

The Study of Agricultural Biotechnology Benefits in Thailand

Presented by
Biotechnology Alliance Association (BAA)

March 2007



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Executive Summary

The Study of Agricultural Biotechnology Benefits in Thailand has been reported in 6 chapters, which are briefed as follows:

Chapter 1: Introduction

World-wide, both developed and developing countries have realized that the tools of “**biotechnology**” will play an important role for their development, similar to the success in “Information Technology –IT” during the last decades. Thus, Thailand has joined other countries in capacity building in order to enable effective use of biotechnology. In 1983, the National Center for Genetic Engineering and Biotechnology (BIOTEC) was established under the Ministry of Science and Energy, the name at that time. Subsequently, when the National Science and Technology Development Agency (NSTDA) was established in 1991, BIOTEC was transferred under this agency. Broad capacity building took place, (infrastructure, human resources, laboratory equipment and supplies, etc.), including drafting biosafety regulatory schemes. Recently, the National Policy on Biotechnology and its Strategy in Implementation for 2004-2009 was developed. This demonstrates the commitment of the Thai government in their support for biotechnology. Although significant progress has been made in terms of conventional biotechnology R&D and its use, limited progress has been made in terms of biotech crop or GM crop development. The country formerly was a leader in the region, with field trials in place as early 1996. Unfortunately, these efforts have been thwarted since 2001, and to date Thailand has lost its lead in the initiative to commercialize biotech crops.

The present “Study of Agricultural Biotechnology Benefits in Thailand” contains key information that may be used to make future decisions about agricultural development. Information gathered from the success in the development of biotech crops world-wide as well as Thailand’s previous experience may help drive further success in this important development area.

1.1 Objectives of the Study

- 1) To examine biotechnology development in Thailand, specifically with regard to agriculture
- 2) To review the socio-economic impact of agricultural biotech in Thailand
- 3) To estimate the opportunity loss incurred in the case that Thailand rejects this technology

1.2 Methodology

Information reported in this Study mainly comes from previous studies as cited in references, and from the researchers’ own experience. Information on worldwide development of biotech crop commercialization uses the ISAAA brief 35 (James, 2006). The information regarding development of biotechnology within Thailand is derived mainly from BIOTEC documents. The socio-economic analyses, especially the cases of GM papaya and GM cotton, use information from previous studies by Kasetsart University researchers and from a recent USDA study on the economic benefits of biotech papaya in Thailand. The economic assessment was the joint effort of a Thai economist with assistance from an international expert in the field of agricultural economics.

Study Structure

The structure of the Study is as follows:

- **Chapter 1:** Introduction and Study Objectives. World-wide, advanced technologies such as biotechnology offer a competitive advantage in the rapidly changing global environment.

- **Chapter 2:** Agricultural Development in Thailand. A summary of traditional agriculture followed by a discussion of challenges in modern agriculture and the potential for integrating advanced technologies already available. Future trends of Thailand's agricultural development are discussed.
- **Chapter 3:** World-wide Development of Biotechnology including Thailand. A brief discussion of development of biotechnology in other countries precedes a look at the specific case in Thailand. Discussion focuses on biotech crop development, future trends and a vision for the development of such crops in order to benefit the country's agricultural development.
- **Chapter 4:** National Policy on Biotechnology. Thailand's National Policy on Biotechnology, with an emphasis on policies for agriculture. The development of biotech crops and its regulatory schemes such as the country's "Biosafety Guidelines", field testing, and the drafting of a biosafety law. The latter is hoped to spur future progress in Thailand's biotechnology arena.
- **Chapter 5:** Socio-economic Impact. This section includes an analysis of the potential agricultural advantages when biotechnology is used, by looking at a ten-year period (2007-2017). An estimate of economic impact on the adoption versus rejection of biotechnology, including gain from adoption is presented. The most appropriate options for Thailand are proposed such that farmers can maximize their competitiveness internationally (e.g. the policy of co-existence in using both biotech and non-biotech crops under strict control measures and the policy for development of strong research and development).
- **Chapter 6:** Conclusion. General opinion on adoption of the technology and challenges in technology transfer are included, as well as a summary of the Study's results, with an emphasis on the socio-economic impact analysis. More recommendations are made in an effort to push forward the application of plant biotechnology on the basis of its advantages grounded on scientific facts and principles.

Chapter 2: Agricultural Development in Thailand

This chapter provides information on Thai agricultural development; past, present and future.

2.1 Traditional Agriculture: In this section, development of agriculture during the past 20 years is discussed. During this period of development, policy has changed but still supports agriculture. The most significant change might be the policy of promoting crop diversification. Previously, rice farming was the only major agricultural practice. This was followed by the promotion of field crops, horticultural crops and animal husbandry, as well as integrated farming plans. The importance of agriculture measured as an export commodity is described plus the trend towards its decreasing importance.

2.2 New Agricultural Development: In order to be competitive in agricultural production, adoption of new technologies such as genetics, breeding, cultivation practices with the application of chemicals as well as mechanization have been made. This was called the "Green Revolution." Problems in production have been briefly described as follows:

- 1) Lack of a good water management
- 2) Soil erosion with the loss of fertile land
- 3) Labor shortage
- 4) Problem of land ownership

The "Green Revolution" was not totally beneficial as it contributed to a decrease of natural resources and biodiversity, and new efforts to develop more sustainable agricultural systems have been made. There are a number of promising systems in Thailand as follows:

- 1. His Majesty the King's New Agricultural System.** If water is available, land could be divided in 4 parts; 30% for water reservoir, 30% for rice farming, 30% for field / horticultural crops, and 10% For residential use / raising animals. The water reservoir portion could be used for raising fish and supplying water for crop plants. This arrangement fits well into an integrated farming system.
- 2. His Majesty the King's Philosophy on the "Sufficiency Economy".** This philosophy could be applied to many economic sectors, and particularly agriculture. There are 3 main principles involved; practicing moderation, risk immunity, and careful consideration and planning.
- 3. Organic Farming.** The rationale behind this strategy is to decrease chemical residues and other dangerous substances brought about by agriculture. There are markets for organic products but it can be difficult to practice due to soil and water contamination, plus reduced soil fertility. Post-harvested products are also vulnerable to pest attack. Once chemical fumigation is used, products are no longer considered to be "organic."
- 4. New Initiative of the Ministry of Agriculture using GAP (Good Agricultural Practices).** In this system, more emphasis is placed on the safety of final products. So, it is important to implement a whole system of production, from farm to table to market. The system of safety assessment in each stage must also be in place. At present, the Ministry of Agriculture has established an agency to manage this practice. Products with acceptable safety quality will be rewarded with a "Q" mark that warrants the quality of the products resulting in wider market acceptability. Additionally, one distinction between 'organic' and GAP systems is that organic farming focuses more on process, while the GAP system focuses on both process and final product.

2.3 Future Development: Advanced technology such as plant biotechnology/genetic engineering resulted in moving from the "Green Revolution" to the "Gene Revolution". Genome sequencing of many crop plants and animal species has already been completed. Thailand has joined the "International Rice Genome Sequencing Project" led by Japan and the US. Sequencing projects result in deciphering the genetic code of living organisms by knowing where genes are located on chromosomes. Once the position and function of genes are known, this knowledge can be used as a means to improve plant, animal, as well as microorganism species. The methods of MAS (molecular-marker-assisted selection) and genetic engineering to improve living organisms are promising techniques and can be referred to as "precision breeding".

Modern technology opens the way to improve the quality of natural genetic resources, and value-added agricultural materials can be used to develop various high-value products. Therefore, agriculture today is no longer about producing only food and feed, but leads to the production of nutraceutical and medicinal products that can be used for both disease prevention and cures. Chemicals from plants can serve as raw materials for various industrial products as well as being a source of renewable energy. The application of advanced biotechnology in improving agriculture is discussed extensively in Chapter 3.

Chapter 3: World-wide Development of Biotechnology Including Thailand

3.1 Brief Historical Development of Biotechnology in Thailand

The history of biotechnology development in Thailand was briefly described with the establishment of the National Genetic Engineering and Biotechnology Center (BIOTEC) under the National Science and Technology Development Agency (NSTDA), Ministry of Science and Technology in 1983. This event included capacity building in terms of increased infrastructure, human resources and research and development. A number of students (more than 200) were sent to study abroad in biotechnology-related fields at advanced educational institutions world-wide. A number of them returned to Thailand and are working at BIOTEC and universities throughout the country. The National Science and Technology Park was developed to accommodate state-of-the-art laboratory facilities. Research and development in the field of biotechnology and genetic engineering are described.

3.2 Research and Development in Agricultural Biotechnology

After establishing BIOTEC, both conventional biotechnology and advanced biotechnology were developed. Only a small part of the techniques encompassed by plant genetic engineering are discussed in this chapter. In supporting R&D in this field, BIOTEC set up the “Plant Genetic Engineering Unit” at Kasetsart University Kampaengsaen Campus, and R&D support was granted to various public agencies, mainly the universities. Accomplishments were made on development of GM tomato, GM papaya, GM cotton, and GM chili pepper, all rendered resistant to problematic pests. Biosafety guidelines were developed and field tests were initiated in the late 1990s. However, pressure from opposition groups requesting drafting of a “National Biosafety Law”, brought those field tests to a halt. Research and development in this field has since been delayed, resulting in opportunity loss for Thailand.

3.3 World-wide Development of Agricultural Biotech: Potential Benefits

According to a recent report issued by ISAAA covering agricultural biotechnology during the past decade, the development and use of GM crops world-wide has resulted in a 40 fold global increase with about one third being grown in developing countries. The global economic and environmental impact of the application of agricultural biotechnology during the same period was studied and analyzed by Brooks and Barfoot (2005). Their report indicated the benefits in farm income increase, and positive environmental impact. World-wide development of biotech crops was discussed at length in this paper using ISAAA (James, 2006) as a primary source. The report includes extensive details on the commercial production of GM crops such as soybean, cotton, corn, canola, and other crops.

Chapter 4: National Policy on Biotechnology

4.1 Development of National Policy: An Emphasis on Agriculture

Thailand had a policy to support science and technology for the first time in 1949. However, the policy on science and technology became more evident later, in the fifth National Economic Social Development Plan. The following National Economic Social Development Plans consistently placed emphasis on science and technology as important tools for national development.

Regarding biotechnology, the previous cabinet under Prime Minister Thaksin Shinawatra established the “National Policy Committee on Biotechnology” chaired by the Prime Minister in 2003. At present that national committee still exists, but it is chaired by a Deputy Prime Minister. A detailed National Policy on Biotechnology was described in the BIOTEC Annual Report B.E. 2548-2549 (2004-2005). However, the policy specific to the application of genetic engineering is still pending. Currently, it only states that the public should be offered alternatives in choosing technology.

4.2 Regulatory Scheme – the Development of “Biosafety Guidelines”

BIOTEC initiated a regulatory scheme on biosafety in the early 1990s. The Biosafety Guidelines were completed in 1993 with the establishment of the National Biosafety Committee (NBC). In 2001 the NBC established the “Guidelines for Food Safety Assessment. The work on biosafety regulation under BIOTEC/ NSTDA continued smoothly until management was shifted to the Ministry of Natural Resources and Environment in 2003. The work was delayed during the transition period but it is now moving forward.

4.3 The Application of Biosafety Guidelines

Owing to the responsibility of BIOTEC on regulating biosafety, an Institutional Biosafety Committee (IBC) was set up at each public/private research institute. This coordination structure enabled the NBC to approve many field test sites as listed in the accompanying Table 4.3. However, there are still barriers for commercializing biotech crops in Thailand. The main impediments are 1) there is limited political will in supporting the policy to commercialize biotech crops and 2) public acceptance remains low due to a lack of public education, awareness and misleading information.

4.4 The Drafting of the “National Biosafety Law”

Due to a lack of trust for public agencies’ capability in regulating biosafety, an opposition group requested drafting of the country’s “Biosafety Law”. The first drafting committee was established by the Ministry of Agriculture and Cooperatives in 2001 and responsibility shifted to the Ministry of Natural Resources and Environment in 2004. The draft was completed in 2005 and has been under public review during 2006. Following approval by the National Drafting Committee, it will be submitted to the cabinet for consideration before it can be enacted as law. The research community is hopeful for the passing of this law so they can continue their research, which stands to benefit Thailand.

Chapter 5: Socio-economic impact

5.1 The Potential Economic Benefits of Bt Cotton and GM Papaya in Thailand

The first generation of agricultural biotechnology benefits small farmers through improving yields and reducing costs. Biotechnology, particularly gene manipulation, is an alternative to conventional breeding that improves plant characteristics; productivity is increased and inputs are decreased. When conventional breeding techniques fall short, genetic engineering is the only solution for integrating desired characteristics into plants.

Bt cotton and PRSV-resistant transgenic papaya are used as case studies in this analysis since they are major economic crops in Thailand and the genetically modified versions of these crops are already available for adoption (after passing the regulatory process). A summary from the Study of the Center for Applied Economic Research of Kasetsart University in July 2000 on the benefits of growing GM Bt cotton in Thailand indicated three measurable monetary impacts as follows:

- **Benefits to the Farmer:** The direct benefits to farmers include an increase in yield and a savings in bollworm insecticide spraying. Even though insecticides are still being used for other insects, a savings in bollworm insecticide significantly reduces total cost of spraying. In all cases of Bt cotton production, net profits are greater than those of Sri Samrong 60. Even in the first case where yield of Bt cotton is assumed to be equal to that of Sri Samrong 60, savings in spraying cost is large enough to compensate for seed cost. In the second and the third case, Bt cotton shows much higher benefits to farmers when yields are assumed to be significantly improved (a reasonable assumption based on field trial of Nucleo Cotton 33 B).
- **Foreign Exchange Savings:** Thailand is a net importer of cotton, so increased cotton production would reduce foreign imports. The amount of foreign exchange savings depends on planted area, yield, and imported price – which are almost the same as the domestic price.
- **Employment Creation:** The ginning business would benefit by the creation of new jobs. In turn, income generated from these jobs would increase the national income as a whole.

Papaya is an important food crop for Thai people. It has limited export value currently, but is extensively used locally for green papaya salad. In 1975 the first outbreak of “*Papaya ring spot virus*” (PRSV) occurred. By 2003 the disease had spread throughout the country (USDA Report, 2005), and approximately 80% of planting areas were infected with the virus causing yield reductions of 50%. There are no effective means of controlling the virus except by employing genetic engineering tools. Genetically modified varieties show 90-100 % resistance to PRSV. Based on field test results at the Department of Agriculture’s field station, it is estimated that GM, PRSV-resistant papaya produces a 20-fold yield increase over non-GM varieties. If GM virus resistant papaya is adopted, farmers stand to profit 22-fold.

5.2 This Study – Socio-economic Conclusions

This Study reported preliminary estimates for two important crops; Bt cotton and GM papaya. Both have been severely affected by pest problems in the past 15 years. The cotton industry has nearly disappeared in Thailand, greatly due to difficulty in controlling cotton bollworm. Similarly, papaya

production has fallen to less than one-third of its former peak. GM crops provide major benefits around the world, and hold great promise for Thailand once biosafety protocols are finalized. If Thailand returns the cotton and papaya industries to levels of a decade ago, and if GM crops are as successful here as elsewhere, Thailand stands to reap significant benefits. Based on our analysis:

- **Bt Cotton; Resistant to Bollworm Insect and Leaf Roll Virus Disease:**
 - Improves yield by 55%
 - Saves 50% pesticide cost or 18% of production cost
 - Increases seed cost by 9% of total production cost
 - Takes 3-years for adoption, and an additional 10-years to reach 80% adoption
 - If cotton production area remains at current level of 11,200 ha (70,000 rai), Thailand would benefit by US\$11.5 million (Baht 400 million)
 - If cotton production area returns to peak level as during the 1990's, at 68,400 ha (427,500 rai), Thailand would benefit by US\$43 million (Baht 1.5 billion)

- **Khaek Dum Papaya; Resistant to Ring Spot Virus:**
 - Improves yield by 471%
 - No perceptible cost benefit
 - Takes 3-years for adoption, and an additional 10-years to reach 80% adoption
 - If papaya production area remains at current level of 17,862 ha (111,638 rai), Thailand would benefit by US\$680 million (Baht 24 billion)
 - If papaya production area returns to peak level as between 1997-2001, at 26,103 ha (163,142 rai), Thailand would benefit by US\$880 million (Baht 30 billion)

Chapter 6: Conclusion

6.1 Potential Benefits in Using Biotech Crop

In Thailand, as in other developing countries, the use of chemical insecticides and herbicides is on the rise. In 1994 total active ingredients were 20,790 metric tons with a value of 3,584 million Baht. In 2005, the volume increased to 80,166 tons with a value of 11,360 million Baht ([Office of Agricultural Economics, 2007](#)). Increased use of chemicals causes soil contamination and unhealthy food and water supplies. This problem could be alleviated through the use of genetically engineered crops. Moreover, disease and insect problems that reduce crop yields can also be reduced by such technologically-enhanced crops. The Socio-economic Benefits Analysis in Chapter 5 uses GM papaya and Bt cotton as case studies to suggest a likely income advantage when GM crops are implemented.

6.2 Genetic Engineering -- Biotech Crop: Alternative Technology

Results from this Study show that if genetically engineered biotech crops are used in Thailand, it will result in decreased chemical use in agriculture. The crop yield will likely increase, while production costs will decrease. The net result will be an increase in farmer income. Benefits will be greatest in areas where plant pest problems are severe and resistant varieties of biotech crops selected for use. In the US, for example, farmers tend to use biotech crop varieties when plant pest outbreaks are severe, based on knowledge of disease occurrence patterns. Such logical approaches result in savings on seeds, since cost of biotech seeds can be higher than traditionally bred varieties. Thus, farmers can make their own cost benefit analyses of when it is in their economic interest to invest in biotech seeds.

6.3 General Remarks on Public Perception of Biotech and its Adoption

The biotechnology revolution has raised some issues, as well as deliver benefits. And, there have been dissenters against adoption of agricultural biotechnology questioning long-term effects of the technology. Caution may be warranted – but it must also be recognized that after more than a decade of crop biotechnology adoption, negative effects have not been demonstrated. Overall, scientific research in agricultural biotechnology and in other advanced technologies must be guided by ethical and safety oriented principles while respecting the private sector's need to earn a decent return.

Chapter 1.

Introduction

Countries across the world seek out suitable technology that can drive in-country development. This is based on often fierce competition due to an increasingly global economy. Agriculture has benefited from the “Green Revolution” and now is encountering the relatively new fields of “Biotechnology” and “Nano-technology,” both of which have significant implications for the agricultural sector. Countries that fail to embrace these new technologies may not be able to compete with other nations. Present biotechnology development, especially in agricultural application or agricultural biotechnology, has advanced rapidly. Farmers world-wide have rapidly adopted the application of biotechnology in developing and commercializing “biotech crops.” The year 2006 is a significant milestone in biotech crop development as more than 100 million hectares (102 million.) are now being planted with crops using this technology. From 1996 to 2006 the use of biotech crops increased 60 fold (ISAAA Brief 35-James, 2006) with 10.3 million farmers choosing to plant biotech crops. This rate of technology adoption is extremely rapid when compared to other technological improvements in corn and wheat varieties. During this 11 year period, more than half (52%) the population in 22 countries turned to planting biotech crops, directly or indirectly benefiting the 6.5 billion people living in these countries. More importantly, 11 out of these 22 countries are developing countries such as India, China and the Philippines. ISAAA estimates that in 2015 the number of farmers that plant biotech crops will increase to 20 million, in a total planted area of 200 million hectares throughout 40 countries world-wide.

