetic maps over large blocks of the chromosomes (Vanavichit 1999). These synthenic relations are important in applying knowledge from rice genome sequencing. It is anticipated that there will be many new areas for research and development that are related to crop improvement after the completion of the rice genome research.

Modern biotechnology—genetic engineering

Modern biotechnology means the application of:

a. *In vitro* nucleic acid techniques, including recombinant DNA and direct injection of nucleic acid into cells or organelles, or

b. Fusion of cells beyond the taxonomic family, that overcome natural physical reproductive or recombination barriers and that are not techniques used in traditional breeding and selection (UNEP Biosafety Protocol Official Text 23 February 2000). So modern biotechnology is, in fact, the genetic engineering technology that results in the production of "**genetically modified organisms –GMOs.**" In fact, molecular genetics could be used in two ways in plant breeding:

   i) **Molecular marker assisted selection (MAS).** Once the trait is physically identified, a molecular marker for that trait or gene could be developed and used in selection. The resulting "improved variety" will be a normal plant variety.

   ii) **Genetic engineering.** This technology involves the gene modification within the species or the gene transformation across the species, family, and genus. The resulting transgenic organisms are of the genetically modified organisms or GMOs.

Commercialization of Transgenic Crops

Between 1996 and 1999, 12 countries, 8 industrial and 4 developing, have contributed to more than twenty-fold the increase in the global area of transgenic crops (James 1999). In 1999, the area increased from 12.1 million hectares to 39.9 million hectares, an increase of 44 percent (Table 1). Seven transgenic crops were grown commercially in 12 countries in 1999, three of which were Portugal, Rumania, and Ukraine, grew transgenic crops for the first time. Table 2 shows the distribution of the seven crops and Table 3 the dominant transgenic crops in 1999.

Three crops still dominate GM plants in the field—maize, soybeans, and cotton. The trait most widely spread by the private sector is herbicide resistance (Table 3). Insect resistance via a gene to express Bt toxin is the second main trait inserted. Lipton (2000) reviews the role of genetically modified plants and stressed the importance of benefit to poor farmers. Presently available commercial varieties of GM crops mainly involve input trait technology such as insect and disease resistance and herbicide tolerance. More research and development is now emphasizing the output traits such as yield, quality, nutritional content, and special chemicals. Agronomic characteristics such as salt tolerance, drought tolerance, and other desirable plant types are under development. If these desirable traits are inserted into cultivated crops, poor farmers will benefit from this technology because of less input used, resulting in low production cost. More important is the reduction in chemical usage leading to a more sustainable agriculture.

Table 1. Global Area of Transgenic Crops in 1996, 1997, 1998 and 1999.

	Hectares (million)	**Acres (million)**
1996	1.7	4.3
1997	11.0	27.5
1998	27.8	69.5
1999	39.9	98.6

Source : Clive James, 1999.

Table 2. Global Area of Transgenic Crops in 1998&1999: By Crop (million hectares).

Crop	1998	%	1999	%	Increase	(Ratio)
Soybean	14.5	52	21.6	54	7.1	(0.5)
Corn	8.3	30	11.1	28	2.8	(0.3)
Cotton	2.5	9	3.7	9	1.2	(0.5)
Canola	2.4	9	3.4	9	1.0	(0.4)
Potato	< 0.1	<1	<0.1	<1	<0.1	(--)
Squash	0.0	0	<0.1	<1	(--)	(--)
Papaya	0.0	0	<0.1	<1	(--)	(--)
Total	**27.8**	**100**	**39.9**	**100**	**12.1**	**(0.4)**

Source : Clive James, 1999.

Table 3. Dominant Transgenic Crops, 1999.

Crop	**Million Hectares**	**% Transgenic**
Herbicide tolerant Soybean	21.6	54
Bt Maize	7.5	19
Herbicide tolerant Canola	3.5	9
Bt/Herbicide tolerant Corn	2.1	5
Herbicide tolerant Cotton	1.6	4
Herbicide tolerant Corn	1.5	4
Bt Cotton	1.3	3
Bt/Herbicide tolerant	0.8	2
Total	**39.9**	**100**

Source: Clive James, 1999.

Problems and Issues

Gene technology is an extremely powerful tool in agriculture, food medicine and natural resource management. However, its applications is one of the most controversial subject with at least two important issues: biosafety and intellectual property. It is very important to have a better understanding of these issues.

