Agricultural Biotechnology in Thailand

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Introduction

Thailand is known to be one of the developing countries that is also world's largest net food exporter. Yet staying at the forefront of the world agricultural market has never been an easy task. Realizing the stiff and increasing competition in the world market, a master plan for the country's agricultural development, approved by the cabinet in early 1998, aims at research and development to raise production, cut costs by using new agricultural biotechnology, and bring product quality and processing up to international requirements. The plan also encourages farmers to use less chemical fertilizer while promoting natural alternatives and organic production, improving management of natural resources and environment.

Though most of the economic sectors in Thailand registered negative growth rates after the economic crisis in 1997, the agriculture sector has expanded by about 2.8 per cent in 1998. The tables given below show the top ten agricultural products' in recent years production, earnings and exports. (Tables 1-3).

Although the country's transition to new agriculture, or agicultural biotechnology, has been hitherto taking place at a rather low pace, the

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Table 1: Production of Major Agricultural Products in 1999/00, 2000/01

Item	Planted area (million rais)		Yield (million tonnes)	
	1999/00	2000/01	1999/00	2000/01
Rice	64.49	65.64	24.17	25.6
Corn	7.80	7.87	4.28	4.39
Tapioca	7.40	Na	18.26	17.8
Rubber	9.77	na	2.37	2.44
Sugar cane	5.90	5.42	53.49	49.07
Coffee	0.44	na	0.8	na
Soybean	1.45	1.46	0.32	0.32
Oil plam	1.30	na	3.25	na
Tomato	0.06	na	0.2	na

Source: Thailand, Office of Agricultural Economics.

Table 2: Earnings from Agriculture Sector in 1999/00 and 2000/01

(million baht)

Item	1999/00	2000/01
Rice	87,609	91,210
Sugar cane	23,858	24,093
Corn	18,387	16,665
Coffee	2,659	2,524
Rubber	48,119	na
Tapioca	12,010	na
Soybean	2,753	2,991
Oil plam	5,405	na
Tomato	2,294	na

Source: Thailand, Office of Agricultural Economics.

Table 3: Thailand's Top Ten Agricultural Products in 2000 and 2001

(Million baht)

Item	2000	2001
Rice	65,504	70,074
Rubber	60,741	58,700
Fresh and frozen shrimp	61,551	56,563
Fresh, chilled or frozen of poultry	16,756	25,592
Tapioca products	13,887	17,970
Fresh fruits	5,215	5,716
Fresh vegetables	1,610	2,452
Orchids	1,231	1,494
Seed	1,121	1,433
Coffee	1,691	1,172

Source: Thai customs department.

transition is soon to increase its speed, thanks to relatively good infrastructure.

The good research infrastructure in agriculture in Thailand can be traced back far into history. The present good human resource situation owes to the establishment first of Mae Jo Institute of Agricultural Technology (now Mae Jo University) in Chiangmai, followed by the establishment of Kasetsart (Agricultural Science) University and other institutes of higher learning with agriculture faculties.

However, research in these academic institutes, as well as in government agencies like the Department of Agriculture, has been mostly of adaptive nature, viz. improvement of existing or imported varieties and their products through conventional breeding and agronomic means.

Changes in research tradition have been gradually occurring, both through new manpower trained abroad, and through programmes and institutes with overseas origin, such as the Rockefeller Foundation programme at Kasetsart University. Although most of the agriculture research to date still revolves around conventional plant and animal breeding, agronomy, animal husbandry, soil science, etc., a significant amount of research is now devoted to the application of new biotechnology, cellular and molecular biology to agricultural problems. These changes are taking place not only in universities, but are also occuring gradually in government research institutes, such as the Department of Agriculture, with linkage to international agencies like the International Rice Research Institute.

Tissue Culture and Seed Technology

Among the subfields of agriculture, those on which biotechnology has had the greatest impact, are probably tissue culture and seed technologies. This is probably because there was already a good infrastructure for these technologies even before the advent of new biotechnology. The two technologies provide the end-users – gardeners and farmers in substantial numbers – with crucial inputs: plantlets and new seed varieties.