Thailand understands and accepts the importance of applying biotechnology in advancing various sectors for the economic development of the country. The Center for Genetic Engineering and Biotechnology (BIOTEC) was established in 1983. The initial establishment of the Center followed a cabinet decision and it was under the umbrella of the Ministry of Science, Technology and Energy (the name at that time). In 1991 the Science and Technology Act was implemented, giving birth to the National Science and Technology Agency (NSTDA). BIOTEC was transferred to and remains under the management of NSTDA along with other two national centers, MTEC (National Metal and Materials Technology) and NECTEC (National Electronics and Computer Technology Center), but still under the Ministry of Science umbrella.

With the establishment of BIOTEC, infrastructure, human resources, and R&D have progressed significantly. Government acknowledged the importance of biotechnology development, and the National Policy and its Implementation Strategy for 2004-2011 was created. Success to date has been somewhat satisfactory in the areas of traditional biotechnology such as plant tissue culture, fermentation, and vaccine production and development of diagnostic kits. However, there has not been much progress in the application of genetic engineering in the development and use of biotech crops on the commercial scale. At the same time, world-wide development of biotech crops and commercial planting of approved varieties has grown quite extensively in many countries as mentioned earlier.

Initially, Thailand was the regional leader in biotech-related research and development. The country built great capacity in developing a number of biotech crops such as tomato, chili pepper, and papaya. Furthermore, it was one of the region’s leading countries in creating National Biosafety Guidelines and was the first to approve field-testing of biotech crops. Unfortunately, a moratorium on open field trials, put in place in 2001, has set Thailand back significantly and many opportunities in this area have since passed Thailand by. We hope that this Study may be a driving force to propel Thailand towards further development, which will increase the competitiveness of the country, and most significantly, benefit the country’s poorest farmers and the rural communities where they live.

1.1 Objectives of the study

- 1.1.1 Review biotechnology development in Thailand, focusing on agricultural applications
- 1.1.2 Examine the socio-economic impact of agricultural biotechnology in Thailand
- 1.1.3 Estimate opportunity loss in the case that Thailand does not embrace the application of biotechnology.

1.2 Methodology

Information reported in this Study mainly comes from previous studies as cited in references and from the authors' own research. Information on world-wide development of biotech crop commercialization is mainly drawn from the ISAAA brief 35, (James, 2006). The history of the development of biotechnology within Thailand is based on BIOTEC documents. The socio-economic analyses, especially the case of GM papaya and GM cotton, use information from previous studies of Kasetsart University researchers and from a recent USDA study on the economic benefits of GM papaya in Thailand. The economic analysis was a joint effort between a Thai economist assisted by an expert in the field of agricultural economics.

1.3 Study Structure

The structure of the Study is as follows:

Chapter 1: Introduction and Study Objectives. World-wide, advanced technologies such as biotechnology offer a competitive advantage in the rapidly changing global environment.

Chapter 2: Agricultural Development in Thailand. A summary of traditional agriculture followed by a discussion of challenges in modern agriculture and the potential for integrating advanced technologies already available. Future trends of Thailand's agricultural development are discussed.

Chapter 3: World-wide Development of Biotechnology including Thailand. A brief discussion of development of biotechnology in other countries precedes a look at the specific case in Thailand. Discussion focuses on biotech crop development, future trends and a vision for the development of such crops in order to benefit the country's agricultural development.

Chapter 4: National Policy on Biotechnology. Thailand's National Policy on Biotechnology, with an emphasis on policies for agriculture. The development of biotech crops and its regulatory schemes such as the country's "Biosafety Guidelines", field testing, and the drafting of a biosafety law. The latter is hoped to spur future progress in Thailand's biotechnology arena.

Chapter 5: Socio-economic Impact. This section includes an analysis of the potential agricultural advantages when biotechnology is used, by looking at a ten-year period (2007-2017). An estimate of economic impact on the adoption versus rejection of biotechnology, including gain from adoption is presented. The most appropriate options for Thailand are proposed such that farmers can maximize their competitiveness internationally (e.g. the policy of co-existence in using both biotech and non-biotech crops under strict control measures and policy for the development of strong research and development).

Chapter 6: Conclusion. General opinion on adoption of the technology and challenges in technology transfer are included, as well as a summary of the Study's results, with an emphasis on the socio-economic impact analysis. More recommendations are made in an effort to push forward the application of plant biotechnology on the basis of its advantages based on scientific facts and principles.

Chapter 2:

Agricultural Development in Thailand

2.1 Traditional Agriculture in Thailand.

Thailand can be classified as an agrarian country as its economy was based on agriculture for several hundred years. The imprinted stone of King Ramkamhaeng in the Sukothai period refers to the fruitfulness of the country stating that “There are fish in the water and rice in the paddy fields”. Thus, in its early development, the country depended on agricultural products, with an especially significant dependence on the cultivation of rice. Since then, rice germplasm and rice farming practices have been improved significantly through the development of better rice varieties, cultivation techniques, as well as rice processing from paddy to white rice for consumption and export. During the recent past, Thailand has been a world leader in the exportation of rice.

Thai agriculture in earlier periods depended mainly on rich and fertile soil. When soil fertility was depleted, farmers moved to new, more fertile sites. This practice combined with population increases, called for the expansion of cropping areas and increased animal husbandry, leading to deforestation. In addition, the government implemented new agricultural policies for diversifying agricultural production, from farming only rice to field crops, to horticultural products and integrated farming systems. However, Thai agriculture in older times may be considered as small, subsistence farming in that the products were mainly for family consumption and only a small surplus was for sale in the local marketplace. Following later developments, this changed to agriculture as an industry or commercial agriculture with larger farms and increased investment in the agricultural business. Small farmers gradually sold their land and shifted roles from landlord to farm laborer. These changes caused a shift from traditional agriculture to some extent. However, small farmers continue to dominate the agricultural landscape in the country.

2.2. Modern Thai Agriculture.

The National Social and Economic plans of Thailand in recent periods emphasize the improvement of high quality products and increasing yield per unit area. These may be grouped into at least two classes, small or subsistence farmers and the agricultural industry or commercial agriculture. Currently, almost all produce is for sale or export. Government policy has emphasized the need to assist small farmers, while commercial farmers rely on their own private resources.

During the period of the “Green Revolution,” Thai farmers adopted new technologies such as improved varieties, chemical fertilizers, pesticides, and mechanization for enhancing farm productivity. However, due to a lack of knowledge and experience with these technologies, pollution and health problems resulted, as well as environmental and biodiversity degradation. Some small farmers did not know how best to invest in agricultural inputs and machinery, resulting in over investment. No doubt that caused higher cost of production and increased debt burden among poor farmers. In general, the primary problems in Thai agriculture can be summarized as follows:

2.2.1. Water Management.

Thai agriculture relies mainly on rain water, or rain fed agriculture. At present, irrigation covers only about 18% of total cropping areas. The main problem is a lack of reliable water sources. Smaller reservoirs lack water for farmer use during the dry season. Moreover, there is no proper water management causing frequent drought and floods.

2.2.2 Soil Erosion and Loss of Fertility

As a result of destroying water resources, including the deforestation caused by intense farming, heavy rain has caused soil erosion and in some cases causes sudden flooding. Moreover, land with a long history of farming has never been properly improved and cared for. Depleted soil leads to increasingly low productivity.

2.2.3. Labor Force Shortage

Regrettably, the basic survival problems of people engaged in the agricultural sector continue today. These include changes in the environment, occurrence of diseases and insect pests. These problems have compromised productivity, while the price of agricultural inputs such as fertilizers, chemicals and seeds has increased with no or little increase in the price of products. The result is an increase in debt among a majority of farmers, with the consequence of urban migration from farm to city. With a scarcity of farm hands, it becomes necessary to turn to mechanization, further increasing production costs.

2.2.4 Land Ownership Problems.

Faced with overwhelming debt, some farmers have to sell their land and shift to leasing land or alternatively, becoming hired farm hands. Increasingly, fertile agricultural land is being used for housing areas or industrial plants. This is due to increased urbanization as well as greater conveniences in communication. The issue of land utilization has not been adequately addressed. Because of these problems, there has been a greater focus on alternative agricultural options.

2.3. Present Popular Alternative Agricultural Systems.

Due to a lack of knowledge and experience in using technology among a majority of farmers, the over and improper use of chemicals have caused pollution in soil and water and a decrease in biodiversity. In some cases, farmers' health is adversely affected. Therefore, alternative agricultural systems in various forms have been put forward. Some of the most promising are discussed below:

2.3.1. Integrated Agriculture. His majesty the King proposed a "New Agriculture Theory." It involves the planting of crops, animal husbandry and raising fish in addition to rice farming. A plot of land could be divided into 4 parts, 30% for water reserves, 30% for rice fields, 30% for planting other field and horticultural crops, and the remaining 10% for housing and raising animals. Access to water is an inherent part of this integrative system. Locations lacking adequate water supplies may not be able to apply this specific approach.

2.3.2. Agricultural System Using the Philosophy of "Sufficiency Economy". This system follows the suggestion of His Majesty the King. It may or not be considered as integrated agriculture, but 3 main principles are practiced; the practice of moderation, careful consideration and built-in risk prevention.

2.3.3. Organic Farming. This is a practice by which crops are produced without chemical applications. Organic or bio-fertilizers and pesticides are used rather than chemicals. The relatively small market for these products and the small volume in which they are produced are limiting factors for organic approaches to farming.

2.3.4. Good Agricultural Practices (GAP). This is in fact a form of integrated agriculture with the use of chemicals and organic or bio-substances. GAP emphasizes the safe use of chemicals through strict control measures from the farm to the table. Implementation involves following recommendations from the administrator and the market. The key objective is to produce safe products for consumers. At present the GAP system is under the control of the Ministry of Agriculture and Cooperatives. Any products with good quality will be given the "Q" mark ensuring their safety. Additionally, one distinction between organic and GAP systems is that organic farming focuses more on process, while GAP focuses on both process and final product.

2.4. Importance of the Agricultural Sector in the Country's Economy.

The importance of the agricultural sector in the country's economy can be measured using the agricultural commodity export figures compared to the gross national products (GNP) ration. Figure 2.1 illustrates this as shown below:

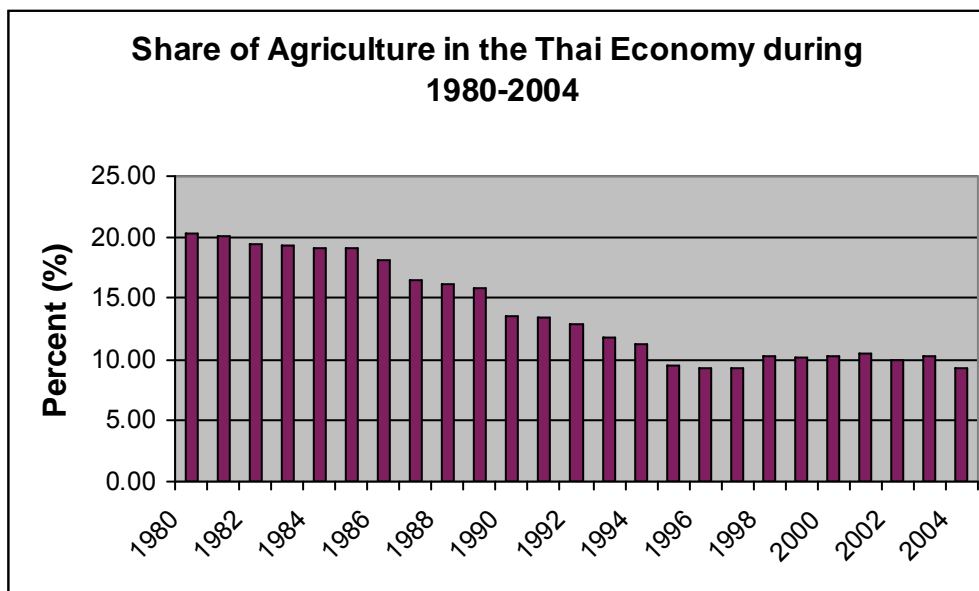


Figure 2.1 Share of Agriculture in Thai Economy during 1980-2004

Source: National Economic and Social Development Board: NESDB, 2006

Figure 2.1 illustrates the decreasing importance of agriculture since 1980. The GDP figure of the agricultural sector decreased from 20% to 9-10% from 1996 to 2004.

It is obvious that the share of agriculture in Thai economy has been decreasing from 20% to 9-10% during 1996-2004. However, the number of people in agricultural sector has not been decreasing in proportion to that trend. As a result, one could expect that farmers can earn less and farming may not be profitable. Therefore, it is necessary to find ways increase the share of agriculture in the country economy so farming in Thailand could be maintained and sustainable development.

2.5. Challenges & Future Development.

During the "Green Revolution", Thailand joined other countries in the adoption of new technologies for agricultural improvement. Such technologies include new crop varieties, chemical fertilizers, pesticides and mechanization. Subsequently, it became clear that some of these changes resulted in several environmental and human health issues. Thailand is among the countries importing a sizable volume of chemical fertilizers, pesticides and other chemical products each year (Appendix Table 1). This higher rate of pesticide use along with their improper application has caused several problems as stated above. The tools offered by biotechnology hold much promise for resolving many of these concerns.

In the period during which the tools of biotechnology were developed, (which we may call the "Gene Revolution"), an important component was researching the genome, or "opening the book of life." The genomes of many living organisms such as microbes, plants, and animals (including humans) have been studied through genomics approaches. The application of such knowledge has been of great value to agriculture. For example, the development of Molecular Marker-Assisted Selection (MAS) technology and gene transformation leads to the development of improved varieties with desirable genes. The latter

is what we refer to as “genetic engineering,” from which there are fewer limitations in transferring genes across species, genera and families. Both MAS and genetic engineering, when applied to the development of new varieties may be referred to as “precision breeding”.

2.5.1. Precision Breeding.

In order to fully realize the potential of plant breeding, we must consider the importance of genetic diversity and the application and use of knowledge garnered from extensive genomics research. After genomic analysis of an organism’s chromosomes takes place, research may continue in two ways as follows:

1) Use of Molecular Markers in Selection (MAS-Molecular-marker-Assisted Selection). Molecular markers could be developed using knowledge from DNA sequencing of specific gene or desirable trait. Such markers could be used in selecting plants or individuals having such gene(s). The resulting plant variety with desirable genotypes is the same as that from conventional breeding, not considered to be “GMO”.

2) Genetic engineering. When a desirable target gene is identified, a transfer of that gene from one plant variety to another can be attempted. This can be considered as an alternative to the strategy above. The plant receiving the gene is referred to as a “**GM plant**” or a “**Biotech crop**”. The principal behind the application of genetic engineering is that when conventional breeding cannot be accomplished, genetic engineering could be applied. In most cases, desirable genes cannot be found in closely related species that allow the use of MAS, so genetic engineering is the only alternative. A good example may be the case of biotech Bt. crop resistant to insect that needs Bt gene from *Bacillus thuringiensis*, soil microorganisms. The gene expresses a protein which protects plants from specific insect pests. Since one cannot breed a plant with bacteria, applying the tools of genetic engineering is the only way to transfer this unique feature of *B. thuringiensis* to the genomes of crop plants.

2.5.2. Golden Period of Plant Breeding.

It is well known that plant crops can be used for food, feed and fiber, but they can also be used as raw materials for the development of industrial products such as pharmaceuticals, chemicals, polymers and energy. This is in addition to horticultural and medicinal crops, which are economically important cash crops. Therefore, contemporary plant breeding has an array of different objectives. Besides the ones mentioned previously, improved crops could be in phyto-remediation to absorb toxic waste and chemicals, resulting in environmental improvement. These endeavors require advanced technology such as the tools of biotechnology. However, it is necessary to use biotechnology appropriately and in conjunction with conventional technology. The potential end-products of agricultural biotechnology are extremely diverse, which speaks to the potential agriculture holds for so many sectors, as shown in Figure 2.2.

Capacity building in the use of biotechnology from 1987 to present has been successful to some degree in Thailand. Advanced biotechnology, such as MAS and genetic engineering, has been applied to plant breeding. The country participated in International Rice Genome Research in 1998 with ten other countries (Vanavichit, 1999). This resulted in the establishment of the Rice Gene Discovery Unit jointly supported by BIOTEC and Kasetsart University. At the same time, the DNA Technology laboratory was established at Kasetsart University (Kamphaengsaen Campus) which has the capacity for using molecular techniques and the tools of biotechnology for the identification of various natural plant products, generating GMOs, true-to-variety, crop mixture, foreign materials, etc. Due to their enhanced infrastructure, Kasetsart University was selected by the Ministry of University Affairs (presently the Commission on Higher Education) to lead and coordinate the Consortium of Agricultural Biotechnology (CAB) with four other universities; Mahidol, King Mongkut University of Technology at Lard Grabang, Chiang Mai and Khon Kaen. The CAB has as its mandate to invest in human resource development by producing a large number of M.S. and Ph.D. graduates in this area.

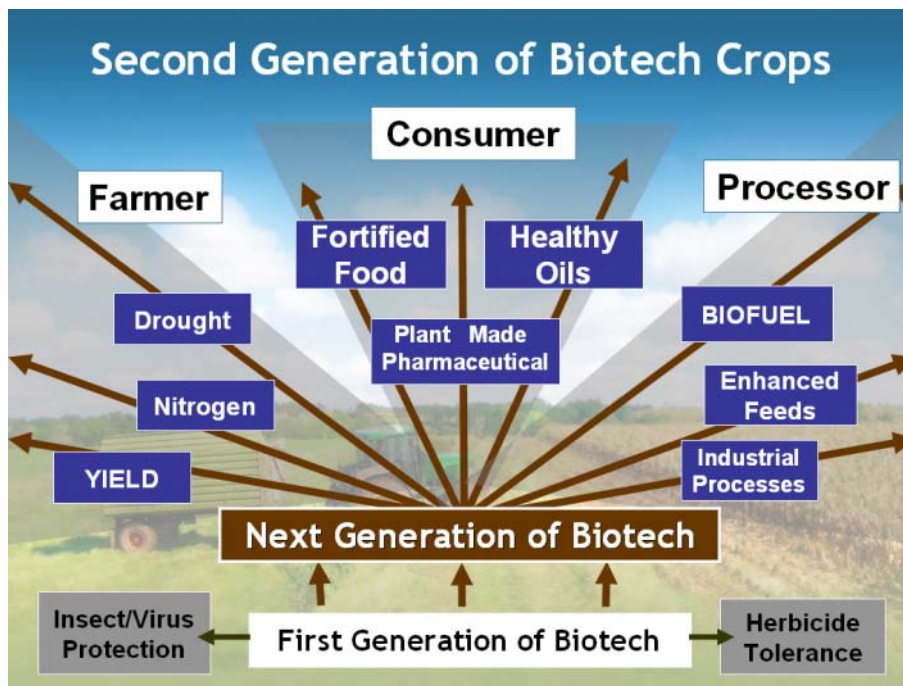


Figure 2.2 Anticipated products from the application of agricultural biotechnology.

