Thailand: Biotechnology for Farm Products and Agro-Industries

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Before the economic crisis in 1997, Thailand was named one of the Asian Newly Industrialized Countries (NICs) with an average economic growth rate of 8-9percent during 1993-95. The crisis resulted in a negative growth rate of –7.8 percent in 1998. Moreover, the impact of the economic recession in the world market has affected the country's total exports, which amounted to US$57 billion (US$1=31.5 bahts) and US$53 billion (US$1=41.6 bahts) in 1997 and 1998, respectively. The economic growth forecast for 1999 is expected to be around 3-4 percent.

Efforts to revive the economy are currently being implemented in both the government and the private sector. The linkage between the status of science and technology and the economic status of a country has long been noted. At this stage, it is crucial for Thailand to increase the technological capability of the country, to make efficient use of its resources, and to reduce the cost of production, thereby increasing economic growth and competitiveness.

Despite the country's industrialization, agriculture has remained a significant part of the economy. Thailand has been moving towards industrial-based agriculture and has focused on the development of postharvest and processing technologies that are the major problems for industry. Biotechnology has become the country's priority for research and development (R&D) and for the benefit of the private sector as well as rural development.

Farm Products and Agro-Industries

Though most of the economic sector registered negative growth rates, the agriculture sector has expanded by about 2.8 percent in 1998. Thailand's Ministry of Agriculture estimated that farmers would earn 650 billion bahts (US$16.2 billion) for 1998, of which 74 percent would come from the major products listed in Table 1.

Estimated earnings might only be 404 billion baht (US$ 9.85 billion), a 16 percent decline in 1999. The situation could result from a weaker demand abroad, coupled with the stronger baht. (Values in this paper are based on a baht/US$ exchange rate of 41). Water shortage will have a major impact on agriculture, particularly with paddy from the second crop.

The government promotion to develop agribusinesses since 1976 has greatly contributed to the expansion of agroprocessing. Thailand's top 10 export products in 1997 and 1998 are rice, canned foods, rubber, frozen shrimp and prawn. Export earnings for the first nine months of 1998 were US$6 and US$3.9 billion for agricultural products and agro-industry products, respectively. Combined export earnings from agriculture accounted for 23 percent of total earnings

Table 1 Production of key agricultural products and earnings in 1997-98 and 1998-99

	Earning [a] (US$ billions)		*Production [c] (million metric tons)*	
	1997-98	*1998-99 [b]*	*1997-98*	*1998-99 [b]*
Rice	4.43	3.27	23.38	21.5
Black tiger prawn	1.56	1.42	0.21	0.20
Rubber	1.33	1.18	2.20	2.31
Swine	1.25	1.23	no data	no data
Sugarcane	0.77	0.60	42.20	42.60
Cassava	0.69	0.45	15.44	16.37
Chicken	0.68	0.70	0.83	0.84
Maize	0.42	0.50	3.84	4.99
Chicken eggs	0.38	0.38	no data	no data
Oil palm	0.023	0.02	2.63	2.67
Soybean	0.009	0.009	0.36	0.37

a. Commerce Ministry.
b. Estimates.
c. Ministries of Commerce and Agriculture.

(Department of Business Economics). Thailand's top ten food exports in 1998 are:

	Export Value (US$ millions)
Rice	2.17
Canned fish	1.69
Fresh chilled/frozen shrimps, prawns and lobsters	1.45
Sugar	0.66
Tapioca (cassava) products	0.57
Chilled/frozen poultry cuts	0.41
Prepared/preserved fruits in air-tight containers	0.38
Fresh chilled/frozen cuttle fish, squids and octopus	0.29
Prepared/processed foods for animal feeds	0.25
Processed poultry	0.22

The value of agricultural exports rose dramatically because of the weakened local currency. However, exports of agricultural products declined in dollar terms 13.1 percent, followed by a 12.1 percent decline in agro-industry products. Recent exports have been hit by tough price competition from lower-wage Asian countries. The result showed that Thailand could not depend solely on its weaker currency to boost exports. To remain competitive, Thailand will have to focus more on the country's development, and be more innovative and creative in R&D.