Intellectual Property Rights

Intellectual property rights (IPRs), as legal instruments, are of increasing importance in encouraging industrial development and economic growth. There have been efforts in the movement toward unified, global intellectual property rights among developed countries. At the same time, developing countries are resisting, both formally in international fora and informally through less-than-aggressive administration of their own intellectual property rights (IPR) legislation . As a result, considerable international tension and animosity exist between most developing countries and many developed countries.

At present, intellectual property issues are attracting the interest of people at all levels in Asia. Researchers are becoming more aware of the issue. They realize the importance of protecting their inventions and, at the same time, are aware of the potential consequences of using proprietary technologies. In fact, the patenting of life forms are not yet allowed in most developing countries. Few countries in Asia, Thailand included, have come up with the Plant Variety Protection (PVP) system. Thailand just completed its PVP Act and, with the parliament's approval, its implementation is under way. The key elements in the PVP Act are to have the protection of new varieties as well as the old, traditional varieties, and the wild plant species.

Biosafety

The application of biotechnology in agriculture and food has been around for a long time. However, recent developments in applying advanced biotechnology, genetic engineering, in agriculture and food production have drawn public attention on safety, or biosafety of the new biotechnologies and their products. Thus biosafety concern is quite new to many countries and is not widely known even among the academe and certain regulatory agencies. The issue of biosafety could lead to world trade conflict if some important aspects such as labelling cannot be resolved. There are at present several issues related to biotechnology and some of these are:

- health and safety concerns;
- ethical questions regarding introduction of traits from one species to another;
- the possibility of resistance developing in weeds, insects, and diseases;
- the potential for biotechnology to limit farmers' approaches to crop management; and
- the impacts on biodiversity so that a wide variety of species is maintained.

Biosafety Development in Asia

Almost all countries, except a few such as Indochina, have their own Biosafety Guidelines (Sriwatanapongse 1999a). These guidelines are relatively well harmonized because they were developed based on the biosafety guidelines from developed countries such as the US, Japan, and Australia. The United Nations Environment Program (UNEP) has been also actively involved in this by holding regional meetings. The Asian Regional Biosafety meeting was held in New Delhi, India in January 1999 where capacity building of developing countries were discussed.

In Asia, field testing of GM plants has been done in China, Japan, Thailand, the Philippines, and Indonesia, while commercialization has been made only in China (James and Krattiger 1996). In order to have a systematic field testing of GM plants, Thailand established the "Biotechnology Product Development Center" where agricultural biotechnology products will be subjected to a systematic testing up to commercialization under the highest standards of safety evaluation.

Capacity Building

Developing countries have faced similar constraints in biotechnology research and development leading to commercialization. The two major problems identified lay in the area of capabilities and linkages between the research and commercial sectors. Most countries face a shortage of skilled personnel in biotechnology as well as in other areas. In Thailand research manpower has been estimated to be only about 2 per 10,000 population compared to 2 in Indonesia, 1 in Malaysia, 20 in Australia, 26 in Korea, 23 in Taiwan, 60 in Japan and 40 in the US in the same period (UNDP Human Development Report 1997). There is a need for a critical mass of scientists to carry out research work. Another limitation is financial support with only 0.2-0.3 percent of the GNP coming from the government budget and a very small share from the private sector. During the 7th National Economic and Social Development Plan the budget for R&D was set for 0.5 percent of the GNP and 0.25 percent should come from the private sector. Other developing countries in the region have more or less the same level of financial situation.

Capacity building in biotechnology in Asia-Pacific has been assessed (Sasson 1993, Tzotzos and Skryabin 2000, Sriwatanapongse 1999). Almost all countries in this region have prepared to cope with a rapid development in biotechnology. Each country has come up with its infrastructure and human resource development as well as reasonable financial support. Capacity building has been made also through various networking, few of which will be discussed.

IMBN--International Molecular Biology Network

The Asia-Pacific International Molecular Biology Network (IMBN) was established in 1997 on the premise that molecular biology and biotechnology can contribute greatly to the benefit of mankind (Yuthavong 1999). The Network intends to facilitate development in molecular biology and biotechnology through cooperation and collaboration with various organizations. The Network shall have the following program areas:

- To encourage scientists and supporting institutes to conduct research and to provide training, educational, and skills enhancement opportunities in molecular biology and genetic engineering;
- To help coordinate the conduct of research and development activities in laboratories designated by supporting institutions as Asia-Pacific IMBN laboratories (IMBL);
- To cooperate with industry to identify areas of common interest for promoting the work of scientists and institutions working with the Network.