2.5.3 Conditions for Successful Development.

At present, Thailand does not have regulatory and legal support to sustain R&D. This includes incentives for carrying out research such as tax incentives and other rewards, especially for the private sector to participate in agricultural development. An example may be the case of plant variety development that almost all transnational companies have been operating in Thailand with the aim to use the country as their research and development base in the region. Because current government policy does not support the investment for R&D leading to the production of biotech crops, the overall environment for development is diminishing.

As mentioned in Chapter 4, the country has successfully developed its National Policy on Biotechnology, though the sections regarding “genetic engineering” that lead to the production of biotech crops are still pending. Development has been carried out by the National Science and Technology Development Agency and BIOTEC, the Secretariat of the National Biotechnology Committee. Policy covers all aspects of the country’s developments in agriculture, public health, food, energy and the environment. Regarding agricultural biotechnology policy, it could be summarized in Figure 2.3 (Sriwatanapongse, 2004).

Figure 2.3 indicates that if agricultural biotechnology is to be used in the agricultural development of the country, it could help increase growth in the agricultural sector from 3.26% to 4% over the next 10 years. It is anticipated that application of genetic engineering technology for development of plant varieties resistant to disease and insect pests, in conjunction with the application of organic and bio-substances, can reduce chemical use substantially. The overall goal is to have high quality agricultural products without any chemical residue, foreign substances such as heavy metals, microorganisms and insect pests. Molecular biotechnology could be used in the production of diagnostic kits to rapidly identify diseases and other contaminants. Such services would create trust in assuring safety and quality of Thai agricultural products. That would lead to the country’s goal of being a “World Kitchen”. In order to accomplishing these goals, quality assurances process such as the biosafety control process and IP (intellectual property) management need to be in place with cooperative networking among concerned public and private organizations.

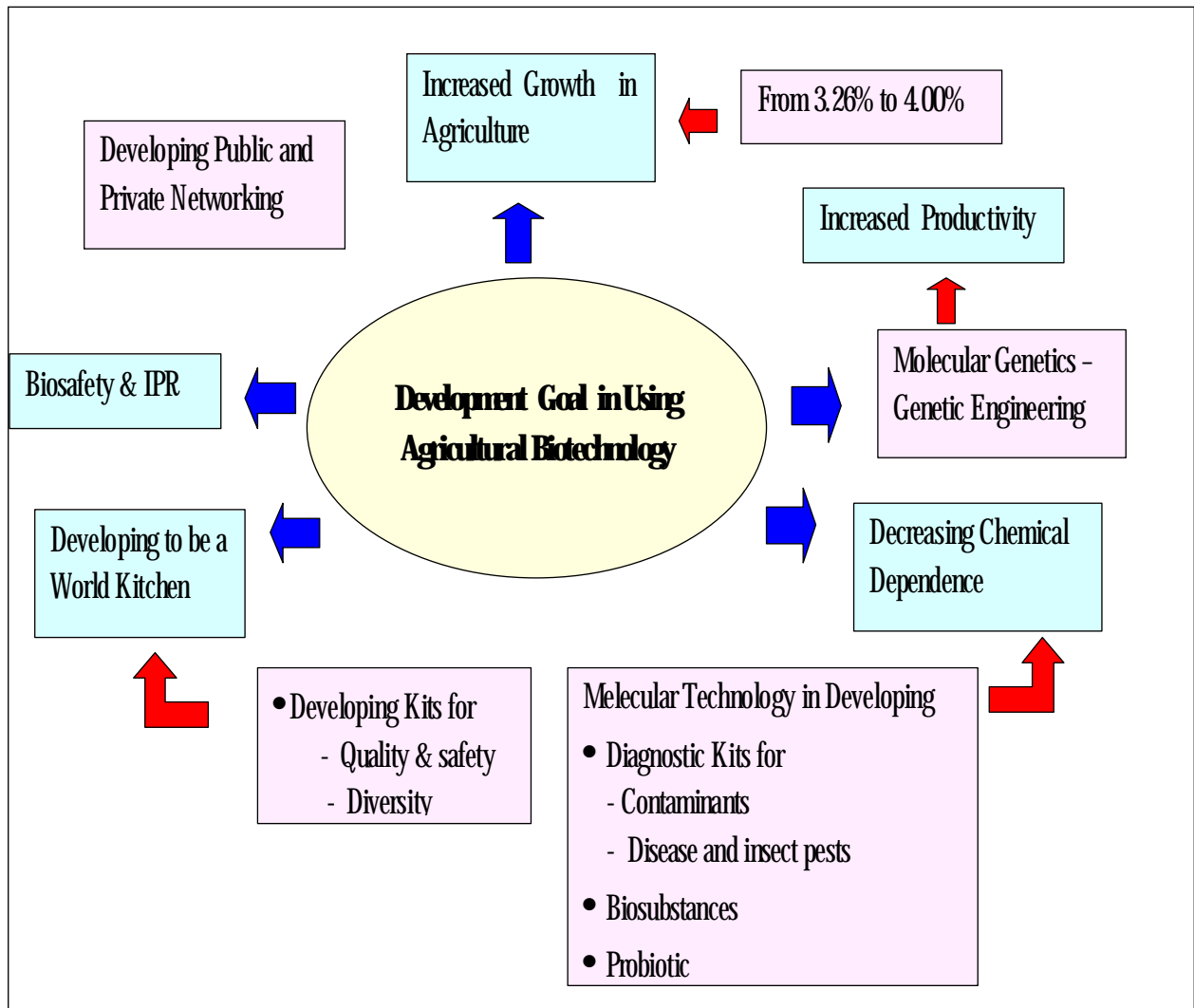


Figure 2.3 The Goal in the Development of Agriculture Using Biotechnology

Source: Sriwatanapongse, 2004

Chapter 3

World-wide Development on Biotechnology Including Thailand

3.1 World-wide Development of Biotechnology

Even though Thailand has not yet fully embraced biotech crops, several other countries have benefited from commercially growing biotech crops and conducting the underpinning R&D. Developed countries such as the United States, as well as developing countries such as China, India and the Philippines, have moved R&D in biotech crops forward and have already approved commercialization of biotech crops. What's more, even countries that have not yet approved the cultivation of biotech crops, still fully support R&D concerning biotech crops. In the case of Thailand, R&D in biotech crops used to be quite well advanced in the region. A few biotech crop species including tomato, papaya and chili pepper were developed in concert with biosafety regulation schemes. However, currently extensive R&D on biotech crops is prohibited, and the ban on confined field trials is an especially problematic hurdle. Jarunya (2005) describes the status and current trends in R&D in the area of genetic engineering as follows:

3.1.1 Current Crop Commodities With R&D in the Area of Genetic Engineering:

Most R&D in the area of genetic engineering in several countries has emphasized developing various biotech crops dependent on the conditions and needs of the country. However, some general categories of R&D in biotech crops based on major crop commodities can be described as follows:

1) Cereal and Flowering Crops:

The main purpose for developing GM cereal crops is to increase yield, control quality and improve varieties. This is accomplished by adding novel traits, which have never been found in that crop. Examples of these novel traits are:

- Resistance to insect pests: This can reduce the use of insecticides that may be harmful to living organisms and the environment. Most research has involved the application of a gene from *Bacillus thuringiensis* commonly referred to as "Bt."
- Virus Resistance: The example contained in this study describes R&D, which resulted in the development of papaya resistant to the papaya ringspot virus, using a gene from the virus itself that codes for the viral coat protein.
- Tolerance to herbicides: Most commercialized crops have employed this trait. This is because companies that have invested heavily in R&D sell a package that confers tolerance to glyphosate, such as the case of Roundup Ready Soybeans.
- Increased nutritional value: In *Japonica* rice, so-called "Golden Rice" was developed, which contains high levels of Pro-vitamin A, by using genes from both daffodil flowers and bacteria. Subsequently, "Golden Rice 2" was developed in *Indica* rice using genes from maize. In addition, R&D on improving oil quality and essential protein quantity are underway.

In the case of flowering and ornamental crops which have high value, R&D on these crops has been conducted in the following areas:

- Change in flower color: The mode and mechanism of altering flower color in various crops has been the subject of much research. Crops that are model organisms in this field are Petunia and Snapdragon. Florigene and Suntory companies which are leaders in R&D on changing flowering color had success in developing blue carnations and blue roses for commercial application.

2) Energy Crops.

R&D concerning the genetic engineering of energy crops, or crops that can be used as a primary product to produce energy substances such as bio-ethanol, bio-diesel, bio-gas and bio-solacell, emphasize three areas:

- Increase production of raw materials that may result in reduced production costs.
- Conversion of raw materials from sugar starch or cellulose into fermented sugar by micro-organisms or enzymes.
- Fermentation of sugar to alcohol.

At present, many companies have intensified R&D in developing crops for producing ethanol. The company Syngenta, for example, developed GM maize for ethanol production, which produces conversion enzymes within the grain. These are the same enzymes that are otherwise added by the ethanol production manufacturer. This maize variety is expected to be sold commercially in 2008

3) Pharmaceutical Crops:

There is increased interest and R&D in the area of pharmaceuticals, which will likely be more readily adopted than previously developed food crops. Progress has been made in maize, tobacco, rice and canola. In the past, the production of pharmaceuticals has typically been conducted in bacteria such as *Bacillus spp*, *E. coli* followed by mammalian and insect cell culture and the generation of transgenic animal lines, such as in laboratory mice.

Genetically modified crops offer several advantages, which have led to their popularity among current users. For example, a 10-100 times decrease in production price compared with the use of yeast or bacteria systems has been reported. This is due to the fact that a cropping system can be employed as opposed to a bioreactor and production can be scaled-up more easily. Most importantly, using plants to produce pharmaceuticals is considered safer, since the crop plants do not produce prions and plant pathogens to not cause diseases in humans. The development of a Hepatitis-B vaccine in banana and tomato is currently ongoing. About 11 companies in Europe are working in this are and will soon be prepared to bring their product to the market.

4) Industrial Crops:

The major industrial crop is cotton, which was transformed with Bt to be resistant to the American Boll Worm. The application of this technology in China has boosted its production rank from fifth to the third largest producer in the world. Apart from developing GM cotton to resist insect pests, ongoing research in China aims to develop blue colored cotton to circumvent commercial dyeing procedures in the textile industry. In addition, mechanisms in producing cotton fiber are being studied including genes controlling polymer production, which will be used in producing wrinkle-free cloth that does not need to be ironed. Other studies have been done on crops that can produce biodegradable plastic, which is in high demand.

1) Genetic Engineering for Environment:

There are endeavors to develop GM crops to help protect the environment. For example, R&D on developing GM crops for resisting insect pests, which aim to reduce insecticide usage. There is R&D on developing maize and soybean for low phytate (phytate is one form of phosphorus stored in plants and difficult to digest) used for feeding poultry and swine. These livestock do not have enzyme phytase to digest phytate resulting in the need to supply phosphorus as a diet supplement. Phytate remains in animal waste and is released to natural water resources, which causes water pollution. In addition, this technology has been applied to develop crops for using in phytoremediation process. That

is, using crops to absorb toxic substances. Those substances will be stored in plants or changed into non-toxic forms before decomposed in the environment.

3.1.2. Status of Commercial Biotech Crops.

1) Type and Trait of Biotech Crops that are Currently Grown Commercially:

Crops have been developed using genetic engineering, which allow for the development of crop varieties that express specific desired traits. These traits can offer a variety of benefits to humans. To date, genetic engineering has been used to improve at least 16 different crops that have been approved for commercial production in various countries. These modified crops include canola, carnation, chicory, cotton, flax, maize, melon, papaya, potato, rice, soybean, squash, sugar beet, tobacco, tomato and wheat. Each GM crop differs in the desired or modified trait, and can be categorized into groups as followed:

- Herbicide tolerant: A prominent example is that of soybean which is rendered tolerant to the herbicide glyphosate.
- Resistance to insect pests: E.g. cotton which is resistant to the American Boll Worm.
- Resistance to diseases caused by bacteria, fungus and viruses: E.g. papaya which is resistant to the ring spot virus.
- Tolerance to environmental stresses: Examples include drought and salinity tolerant rice.
- Increased nutritional value: Such as rice which has high pro-vitamin A content.
- Extended shelf life: Such as slow ripening tomato.

2) Adoption of Biotech Crops:

The year 2006 (James, 2006), marked the second decade of commercial cultivation of biotech crops. In 2006, planting areas of biotech crops continued to increase, with up to 102 million hectares planted with biotech varieties (Figure 3.1). In 2006 10.3 million farmers grew biotech crops in 22 countries around the world. This is a remarkable rate of adoption, which reflects the trust of millions of farmers and consumers towards biotech crops.

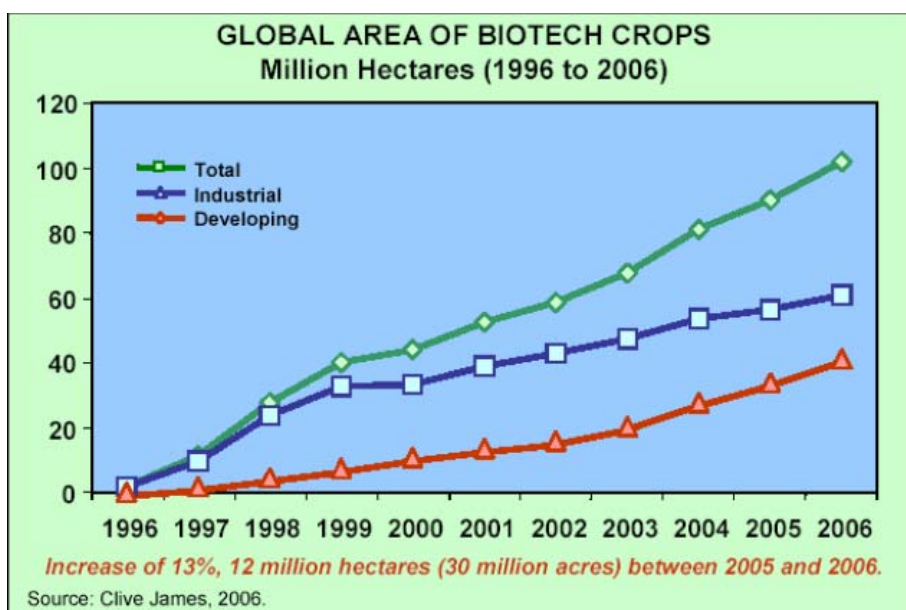


Figure 3.1 Global planting area of biotech crops, which has continuously increased during the period from 1996-2006.

In 2006, the number of countries growing biotech crops increased from 21 in 2005 to 22 countries in 2006. The addition of one new EU member country (Slovakia) resulted in a total of 6 EU countries that chose to grow biotech crops; specifically, Portugal, France, Czech Republic, Germany, Spain and Slovakia.

During the year of 2006, for the first time, India grew more Bt cotton (3.8 million hectares) than China (3.5 million hectares) and moved up the world ranking by two places to number 5 in the world, overtaking both China and Paraguay.

Among the 22 countries that currently grow biotech crops, 11 countries are developing countries and 11 are industrialized countries. Planting areas in each country ranking from high to low as followed: USA, Argentina, Brazil, Canada, India, China, Paraguay, South Africa, Uruguay, the Philippines, Australia, Mexico, Romania, Spain, Columbia, France, Iran, Honduras, Czech Republic, Portugal, Germany, and Slovakia as shown in Figure 3.2.

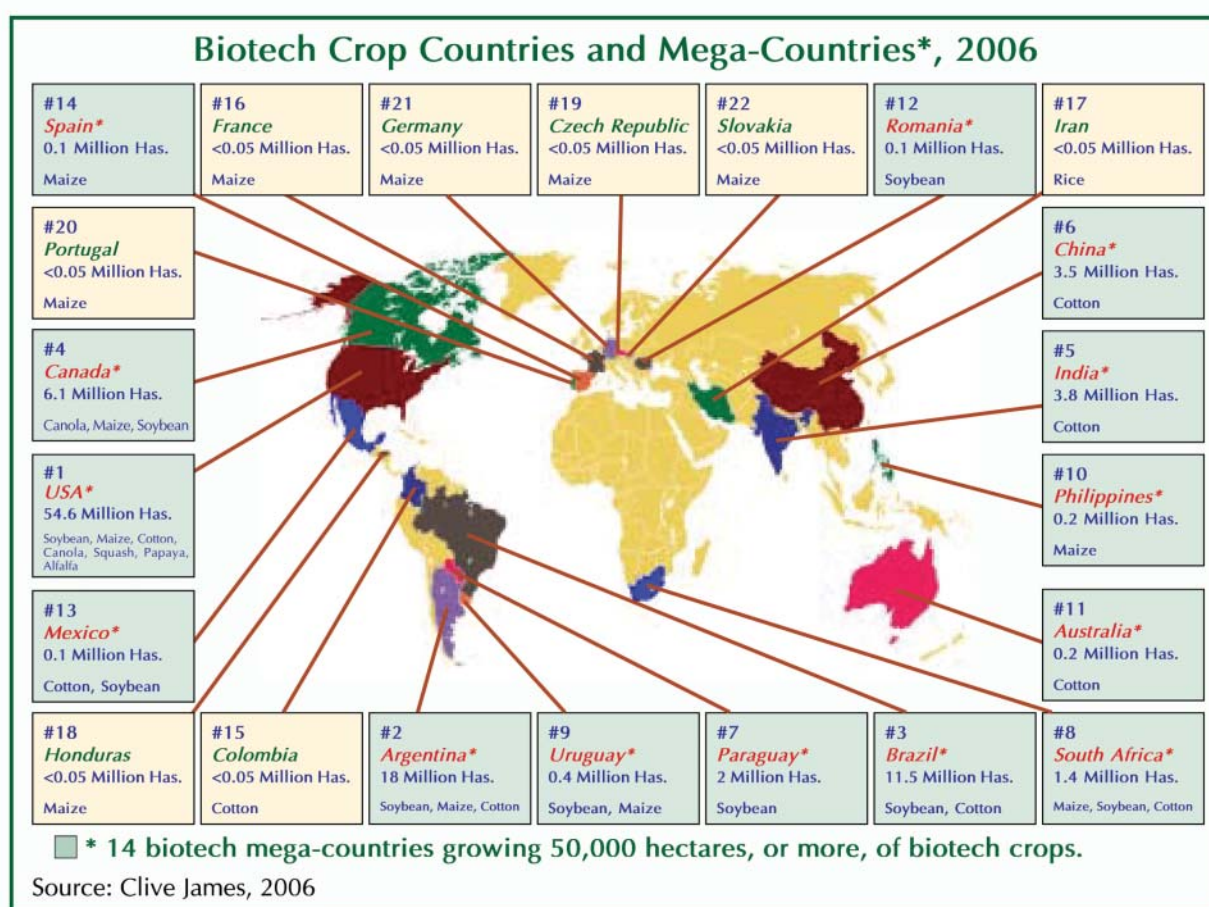


Figure 3.2 Twenty-two countries globally chose to grow biotech crops in 2006.

Biotech Soybean is the most predominant crop, the planting area of which has continuously expanded to 58.6 million hectares in 2006, or 57% of the total biotech crop global growing area. Soy is followed by biotech maize at 25.2 million hectares, comprising 25.2%. Biotech cotton at 13.4 million hectares, comprises 13% and biotech canola at 4.8 million hectares comprises 5% of biotech crop global growing area. When compared with the total areas of global planting areas of the same crop, they accounted for 64, 38, 18 and 17 percent of soybean, cotton, canola and maize production, respectively (Table 3.1).