R&D Priorities

Improving crop yield and protecting agricultural crops from diseases and pests, improving postharvest handling, and diversifying products are all priorities for Thailand.

There is a need to improve productivity of Thai crops, while retaining their unique qualities (for example, the fragrant Thai rice Khao Dawk Mali). Rice productivity in Thailand averages only 2.42 metric tons/hectare compared to 6.3, 6.0, 4.3, and 3.6 metric tons/hectare in the United States, China, Indonesia, and Vietnam, respectively. Thai sugarcane yields are only 48.8 metric tons/hectare compared with 93.8 in Brazil. The country's 46 sugar mills, meanwhile, have the capacity to process more than double the amount of cane they now receive. Another problem with Thai cane is the sweetness. The international grading system has given a rating of 11 ccs (commercial cane sugar) for Thai sugar compared with 13 to 14 for other countries. The Office of the Cane and Sugar Board's main activity at the moment is to develop better sugarcane varieties with the goal of increasing the sweetness grade of Thai cane to 15 within five years. The new varieties should also be resistant to drought, salty soil, and diseases.

Agricultural Development Priorities

A master plan for Thailand's agricultural development was approved by the government in early 1998 to make exports more competitive. The objectives are supported by a master plan for industrial restructuring approved in April 1998. Thirteen industries will be promoted to make Thailand a key export center in Asia within two years. Three industries using agricultural products (food and animal feed, rubber and rubber products, and wooden products including furniture) are included in 13 industries. Key agricultural projects planned by a committee chaired by the Deputy Agriculture Minister are:

- The establishment of integrated agricultural zones for exports.
- R&D to raise production and cut costs by using new technology with emphasis on biotechnology. Rice, livestock, rubber, durian, longan, and orchids have priority.
- Bringing product quality and processing up to international requirements. A center to control quality from the raw material stage to the finished product will be established.
- Restructuring the Agriculture Ministry to modernize its management and services.
- Encouraging farmers to use less chemical fertilizer while promoting natural alternatives and organic production.
- Improving management of land use and ownership, natural resources, irrigation, and coastal areas.
- The establishment of weather warning systems in high-risk areas.
- Improving farm methods and technology.

The Agriculture Ministry outlined five strategic plans for 1999 with a budget of about US$1 billion:

- Increase competitiveness of farm products for export and import substitution (US$305 million), and to promote self-sufficient farm projects (US$24 million)
- Management of natural resources and the environment (US$372 million)
- Development of agricultural institute (US$225 million) to encourage community-based production
- Plans initiated by His Majesty the King (US$78 million)
- Preparation for the 21st century (US$4 million).

Apart from the government's annual budget, the ministry has obtained US$600 million, mainly from the Asian Development Bank (ADB) to improve the agricultural economy through a series of short and long-term programs.

National Center for Genetic Engineering and Biotechnology (BIOTEC)

The Center, known as BIOTEC, was first set up under the Ministry for Science, Technology and Energy on September 20, 1983. In 1991, Thailand established the National Science and Technology Development Agency (NSTDA), and BIOTEC became one of the NSTDA centers, operating autonomously outside the normal framework of civil service and state enterprises. This enabled the Center to operate more effectively to support and transfer technology for the development of industry, agriculture, natural resources, environment, and the socioeconomy.

BIOTEC policy provides the resources for the country to develop the critical mass of researchers necessary to achieve Thailand's national R&D requirements in biotechnology. This is achieved through R&D projects, the facilitation of transfer of advanced technologies from overseas, human resource development at all levels, institution building, information services, and the development of public understanding of the benefits of biotechnology.

BIOTEC is both a granting and implementing agency. BIOTEC allocated approximately 70 percent of its R&D budget to several universities and research institutes around the country and 30 percent to carry out in-house research projects. The infrastructure of national and specialized laboratories is made available for in-house research programs as well as visiting researchers. It is expected that the construction of a Science and Technology Park will be finished in early 2001 and will house BIOTEC's main laboratories including pilot plant, greenhouse, and incubator unit.