Tissue culture techniques were introduced to Thai orchid growers in the 1970s, and the former rapidly proved to be superior to traditional seed propagation techniques in reproducing orchid plants. As the production site for many transnational seed companies, Thailand today is one of the most important seed producing and exporting countries in the world. Some of these companies have also invested in R&D activities. However, these R&D, are mostly of the adaptive type, as the transnational and joint venture companies rely primarily on their parent companies abroad for fundamental seed technology research. The lack of an appropriate seed variety protection law appears to have been one of the reasons for the reluctance of the private sector to invest in basic seed technology R&D. The Plant Variety Protection Law, promulgated recently, will help in promoting such R&D in Thailand in the near future. Despite lack of basic R&D, Thai researchers in tissue culture and seed technologies have been relatively productive, and are well linked to the users, although they produce relatively few written scientific publications.

Plant Biotechnology and Genetic Engineering

The work focus on plant biotechnology and genetic engineering have been focused on two main areas, plant transformation and DNA fingerprinting.

The first area should lead to the production of transgenic plants with superior properties including the resistance to diseases, insect pests and abiotic stress.

Research activities in this field were pioneered by the Plant Genetic Engineering Unit (PGEU), the satellite laboratory of the National Center for Genetic Engineering and Biotechnology (BIOTEC) at Kasetsart University, Kamphaengsaen, Nakorn Pathom. Transgenic tomato plant carrying the coat protein gene of tomato yellow leaf curl virus (TYLCV) was first developed to control the serious virus disease of tomato. The same approach was taken to develop transgenic papaya and pepper for the resistance to papaya ringspot virus (PRSV) and chilli vein-banding mottle virus (CVbMV), respectively. Another key biotic stress of crop production is the loss due to insect pests. Sri Somrong 60, a Thai cotton variety, was successfully transformed with cryIA(b) gene expressing a *Bt* toxin from *Bacillus thuringiensis*. Transgenic cotton plants will be used for controlling the cotton bollworm *Helicoverpa armigera*. For abiotic stress resistance, attempts has been made to transform Khaw Dawk Mali 105 – an aromatic Thai rice with 1-purroline-5-carboxylate synthase gene (P5C5) for salt and drought tolerance using particle bombardment technique.

Most of the transgenic plants developed in Thailand are now being tested under greenhouse conditions and field testings in accordance with the biosafety suidelines. More issues about biosafety and the debate over genetically modified organisms (GMOs) will be discusse later in this paper.

The rice biotechnology programme was launched by the National Center for Genetic Engineering and Biotechnology (NCGEB) in collaboration with the Rockefeller Foundation. Researchers from universities, Department of Agriculture and other agencies were given support to work on such areas as development of molecular markers for rice breeding, development of salt-tolerant rice varieties, wide hybridization between cultivated and wild rice species, development of transgenic rice varieties, mechanism of pathogenesis in rice bacterial and viral diseases, and identification of aromatic components of jasmine rice, etc.

The locations of important genes have been identified. Identification of molecular markers linked to aromatic gene in rice utilizing random amplified polymorphic deoxyrobonucleic acid (RAPD) technology was developed and genetic locus of aromatic trait in Thai rice was identified. Bulked line analysis method was developed for identification of the restriction fragment length polymorphism (RFLP) markers associated with a target gene. With the method, a fertility-restoring gene was identified and mapped. Work on quantitative trait loci (QTL) mapping has discovered a tightly-linked markers of flood-induced elongation and leaf senescence to recover from flooding. This finding may provide breeders to design an efficient marker-assisted selection scheme and marker-based gene cloning. Genes controling intermediate amylose content in rice were also mapped.

In 1999 BIOTEC has provided 60 million bahts funding to start the Thailand Rice Genome Project. BIOTEC on behalf of Thailand has joined the International Collaboration for Sequencing the Rice Genome (ICSRG) led by Japan, by sequencing 1 Mb annually of chromosome 9 for the next five years. Chromosome 9 was selected based on previous extensive works on the fine genetic and physical maps surrounding the submergence tolerance QTL mentioned above, prospecting for gene richness on a relatively small chromosome. Joining ICSRG enabled Thai scientists to directly access the rest of the genome sequence made available by the other collaborating members. In parallel, gene discovery from wild rice germplasm will be undertaken to efficiently utilize the genome sequence data. The project will bring Thailand to international scientific arena, incorporate state of the art technology and finally improve the competitive edge of Thailand in the international rice market.