Table 3.1 Biotech crops adopted for growing commercially in 2006.

| Biotech crops | Traits | Global planted areas (million hectares) | Biotech crops planting areas in percentage of total global planting areas of GM crop (percent) | Biotech crops planting areas; percentage of total global planting areas of that crop (percent) |
|----------------|---|---|--|--|
| Soybean | Herbicide tolerance | 58.6 | 57 | 64 |
| Maize | Herbicide tolerance Insect pest resistance | 25.2 | 25 | 17 |
| Cotton | Herbicide tolerance Insect pest resistance | 13.4 | 13 | 38 |
| Canola | Herbicide tolerance | 4.8 | 5 | 18 |
| Total | | 102 | 100 | - |

Source: James, C. 2006

In 2006, biotech alfalfa that is tolerant to herbicide was first approved to be grown in USA and was seeded on 80,000 hectares or roughly 5% of the 1.3 million hectares of alfalfa seeded in the USA. Biotech cotton, tolerant to herbicide was launched in 2006 as well, occupying a substantial area of over 800,000 hectares.

In 2006, around 10.3 million poor farmers chose to grow biotech crops in 22 countries. This reflects an increase from the 8.5 million in 21 countries who were previously growing biotech crops. Ninety percent of the farmers who obtained benefits from biotech crops are poor farmers from developing countries. Their incomes increased significantly, thereby alleviating poverty. In 2006, about 9.3 million people benefited from biotech crops, which increased from 7.7 million people in 2005. Of those, 6.8 million are in China, 2.3 million are in India, with the balance in the Philippines, South Africa and seven other developing countries.

While 22 countries grew biotech crops commercially in 2006, there are 29 additional countries that have approved the introduction of GM products used for food, animal feed, food processing and intentional release into the environment since 1996. This includes countries that import large amounts of food but do not yet actually cultivate biotech crops, such as Japan.

3) The Global Value of the Biotech Crop Market:

In 2006, the global market value of biotech crops, estimated by Croprosis, was \$6.15 billion representing 16% of the \$38.5 billion global crop protection market in 2006 and 21% of the ~\$30 billion 2006 global commercial seed market. The \$6.15 billion biotech crop market comprised of \$2.68 billion for biotech soybean (equivalent to 44% of global biotech crop market), \$2.39 billion for biotech maize (39%), \$0.87 billion for biotech cotton (14%), and \$0.21 billion for biotech canola (3%). The market value of the global biotech crop market is based on the sale price of biotech seed plus any technology fees that apply. The accumulated global value for the eleven-year period, since biotech crops were first commercialized in 1996, is estimated at \$35.5 billion. The global value of the biotech crop market is projected at over \$6.8 billion for 2007 (James, 2006).

3.2 History of Biotechnology Development in Thailand: Capacity Building.

3.2.1 Biotechnology: Biotechnology refers to techniques that utilize organisms or products obtained from genetically modified organisms. The tools of biotechnology have been used in age-old processes for a long time, such as in fish sauce production, soy sauce, fermented food and the fermentation of alcohol. All of these techniques are referred to as conventional technology. There are more advanced tools of biotechnology used for plant and animal breeding in order to increase high yield, high quality or use of herbal plants for curing diseases and aiding in other health-related issues. This is still called conventional biotechnology.

However, modern biotechnology can be referred to as genetic engineering, which can be employed in various areas including medical, industry and agriculture (Shrimp Zone, 2003).

3.2.2 Agricultural Biotechnology: Agricultural biotechnology is the technology developed for use in the following areas:

- Plant breeding to improve new varieties such as field crops, vegetable crops, flowering crops and for crop propagation.
- Animal breeding and improved breeding of livestock.
- Biological pest control and use of microorganism for improving environmental conditions.
- Exploration of untapped resources and development of new resources.

3.2.3 Past to Present: the Use of Agricultural Biotechnology.

This paper will address only the use of biotechnology in crop production, which has been applied to three areas: varietal improvement and propagation, microorganism development in agriculture and bio-control development (Tanticharoen, 2004).

1) Varietal Improvement and Propagation: Apart from successfully using conventional techniques in crop breeding for commercial use, tissue culture techniques have been used for a large amount of non-seed propagation including plant breeding and selection, disease free plant material and exchange of germplasm.

2) Microorganism Development in Agriculture: A great deal of research and development has been performed on beneficial microorganisms in agriculture, which can be divided into 2 areas:

2.1) Microorganisms that can fix nitrogen: These microorganisms will help to increase nitrogen to a form that is readily available for uptake by plants. They can be categorized into two groups:

- Free-living nitrogen-fixing microorganisms: Examples include *Azotobacter* and green algae.
- Symbiotic nitrogen-fixing microorganisms: *Rhizobium*, which associates with legumes, is well-studied example.

2.2) Microorganisms that are used in fermentation: They usually have been used in various agro-industries such as cheese, wine, vinegar, fermented whole soybean and seasoning powder production.

2.3) Microorganisms that are used to convert biomass to bio-energy: These organisms decompose biomass in the soil to organic matter and minerals that are useful for plant growth and low price bio-gas.

3) Bio-control Development: Work is being done to develop microorganisms that are used for pest control. Examples include the use of *Beauveria bassiana* in controlling European corn borer in maize and the use of *Bacillus thuringiensis* in controlling insect pests etc.

Even though more traditional biotechnology tools have served as invaluable solutions for many aspects of crop production, some challenges in agriculture cannot be tackled with the limitations of traditional biotechnology. Control of the cotton boll worm and the papaya ringspot virus, are such examples.

3.3 Use of Modern Biotechnology or Genetic Engineering:

The tools of modern biotechnology or genetic engineering, on the other hand hold promise to solve many of the outstanding challenges in agriculture. In the early phases of modern biotechnology,

Thailand recognized its value and embraced this technology in order to enhance the development of agriculture in Thailand. Development in Thailand was as follows:

3.3.1 Transgenic Technology in Economically Important Crops: Modern

biotechnology results in the development of biotech crops, which have desired traits such as resistance to disease and insect pests. The Plant Genetic and Engineering Unit, BIOTEC, located at Kampaengsaen Campus, Kasetsart University first started employing these techniques in 1985 by transferring a virus coat protein gene into tomato to resist *yellow leaf curl virus*. Subsequently, the same technique was used in developing papaya and chilli that resist *papaya ring spot virus* and *vein-banding mottle virus*, respectively. In addition, the Kao Horm Dok Mali rice line 105 enhanced for saline and drought tolerance was developed. The case that has progressed the furthest, is the development of papaya that is resistant to the ring spot virus by the Department of Agriculture, in conjunction with Cornell University in the US. It was at the stage of confined field trials and assessment of environmental impact as early as 1999. Results from three-year studies indicated that biotech papaya was resistant to the ring spot virus in field conditions and no adverse effects on the environment were found. This work was conducted under the biosafety guideline.

3.3.2 Marker Assisted Selection: This is an extremely useful technology for plant breeding which uses target genes as markers in selecting resistant lines or lines that bear a desired trait. This technique speeds up the plant breeding process tremendously. Research conducted in Thailand used this technique to select for tomato lines that are resistant to bacterial wilt as well as other diseases caused by nematodes, the tobacco mosaic virus and powdery mildew.

3.3 Human Resource Development:

Fully aware of the importance of biotechnology to a country's development, the National Science and Technology Development Agency (NSTDA) supported and promoted capacity building on research in this area. The budget allocated funds to train researchers by education grants in the area of biotechnology and the environment. There were two phases, (1) from 1990 to 1995 and (2) from 1996 to 2003, during which 638 researchers received such grants. Details of the grants varying by degree level and year are shown in Table 3.2.

Table 3.2 Number of research grants to study in the area of biotechnology and environment during two phases.

Phase 1: During the 1990-1995 period, 203 researchers total

| Degree's Levels | Financial Year | | | | | | Total |
|-----------------|----------------|------|------|------|------|------|-------|
| | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | |
| B.Sc-M.Sc-Ph.D | 4 | 6 | 9 | 8 | 4 | 12 | 43 |
| M.Sc | 2 | 5 | - | - | - | 1 | 8 |
| M.Sc-Ph.D | 11 | 15 | 9 | 7 | 5 | 25 | 72 |
| Ph.D | 12 | 24 | 10 | 11 | 9 | 14 | 80 |
| Total | 23 | 39 | 19 | 18 | 14 | 39 | 203 |

Phase 2: During the 1996-2003 period, 435 researchers total

| Degree's Levels | Financial Year | | | | | | | | Total |
|-----------------|----------------|------|------|------|------|------|------|------|-------|
| | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | |
| B.Sc-M.Sc-Ph.D | 19 | 6 | - | 10 | 2 | - | - | - | 37 |
| M.Sc | 19 | 24 | 6 | 14 | 20 | 8 | 1 | 7 | 99 |
| M.Sc-Ph.D | 23 | 24 | 14 | 37 | 15 | 14 | 13 | 33 | 173 |
| Ph.D | 21 | 29 | 13 | 7 | 12 | 12 | 2 | 30 | 126 |
| Total | 82 | 83 | 33 | 68 | 49 | 34 | 16 | 70 | 435 |

Source: National Science and Technology Development Agency, 2007

3.5 Research and Development on Biotech Crops in Thailand:

In general, in order to develop biotech crops and to conduct research and development at various levels, the following must be accomplished: (BIOTEC, 2003)

1. The identification of novel genes
2. Identifying gene promoters, which can appropriately drive gene expression
3. Elucidating gene (or protein) function
4. The development of gene constructs and gene transformation
5. Selection of plant cells that have been transformed and can be differentiated
6. Plant tissue culture
7. Experimental trials conducted in glass houses and confined field trials.
8. Conduct thorough environmental risk assessment
9. Conduct thorough health risk assessment
10. Mass production for commercial use

Several research units in Thailand that have conducted research and development in the area of biotechnology have followed all steps mentioned above. Most work was done to successfully transfer novel genes into economically important crops that are beneficial for agriculture and agro-industries. Some work advanced as far as the field trial and risk assessment stages. Currently, no mass production for commercial use is being done in Thailand.

Most research and development on biotech crops in Thailand has been conducted at The Plant Genetic and Engineering Unit, Kampaengsaen Campus, Kasetsart University, an arm of BIOTEC. It was established in 1995 and about 60 million Baht were allocated for a 10-year total budget. In the early stages, it aimed to develop and build capacity for doing such research in Thailand. Up until now, research and development has been conducted in various crops such as:

- Chilli, tomato and papaya to resistant to viral diseases
- Yard long bean and cotton to resist insect pests such as boll worm
- Kao Dok Mali Rice to resist *rice ragged stunt virus* and increase production in saline soils

In addition, research and development on biotech crops has been done by other entities such as the Department of Agriculture and Ministry of Agriculture and Cooperatives which are:

- Papaya that is resistant to the *papaya ring spot virus*
- Rice that is resistant to *bacterial leaf blight*

More over, R&D on biotech crops has been conducted at several academic institutions, such as:

- Papaya that is resistant to the *papaya ring spot virus*, conducted at Mahidol University
- Pineapple that is tolerant to herbicide was conducted at Nakorn Sri Thamaraj Rajchamomkol Technology Institute

3.5.1 Example of R&D on Biotech Papaya:

Papaya is grown in all regions of Thailand. It is recognized as a local and sustainable crop of the people in the northeast region, where typically, people eat green papaya salad daily. There are commercial papaya plantations in all regions of the country. From a survey on papaya growing areas around the country conducted from 1997-2002, total growing areas were averaged at 165,297 rai annually (average production is at 461,179 tons). 90% of total production is used for domestic consumption and the rest is used as raw material for canned ripe papaya and other products, that are exported to the EU, China and the USA. To present, papaya products have increased every year from 416 tons in 1987 to 2,851 tons in 2003, and account for a total value of 95 million baht (Office of Biotechnology Research and Development, 2003).

The major problem of growing papaya is a viral disease called the "*papaya ring spot virus*" (or PRSV). It spreads throughout all commercial growing areas of the world where the aphid vector is found. It was first reported in Hawaii in 1945. In Asia, it was first found in the Philippines and in Thailand in 1975. More recently, it was also found in Malaysia and Japan. After Thailand first reported the appearance of PRSV, a survey for disease infestation in the northeast region was done from 1979 to 1981. This study found ring spot virus disease in 11 provinces and disease incidence ranged from 20% to 100%. At present, however, the ring spot virus disease is found in all provinces in the northeast region and typically 100% of mature trees are infected, causing a yield reduction of 50%. The current means of addressing this problem for commercial farmers is to move to new growing areas every 2-3 years. This is of course not feasible for subsistence farmers.

Much work has been done to try to find a means of controlling the ring spot virus disease. Examples include attempts to use insecticides to control the aphids which spread the disease, the crossing of desired varieties with varieties that are naturally more tolerant to the disease by conventional breeding, tree eradication, and the use of cross protection in which seedlings are first inoculated with a mild strain of the virus so that they may exhibit enhanced immunity when they come into contact with amore severe strain of the virus. However, many of these methods require an increase in capitol input and none of these methods were found to be an effective means of controlling PRSV.

Using the tools of genetic engineering, it is possible to control the papaya ring spot virus disease. With these techniques, the coat protein gene (CP gene), which codes for the protein that makes up the outer shell of the virus body, was transformed into an embryo cell from a papaya seed using either microprojectile bombardment or *Agrobacterium*-mediated transformation techniques. Following transformation, the papaya embryos are brought to the seedling stage using tissue culture and the seedlings containing the coat protein gene are selected. When these transformed varieties were challenged with the virus, it was found that papaya transformed with the coat protein gene from PRSV was highly resistant to the virus (90-100%). Furthermore, this trait is heritable and subsequent generations of papaya are also resistant to the virus.

3.5.2 Environmental Risk Assessment. Environmental risk assessment was performed by the Department of Agriculture to study the effects of genetically modified (i.e. biotech) papaya on the environment. The results can be summarized as followed: (Office of Biotechnology Research and Development, 2003)

1. Gene transfer: The possibility of genetic transfer (gene flow) from transformed GM papaya to local varieties was found not to occur at a distance of more than ten meters.

2. Soil microorganisms: There was no significant difference in the amount of microorganisms growing in soil where the transformed GM papaya was grown versus soil where local non-GM varieties were grown.

3. Beneficial insects: There was no significant difference in survival rate and larva development of honeybees aged 2-3 days after feeding with pollen obtained from transformed GM papaya.

4. Mite, disease's vector: Abnormalities of mites after feeding on transformed GM papaya were not observed.

5. Subsequent crops: Normal development of crops grown in soil where transformed GM papaya was grown prior was observed.

6. Transferring between virus ORSV-p pathogens in biotech crop papaya: Virus PRSV has two types, which are PRSV-p which infect Cucumbers and papaya and PRSV-w which infect only Cucumbers. They are genetically very similar but have never been found to transfer genetic material between them in transformed GM papaya.

However, the Department of Agriculture has only completed two levels of risk assessment (both laboratory/glasshouse and confined field trial). Still outstanding is the need for an open field trial, but at the moment, such studies are not permitted in Thailand, so the project remains at a standstill. This is a consequence of the Assembly of the Poor's request that the government prohibit field testing until the biosafety law has been drafted.

3.5.3 Food Risk Assessment: To assess food risk, there is the need to compare transgenic GM (biotech) papaya and non-biotech crop papaya in the following areas: equivalent nutritional value, toxicity and allergenicity. These comparisons must show "substantial equivalence," which means that there should be no other unintended differences between the two compared groups.

3.6 Potential of Biotech Crop Development in the Future:

The potential for the development of biotech crops in Thailand (Jarunya Narongkachavana (2005- in Thai) will be based on strategies that are suitable for the country in its present condition. Research and development on biotech crops in the past faced several obstacles such as:

Technical Problems: Mastering transformation techniques and success with tissue culture or adequate gene expression levels in transformed plants.

Policy Problems: There is no clear government policy to support research and development on modern biotechnology. Most pertinent is the lack of a firm stance when it comes to a policy on allowing field trials to resume.

Infrastructure Problems: Lacking are facilities and land areas where research such as risk assessment can be performed.

However, these obstacles can be easily overcome if Thailand decides to move forward with the development and use of biotech crops. In order to deal with these obstacles, it is important to begin establishing goals and strategies as well as to create activities that will advance Thailand's progress towards developing and implementing biotech crops.

From the point of view of relevant stakeholders, it has been suggested that Thailand select particular products as ultimate outcomes of future R&D. These should be:

1. Products that meet the market demand and are niche products particular to Thailand. They are not necessarily high value products.

2. Products that are not controversial will have a greater chance of success. That means the products should be ones that are accepted by consumers both within Thailand as well as overseas.

3. Products that can be developed using the capabilities and technology already found in Thailand or soon to be implemented in the country.

If these guidelines are followed, Thailand should be able to accelerate its progress towards successfully implementing small specialty biotech crops in the country within the next three years. In addition, these should be crops that only require a small growing area or that can be grown in a glasshouse where they can be easily managed by a small number of people. Moreover, these initial products should not be food crops, which tend to spur more controversy and should only employ techniques (such as transformation and tissue culture techniques) that are already well developed within the country. It is strongly recommended that a strict risk assessment process follow alongside product development.

Crops that may be promising products include flowering or ornamental crops such as new orchid varieties that have novel flower color. These will serve the current market need or create new market demand. Biotech crops that can serve as alternative energy sources are also extremely promising.

On the other hand, in the long term, the consideration should emphasize economically important crops that have high market value or high productivity within the country, such as rice, sugarcane and rubber tree. In order to develop products in this class, there needs to already be in place a clear and well accepted national policy. In the meantime, basic laboratory research that may ultimately contribute to these products' development can be ongoing. Policy study in the area of negotiating intellectual property rights must also be done. More importantly, studies on economic impacts and cost benefits compared with other alternatives will be a valuable resource for all concerned stakeholders. We anticipate that after gaining more experience in R&D and generating increased income from initial biotech crops, the country will then be in a position to enhance more economically important, high-value crops using modern biotechnology. This is a long-term goal.

Strategies that should be considered such that these goals can be realized must consider the following:

- 1. Technology Support:** Building basic knowledge skills and training for research should be supported, especially allowing new young scientists to do cutting edge research.
- 2. Effective International Partnership:** International cooperation is essential. Collaborations should be forged to create good relationships and generate mutual benefits.
- 3. Consortium Building:** Gathering all relevant stakeholders as one organization so that they can participate throughout the entire process.
- 4. IP and Resource Management:** Intellectual property and bio-resource management needs to be addressed. Patented technology will inevitably be used in conducting research yet the intellectual property obtained from Thai researchers needs to be protected.

If these strategies are followed Thailand can immediately begin pursuing its short-term goals, while looking ahead to its long term vision.

According to the government's policy that it would like Thailand to be the "Kitchen to the World" and at the same time would like to find alternative ways to reduce the consumption of oil, the potential of biotech crops to be used as food crops and energy crops must be considered. These crops may not only include major commodities such as rice, maize, soybean, cotton, but also crops more important to Thailand specifically, such as sugarcane, oil palm and cassava.