Several research programs have been undertaken by a BIOTEC-appointed committee of recognized experts in the field. Some major programs and activities are described below.

Shrimp Biotechnology Program

Until recently, basic knowledge about the major cultivated shrimp species has lagged far behind technical innovations that have led to successful intensification of culture, and to ever-increasing world production. Basic knowledge must be addressed to maintain high levels of production. Moreover, sustaining high production levels will also require further innovation to minimize adverse environmental impacts. Biotechnology will play a central role in helping us to understand the shrimp and to improve rearing practices. BIOTEC's support will focus on issues dealing with shrimp diseases and with improvement of the seed supply. The disease work has so far emphasized the characterization, diagnosis, and control of serious shrimp pathogens, particularly yellow-head disease (YHD) and white-spot syndrome (WSS) disease. Luminescent bacterial infections have contributed to the declining production to a lesser degree. These diseases become progressively more serious threats to the industry as it has grown and intensified. Indeed, the work on YHD virus and WSS virus supported by BIOTEC has been instrumental in substantially reducing the losses caused by these viruses in Thailand during 1995-97. The losses to YDH (probably exceeding US$40 million in 1995) and those to WSS (probably exceeding US$500 million in 1996) could have been much worse without the basic knowledge and the DNA diagnostic probes made available to the industry by Thai researchers. Checking for subclinical WSS virus (WSSV) infections by PCR has been a common practice in Thailand, to help farmers in screening out WSSV +ve PL (post larvae) before stocking (Flegel 1997).

The Shrimp Biotechnology Service Laboratory was established in July 1999 at BIOTEC to summarize the reference PCR methods for shrimp viral disease detection for Thai shrimp farming. SBSL objectives are to serve as the reference laboratory for major shrimp pathogen diagnosis based on molecular techniques, to conduct research, and to provide assistance for molecular detection of various shrimp viruses.

It has been reported that WSSV can be vertically transmitted and widespread among wild broodstock. In addition to the disease problem, a decline in the growth rate of shrimp produced from currently available wild broodstock has also been observed. Production of specific pathogenic free (SPF) animals and the development of specific pathogen resistant (SPR) strains are now being used in the USA, Venezuela, and French Polynesia with *Penaeus stylirostris* and *P. vannamei.* This could be considered a breakthrough since production of *P. vannamei* more than doubled during 1992-94. Currently the most important program involves the domestication and genetic improvement of *P. monodon* stocks (Withyachumnarnkul and others 1998). The project will lead to the development of SPR stocks and improved growth performance through selective breeding. The first domesticated stocks from this program were to be ready for pond production tests in 1999. BIOTEC is also supporting advanced studies on DNA characterization and DNA tagging of the shrimp stocks. These studies are providing the tools that will be important for rapid genetic improvement strategies.

BIOTEC is dedicated to the principle that the players in the shrimp industry should take an active role in the R&D effort for their industry, in both planning and finance. BIOTEC took an active part in promoting the formation in 1996 of an industry consortium (the Shrimp Culture Research and Development Company) dedicated to solving problems common to the shrimp aquaculture industry as a whole. This consortium serves the industry directly and also serves as a bridge to other public and private institutions involved in relevant research, not only in Thailand, but throughout the world.

Cassava and Starch Technology

About 70 percent of the 16 million metric tons of cassava roots produced in 1998 is used in the production of pellets and chips, and the remaining 30 percent is mainly used to produce flour and starch. A production shortage in 1997-

98 prompted the Thai Tapioca Development Institute (TTDI) and Kasetsart University to recommend a new variety with a higher yield. Kasetsart 50 is the new variety with an average yield of 26.4 metric tons of roots per hectare, and a starch content of 26.7 percent compared with 13.75 metric tons per hectare and 18 percent starch content of the best strain available.

The tapioca starch industry is one of the largest in Thailand. In 1998, tapioca starch was worth about US$120 million. About 40 percent of starch was used domestically for the production of modified starch, sweetener, and monosodium glutamate. Most of the remaining 60 percent was exported. Efficient production, low production costs, and the development of value-added products are vital to the starch industry and the farming sector (total of 1.3 million hectares planted in cassava).