Cassava and Starch Technology

Of 16 million tonnes of cassava roots in 1998, approximately 70 per cent, are used in the production of pellets and chips while the remaining are mostly used in the production of flour and starch. Production shortage in 1997-1998 prompted the Thai Tapioca Development Institute (TTDI) and Kasetsart University to develop new strain of higher yield to gear towards making Thailand a production base for the tapioca industry. Kasetsart 50 is the newly developed strain with an average yield of 26.4 tonnes of roots per hectare and a starch content of 26.7 per cent as compared with the 13.75 tonnes per hectare and 18 per cent starch content of the best strain available before.

Tapioca starch industry is one of the largest industries of Thailand. In 1998, tapioca starch was worth 5 billion bahts. About 40 per cent of starch were used domestically for the production of modified starch, sweetener and monosodium glutamate while the remaining 60 per cent were mostly exported. Efficient production process, low production cost, and the development of value-added products are vital to the starch industry and the farming sectors of totally 1.3 million hectares planting area. On this basis, the programme on starch and cassava products was established to provide support and funding for research and development. The programme is funded jointly by BIOTEC and TTDI to carry out research and development in three core activities. The short-term project is to improve the processing efficiency of starch production, particularly to minimize water and energy consumption. Reduction of water usage not only can lower water cost, but also lessen the need for wastewater treatment. A benchmarking on water usage is a priority for the Thai starch industry. Besides, attempts have been made for protein enrichment using various micro-organisms such as *Aspergillus* and *Rhizopus*, but the economic feasibility is still in doubt and further technological development is needed.

Basic studies of cassava starch structure and physicochemical properties are now being undertaken at the Cassava and Starch Technology Unit, a specialized BIOTEC laboratory established in 1995 at Kasetsart University. The unit is well equipped; hence regular service and training on instrumental analysis of starch properties have been provided to the private sector and governmental agencies.

Biocontrol Agents and Biofertilizers

Related to the development in plants resistant to diseases and pests, transgenic or otherwise, is the effort to find biocontrol agents, which can either be used as such, or the genes which can be incorporated into the transgenic plants. Over the past two decades, the developmental work on biocontrol and biofertilizers in Thailand has continued to receive active support from BIOTEC and Thailand Research Fund (TRF).

Recent development study on biological control of root-knot nematodes by soil fungus, mass production and application of *Trichoderma* for biocontrol of *Sclerotium rolfsii Sacc.*, *Ketomium* for the control of soil fungi such as *Phytophthora*, field application of *Hirsutella thomsonii* for microbial control of agricultural mites, local production of nuclear polyhedrosis virus (NPV) to control cotton bollworm (*Heliothis sp*.) and other insects. Two companies are now producing *Trichoderma* and *Ketomium* commercially. BIOTEC and Department of Agriculture have combined strength to set up a pilot scale production facilities for the production of NPV, *B. thuringiensis* and *B. sphericus*. NPV is widely used to control Spodoptera moth in the production of grapes.

For the control of vegetable pests such as *Plutella* and *Spodoptera*, locally produced *B. thuringiensis* and *B. sphericus* have gained popularity over the last few years. The bacillus production has taken up the production capacities of pilot plants at Mahidol University and King Mongkut University of Technology Thonburi (KMUTT). It is anticipated that commercial production (100 tonnes per year) will begin within a couple of years. In order to improve the efficacy, a group of researchers at Mahidol University, with support from BIOTEC, is working on transferring the chitinase gene into *B. thuringiensis israelensis*. There has also been much development in the use of neem for the control of diamond back moth and the leafminer which have developed high resistance to conventional insecticides.

The use of biofertilizers can lessen dependence on chemical fertilizer, resulting in cost saving as well as reducing deleterious environmental and human effects. The Department of Agriculture pioneered the production of *Rhizobium* for use with leguminous plants. Appropriate strains were selected for this purpose, and commercial scale production has been carried out. Blue-green algae appropriate as biofertilizer was also selected and produced at the commercial scale by Thailand Institute of Scientific and Technological Research (TISTR).