Currently and most unfortunately, most of these crops suffer from low productivity, which can be seen in Appendix Table 2-7. Consequently, concerning these commodities, Thailand is not competitive in the world market. Major problems in crop production are caused by pests (diseases, insect pests and weeds), which cannot be controlled by conventional methods. In response to increased costs of labor (Appendix Table 8) and other input factors, the need for biotech crops will be increasingly pertinent. To date, biotech crops have been approved for commercial cultivation for more than 10 years and have provided a wealth of benefits to users, which are summarized in Appendix Box 1.

Chapter 4

National Policy on Biotechnology

4.1 National Policy on Agricultural Biotechnology Development:

Biotechnology and its potential applications have received considerable attention over the past 20 years. This is in part due to many countries recognizing the potential of biotechnology as important for national development. Thailand created its first policy for science and technology in 1949, included in Article 65 of the Kingdom of Thailand's Constitution. In this document the Thai government committed to support research in both art and science. In subsequent constitutions, policies for support of science and technology have always been included as part of the national priority program. This confirms the commitment Thailand has to increasing development by using science and technology.

A policy on science and technology appeared to be effective when it was included in the fifth national economic and social development plan. The sixth national economic and social development plan also emphasized support for R&D in science and technology – particularly in areas where capacity could be improved, such as in genetic engineering and biotechnology. However, progress in this area has not yet reached the goals set by the country at that time. This is somewhat due to limited interaction between those responsible for science and technology development, and their counterparts for economic and social development. With the eighth national economic and social development plan, integrated development has been emphasized at last. In this plan, the use of science and technology for economic development is a key driver, with a goal of maximizing the country's strengths to attain realistic and sustainable growth.

For biotechnology, the cabinet appointed a National Policy on Biotechnology Committee, with the (then) Prime Minister, Dr. Thaksin Shinawatra as the committee head. This committee agreed on a national biotechnology policy development framework (2004-2011) on December 23, 2003. The 6 strategic targets resulting from this work are shown in Table 4.1:

Table 4.1 Thailand Biotechnology Development Framework (2004-2011)

| Order | Strategic Target | Example Activities-Work plan |
|-------|---|---|
| 1 | Identify and develop new bio-business | Set up Bio-park Support set-up of Modern Bio-Business Companies |
| 2 | Promote Thailand as a "Kitchen to the World," using biotechnology tools as a platform | Create a clear policy on GMOs; Shrimp Cluster Increase use of Agri-Biotechnology |
| 3 | Ensure the health of Thai society, and promote Thailand as the Health Center of Asia | Set up a surveillance system for epidemic diseases |
| 4 | Protect the environment and produce clean energy -- using biotechnology tools | Support waste to energy conversion Increase use of Biomass as a source of alternative energy |
| 5 | Use biotechnology tools to support the goals of the Sufficiency Economy | Establish a local resource database for sustainable Bio-Business |
| 6 | Support a national system for Human Resource development | Biological Diversity Center Human system development -- continue to foster biotechnology careers |

Source: National Science and Technology Development Agency, 1999

Strategic targets in Thailand's framework on biotechnology development, especially for the agricultural sector, indicate that the country has a clear policy for using biotechnology to support Thailand as the "Kitchen to the World". The framework emphasizes increased use of agricultural biotechnology, such as applying molecular markers to plant and animal breeding programs. However, in order to use genetic engineering techniques, the country must have a clear policy on GMOs. The Policy Committee has agreed on applying a Social Choice Policy (more details in section 4.6) with the following conditions:

1) Measurement System in Promoting R&D on Genetic Engineering: This will help Thai scientists to thoroughly assess global knowledge about GMOs, both in terms of research on GMO-related product development, and research on risk assessment. For environmental risk assessment, there must be clear definitions and guidelines for land designated for use in regulated field trials.

2) Measurement System for Administration and Regulation: Regulations should be strict, transparent and include liability issues, as well as have guidelines for review on a case-by-case basis.

3) Measurement System for Public Awareness and Education: It should support the study of GMOs on all levels, both within a defined system, and out of the system. There should also be a mechanism to enable easy-access to information on past and on-going studies. All stakeholders should have a chance to participate.

4) Measurement System in Capacity Building: It should put emphasis on ensuring sufficient local capacity to conduct research and development on GMOs, and on having the skill-base and experience to manage risk assessment.

It is clear that in these Systems, an inherent biosafety regime is required. In response, BIOTEC has defined a national policy guideline for biosafety under a strategy for capacity-building; in GMO research and development, and in GMO risk assessment. See Table 4.2 for this capacity building strategy.

Table 4.2 Strategy on building capacity for both research and development on GMOs and risk assessment (2007-2010)

| Order | Strategic Target | Example Activities-Work plan |
|-------|---|---|
| 1 | Build capacity for Thai researchers to ensure 'front line' competency with advanced technologies – and competitive edge in the future | Transformation technology development Gene construction development |
| 2 | Develop crops that are important for economic and social development – and that improve the environment | Flowering/ornamental crops: <i>Dendrobium spp</i> Energy crops: Cassava, Sugarcane, Oil palm Industrial crops: Cotton, Teak, Rubber tree Crops for improved environment Phytoremediation: Crops to absorb heavy metal |
| 3 | Build capacity for conducting trials and regulating biosafety under confined field trials and field conditions | Build a strong regulatory system and administrative network at both national and international biosafety levels |
| 4 | Build public awareness and ensure participation | Develop media awareness on GMOs Develop science communication strategies |

Source: Modified from Tanticharoen, 2005

4.2 Policy on Biosafety: Biosafety Guideline Development:

Considering that policy guidelines for biotechnology were based on a science and technology policy framework, and as the same applies for agricultural biotechnology, it is clear that all have focused on the importance of biosafety. Stakeholders must ensure that the technologies or technology produced in-country will not have a negative impact on environmental, animal or human health. This mandate was made clear after setting up the National Center for Genetic Engineering and Biotechnology (BIOTEC) in 1983 under the Ministry of Science Technology and Energy. Later, in 1990, BIOTEC appointed a Biosafety Measurement Sub-Committee to work on genetic engineering and biotechnology, under the National Science and Technology Development Agency (NSTDA). This sub-committee acted as an *ad hoc* committee on biosafety, and developed biosafety guidelines in 1992 for submission to NSTDA. In 1993, the NSTDA agreed to set up the National Biosafety Committee (NBC) with responsibility for regulating and overseeing the study of modern biotechnology or genetic engineering – as well as other relevant organizations working in this area. The main objective was to support the effective and safe use of biotechnology rather than to thwart its use and adoption. The committee called for following the guidelines on a voluntary basis while recommending that stakeholders respond responsibly to social and environmental issues.

In 2001, the Food Biosafety Sub-Committee under the NBC developed guidelines for assessing food safety derived from genetically modified organisms and also updated prior guidelines such that they could be put into place more easily. This more recent guideline became the “Biosafety Guidelines for Work Related to Modern Biotechnology or Genetic Engineering” in 2004.

4.3 Biosafety Regulation Pattern:

Biosafety regulation has the following elements: (BIOTEC, 2004)

4.3.1 National Biosafety Committee –NBC: This is the main body for regulating work related to genetic engineering, in accordance with the guidelines and also in keeping with the Cartagena Protocol on Biosafety under the Convention on Biological Diversity. NBC consists of representatives from related agencies that regulate introduced organisms and use of bio-material products; Department of Agriculture, Department of Livestock, Office of Food and Drug Committee, Medical Science Department and experts in fields related to biotechnology and genetic engineering. BIOTEC is the secretariat for NBC.

Subsequently, there was a re-organization in this government section, and the Ministry of Natural Resources and Environment was set up in October 2002. It was designated as the official focal point for issues related to the Cartagena Protocol on Biosafety. Thus, NBC which was appointed by NSTDA, became the Central Biosafety Committee (CBC) in June 2005, and BIOTEC remains as the secretariat for CBC. These groups act as technical consultants in implementing the biosafety guideline and educating the public on biosafety.

At present, the new NBC is now considering an appointment by the Ministry of Natural Resource and Environment in order to operate new missions.

4.3.2 Institutional Biosafety Committee-IBC: IBC is the major hub for conducting R&D on biotechnology and genetic engineering. This is because IBC is responsible for all research projects. In some IBCs such as those of the Department of Agriculture, (the agency regulating introduction of GMOs to the country under the Plant Protection Act of 1964) if technical problems occur, the IBC can seek advice by coordinating directly with NBC. Currently, there are 28 IBCs, most of which are in the government sector, at various universities and institutes. Only a few are in the private sector. The national biosafety framework is currently being worked on by the national biosafety framework working group which has support from UNEP-GEF. This work falls under the Office of Policy and Planning, Ministry of Natural Resource and Environment and is expected to be finished in 2007.

4.4 Implementation of Biosafety Guidelines:

The guideline provides details on how to do research on GMOs in a safe and responsible manner. Details will also include guidelines for doing R&D in the laboratory, guidelines for doing R&D using bioreactors on a large scale (more than 10 liters) and guidelines for doing R&D in field conditions.

Agencies or organizations that must follow the guideline will be determined as follows:

4.4.1 Organizations that have R&D on Genetic Engineering: These organizations include Institutes and Universities that have courses on modern biotechnology.

4.4.2 Organizations Assigned as a Competent Authority: These organizations include entities that authorize by-laws, for example the Department of Agriculture (DOA), which has the Plant Quarantine Act, 1964, and the Office of Food and Drug Committee which has the Food Act, 1979 etc.

Previously, DOA used the Plant Quarantine Act of 1964, amended in 1999 to regulate and launch Ministerial decrees about prohibiting the introduction of 89 species exempted for R&D only. However, the exception also included GM maize and GM soybean used as raw materials in feed industries or other related industries. This was because Thailand cannot produce sufficient amounts of these commodities for domestic use. No strict regulation has been imposed to this section, nor one to force the examination of whether introduced raw materials are GM or not. Rather, it depends on an agreement between importer and exporter.

In addition, to introduce prohibited materials, approval from the director of DOA is required. The importer must import for R&D purposes only, and must follow certain conditions when approved; such as:

- The experiment must operate under strict control of the Field Examine Biosafety Working Group. This working group will examine and monitor at both laboratory/container levels, and in the field
- Biosafety guidelines must be strictly followed
- The working group will summarize and create a report for submission to the Risk Assessment Sub-Committee for evaluating risk and safety
- The Risk Assessment Sub-Committee will report to the Biosafety in Agriculture Committee with their recommendation
- The Director of DOA will send the recommendation for deregulating (if there are no adverse impacts) to the Ministry of Agriculture and Cooperatives
- Final decision will be made by the Minister

Introduced food derived from GM crops will be regulated by the Office of the Food and Drug Committee, Ministry of Public Health under Food Act, 1979. Previously, two ministerial decrees were enforced (1) Labeling on foods derived from GM crops for consumer choice (Issue number 251/2545) and (2) Foods prohibited for production, importing or selling (Issue number 215/2544) which relates to GM maize containing the Cry9c gene.

Since the guidelines were implemented to ensure protection from any related risks that might occur from conducting R&D on biotech crops until 2001, some introduced biotech crops were approved for study only. More details on these crops can be found in Table 4.3.

Table 4.3 Biotech crops approved for study in the country during 1992-2000

| Crop's Name | Introduced Agency | Year | Details about gene | Status |
|-----------------------------|---|-------------|--|---|
| 1. Maize | Plant Genetics System N.V.Co.Ltd. | 1992 | - | Approved but company did not follow up |
| 2. Cantaloupe | Asgrow Seed and Up John Co., Ltd. | 1992 | Virus resistance | Approved but company did not follow up |
| 3. Squash | Asgrow Seed and Up John Co., Ltd. | 1992 | Virus resistance | Approved but company did not follow up |
| 4. Tomato | Zeneca Seed Co., Ltd. | 1993 | Antisense RNA (Slow ripening) | Request for information and guideline but did not have any connection |
| 5. Tomato | Calgene Co., Ltd. | 1993 | Antisense RNA (Slow ripening) | Approved and studied at Bangrakum District, Phitsanuloke Province |
| 6. Squash | Asgrow Seed Thailand Co.,Ltd. | 1994 | - | - |
| 7. Tomato | Thai Pan Trading Co.,Ltd. | 1994 | - | Non-approval |
| 8. Tomato | Upjohn Co., Ltd | 1995 | Antisense RNA (Slow ripening) | Finished and Debris destroyed |
| 9. Tomato | Thai Pan Trading Co.,Ltd | 1995 | - | Not introduced |
| 10. Cotton | Monsanto (Thailand) Co.,Ltd. | 1995 | Bt Cry 1A © (Resistance to Boll worm) | Finished and Debris destroyed |
| 11. Maize | Novartis (Thailand) Co., Ltd. | 1996 | Bt (Resistance to stem borer) | - |
| 12. Cotton | Monsanto (Thailand) Co.,Ltd. | 1996 | Bt Cry 1A © (Resistance to Boll worm) | Finished and Debris destroyed |
| 13. Cucumber | Plant Pathology and Microbiology, Department of Agriculture | 1996 | Coat Protein PRSV (Virus resistance) | Laboratory and Glasshouse |
| 14. Kao Dok Mali Rice | Rice Research Institute, Department of Agriculture | 1997 | Blast resistance gene (Xa21) inserted in Ps822 plasmid, Original Vector: PCRII | 123 Seeds studied in the glasshouse were packed in the aluminum foil and kept in a cold stored room |
| 15. Tomato | DNA Plant Technology Co.,Ltd. | 1997 | Antisense RNA (Slow ripening) | Not approval from NBC due to lack of qualified technical people |
| 16. Papaya | Horticulture Research Institute, Department of Agriculture | 1997 | CP-gene, PRSV (Virus resistance) | Confined field trial at Khon Kaen Horticulture Station |
| 17. Cotton (NUCOTN33-B) | Monsanto (Thailand) Co.,Ltd | 1997 | Bt Cry 1A © (Resistance to Boll worm) | Finished and Debris destroyed |
| 18. Cotton event 1445, 1698 | Monsanto (Thailand) Co.,Ltd | 1997 | CP 4 EPSPS (Tolerant to Roundup) | Finished and Debris destroyed |
| 19. Maize | Pioneer Oversea Corporation (Thailand) Co., Ltd. | 1997 | Bt (Mon 810) (Resistance to stem borer) | Conduct in the glasshouse, efficiency to resist corn borer |

| Crop's Name | Introduced Agency | Year | Details about gene | Status |
|--------------------------|-------------------------------|------|--|--|
| 20. Dry leaf sample | Dekalb | 1997 | Bt and maize grind to powder (contained Bt gene) | Not under Plant Quarantine Act, 1964 |
| 21. Maize | Monsanto (Thailand) Co.,Ltd | 1997 | Bt (Resistance to stem borer) | Non-compliance in accordance with rule and regulation under P.Q. Act and destroyed seeds. |
| 22. Maize | Monsanto (Thailand) Co.,Ltd | 1997 | Roundup Ready gene (Tolerant to Roundup) | Non-compliance in accordance with rule and regulation under P.Q. Act and destroyed seeds. |
| 23. Tomato | Mr. Sophon Heang | 1997 | - | Not approved, because seeds obtained from the trial have to send back to USA (seed production) |
| 24. Maize | Monsanto (Thailand) Co.,Ltd | 1998 | mEPSPS (Tolerant to Roundup) | Conducted in the glasshouse |
| 25. Maize (DLL25) | Charoen Cereals Co., Ltd. | 1998 | PAT (Glyfosinate resistance) | Not approved due to incomplete documentation |
| 26. Maize | Monsanto (Thailand) Co.,Ltd | 1998 | Bt (Mon 810) (Resistance to stem borer) | Finished testing in glasshouse condition |
| 27. Maize (CHAW 9703 Bt) | Cargill Seeds Co.Ltd. | 1998 | Bt (cry1 A(b)) (Resistance to stem borer) | Terminated due to overtaken by Monsanto (Thailand) Co.,Ltd |
| 28. Inbred maize | Novartis (Thailand) Co., Ltd. | 1998 | Bt event 176 (Resistance to stem borer) | Proposal for testing was cancelled and material destroyed |
| 29. Hybrid maize | Novartis (Thailand) Co., Ltd. | 1998 | Bt event 176 (Resistance to stem borer) | Finished and Debris destroyed |
| 30. Hybrid cotton | Monsanto (Thailand) Co.,Ltd | 1999 | Bt (cry1 A(c)) (Resistance to Boll worm) | Finished and Debris destroyed |
| 31. Cotton line 1445 | Monsanto (Thailand) Co.,Ltd | 1999 | CP 4 EPSPS (Tolerant to Roundup) | Finished testing in glasshouse condition |
| 32. Maize GA 21 | Monsanto (Thailand) Co.,Ltd | 1999 | mEPSPS (Tolerant to Roundup) | Conducted in glasshouse condition |
| 33. Maize | Monsanto (Thailand) Co.,Ltd | 1999 | Bt (MON 810) (Resistance to stem borer) | Testing in small isolated areas |
| 34. Maize CHAW 9703 | Monsanto (Thailand) Co.,Ltd | 2000 | Glyphosate tolerance gene | - |
| 35. Maize line C-919 Bt | Monsanto (Thailand) Co.,Ltd | 2000 | Bt Cry 1A (b) (MON 810) (Resistance to stem borer) | Applied for conducting field trials |
| 36. Maize line C-919-603 | Monsanto (Thailand) Co.,Ltd | 2000 | CP4 EPSPS (Tolerant to Roundup) | Applied for conducting field trials |

| Crop's Name | Introduced Agency | Year | Details about gene | Status |
|-------------------------------------|---|------|---|---|
| 37. Kae Dum papaya (tissue culture) | Plant Genetic Engineering Unit, Kampaengsean Campus, Kasetsart University | 2000 | CP gene, PRSV (Virus resistance) | Conducted in laboratory and glasshouse |
| 38. Cotton NUCOTN33 | Monsanto (Thailand) Co.,Ltd | 2000 | Bt (cry1 A(c)) (Resistant to boll worm) | Finished large scale field trial and Debris destroyed |

Source: Department of Agriculture and National Biosafety Committee, referred by BIOTEC, 2004

It is clear that under guidelines existing at that time, and with good coordination between NBC and IBC, field trials of biotech crops were conducted efficiently. However, following events in 2001, Thailand banned field trials of biotech crops. As a consequence, R&D has encountered a significant barrier, and the benefits from commercial adoption of biotech crops have not been realized.

Major constraints in growing biotech crops commercially in Thailand can be attributed to two issues:

1) Policy Constraints: The Department of Agriculture and the Ministry of Agriculture and Cooperatives have defined that 89 biotech crops are prohibited in accordance with the Plant Protection Act, 1964 amended (issue no.2) 1999. However, the Act exempts all processed foods containing maize and soybean in the form of grains used as raw materials for human food and animal feed. In order to introduce biotech crops into the country, approval must be granted from the General Director, Department of Agriculture, and such approval will allow only research following the guidelines and conditions defined

by the Department of Agriculture. However, there is no clear national policy for conducting field trials at present.

2) Social Constraints: In 2001, the Assembly of the Poor sent a petition letter to request that the government draft a Biosafety Law and ban all field trials on biotech crops. They also suggested that the Ministry of Agriculture and Cooperatives should stop conducting field trials on biotech crops. The cabinet agreed to the request and brought this issue to the consideration of various committees. Until 2003, the conclusion was still unclear. However, it led to the appointment of the drafting Biosafety Law committee assigned by the Ministry of Natural Resource and Environment in 2004.