The program on starch and cassava products was established to provide support and funding for R&D. The program is funded jointly by BIOTEC and TTDI to carry out R&D in three core activities. The short-term project aims to improve the processing efficiency of starch production, in particular to minimize water and energy consumption. This will reduce water use and costs, and also reduce wastewater treatment. Wastewater discharge varies from 13 to 50 cubic meters/ton of starch produced, with an average of 20 cubic meters. A benchmark on water use is a priority for the Thai starch industry.

Biotechnology can play an important role in waste utilization. Solid waste (after starch extraction) still contains 50 percent of starch (dry weight) and has been utilized as animal feed. Tapioca, however, is not suitable for the production of feed requiring high protein content. Attempts have been made for protein enrichment using various microorganisms such as *Aspergillus* and *Rhizopus*. Nevertheless, the economic feasibility is still in doubt and further technological development is needed. In contrast, turning wastewater into energy through high-rate anaerobic digestion is promising. Though the technology is proven, an adaptation to such high-strength wastewater and low buffering capacity is required to ensure stability of the system. In comparison with the UASB technology, the fixed bed is easier to control and operate. R&D, however, is focused on increasing loading efficiency. Based on calculations, methane generated from anaerobic treatment of starch wastewater from 60 factories would be approximately 630 million cubic meters annually. This could be substituted for fuel oil used in drying, saving energy costs of about US$4 million annually. There is also the environmental cost of large land areas required for conventional pond systems. In addition to native starch, production of modified starch is increasing, leaving an excessive amount of sulfate in wastewater. This may interfere with the anaerobic digestion intended for energy production. A number of papers have been published recently on the interactions between the sulfate reducing bacteria (SRB) and the methanogenic bacteria (MGB). Molecular diagnosis has been developed and applied for the mixed cultured system. A better understanding of these anaerobic microbes could lead to the biological removal of sulfate, which is the main problem of various industries.

EU has set a quota for tapioca pellets imported from Thailand. Product diversification is part of the second core research activity. As a result, production of biodegradable plastic from cassava starch is being investigated. Increasing use of cassava as a raw material for fermentation industries such as amino acids and organic acids must proceed at furthering the development of value-added products. To reduce costs of production, however, research is oriented toward the production of good quality cassava chips as a starting material to replace the starch.

Finally, basic research on cassava starch structure and properties will add to our knowledge and help increase the use of cassava starch. The Cassava and Starch Technology Unit, a specialized BIOTEC laboratory established in 1995 at Kasetsart University, has been engaged in studying the physicochemical properties of cassava. The unit is well equipped, and provides regular service and training on instrument analysis of starch properties to the private sector and government agencies.

Rice Biotechnology Program

Rice yields in Thailand are low. One of the major constraints in cultivation is blast disease, especially in high-quality rice cultivars such as the aromatic "Khao-Hom Dawk-Mali." In northern Thailand, about 200,000 hectares of rice were affected by blast in 1993, causing serious economic loss and resulting in government intervention of about US$10 million to assist disease-struck farmers. Another US$1.2 million was spent on fungicides (Disthaporn 1994). Attempts have been made to breed higher resistance levels to blast in Thai rice. Limiting factors, however, are lack of insight and information on resistance genes, and the complex structure of the pathogen populations. Genetic analysis provides an efficient tool to identify useful resistance genes in the host while analyzing the race composition of the pathogen population. Recent research activities applying molecular genetic methods (DNA fingerprinting of a blast isolate collection at Ubon Ratchathani Rice Research Station, mapping of host resistance genes by the DNA Fingerprinting Unit at Kamphaengsaen campus of Kasetsart University) are providing baseline data on the interaction between rice and blast. The project is working on three closely related areas as follows:

- Establishment of a suitable differential cultivar series; identification of resistance genes conferring complete and partial resistance to blast disease in rice. This activity follows up on the project "Identification, mapping and utilization of rice blast resistance QTLs in improved aromatic rice varieties for Thailand."
- Pathotype and molecular genetic characterization of the blast pathogen population in Thailand. So far, more than 500 monospore isolates have been deposited with the BIOTEC specialized culture collection.
- The special case of fertile isolates; the potential of using Thai isolates of *Magnaporthe grisea* for the development of a molecular, diagnostic tool for pathogen race analysis. The degree of fertility can be assessed from the timing and number of perithesia that develop. BIOTEC has the capacity to test the mating type of about 80 isolates per month.