Animal Biotechnology

Recent development of animal biotechnology in Thailand has mainly revolved around import and adaptation of new, high-yielding strains of farm animals such as cows and pigs. The major problems encountered for imported species are development of resistance to infectious diseases, adaptation to hot and other conditions of the tropics, finding of optimal growth conditions and development of appropriate feeds.

Foot and mouth disease has increasingly become an important endemic disease threatening not only Thailand, but the whole of Southeast Asia and beyond, creating an important obstacle for development of export industry for animal products.

Much research in animal science, accomplished in Kasetsart and Mahidol Universities, has been devoted to embryo transfer technology. A Mahidol University team has, for example, developed embryo transfer technology for cattle including the ability to recover immature oocytes from valuable donor cows, intracytoplasmic fertilization with spermatozoa from genetically superior but infertile bulls, and sexing and cryopreservation of preimplantation embryos. These techniques are being applied to conserve endangered animal species such as the Thai elephant.

More recently, cows had been cloned by a team at Chulalongkorn University (CU) together with Suranaree University of Technology (SUT) using embryo transfer technique, same of which gave birth to “Dolly the sheep”. Since then animal cloning has become a fast developing area of animal research in Thailand. Application of this technology is expected in the field of animal breeding and production as well as conservation of endangered species.

Over the past decade, Thailand has been a major producer of prawns, especially tiger prawns, for exports. This has been the result of expansion of land, first in the shoreline areas and later in the inland areas as well, used for intensive culture of prawns, often with little environmental consideration. It is, therefore, necessary to develop sustainable systems for prawn aquaculture. One main problem is the development of the parent stocks, so that they need not be harvested from the sea. Other important problems include production of disease-free broodstock, disease-resistant varieties and early diagnosis of viral and other diseases.

Since the beginning of the 1990s Thailand has led the world in the export of farmed shrimp and the industry has been worth approximately US$ 2 billion in yearly export earnings for the country. These earnings are especially important because they are based very largely on inputs of local origin. The shrimp farming industry has not developed without production and environmental difficulties but both government and industry are unified in efforts to reach the goal of a sustainable aquaculture with minimal negative impact on the environment. BIOTEC has been particularly active in supporting research and in stimulating cooperation to solve production and environmental problems in the shrimp industry.

An important milestone was achieved in 1996 when a five-year effort of BIOTEC culminated with the establishment of the Shrimp Culture Research and Development Company Limited (SCRD), a government-industry consortium dedicated to the development of sustainable shrimp aquaculture. Currently, the most important programme of SCRD involves the domestication and genetic improvement of shrimp stocks. Up to now, SCRD has successfully reared Black Tiger prawn (*P. monodon*) in captivity in southern Thailand for five years. The shrimp, which have been screened to exclude both white spot syndrome virus (WSSV) and yellow head virus (YHV), are now in their fifth generation in captivity and have been selected for their growth rate to normal market size of 25-30g. They have shown excellent performance under culture and the reproductive performance continues to improve and in some cases has approached that of wild spawners. SCRD now plans to expand its operations on a more commercial basis to produce nauplii, postlarvae and broodstock for sale to Thai farmers and hatcheries. Its plan is to construct a single Nucleus Breeding Center (NBC) and one Broodstock Multiplication Center (BMC), and to work with several other partners to develop additional BMCs to meet market demands.

The BIOTEC is also supporting advanced studies on DNA characterization and DNA tagging of the shrimp stocks for the genetic improvement part of the SCRD programme. These studies are providing the tools that will be important for rapid genetic improvement strategies.

Other important milestones in the BIOTEC programme have been the development of DNA probes for the rapid detection of major shrimp pathogens. These probes are essential for the development and monitoring of certified shrimp broodstock and fry. They detect for diseases that present no health risk to shrimp consumers, but the probes are critical tools for the prevention of shrimp diseases that sometimes cause disastrous production losses. Indeed, BIOTEC's support for research on the development of a DNA probe for WSSV, one of these pathogens, has yielded a benefit that can be valued at approximately US$1 billion per year for Thailand since 1996. This example serves to illustrate clearly how research can be vitally but unpredictably important to the Thai economy.