4.5 Drafting of the Biosafety Law: a Way to Solve Biotech Crop Development

Drafting the Biosafety Law has been ongoing since 2001 by the Ministry of Agriculture and Cooperatives in order to respond to the requisition of the Assembly of the Poor. Subsequently, when the Ministry of National Resources and Environment was established, changes were made in the Biosafety Law working group in 2003 – putting it under the National Environment Committee. They set up a new committee, the Drafting the Biosafety Law Sub-Committee. Details of the draft will include regulation of GMOs in the context of R&D, field trials, public education, biotech crop utilization and foods derived from biotech crops, which may have some adverse effects to the environment, consumers, farmers and the overall socio-economic status of the country.

In 2004, the National Policy on Biotechnology Committee agreed to implement a policy of biotechnology and genetic engineering as a way of “giving society choices” and to speed up implementation of the Biosafety Law. Additionally, the policy included means for the development of proper biosafety regulation. The Ministry of National Resources and Environment appointed a new Drafting of Biosafety Law Committee, which then assigned a group to work on the draft in 2005. The drafting of the Biosafety Law is finished and approved in principle. The Office of National Resources and Environment Policy and Planning, which acts as the secretariat of the Drafting of Biosafety Law Committee, launched this law for public opinion and hoped to complete the review process within 2006 of shortly thereafter, to enable submission to the cabinet; currently pending.

4.6 National Policy on Biotechnology: the Suitable Alternative for Thailand

From the National Policy on Biotechnology Committee meeting (1/2003) on December 23, 2003, a need was recognized for the country to have a clear, suitable and transparent policy on use and

management of genetic engineering. A goal to enable development and use of the most advanced technology was made clear. Those who attended the meeting agreed to appoint an *ad hoc* sub-committee to develop a policy on genetic engineering and biosafety, and to be responsible for setting up a policy framework on strategies and mechanisms for submission to the National Policy on Biotechnology Committee.

The *ad hoc* sub-committee planned to come to an agreement on the 'Permissive Social Choice' policy regarding genetic engineering and biosafety. They held two stakeholder hearings and four meetings for the *ad hoc* sub-committee. All information and suggestions have now been compiled with previous studies. Alternative policies for using biotechnology/genetic engineering especially that most suitable for international trade, have been proposed by the National Biotechnology Policy Committee (National Science and Technology Development Agency, 2004) as follows:

4.6.1 Alternative Policy 1: Promotional Policy

The government has a policy for promoting commercialization of GMOs in all areas such as crop cultivation, livestock, fishery, industry and medicine.

4.6.2 Alternative Policy 2: Permissive (Social Choices) Policy

The country has a choice as to whether or not to use GMOs that pass through strict risk assessment processes, for environmental and human health, as well as for traditional production practices. The permission process is on a case-by-case basis, as well as on a scientific basis. Therefore, it is necessary to build capacity for research and development on genome technology and biosafety in order to effectively regulate end-products. This policy may also be referred to as the 'Permissive Policy'.

4.6.3 Alternative Policy 3: Precautionary (Wait and See) Policy

Wait and see means not yet promoting GMO usage but to follow up on the market acceptance situation and continue to gather scientific information for further consideration.

In fact, Thailand has been internationally recognized as an agricultural country. But, assuming that Thailand can continue to prosper on the basis of its current food crops represents short-term vision. At present this may be true, as Thailand is today a major exporter of agricultural products. However, without the application of advanced technologies, the country's agricultural development will only be weakly competitive -- and ultimately, Thailand will be dependent on importing the majority of its food requirements. Thus, it is most suitable for Thailand to accept the Social Choice Policy or as it is also known, the Permissive Policy. In fact, Thailand uses this policy, i.e the Social Choice/Permissive Policy at present.

Therefore, it is critical for Thailand to make a firm and clear decision about the use of advanced technologies as soon as possible so that research and development in this area can move ahead. Once, the late President Kennedy stated, "**We should not let fears hold us back from pursuing our hope**". **So let us continue to move forward thoughtfully with biotechnology in agriculture with appropriate measures (Glickman, 1999).**

It is anticipated that if Thailand can make the right decisions in accepting this advanced technology, it will also help upgrade agricultural productivity, and help alleviate poverty in the country.

4.7 Chronology in the Development of Biotech Crops in Thailand

Tanticharoen et. al. (2003) compiled all events related to genetic engineering organisms in a report presented at the Consultative Meeting of Asia Cooperation Dialogue in Biotechnology during a 6-7 October 2003 meeting which is summarized in the Table 4.4.

Table 4.4 Thailand's GMO 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, stating 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 <i>ad hoc</i> sub-committee to draft Thailand's first biosafety guideline |
| 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 Committee (IBCs) at various research institutes |
| 1993 | First application for importing transgenic plants 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 Nakhornpathom, 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 |
| 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) move 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 at the Department of Agriculture and Department of Medical Science |
| 2000 | Thailand Food and Drug Administration (FDA) commissioned a working 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 exception for grains of GM corn and soybean |
| April 2000 | Trade dispute between Thailand and Kuwait/Saudi Arabia over tuna in oil (suspected to be made from GM soybean) |
| 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 parties agree 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 consultation meeting with stakeholders on GMOs issue |
| 3 April 2002 | Cabinet accepted the proposal of Assembly of the Poor on prohibiting GM field trials unless Biosafety Law is drafted |
| 8 April 2002 | Minister of Health signed the GMO labeling regulation |
| 10 May 2002 | The GMO labeling regulation was noted and became effective |
| 10 May 2003 | The GMO labeling regulation is enforced |
| 27 July 2004 | Greenpeace destroyed GM papaya field trial of DOA at Khon Kaen Province |
| 31 August 2004 | Cabinet agreed to assign the Office of National Resource and Environment Policy and Planning acting as the National Focal Point of Cartagena Protocol on Biosafety under the Convention on Biological Diversity to draft Biosafety Law and make it complete before GM crops are commercially grown. |
| 14 September 2004 | Minister of Agriculture and Cooperatives made a decision to destroy papaya grown by farmers at Thapra Subdistrict, Mueng District, Khonkaen Province |
| 15 September 2004 | Minister of Agriculture and Cooperatives made a decision to destroy papaya grown at Khon Kaen Horticultural Research Station, Khon Kaen Province |
| January 2005 | Started to draft Biosafety Law by the Committee on drafting Biosafety Law and Working group on drafting Biosafety Law |
| 10 November 2005 | Thailand applies to be a party member of Cartagena Protocol on Biosafety |
| January 2006 | Thailand begins to work on National Biosafety Framework by the Office of National Resource and Environment Policy and Planning |
| 8 February 2006 | Cartagena Protocol on Biosafety is effectively enforced |
| 9 June 2006 | The Committee on Drafting Biosafety Law approved a draft Biosafety Law and opened it for public hearings before further process |

Source: Modified from Tantichareon et. al. (2003)

4.8 Conclusion:

Thailand National Policy on Biotechnology can be concluded as follows:

- 1) It is suggested that the country adopt the Permissive Policy using regulatory schemes already in place; the National Biosafety Guidelines together with existing laws. Approval of products is science-based and on a case-by-case basis.
- 2) Research and development to be carried out in all areas covering all phases of research including field testing in the case of biotech crops.
- 3) It is recommended that commercial production of biotech crops be carried out within 1-2 years, after careful science-based review of the potential benefits of agricultural biotechnology.

Chapter 5

Socio-Economic Impact:

The Potential Economic Benefits of Bt Cotton and Genetically Modified (GM) Papaya in Thailand

5.1 Introduction

Biotechnology, particularly gene manipulation, is an alternative to conventional breeding to improve a plant's characteristics so that productivity is increased. In some cases, genetic engineering has succeeded in incorporating useful desired characteristics where conventional plant breeding has failed. The first generation products of agricultural biotechnology have benefited producers through improved yields and reduced input use.

New, more efficient production methods of producing food and other goods may raise production levels while conserving labor, capital and material inputs that can then be reallocated to other production goals. It is through improvements in productivity that a country's living standard increases. Economists refer to the increased economic efficiency as welfare increases. Measurement of welfare changes is often decomposed into those benefits accruing to consumers (consumer surplus) and those accruing to producers (producer surplus) (Appendix Box 2).

Biotechnology can benefit producers by reducing input use and improving yield. Because of lowering production cost, farmers could sell the products at a lower price and also expand the production area. Previous economic studies have examined the impacts of agricultural biotechnology on farmers, consumers, and industry. This study will perform a similar analysis of the impact of the introduction of Bt cotton and GM papaya in Thailand. Bt cotton and GM papaya were chosen for our case studies because they are important crops in Thailand, and genetically modified varieties that are already being grown in other countries are readily available to be adopted in Thailand after passing through the biosafety regulatory process. In addition, insects and viral diseases have destroyed most of the production areas of these two commodities, and thus the potential for preventing damage via biotechnology are expected to be considerable.

We analyze the benefits from biotechnology in the small open economy framework. This is because Thailand is a relatively small producer of both papaya and cotton compared to the rest of the world. In other words, changes in domestic production would not affect the world price. Thailand is a net exporter of papaya. In 2004, Thailand produced less than 2% of the world's papaya crop, ranking as the world's 12th largest producer (FAOSTAT, 2006). The country produces an even smaller share of the world's cotton crop and is a net importer of cotton. At present there are no authorized field trials or commercial production of any genetically modified crops in Thailand. In this study, we will focus our analysis on the potential economic gains from the use of transgenic technology in these two commodities. Our analysis will use information from studies of these crops conducted in other countries and from field trials previously conducted in Thailand.

The benefits from Bt cotton result from reduced pesticide use and from higher yields due to reduced pest damage. Pesticides are not currently used on papaya, so the benefits of GM papaya are generated entirely from increased yields. Because neither Bt cotton nor GM papaya are yet grown commercially in Thailand, the farm level cost savings must be estimated using data from experimental plots and results in countries where commercialization has occurred.

The relative performance of GM crops is highest when pest pressure is heaviest and when chemical pesticide resistance is common. Ring spot virus pressure is high in virtually all commercial papaya areas of Thailand. There is a similarly high incidence of damage to cotton from pesticide resistant Lepidoptera, so Bt cotton has a very large yield advantage over conventional cotton varieties in Thailand. An important advantage of Bt cotton over chemical control of pests is that Bt control is always present in the plant. Because farmers apply chemical controls only after noticing the presence of pests on the cotton plants, some damage will have already occurred by the time chemical control is attempted. The effectiveness of chemical insecticide applications, unlike transgenic Bt, also depends on the weather, since rain can wash the chemical away. Bt cotton offers farmers increased certainty of control because it is effective against insects that have developed resistance to available chemical pesticides. As a result, Bt varieties have superior yield performance over a wide range of growing conditions (Fernandez-Cornejo and McBride, 2000).

5.3 Potential Benefits from Bt Cotton

Cotton was an important crop in Thailand during the 1980's. Area peaked with the planting of more than 150,000 hectares and production at more than 64,000 mts (Figure 5.1). Production area of cotton during the recent years was less than 70,000 rai (11,200 ha¹) (Table 5.1). In 2003, important areas of production were in Pa-yao, Prae, Nan, Lopburi, and SraKaew (Figure 5.2). Pest resistance to pyrethroid insecticides was one of the major reasons that production in 2006 stood at less than 20% of the peak level of the 1980s. A number of other cotton pests infest cotton but cotton bollworm, to which Bt cotton is resistant, is the major limiting factor, affecting an estimated 90% of cotton area (Katsara *et al*, 2002, Center for Applied Economic Research, 2000).

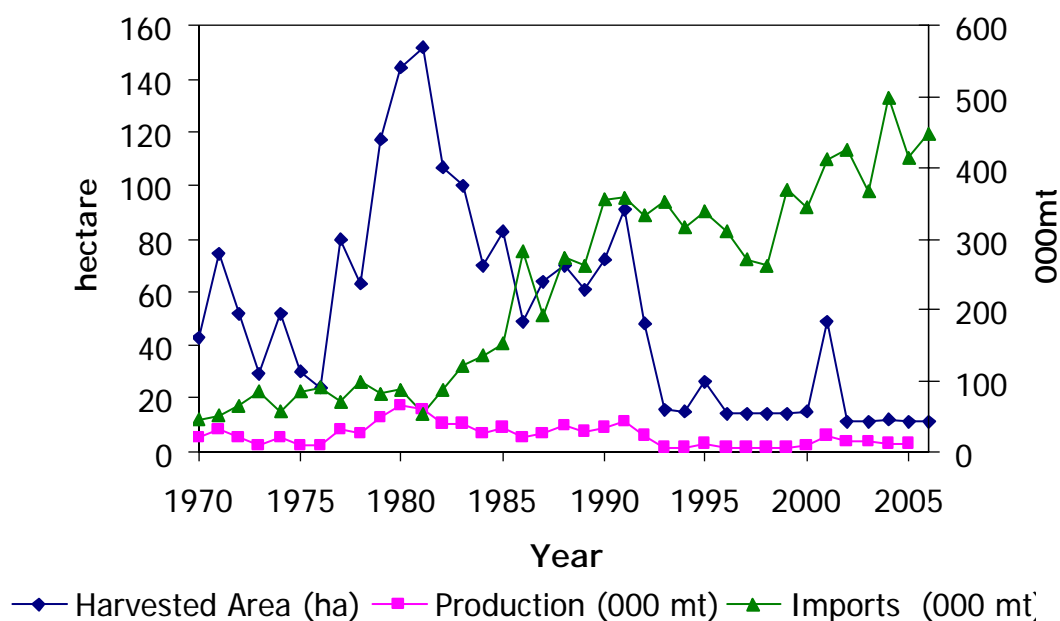


Figure 5.1 Cotton Area and Production, 1970-2006.

Source: USDA/Foreign Agricultural Service, 2007.

The economic benefits of Bt cotton have been documented in several studies. The direct benefits to farmers from adopting Bt cotton are summarized in Table 5.2 The direct benefits of Bt cotton to farmers include savings in insecticides and labor cost. Bt cotton has reduced the cost of insecticides by as much as 77% (Traxler *et al.*, 2001 cited by Elbehri and Macdonald, 2004) In other cases, Bt cotton has saved on labor costs (Huang *et al.*, 2002 cited by Elbehri and Macdonald, 2004), but in other cases labor costs have increased due to an increase in harvesting cost from higher yields. The price of Bt cotton seed was considerably higher than non-Bt cotton seed. Nevertheless, net returns of Bt cotton were positive in all published studies.

¹ 1 hectare = 6.25 rais

Table 5.1 Cotton Planted Area, Production, and Average Productivity, 1996-2005

| Year | Planted Area (1,000rai) | Harvested Area (1,000rai) | Production (1,000mt) | Yield per rai (kg) | Farm Price (baht/kg) | Farm Value (million baht) |
|-------------------|----------------------------|------------------------------|-------------------------|-----------------------|-------------------------|------------------------------|
| 1996 | 337 | 321 | 75 | 234 | 15.05 | 1,131 |
| 1997 | 232 | 220 | 51 | 234 | 12.51 | 643 |
| 1998 | 186 | 180 | 40 | 225 | 20.37 | 823 |
| 1999 | 162 | 159 | 35 | 218 | 14.49 | 501 |
| 2000 | 165 | 160 | 36 | 228 | 12.20 | 445 |
| 2001 | 284 | 261 | 61 | 232 | 18.49 | 1,121 |
| 2002 | 70 | 67 | 14 | 212 | 9.62 | 136 |
| 2003 | 47 | 45 | 11 | 235 | 13.66 | 145 |
| 2004 | 66 | 64 | 14 | 224 | 15.03 | 215 |
| 2005 ^p | 51 | 48 | 10 | 212 | 14.47 | 149 |

^pPredicted

Source: Department of Agricultural Extension

Table 5.2. Estimates of Bt cotton impact on input cost and yield/net returns changes in cotton

| Country/source | Input cost changes from Bt cotton | | | Net return/output advantage due to Bt (%) |
|----------------------------------|-----------------------------------|-------------------------------------|-------------------|---|
| | Savings in insecticides (%) | Seed cost increase ^a (%) | Labor saving (%) | |
| United States | | | | |
| Deville et al. (2002) | | | | 9.0 |
| Marra et al. (2002) ^b | -17.0 | | | 14.3 |
| China | | | | |
| Hebei region, 1999 (Du, 2001) | -82.0 | 673.0 | | 14.6 ^c |
| Shandong region, 1999 (Du, 2001) | -84.0 | 50.0 | | 20.0 ^c |
| Huang et al. (2002) | -83.3 | 120.0 | -9.5 | 5.8 ^c |
| South Africa | | | | |
| Ismail et al. (2002) | -34.0 | 109.0 | | 18.0 |
| Mexico | | | | |
| Traxler et al. (2001) | -77.0 | 500.0 | | 8.5 ^c |
| Argentina | | | | |
| Qaim and de Janvry (2002) | -46.0 | 166.0 | 17.0 | 33.0 ^c |
| India | | | | |
| Qaim (2003) | -59.0 | 386.0 | 34.0 ^d | 58.0 ^c |

^aInclusive of technology fees.^bUnweighted average of state-level impacts assessments from 1997 through 2001 compiled by the citation authors.^cOutput advantage of Bt cotton in percentage value.^dInclusive of reduced labor costs from insecticide use and increased harvesting labor cost due to larger yields.

Note: Excerpted from Elbehri and Macdonald, 2004.