This project is a nationwide, network-type collaboration combining molecular genetics and classical approaches to help scientists breed rice cultivars with improved blast resistance.

BIOTEC provided US$1.5 million in 1999 to fund the "Rice Genome Project Thailand." BIOTEC on behalf of Thailand has joined an International Collaboration for Sequencing the Rice Genome [ICSRG] by sequencing 1 Mb annually of chromosome 9 for the next five years. BIOTEC is expected to provide about US$3.7 million to cover this work. Chromosome 9 was selected based on the previous extensive work on the fine genetic and physical maps surrounding the submergence tolerance QTL, the prospect of gene richness, and the small chromosome size. Joining ICSRG will allow Thai scientists to access directly the rest of the genome sequence made available by the other collaborating members. Gene discovery from wild rice germplasm will be undertaken in parallel to use efficiently the genome sequence data. The project will bring Thailand into the international scientific arena, incorporate state of the art technology, and improve Thailand's competitive edge in the international rice market.

Dairy Cow Program

In 1997, Thai milk consumption was 12 liters/person/year. Milk production is still insufficient to meet local demand, and Thailand has to import more than 50 percent (worth US$305 million) of the dairy products consumed in the country. To meet the national demand, it is estimated we need an additional 130,000 dairy cows, assuming present productivity averaged from total cows.

Reproductive efficiency is a primary determinant of dairy herd production profitability. Milk yield is still far below the average of most developing countries at approximately 10 kilograms/day, as compared to 30 kilograms/day. It is, therefore, important to promote an increase in dairy production through science and technology. The major programs are breeding and feeding. The lack of proper management is another major contributing factor to an underproductive dairy industry.

Traditional breeding practices in Thailand have been too slow to meet national requirements, and importing pregnant heifers and/or young quality-bred calves from abroad is too costly. Cutting-edge technologies such as embryo transfer, in vitro fertilization, embryo sexing, and semen sexing have been studied by Thai scientists for more than ten years. Nevertheless, the technologies have not yet been adopted, for several reasons. Technology transfer and training of Thai researchers at the leading laboratories/companies are now under discussion. The goal is to increase production of high-quality heifer calves at the most economical cost.

Agriculture and Gene Engineering

By the mid 1970s, with modern biotechnology developing through the use of recombinant DNA technology and molecular biology, Thailand was ready to adopt the new tools and apply them to various practical problems, in the biomedical field first and later in agriculture and other areas. A few specific examples will be given here to highlight the application of molecular biology and genetic engineering to agricultural development. Efforts in agricultural biotechnology and genetic engineering have been focused on three main areas: crop improvement through plant transformation, DNA fingerprinting, and molecular diagnosis of plant and animal diseases.

Crop Improvement

Crop improvement should lead to the production of genetically improved (transgenic) plants with superior properties including resistance to diseases, insect pests, and abiotic stresses. The Plant Genetic Engineering Unit (PGEU), the specialized laboratory of BIOTEC at Kasetsart University, Kamphaengsaen Campus was established in 1985 to carry out work on plant biotechnology and genetic engineering. A transgenic tomato plant carrying the coat protein gene of tomato yellow leaf curl virus was first developed to control this serious virus disease of tomato (Attathom and others 1990). The same approach was taken to develop transgenic papaya and pepper for resistance to papaya ringspot virus and chili vein-banding mottle virus, respectively (Chaopongpang and others 1996; Phaosang and others 1996). Sri Somrong 60, a Thai cotton variety, was successfully transformed with cryIA[b] gene expressing a toxin from *Bacillus thuringiensis.* Development of transgenic rice varieties has been supported by the Rice Biotechnology Program launched by BIOTEC and Rockefeller Foundation. An example is the transformation of Khaw Dawk Mali 105, an aromatic Thai rice with D^1 pyrroline-5-carboxylate synthetase (P5CS) for salt and drought tolerance. Most transgenic plants are now being tested under greenhouse conditions in accordance with the Biosafety Guidelines (Attathom and Sriwatanapongse 1994; Attathom and others 1996). Field testing of transgenic plants developed in Thailand is expected to get under way in 2000.