Work on WSSV in Thailand began unpredictably in 1994 as the result of a chance infection of laboratory reared shrimps. These shrimps were under observation for a different major shrimp viral pathogen, the yellow head virus, originally discovered in Thailand in 1992. In retrospect, we now know that WSSV originated in China in 1993 and gradually spread from there to the rest of Asia in succeeding years. In China, it resulted in a drop of shrimp production from approximately 155,000 metric tonnes in 1992 to 35,000 metric tonnes (77 per cent decrease) by 1994. When the chance discovery of WSSV occurred in the laboratory in Thailand, the virus had not yet caused any known farm losses. In the meantime, work was done to investigate the nature of the virus and to develop diagnostic probes for it. A major discovery with the probe was that shrimp fry used to stock shrimp ponds could be the source of the virus. By the time the virus began to affect farms in Thailand, a good amount of research information had already been accumulated and this helped considerably in mitigating its negative impacts. The research allowed for the development of effective prevention programmes which included the use of DNA technology to screen stocking fry so that WSSV positive batches could be rejected. The benefit of this research can be roughly estimated from the prevention of farm loss of no less than $1 million per year.

BIOTEC is now moving to the next step from producing WSSV- and YHV-free stocking fry, to fund more research in other shrimp diseases. It will also promote research into the breeding of virus-resistant shrimp (the so-called 'super shrimp') in the near future.

Safety Issues of Genetically Modified Plant and the GM Debate

Thailand is one of the first countries in the region to adopt its national biosafety guidelines as early as 1992 both for laboratory work and for field testings and planned release. The guidelines were initiated by BIOTEC and the completion was largely the efforts of individual scientists and officials of relevant governmental agencies.

Subsequently in 1993 the National Biosafety Committee (NBC) was established with BIOTEC serving as the coordinating body and secretariat. Later on many Institutional Biosafety Committees (IBCs) were established at various major research and academic institutes throughout Thailand. Currently, there are 14 IBCs including one private enterprise laboratory overseeing all the research activities involved in the use of genetically modified organisms.

As the technical support to various government authorities in the decision making related to the safety of genetically modified organisms, NBC has established three specialized biosafety subcommittees, focussed on plants, micro-organisms and food. These subcommittees are functioning as technical advisory groups and risk assessment bodies. They work in coordination with relevant government agencies in the GMO approval process.

The first request of introduction and field testing of genetically modified organism in Thailand was the Flavr Savr tomato. The Department of Agriculture, Ministry of Agriculture and Cooperatives acted with technical recommendation from NBC, granted permission for the field trial of Flavr Savr tomato in 1994. The purpose of the field trial was to produce seeds destined for export only. The request for field trial of genetically modified cotton with toxin gene from *Bacillus thuringenesis* was made in 1995. Field trial of this *Bt* cotton started in March of 1996. But until today, permission for the commercial release of *Bt* cotton is still pending.

In October 1999, with the controversy concerning the safety of GMOs escalating around the globe particularly in the European Union countries, Thailand's Committee for International Economic Policy issued a policy statement affecting the commercialization of genetically modified plants. The statement prohibited any commercial import or release into the market of any GM plant seed. Field trials, however, were still allowed under the jurisdiction of Department of Agriculture. This was actually in accordance with the Plant Quarantine Act. Legally, Thailand's 1964 Plant Quarantine Act (amended in 1994 and 1999) restricts importation of 40 different varieties of transgenic plants unless it is permitted case by case and only for research purpose. However, for practical purpose, the above Committee has agreed to exempt the import restriction of transgenic soybean and maize grains (not seeds) based on the fact that risk assessment has been performed on these commercial crops and they are regularly traded in the world market.

Nevertheless, recognizing the urgent need for Thailand's own risk assessment capability in GM food, the NBC's subcommittee on Food Safety drafted a guideline for safety assessment of genetically modified foods in 1999. It is now being considered by the Thai's FDA for use as a national guideline. The guidelines followed the internationally accepted concept of substantial equivalence. The first transgenic food plant product, that is seeking approval for use in food industry, is the Bt cottonseed oil. The decision is still pending by the Thai's FDA. Using this guideline, Roundup Ready soybean and both Bt and Round up Ready maize varieties from Monsanto have been evaluated as safe for human consumption.