ARBN – Asian Rice Biotechnology Network

It has been recognized by rice-growing countries in Asia that biotechnology could provide powerful new tools for rice improvement. Universities and rice research institutes across the region are receiving funding to improve their capacity and capabilities that will enable them to conduct basic and applied research in this field. The International Rice Research Institute (IRRI) in Los Baños, Laguna, Philippines shares this enthusiasm for rice biotechnology. Since circa 1988, it has devoted about $2 million annually to research programs in tissue culture; wide hybridization; genetic engineering; DNA marker technology; and DNA fingerprinting of pests, diseases, and rice germplasm. The ARBN was initiated by IRRI in 1993 to provide a vehicle for collaborative research in these areas with universities and rice research institutes of the national agricultural research systems (NARS) of Asia.

The objectives of ARBN are:

- To promote manpower and infrastructure development for biotechnology at selected NARS institutes through joint research activities and training coordinated by IRRI, and

- To generate biotechnology tools and products for use by NARS through research and infrastructure development at IRRI.

DNA marker technology and genetic engineering are key innovations that would lead to the improvement of rice research and development. ARBN has been set up to provide a comprehensive mechanism for NARS and IRRI to work together in these two important areas.

ARBN was established with funds provided by the Asian Development Bangk (ADB) and the German Government's Bundesministerium fur Technische Zusammenarbeit (BMZ). ADB prefers to support research and infrastructure development at NARS with additional funding for training and shuttle research by NARS scientists at IRRI. BMZ has been supporting research and development at IRRI in developing biotechnological products that will be of direct use to NARS.

There are three types of membership:

- Full member: China , Indonesia, Pakistan , Philippines and Thailand
- Associate member : Vietnam, Bangladesh and Sri Lanka
- Supporting member : Japan and Germany

The ARBN Steering Committee (SC) assists IRRI in guiding the work. SC consists of five senior biotechnologists from member countries and one from IRRI (Deputy Director General for Research). A chairperson is elected among representatives of member countries who take turns every two years. One of the IRRI ARBN staff acts as its Coordinator. There are 7-8 resource persons from supporting countries and donors joining the SC meeting held annually. The task is to review progress and approve workplans, to discuss general operational matters, and to make decisions concerning strategy and funding. The ARBN coordinator manages the day-to-day work with responsibility in maintaining strong links among stakeholders in the Network (donors, steering committee, and NARS and IRRI scientists).

There is a diversity of collaborative mechanisms under ARBN. Some ARBN activities are conducted at NARS principally by NARS staff, and some are conducted at IRRI by IRRI staff. These research activities are supported by training activities at IRRI and in-country. The ARBN Training and Shuttle Research Laboratories accommodates 10-15 trainees and is located within the Biotechnology User Laboratories at IRRI, giving NARS scientists the opportunity to learn a wide range of techniques and use instruments that may not be available at their own institutes. In addition, ARBN enables NARS scientists to conduct research activities in collaboration with IRRI scientists at IRRI and in-country-the so-called **"Shuttle Research."**

AMBIONET --Asian Maize Biotechnology Network

CIMMYT (International Maize and Wheat Improvement Center) established the AMBIONET with similar objectives as the IRRI ARBN. Experience shows that, through training and region-wide collaboration, national programs can achieve the critical mass of scientific human capital needed to sustain effective agricultural research. The network functions through collaborative research and a range of training and information sharing activities. AMBIONET has been in operation since April 1998 with financial support from the Asian Development Bank (ADB).

General Goals of AMBIONET are:

- Increase the scientific capacity of the region's maize biotechnology Programs so as to ensure higher, more stable, and more sustainable maize productivity for farmers in Asia, and thereby help meet the region's rapidly growing demand for maize.
- Develop sustainable, environment-friendly and natural resource-conserving maize production systems.

General Objectives:

- Empowering national programs to effectively use modern biotechnology for maize improvement.
- Strengthening the ability of national programs to identify and overcome the key production constraints faced by maize farmers in the region.
- Generating and distributing improved maize cultivars, and implementing improved crop management strategies, in collaboration with existing national program personnel, and by using existing facilities and other resources more effectively, avoiding duplication of effort.
- Ensuring the long-term sustainability of integrated maize and biotechnology research programs in participating countries.

Membership and organization are:

- Member countries are China, India, Indonesia, the Philippines, and Thailand.
- The Steering Committee consists of a representative from each member country and one of them is elected as the chair. The committee provides guidance on the programs and activities of the network and meet once a year.
- CIMMYT has appointed one staff as the Network Activity Director and one as a coordinator. Both of them are in the Steering Committee.