DNA Fingerprinting

Each living creature has a unique DNA sequence. Using DNA fingerprinting and polymerase chain reaction (PCR) scientists can identify organisms and genes. Important genes can be located (genetic maps). Moreover, the availability of DNA probes and specific sequence has made it possible to develop appropriate molecular methods for diagnosis of plant and animal diseases. Molecular mapping of genes in rice involving flooding tolerance, rice blast, aroma, cooking quality, and fertility restoration were accomplished using three mapping populations. A backcross breeding program for the improvement of Jasmin rice was initiated. In the first stage, resistance to bacterial leaf blight, flooding tolerance, resistance to brown planthopper/gall midge, and photoperiod insensitivity were main areas of focus. RFLP-based markers were an important limiting factor for high throughput and cost effectiveness. The PCR-based marker for Xa21 is the most reliable marker for marker-assisted backcrossing in rice.

Tomato production in the tropics and subtropics faces serious constraints due to bacterial wilt (BW), a disease caused by the bacterial pathogen recently reclassified as *Ralstonia solanacearum* (formerly *Pseudomonas solanacearum*). In Thailand, an endemic outbreak of BW in tomato, potato, pepper, ginger, and peanut occurs each year, causing a yield loss of approximately 50-90 percent depending on growing conditions. BW-resistant varieties cannot easily be developed due to the nature of the (quantitatively inherited) resistance that involves several genes. Marker-assisted selection (MAS), a breeding method of selecting individuals based on markers linked to target genes in addition to phenotypic measurement, is essential and useful only for enhanced resistance to diseases. At this time, three putative QTLs (quantitative trait loci) corresponding to BW resistance have been found using AFLP ('A' fragment length polymorphism) markers. Once markers closely linked to BW-related QTLs are well established, they can be used for marker-assisted breeding for enhanced resistance to bacterial wilt in tomato. A tomato consortium has been set up to extend public-private collaboration.

BIOTEC has set up the DNA Fingerprinting Service Unit at Kasetsart University. The unit has provided services to public and private concerns for more than two years. The main services are DNA fingerprinting and DNA diagnosis (Table 2).

Biocontrol Program

In 1996, Thailand imported 38,000 metric tons of chemicals, mainly insecticides and herbicides. The global trend of going organic is an opportunity for Thai farmers to supply fresh organic produce, especially fruit and vegetables, to the world. Over the past decade, the developmental work on biocontrol in Thailand has continued to receive active support from BIOTEC and the Thailand Research Fund (TRF).

Two companies are now producing commercially *Trichoderma* to control *Sclerotium rolfsii* Sacc., and *Chaetomium* to control soil fungi such as *Phytophthora* (Yuthavong 1999). BIOTEC and the Department of Agriculture have set up a pilot-scale production facility to produce NPV (nuclear polyhedrosis virus), *Bacillus thuringiensis* and *B. sphericus*. NPV is widely used to control *Spodoptera* moth in grapes. *Bacillus thuringiensis* (Bt) produced locally has gained popularity over the last few years. The capacities of pilot plants at Mahidol University and King Mongkut's University of Technology (Thonburi) are taken up with Bt production. Commercial production may begin soon. A project at Mahidol University to transfer the chitinase gene into *B. thuringiensis* subsp. *israelensis* has received support from BIOTEC.