Table 3: Thailand's GMOs Chronology

Date	Events
1983	Inauguration of Thailand's National Center for Genetic Engineering and Biotechnology (NCGEB, now BIOTEC).
1985	Establishment of BIOTEC's Plant Genetic Engineering Unit (PGEU) in Nakhornpathom, Thailand.
1986	BIOTEC commissioned a status report on the prospects of biotechnology in agriculture and stated the need for the country's biosafety regulatory system.
1990	A feasibility study on biosafety by BIOTEC.
1990	Biosafety Subcommittee was established under BIOTEC.
April 1992	BIOTEC appointed an ad hoc subcommittee to draft Thailand's first biosafety guidelines.
June 1992	Complete draft of biosafety guidelines (for laboratory and for field test).
January 1993	National Biosafety Committee (NBC) established with BIOTEC as secretariat, followed by establishment of Institutional Biosafety Committees (IBCs) at various research institutes.
1993	First application for importing transgenic plant for field test on seed production (Calgene's Flavr Savr tomato).
1994	A list of 40 prohibited transgenic plants added to the 1964 Plant Quarantine Act.
1994	Flavr Savr tomato granted permission for field test.
1995	Application of Monsanto's *Bt* cotton.
1995	Establishment of DNA Fingerprinting Unit, BIOTEC in Nakhorn Pathom, Thailand.
March 1996	*Bt* cotton field test experiment started in northeastern Thailand.
1997	Establishment of Plant Biosafety Subcommittee under NBC.
1998	Establishment of Food Biosafety Subcommittee under NBC.
1998	Establishment of Microbial Biosafety Subcommittee under NBC.
1999	Trade dispute between Thailand and some EU countries over detention of tuna in oil from Thailand. Other trade dispute cases follow suit.
1999	Subcommittee for Policy on Trade of Biotechnology Products set up under the Committee for International Economic Policy
1999	Amendment of the 1964 Plant Quarantine Act to strengthen regulation of transgenic plants.

(Table 3 continued)

Table 3 continued

Date	Events
September 1999	A report "Status of GMOs in Thailand" published by BIOTEC.
September 1999	First public hearing on GMOs organized by Department of Agriculture (DOA) held in Bangkok.
October 1999	First survey in Bangkok by BIOTEC on public awareness and attitude towards GMOs.
December 1999	Inauguration of Thailand Biodiversity Center (TBC) as the potential national focal point for the Cartagena Protocol on Biosafety (Thailand has not yet signed the protocol). NBC's secretariat (including subcommittees) moved to TBC.
2000	Establishment of DNA Technology Laboratory (former part of DNA Fingerprinting Unit), with a mandate to detect GMOs on service basis, among other tasks.
2000	Establishment of two separate GMOs detection laboratories in Department of Agriculture and Department of Medical Science.
2000	Thailand Food and Drug Administration (FDA) commissioned a work group to consider labeling method for GM foods.
March 2000	Ministry of Agriculture and Cooperatives' declaration on import prohibition of 40 transgenic plants (revised) with exceptions for grains of GM corn and soy bean.
April 2000	Trade dispute between Thailand and Kuwait/Saudi Arabia over tuna in oil (suspected to be made from GM soya bean).
October 2000	A National Subcommittee on Biosafety Policy proposed to the National Committee on Conservation and Utilization of Biodiversity (NCCUB), with TBC as secretariat office.
January 2001	Trade dispute between Thailand and Egypt over tuna in oil reached its peak. Both party agreed to sign MOU.
February 2001	A draft of GMOs policy approved by the Subcommittee for Policy on Trade of Biotechnology Products.
March 2001	BIOTEC starts a series of consulatation meeting with stakeholders on GMOs issue.
April 2001	A controversial resolution by the cabinet to hault Ministry of Agriculture's large scale field trials according to a request from a pressure group, until a biosafety law is finished.
August 2001	BIOTEC conclude consultation series.

Currently, the products being assessed by the subcommittee includes genetically engineered papaya for viral resistance developed domestically and separately by BIOTEC, Department of Agriculture and Mahidol University.

The Department of Agriculture is soon to announce 37 additional GM varieties to be prohibited by Plant Quarantine Act. The Thai Food and Drug Administraion (FDA), on the other hand, is moving to label GM food. Meanwhile the Ministry of Agriculture is making a petition for the cabinet to reconsider its decision in haulting the field trials back in April 2001, claiming that such move is inhibiting the progress in scientific research and development of the country (Table 3).

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