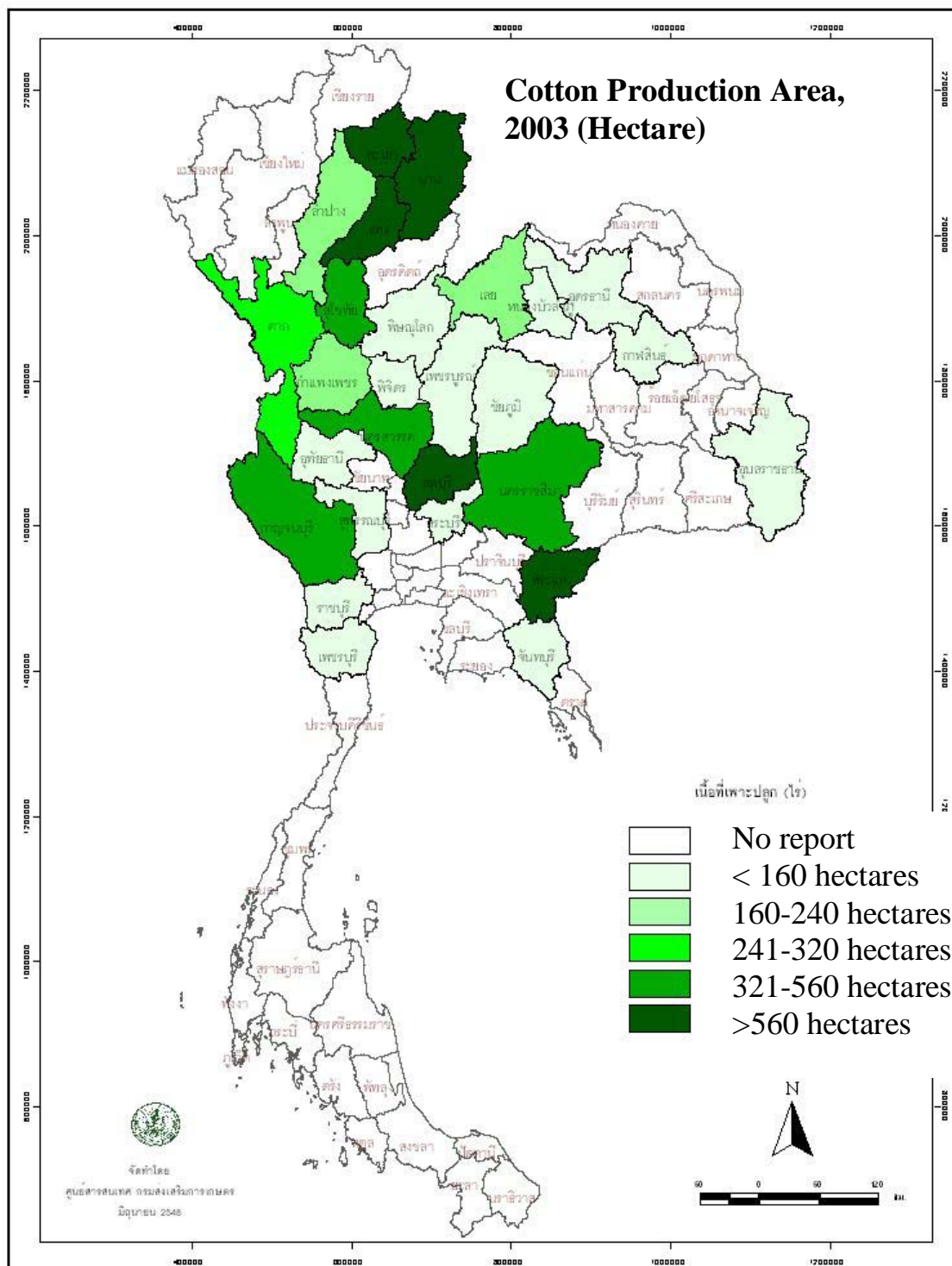


Figure 5.2 Cotton Production Area, 2003
Source: Office of Agricultural Economic, 2007

5.3 Previous Studies of GM Crops in Thailand

5.3.1 Studies of Bt cotton in Thailand

A study in the year 2000 by the Center for Applied Economic Research (CAER) at Kasetsart University estimated the economic impacts of Bt cotton in Thailand. The study estimated the cost of cotton production in Thailand using two sources. The first source is cotton production survey data collected by Office of Agricultural Economics (OAE) (Table 5.3). The second data source is field records collected by Department of Agriculture (DOA) under their integrated pest management (IPM) program (Table 5.4).

The values in Table 5.3 and 5.4 are for non-Bt cotton varieties. Each table shows that the cost of spraying insecticides and herbicides accounts for approximately one-third of the total cost of production. The CAER study stated that the information from the IPM data was more reliable since the OAE survey data were usually collected after harvest based on farmers' memory. The cost of spraying generally will be equal to or slightly higher than farmer-practiced under IPM, but still less than normal practice.

Table 5.3 Cost of cotton production from OAE survey data

| Year | Total Cost (baht/rai) | Cash-cost (baht/rai) | Insect. & Herb. Cost (baht/rai) | % Insect. & Herb. Cost to total cost |
|-----------|--------------------------|-------------------------|------------------------------------|---|
| 1977/78 | 932 | 550(59) ¹ | 283(59) ² | 30 |
| 1982/83 | 1,990 | 1,154 (58) | 641 (58) | 32 |
| 1985/86 | 1,975 | 1,125 (57) | 532 (57) | 27 |
| 1988/89 | 2,020 | 1,252 (62) | 484 (62) | 24 |
| 1989/90 | 2,048 | 1,269 (62) | 522 (62) | 25 |
| 1994/95 | 2,490 | 752 (30) | 641 (85) | 26 |
| 1997/98 | 3,098 | 1,154 (37) | 1,013 (88) | 33 |
| 1998/99 | 3,251 | 1,259 (39) | 1,098 (87) | 34 |
| 1999/2000 | 3,129 | 1,052 (34) | 837 (79) | 27 |

¹Figures in parentheses are percentage of cash expense to total cost

²Cost of insecticides and herbicides as percentage of cash expenses

Source: estimated from Center for Applied Economic Research, 2000 (OAE survey data)

Table 5.4 Cost of cotton production from IPM program data

| Year | 1996 | | 1997 | | 1998 | |
|--|------------------|------------------|-------|----------|-------|-------|
| | TDP ¹ | FPP ² | TDP | FPP | TDP | FPP |
| Avg. planted area (rai) | 5 | 7.4 | 5 | 7 | 5 | 10.2 |
| Yield (kg/rai) | 268.5 | 212.5 | 245.1 | 196.6 | 250.3 | 207.5 |
| Cost of production ³ (baht/rai) | 2,418 | 2,209 | 2,180 | 2,372 | 2,865 | 2,697 |
| Cost of spraying ⁴ (baht/rai) | 668.8 | 596.3 | 752.6 | 1,031.30 | 990.8 | 991 |
| % of spraying cost to total cost | 28 | 27 | 34 | 43 | 34 | 37 |
| Price received (baht/kg) | 15 | 15 | 19 | 19 | 18 | 18 |
| Total receipts (baht/rai) | 4,024 | 3,188 | 4,657 | 3,735 | 4,505 | 3,736 |
| Net return (baht/rai) | 1,609 | 978 | 2,477 | 1,364 | 1,641 | 1,039 |

¹ Test and demonstrating plot

² Farmer-practiced plot

³ Cash cost including family labor

⁴ Included insecticides, labor and fuel

Source: estimated from Center for Applied Economic Research, 2000 (DOA, IPM program data)

Yield information for a Bt bollworm resistance variety (Nucotton 33B) and a non-GM variety (Sri Samrong 60) was collected by the Department of Agriculture in field tests in 1997 in four districts in four provinces. Sri Samrong 60 (SR 60) is one of the best cotton varieties developed in the country. SR 60 is resistant to leaf roll virus (LRV), but is not resistant to bollworm. Nucotton 33B is a transgenic variety developed by the US company Delta and Pineland Co. for the US cotton market that is resistant to bollworm, but very susceptible to leaf roll virus disease. Tables 5.5 and 5.6 summarize yield information from farmer plot trials and field crop station trials. The shaded cells highlight the highest yield at each location.

Table 5.5 Bt and non-Bt cotton yield from farmer plot trial (kg/rai)

| Location | SR 60 | Nucotton 33B |
|-------------|-------|--------------|
| Pak Chong | 278 | 288 |
| Pak Tho | 250 | 234 |
| Phu Nam Yod | 218 | 272 |
| Kok Chareon | 273 | 243 |
| Average | 255 | 257 |

Source: estimated from Center for Applied Economic Research, 2000

Table 5.6 Bt and non-Bt cotton yield from field crop station trial (kg/rai)

| Location | w/o bollworm insecticide application | | with bollworm insecticide application | |
|---------------------|--------------------------------------|--------------|---------------------------------------|--------------|
| | SR 60 | Nucotton 33B | SR 60 | Nucotton 33B |
| Loei | 314 | 264 | 381 | 266 |
| Nakhon Rajasima | 343 | 426 | 482 | 450 |
| Sukhothai | 187 | 213 | 195 | 264 |
| Nakhon Sridhammaraj | 16 | 433 | 151 | 464 |
| Average | 215 | 334 | 302 | 361 |

Source: estimated from Center for Applied Economic Research, 2000

In Table 5.5, the farmer plot trials cover lower central to lower north and northeastern regions. The yields of the two varieties vary from location to location. The Bt cotton variety has a higher yield than the local variety in two out of four locations, but the averages differ by only two kg/rai. The fact that Bt cotton yields no more than SR 60, suggests that both LRV and bollworms are yield-limiting production constraints in Thailand. Therefore to be successful, any Bt variety must also incorporate LRV resistance.

The importance of Bt insect resistance is more clearly demonstrated by the field station trial data in Table 5.6. In trials without bollworm insecticide application, Bt cotton has a much higher yield than the local variety in all but one location. On average, Bt cotton is superior to SR 60 by 55% (119 kg) when bollworm insecticide is not applied. When a bollworm insecticide is applied, Bt cotton shows a higher yield than SR 60 in two out of four locations, and on average has a 20% higher yield (59 kg). This implies that Bt cotton is superior to SR 60, except in areas with heavy spread of LRV disease such as Loei, regardless of bollworm insecticide application. The French *Centre de cooperation Internationale en Recherche Agronomique pour le Development* (CIRAD), working with Kasetsart University has transferred Bt resistance to SR 60, but the project has been suspended, in part due to regulatory difficulties.

The CAER study estimated three economic impacts from growing Bt cotton in Thailand:

1) Direct Benefits to Farmers: the direct benefits to farmers include an increase in yield and a saving in bollworm insecticide application. Even though some insecticides are still being used for other insects, the total cost of spraying is significantly reduced. The estimated benefits to farmers are shown in Table 5.7. In all cases, net profits are greater for the Bt variety than for SR 60. Even in the first case where yield of cotton is assumed to be equal to that of SR 60, savings in spraying cost are large

enough to compensate for the higher cost of Bt cotton seed. In the second and the third cases, Bt cotton shows much higher benefits to farmers when yields are assumed to be significantly improved.

2) Foreign Exchange Savings: Because Thailand is a net importer of cotton (Table 5.8), an increase in the domestic production of cotton would improve the trade balance. The amount of foreign exchange that can be saved depends on planted area, yield, and the cotton import price which is almost the same as the domestic price.

3) Employment Creation: An increase in cotton production would create more jobs in the ginning business, and income generated from these jobs would increase the national income.

Table 5.7 Evaluation of benefits to farmers from Bt cotton production

| | Case I ¹ | Case II | Case III |
|---|---------------------|--------------------|--------------------|
| Yield/Rai (kg) | 205.5 | 250 | 280 |
| Selling price (baht/kg) | 17.3 | 17.3 | 17.3 |
| Revenue (baht/rai) | 3,553 | 4,325 | 4,844 |
| Cost of spraying (baht/rai) | 872.9 ² | 300 ³ | 300 ³ |
| Total cost (baht/rai) | 2,426 ² | 1,853 ⁴ | 1,853 ⁴ |
| Net profit (baht/rai) | 1,700 ⁵ | 2,472 | 2,991 |
| Less seed cost ⁶ (baht/rai) | 297.5-377.5 | 297.5-377.6 | 297.5-377.7 |
| Net profit less seed cost (baht/rai) | 1,322.5-1,402.5 | 2,094.5-2,174.5 | 2,613.5-2,693.5 |
| Additional net profit ⁷ (baht/rai) | 275.5-195.5 | 967.5-1,047.5 | 1,486.5-1,566.5 |

¹ Case I: Assume yield of SriSamrong 60, Case II and III: Bt cotton with yield 250 and 280 kg/rai

² Average from farmer practice plot in Table 3

³ Estimates of cost of spraying other insecticides

⁴ Average from farmer practice plot in Table 3 less 573 (spraying cost saving from using Bt cotton)

⁵ Average from farmer practice plot in Table 3 plus 573

⁶ Calculated at 400 baht/kg and 0.8 kg/rai

⁷ Difference between net profit and net profit of SR 60 (1,127 baht)

Note: Adapted from Center for Applied Economic Research, July 2000

Table 5.8 Raw cotton and cotton wool trade balance quantity (mt) and value (million baht)

| Year | Exports | | Imports | | Net imports | |
|------|----------|-------|----------|--------|-------------|--------|
| | Quantity | Value | Quantity | Value | Quantity | Value |
| 2000 | 3,194 | 80 | 391,211 | 19,033 | 388,017 | 18,953 |
| 2001 | 3,061 | 113 | 410,693 | 21,892 | 407,632 | 21,779 |
| 2002 | 5,856 | 226 | 443,873 | 20,182 | 438,017 | 19,956 |
| 2003 | 11,001 | 362 | 419,346 | 22,095 | 408,345 | 21,733 |
| 2004 | 7,931 | 266 | 370,703 | 22,625 | 362,772 | 22,359 |
| 2005 | 7,412 | 235 | 575,835 | 24,998 | 568,423 | 24,763 |
| 2006 | 6,665 | 163 | 365,794 | 18,699 | 359,129 | 18,535 |

Source: Office of Agricultural Economics in collaboration with the Custom Department

Last updated: November 24th, 2006

5.3.2 Previous Studies of the Economic Impact of GM Papaya in Thailand

Most papaya grown in Thailand is consumed domestically as vegetable (salad), fresh fruits and as processed foods. Two of the most popular local varieties are Khaek Dum and Khaek Nuan. Khaek Dum is the most popular for fresh consumption and processing, both in domestic and export markets. Khaek Nuan is a variety grown mainly for green consumption.

Table 5.9 represents papaya production and productivity. The average yield of papaya was between 2.6 and 3.4 mts/rai during 1995-2006. Figure 3 shows the production area of papaya in 2003. The areas where papaya is most heavily grown are in the northeastern, east, western, and central parts of the country. Table 5.10 shows papaya export volumes and values. The total export quantity (fresh and canned) is less than 2% of total production during 1995-2005. During this period, canned papaya accounted for about 74% of total papaya export quantity, and was about 84% of total papaya export value.

Table 5.9 Papaya Planted Area, Production, and Average Productivity, 1995-2006

| Crop Year | Production Area (rai) | | Total Product (mt) | Average Yield (kg/rai) |
|-----------|-----------------------|------------------------|-----------------------|---------------------------|
| | Planted | Harvested ¹ | | |
| May-April | | | | |
| 1995 | 153,280 | 115,572 | 342,772 | 2,965 |
| 1996 | 160,241 | 119,725 | 335,433 | 2,801 |
| 1997 | 153,060 | 118,051 | 316,879 | 2,684 |
| 1998 | 172,793 | 118,938 | 367,861 | 3,092 |
| 1999 | 187,648 | 138,504 | 412,138 | 2,975 |
| 2000 | 155,959 | 126,422 | 366,828 | 2,901 |
| 2001 | 146,248 | 102,045 | 290,854 | 2,850 |
| 2002 | 156,791 | 105,826 | 295,831 | 2,795 |
| 2003 | 151,796 | 100,795 | 276,006 | 2,738 |
| 2004 | 133,447 | 92,719 | 247,178 | 2,665 |
| 2005 | 48,229 | 21,979 | 74,661 | 3,397 |
| 2006 | 67,928 | 40,060 | 126,759 | 3,164 |

Source: Department of Agricultural Extension and Angyurekul and Tugsinavisuth, 2003. Table

¹Data during 1995-2001 represent bearing area

These statistics show that most of the papaya produced is sold in the domestic market, and that papaya is exported mainly as a processed (canned) product rather than as a fresh product. This is similar to the findings in the study by Angyurekul and Tugsinavisuth (2003) during 1988-2001. This same study of papaya production and marketing found that ring spot virus was the most serious production problem. The Strengths, Weaknesses, Opportunities, Threats (SWOT) analysis revealed that one of the weaknesses in the papaya industry was ring spot virus disease, and that the industry was threatened by a lack of research and development, by disease resistance, and by a lack of clarity in GM papaya policies.

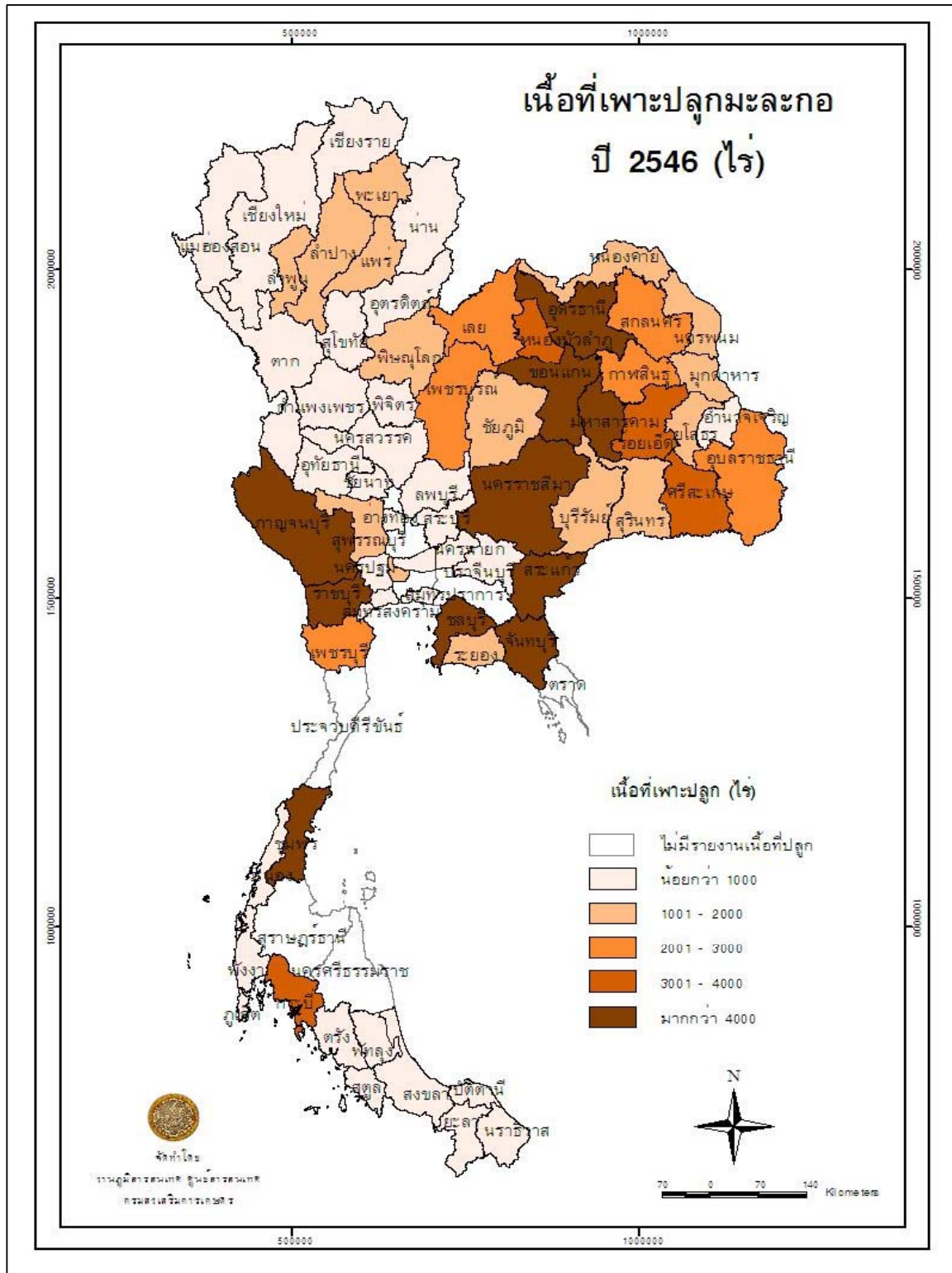


Figure 5.3 Papaya Production Area, 2003

Source: Office of Agricultural Economic, 2007

The Foreign Agricultural Service of United States Department of Agriculture (USDA) published a report on the economic benefits of ring spot virus-resistant papaya in Thailand (USDA, 2005). Data on the costs and benefits of widespread adoption of biotech papaya in Thailand were collected from published documents and from interviews with government officers from the Ministry of Science, Technology and Environment (BIOTEC), the Ministry of Agriculture and Cooperatives (Plant Quarantine Subdivision), the Ministry of Public Health (Food and Drug Administration), and from researchers at Maejo University and Kasetsart University.