Table 2 Services provided by the DNA Fingerprinting Unit

Service	Organism	Marker technology
DNA fingerprint	Maize, rice	SSLP
	other plants	AFLP
DNA diagnosis		
animal (paternity test)	Dairy cow	SSLP
plant (hybridity, purity	Maize, rice	SSLP
test)	others	AFLP
agricultural product		
adulteration	rice	
GMOs	soybean	
species diversity	tuna	

SSLP= Simple sequence length polymorphism
AFLP=Amplified fragment length polymorphism

Trade in Agricultural Products

Although Thailand is a leading exporter of food products, it also imports food commodities that are not available or that cannot be adequately supplied through local production. Among Thailand's top ten food imports in 1998 are fresh and frozen tuna used for canning and vegetable materials for animal feed preparation. Exports of frozen and processed chicken are expected to remain at 1998 levels of 140,000 metric tons for the next two years. Maize, soybean meal, and fishmeal are key ingredients for feed industries. Maize production for the 1998-99 crop year will be approximately 4.9 million metric tons, whereas local demand, mainly from animal feed factories, is expected to be 3.8 million metric tons. With adequate supplies, no maize imports were permitted in 1999 beyond the 53,250 metric tons that Thailand had committed to allow under the World Trade Organization agreement. In contrast, soybean output was about 375,000 metric tons in 1999, with consumption expected to increase marginally to 1.17 million metric tons. This means that soybean imports will rise to 800,000 metric tons. In addition, about 680,000 metric tons of soybean meal were produced in 1999 —100,000 from local soybeans and the rest imported.

Over 50 percent of world soybean production comes from new genetically improved varieties, mainly from North America. Regulations governing the movement of new genetically improved crops are becoming more restrictive. In mid 1999, for example, the European Agriculture Commissioners made a political agreement with regard to the ban on the use of GIOs in feed. As a net food producer, Thailand should be able to deal with potential problems. DNA diagnosis has been used to confirm the origin of raw materials used in food processing to comply with trade agreements. For example, the DNA Fingerprinting Unit will check the species identification of tuna already canned. This addresses the conflict between global free trade and environmental protection. The US Department of Commerce proposes to inhibit the importation of Atlantic-caught bluefin tuna harvested from countries using methods that are inconsistent with the International Convention for the Conservation of Atlantic Tunas.

Biosafety Issues

Biosafety issues are increasingly being debated in Thailand. The National Biosafety Committee (NBC) was established in January 1993 under BIOTEC. The NBC has introduced two biosafety guidelines: one for laboratory work, and the other for field work and the release of genetically improved organisms (GIOs) into the environment. The establishment of institutional biosafety committees (IBCs) at various public institutes and private companies was also strongly recommended by the NBC, and in many cases these recommendations have been implemented.

The importation of prohibited materials under Plant Quarantine Law B.E. 2507 implemented by the Department of Agriculture also controls to a certain degree the use of GIOs. Article 6 empowers the Ministry of Agriculture to impose rules regarding prohibited organisms. Ministry regulation II (B.E. 2537) identifies certain prohibited transgenic plants. Permission from the Ministry of Agriculture is required to perform field testing of genetically improved plants brought into Thailand. The following have received permission to be evaluated in Thailand: the Flavr Savr tomato produced by Calgene for the production of seeds (1994); a field trial of Monsanto Bt cotton was carried out under restricted containment in a netted house in 1996; in 1997, a Bt corn field trial was approved to be carried out by Novartis at their experiment station under netted screenhouse.

The public seems to pay more attention to the introduction of GIOs into the country by the multinational companies than to considerations of technological information. An issue not presently discussed or debated, in particular at the political level, is whether or not Thailand should be more aggressive on the development of genetically improved organisms, making best use of Thailand's genetic resources. Thailand is rich in biodiversity, and several genes resistant to biotic and abiotic stresses embedded in wild plants and other bioresources need to be discovered and utilized. This illustrates the potential benefits of biotechnology and genetic engineering. In the 1980s, when genetic engineering and biotechnology first made their impact felt, genetic engineering capability was present in only two or three institutions in Thailand (Yuthavong 1987). Ten institutions now have genetic engineering capability. Nevertheless, the most important challenge for the future of GIOs is not technical in nature, but the attitude of the public towards the technology. These issues need to be studied and debated among the scientists, the public, and the policymakers, and an optimal policy needs to be developed. BIOTEC realizes that genetic engineering depends critically on public support, so the Center has emphasized public education, with information programs on biotechnology and GIOs being introduced to the public and to industry.

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