AMBIONET emphasizes the development of molecular markers for specific traits and use them in selection of plants – the so-called "MAS or molecular marker aided selection." The resulting variety from this technique of improvement will be the same as those developed using traditional breeding. However, genetic engineering that will lead to the production of transgenic plant varieties will be carried out at a later stage.

Papaya Biotechnology Network of the Southeast Asia

ISAAA (International Service for the Acquisition of Agri-Biotech Application) has supported the establishment of this network in 1998. The objectives are similar to those of ARBN and AMBIONET in emphasizing the capacity and capability building among member countries. It may have only one distinct feature in terms of greater involvement of private sector, forming a so-called "**partnership arrangement**". More emphasis has been placed on dealing with biosafety and IPR issues.

Member countries are Malaysia, Indonesia, the Philippines, Thailand, and Vietnam. ISAAA has been playing a key role in technology transfer with the following objectives (James 1999):

- To facilitate the transfer and adoption of proprietary agri-biotechnology applications to increase the productivity of food and feed in Asia, within the context of sound and sustainable strategy.

- To build national capacity in agri-biotechnology in member countries and facilitate its sharing within Asia through networking.
- Build institutional capacity in regulatory oversight that will ensure the safe testing and adoption of biotechnology products and to address the policy issues of biosafety, food safety, biodiversity, and intellectual property rights related to plant genetic resources.
- To foster a significant effort in human resource development through product-specific training that will ensure the long-term sustainability of activities.

Papaya networking has been used as a pilot project in partnership arrangement. ISAAA has played a role in negotiating with private companies who own needed proprietary technologies. In this case there are two: the delayed ripening gene of Zeneca and PRSV (papaya ringspot virus) resistance gene of Monsanto.

The principles in the arrangement of the Network are:

- The company would give the member country a license-free use of technology.
- The technology could be used only for papaya transformation.
- Commercialization of products could be made only within the country and among member countries.

Future Development

In reviewing the capacity and capability of developing countries in technological development, it is quite clear that the chance to catch up with developed countries is slim. The lack of human and financial resources coupled with poor infrastructure and research environment have caused a great delay in development. At present, it is not possible for a research team in developing countries to compete with researchers in developed countries in technology development. It may take a long while to be able to do so. Therefore, careful strategies should be made in each country. The following suggestions could be made:

1. Building up public education and awareness. It is important to convince the government, public and private agencies, including all stakeholders, to believe that biotechnology is a key in the country's development.
2. Establish a national policy on biotechnology. This will allow for a clear direction for implementation.
3. Establish an infrastructure for a more effective implementation. It may be necessary to improve the present system of working through the reorganization of the government agencies.
4. Encourage partnership arrangement. With scarce resources partnership arrangement through networking with other agencies in the country and outside, as well as with the private sector is an ideal approach.

At present, there are many international and regional organizations that may help developing countries in capacity building. For example, UN agencies, CGIAR Centers

(IRRI, CIMMYT, etc.), ISAAA and SEAMEO SEARCA are among those potential contributors.

Concluding Remarks

Biotechnology – one of many tools of agricultural research and development -- could contribute to food security by helping in the promotion of sustainable agriculture centered on smallholder farmers in developing countries (Serageldin 1999). Agricultural biotechnology, especially genetic engineering, will play an important role in improving agricultural productivity, food, fiber, pharmaceutical, and other industrial products. At the same time, it has been under debate with opposing factions making strong claims of promise and peril. The concerns on biosafety as well as on intellectual property cannot be ignored. Effective regulatory mechanisms and safeguards need to be universal so that the impact of agricultural biotechnology is both productive and benign.

There has been widespread public unease about biotech products. In Europe consumers demand to have choice to eat genetically modified foods or not. In the US, foods derived from GMOs seem to be acceptable to consumers. In fact, the genetic modification of plants does not differ to such an extent from conventional plant breeding. Foods derived from these plants are substantially equivalent to those developed by traditional means. The development will make a substantial contribution to food security and truly benefits the poor. There is a moral imperative to make GM crops readily available to developing countries that want them to help combat world hunger and poverty.

There may be plenty of food at present but not for everybody. An excerpt cited by Dr. C.S. Prakash 1999 said, **"A man who has food has several problems. A man without food has only one problem."** As former US President John F. Kennedy said, "We should not let our fears hold us back from pursuing our hopes." So let us continue to move forward thoughtfully with biotechnology in agriculture, with appropriate measures (Glickman 1999).

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