The USDA study notes that RSV occurred in Thailand for the first time in 1975. By 2003, it had spread throughout the country and damaged 80% of the entire plantation area. During the years 1997 to 2002, the average papaya area was 120,000 rai, with production of about 350,000 mts with an average yield of 2.9 mts/rai, a reduction of about 50% in productivity. In 1997, transgenic papaya that resists RSV was successfully discovered by editing the genes of the local varieties: Khaek Dum and Khaek Nuan. Between 2002 and 2003, researchers selected three papaya species that have 97% resistance to ring spot virus and give average yield of 11.8 mts/rai. One line which was 100% resistant to ring spot virus was also selected.

Table 5.10 Exported Quantity and Value of Fresh and Canned Papaya, 1995-2006

| Year | Fresh Papaya | | Canned Papaya | | Total | |
|-----------------|---------------|--------------------|---------------|--------------------|---------------|--------------------|
| | Quantity (mt) | Value (1,000 baht) | Quantity (mt) | Value (1,000 baht) | Quantity (mt) | Value (1,000 baht) |
| 1995 | 8 | 253 | 2,005 | 41,655 | 2,013 | 41,908 |
| 1996 | 5 | 209 | 2,450 | 51,768 | 2,455 | 51,978 |
| 1997 | 44 | 1,184 | 1,133 | 29,165 | 1,177 | 30,349 |
| 1998 | 29 | 1,264 | 2,065 | 62,534 | 2,095 | 63,798 |
| 1999 | 103 | 3,024 | 3,685 | 42,150 | 3,788 | 45,174 |
| 2000 | 182 | 7,874 | 1,462 | 49,232 | 1,644 | 57,105 |
| 2001 | 495 | 16,568 | 2,851 | 94,582 | 3,346 | 111,150 |
| 2002 | 2,681 | 40,036 | 2,642 | 82,967 | 5,323 | 123,003 |
| 2003 | 2,123 | 34,924 | 2,955 | 95,816 | 5,077 | 130,740 |
| 2004 | 2,417 | 24,291 | 3,076 | 113,254 | 5,493 | 137,545 |
| 2005 | 1,715 | 17,845 | 3,542 | 129,867 | 5,257 | 147,713 |
| Average | 980 | 14,747 | 2,787 | 79,299 | 3,767 | 94,046 |
| Percentage | 26.02 | 15.68 | 73.98 | 84.32 | 100.00 | 100.00 |
| Growth Rate | 0.9951 | 0.9858 | 0.4340 | 0.6793 | 0.6170 | 0.7163 |
| 2006 Jan-Oct | 951 | 14,159 | 2,080 | 66,851 | 3,030 | 81,010 |

Source: The Custom Department

HS-CODE: 0807200004=fresh papaya; 2008990156=papaya in airtight containers (canned papaya)

The study by the Department of Agriculture reported that farmers could be expected to increase their papaya yield from 2.79 mts/rai to 42 mts/rai by planting GM papaya. Based on this assumption, the comparison between gross income before and after the adoption of GM papaya was estimated in Table 5.11. Calculations are based on the same assumption that GM papaya could increase the yield to 42 mts/rai. This estimated yield increase may be optimistic. A more conservative estimate would be that yields would increase from 2.79 to 11.8 mts/rai, a 4.2 fold increase in yields and gross income.

Prices of papaya vary by region, and ripe fruits sell at a higher price than raw fruits. Cash investment includes seeds, utensils, fertilizer, chemicals, water feeding through shower, oil, soil preparation for plantation, control of unwanted flora, fertilizer application, chemicals spraying, feed water, harvest, transportation, and hired labor. Non-cash investments include household labor and depreciation of equipment. Table 5.11 summarizes the country's average income of GM and non-GM papaya by farming technique and by raw or ripe fruits market. Though the actual income varies by region, the reported figures clearly show that GM papaya generates much higher income after initial investment than non-GM papaya. For example, the average net income after initial investment of GM papaya when growing in open space, mixed plantation and selling ripe fruits is more than 22 times higher than that of non-GM papaya.

Table 5.11 Estimates of income before and after GM papaya

| Region | Plantation Area (rai) | Harvested Area (rai) | Average Yield Before Biotech Papaya (mt/rai/crop) | Average Selling Price (bath/mt) | Total gross income Before Biotech Papaya (bath/rai/crop) | Average Yield After Biotech Papaya (mt/rai/crop) | Average Selling Price (bath/mt) | Total gross income After Biotech Papaya (bath/rai/crop) |
|------------|-----------------------|----------------------|---|---------------------------------|--|--|---------------------------------|---|
| North | 16,413 | 12,035 | 1.98 | 4,710 | 9,345 | 42 | 4,710 | 228,900 |
| North/East | 35,321 | 29,852 | 2.50 | 5,380 | 13,466 | 42 | 5,380 | 225,960 |
| Center | 3,464 | 1,954 | 6.67 | 6,690 | 44,602 | 42 | 6,690 | 280,980 |
| East | 26,357 | 18,846 | 3.17 | 5,020 | 15,908 | 42 | 5,020 | 210,840 |
| West | 36,089 | 19,669 | 3.10 | 5,620 | 17,428 | 42 | 5,620 | 236,040 |
| South | 18,736 | 14,234 | 2.49 | 6,330 | 15,755 | 42 | 6,330 | 265,860 |
| Total | 123,380 | 96,592 | 2.77 | 5,450 | 15,097 | 42 | 5,450 | 228,900 |

Source: Department of Agricultural Extension

Source: Department of Agricultural Technology cites that if farmers are able to grow GMO papaya, their yield would increase from 2.79 to 42 mt or 20 times

Note: Excerpted from USDA, 2005

5.4 Welfare Economic Impact of GM Crops

5.4.1 Economic Surplus from Bt cotton

The field data suggest that Bt cotton is capable of providing farm level benefits to farmers from increased yields as well as from reduced pesticide applications. Available data do not provide a direct estimate of the level of increased profit per rai for two reasons. First, the field data do not separate yield losses due to LRV from yield losses due to bollworm. Secondly, pesticide savings from Bt cotton are not directly reported. Given these data imperfections, we use the following assumptions about yield advantage and pesticide cost savings from Bt cotton use in Thailand. CIRAD and Thai researchers have already developed a Bt version of SR 60, so we assume that the Bt cotton variety that will be released will have LRV resistance as well as Lepidoptera resistance. In the surplus calculations we use the Bt variety yield advantage of 55% reported in Table 5.6. While data are not available on the potential savings in pesticide application costs from Bt cotton in Thailand, studies from other developing countries reported in Table 5.2 report average pesticide savings of 59% for Bt varieties in China, South Africa, Mexico, Argentina and India. Therefore we will conservatively assume that Bt varieties will result in a 50% pesticide savings over conventional varieties in Thailand. Pesticide costs average 36% of total production costs in the farmer-managed plots reported in Table 5.4, so we will assume an 18% cost of production savings from Bt cotton (i.e., 50% of 36%). The seed price and technology fee will be assumed to be one-half of the pesticide savings, resulting in a net cost reduction from Bt cotton of 9%.

The full list of parameters used in the economic surplus calculations are reported in Table 5.12. We use the averages of domestic area, production level, and current yield during 2002-2006 from Foreign Agricultural Service, USDA and use farm price average during 2001-2005 from Thailand Department of Agricultural Extension. Conservative choices were made for most parameters. For example, the total cotton area to apply the per rai cost savings to is a key parameter. Cotton area has fallen by about three-fourths in Thailand during the past decade. Whether access to effective control of cotton bollworm will induce farmers to return to previous planting levels is uncertain, but it seems likely that cotton area will expand to some degree. Nonetheless in scenario one (Table 5.13), we assume that cotton area will remain at the 2002-2006 average of 70,000 rai or 11,200 hectares. Other key assumptions are that once researchers have permission to resume Bt cotton field trials, there will be a three year lag before adapted varieties begin to diffuse, and that it will take ten years for maximum diffusion to 80% of cotton area to occur.

Annual benefits are estimated for a 14 year horizon (Table 5.13). Economic surplus is modest in the early years of adoption because of the small area over which the new technology is assumed to be applied. In the final year of the analysis, total benefits are over 100 million baht or over 3 million USD. At a 5% discount rate the present value of the benefit stream is about 400 million baht or 11.5 million USD. Because of the uncertainty about area expansion, we calculated economic surplus

under a second scenario using the assumption that farmers would expand area to the 1988-1992 average level (427,500 rai or 68,400 hectares) once Bt cotton is made available for bollworm control. This level of area is when cotton was widely grown before a dramatic decrease in the early 1990s. The economic surplus in the second scenario is calculated based on an equal annual change of the area from 70,000 rai to 427,500 rai during year 4 to year 13, assuming the production in each year is calculated from average current yield. Using this acreage assumption, and leaving all other assumptions unchanged, results in a total discounted economic surplus estimate that is nearly four times higher. Under this area assumption, approximately 600 million baths or 17 million USD in annual surplus is generated once Bt cotton adoption reaches 80%, and the total discounted value is more than 1.5 billion bath or 43 million USD.

Table 5.12 Parameters used for small open economy models of Bt cotton

| | |
|---------------------------------------|-------------|
| Average total domestic area (rai) | 70,000 |
| Production (mt) | 12,698 |
| Farm Price (bahts/mt) | 14,254 |
| Average total value of crop (baht/mt) | 180,997,292 |
| Expected GM yield (kg/rai) | 281 |
| Average current yield (kg/rai) | 181 |
| % Yield Increase | 55% |
| % Cost Decrease | 9% |
| Supply elasticity (e) | 1 |
| Adoption Ceiling (% area) | 80% |
| Adoption Lag (years) | 3 |
| Years to full adoption | 10 |

Table 5.13 Total Economic Surplus of Bt Cotton

| Year | Annual Adoption (%) | Scenario 1 Total Surplus (million baht) | Scenario 1 Total Surplus (million US\$) | Scenario 2 Total Surplus (million baht) | Scenario 2 Total Surplus (million US\$) |
|--------------------------------------|---------------------|---|---|---|---|
| 0 | 0 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1 | 0 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2 | 0 | 0.00 | 0.00 | 0.00 | 0.00 |
| 3 | 0 | 0.00 | 0.00 | 0.00 | 0.00 |
| 4 | 8% | 9.02 | 0.26 | 9.01 | 0.26 |
| 5 | 16% | 18.47 | 0.53 | 18.46 | 0.53 |
| 6 | 24% | 28.34 | 0.81 | 44.40 | 1.27 |
| 7 | 32% | 38.65 | 1.10 | 82.46 | 2.36 |
| 8 | 40% | 49.38 | 1.41 | 133.37 | 3.81 |
| 9 | 48% | 60.54 | 1.73 | 197.85 | 5.65 |
| 10 | 56% | 72.13 | 2.06 | 276.63 | 7.90 |
| 11 | 64% | 84.14 | 2.40 | 370.45 | 10.58 |
| 12 | 72% | 96.59 | 2.76 | 480.02 | 13.71 |
| 13 | 80% | 109.46 | 3.13 | 606.09 | 17.32 |
| Net present value (5% discount rate) | | 403.15 | 11.52 | 1,512.51 | 43.21 |

Note: assume US\$ 1 = 35 Baht

5.4.2 Economic surplus from GM papaya

Because Thailand is a small exporter of papaya, the domestic price received by farmers is determined by the world price of papaya. The average farm price of papaya during 2000-2003 was 4,040 baht/mt. Average production area during 2002-2006 was 111,638 rai. We assume that the potential yield of the ring spot virus resistant papaya is of the Khaek Dum ThaPra variety which is the cross between Florida Tolerant and Khaek Dum, and was considered the recommended variety by Department of Agriculture. The average yield of green Khaek Dum ThaPra in four provinces (Khonkhaen, Srisaket, Nong Bua Lumpoo, and Nong Kai) during 1995-1996 was 10.624 mts/rai (Prasartsri and Chaikietiyod, personal communication). The current yield of papaya fell to 1.86 mts/rai during 2002-2006.

The assumptions used for this analysis are summarized in Table 5.14. As was assumed for Bt cotton, a three year lag between resumption of field trials and availability of GM varieties is assumed. GM adoption is assumed to attain 80% in ten years. We assume a potential yield of 10.624 mts/rai for GM papaya, a 471% improvement on current yields. A very conservative assumption on total papaya area was used. In the first scenario, we assume that papaya area was 111,638 rai (17,862 hectares) which is the 2002-2006 average area. This is about 68% of the average area of the previous five year period. The model suggests that GM papaya will be generating about \$US 256 million or nearly 9 billion baht in annual benefits by the time of full adoption, and will generate a total discounted value of more than 683 million USD or nearly 24 billion baht (Table 5.15). In the second scenario, we assume that the total area of production returned to 163,142 rai which is the 1997-2001 average area in year 13 when the adoption reaches 80%. Running the model, by assuming that the annual increase of the papaya area spread equally from 111,638 rai to 163,142 rai (26,103 hectares) during year 4 to year 13, results in a total discounted economic surplus about 880 million USD or well above 30 billion baht.

Table 5.14 Parameters used for small open economy models of GM papaya

| | |
|---------------------------------------|-------------|
| Average total domestic area (rai) | 111,638 |
| Production (mt) | 204,087 |
| Farm Price (bahts/mt) | 4,040 |
| Average total value of crop (baht/mt) | 824,511,480 |
| Expected GM yield (mt/rai) | 10.624 |
| Average current yield (mt/rai) | 1.86 |
| % Yield Increase | 471% |
| Supply elasticity (e) | 1 |
| Adoption Ceiling (% area) | 80% |
| Adoption Lag (years) | 3 |
| Years to full adoption | 10 |

Table 5.15 Total Economic Surplus of GM Papaya

| Year | Annual Adoption (%) | Scenario 1 Total Surplus (million baht) | Scenario 1 Total Surplus (million US\$) | Scenario 2 Total Surplus (million baht) | Scenario 2 Total Surplus (million US\$) |
|--------------------------------------|---------------------|---|---|---|---|
| 0 | 0 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1 | 0 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2 | 0 | 0.00 | 0.00 | 0.00 | 0.00 |
| 3 | 0 | 0.00 | 0.00 | 0.00 | 0.00 |
| 4 | 8% | 369.37 | 10.55 | 375.82 | 10.74 |
| 5 | 16% | 855.90 | 24.45 | 870.83 | 24.88 |
| 6 | 24% | 1,459.58 | 41.70 | 1,561.16 | 44.60 |
| 7 | 32% | 2,180.41 | 62.30 | 2,445.89 | 69.88 |
| 8 | 40% | 3,018.40 | 86.24 | 3,543.32 | 101.24 |
| 9 | 48% | 3,973.54 | 113.53 | 4,871.81 | 139.19 |
| 10 | 56% | 5,045.84 | 144.17 | 6,449.67 | 184.28 |
| 11 | 64% | 6,235.29 | 178.15 | 8,295.24 | 237.01 |
| 12 | 72% | 7,541.89 | 215.48 | 10,426.85 | 297.91 |
| 13 | 80% | 8,965.64 | 256.16 | 12,862.82 | 367.51 |
| Net present value (5% discount rate) | | 23,915.23 | 683.29 | 30,870.46 | 882.01 |

Note: assume US\$ 1 = 35 Baht

5.5 Conclusions

This study has reported preliminary benefit estimates for two important crops – Bt cotton and GM papaya. Both crops have been severely affected by pest problems in the past 15 years. The cotton industry has nearly disappeared in Thailand, in great part due to the difficulty in controlling cotton bollworm. Similarly, papaya production has fallen to less than one-third of what it was at its peak. Adapted transgenic varieties of both of these crops have been developed, suggesting that seeds could be made available to farmers within a relatively short time after field trials are permitted to resume. Based on discussions with farmers, we believe that they are willing to adopt GM varieties once they are commercially available.

GM crops have already provided large economic benefits in several countries of the world, and hold great promise for delivering large benefits in Thailand once biosafety protocols are established. If Thailand is able to return its cotton and papaya industries to the size they had a decade ago, and if GM varieties are successful, Thailand stands to reap large economic benefits.

Based on our analysis:

Bt Cotton; Resistant to Bollworm Insect and Leaf Roll Virus Disease:

- Improves yield by 55%
- Saves 50% pesticide cost or 18% of production cost
- Increases seed cost by 9% of total production cost
- Takes 3-years for adoption, and an additional 10-years to reach 80% adoption
- If cotton production area remains at current level of 11,200 hectares (70,000 rai), Thailand would benefit by US\$11.5 million (400 million baht)
- If cotton production area returns to peak level as during the 1990's, at 68,400 hectares (427,500 rai), Thailand would benefit by US\$43 million (1.5 billion baht)

Khaek Dum Papaya; Resistant to Ring Spot Virus:

- Improves yield by 471%
- No perceptible cost benefit
- Takes 3-years for adoption, and an additional 10-years to reach 80% adoption
- If papaya production area remains at current level of 17,862 hectares (111,638 rai), Thailand would benefit by US\$680 million (24 billion baht)
- If papaya production area returns to peak level as between 1997-2001, at 26,103 hectares (163,142 rai), Thailand would benefit by US\$880 million (30 billion baht)

Chapter 6:

Conclusion

6.1. Potential Benefits from Using Crop Biotechnology

Agricultural biotechnology benefits small farmers through improving yields and reducing costs. Biotechnology, particularly gene manipulation, is an alternative to conventional breeding that improves plant characteristics by increasing productivity and decreasing input. When conventional breeding techniques fall short, genetic engineering is the only solution for integrating desired characteristics into plants – and realizing these benefits.

6.2. Genetic Engineering -- Biotech Crops: Alternative Technology

Results from this Study indicate that if biotech crops are used in Thailand, they will firstly decrease chemical usage in agriculture. Amounts of chemical insecticides and herbicides in the country have increased significantly in the recent past. In 1994 total active ingredients were 20,790 metric tons with a value of 3,584 million Baht. In 2005, the total volume increased to 80,166 tons with a value of 11,360 million Baht (Office of Agricultural Economics, 2007). This typically results in chemical contamination of soil, plus contamination of water and food crops. Plant diseases and insect problems reduce crop yields, another issue that can be remedied by the use of biotech crops. Thailand should benefit from technology advances and make use of the country's rich biodiversity by maximizing the value of its food, feed and fiber crops. Plus, through technologies such as plant biotechnology, value can be added to high potential genetic resources by developing new industrial products; pharmaceuticals, polymers, and energy products as described in Chapter 2. Finally, the analyses of socio-economic benefits described in Chapter 5 indicate income and employment advantages for Thailand through the adoption of GM crops.

6.3 General Remarks on Biotechnology Perception

The biotechnology revolution has raised some issues, as well as deliver benefits. There have been dissenters against the adoption of agricultural biotechnology who have questioned the long-term effect of this technology. Caution in this regard may be warranted – but it must also be recognized that after more than a decade of crop biotechnology adoption, negative effects have not been demonstrated. Overall, scientific research in agricultural biotechnology and in other advanced technologies must be guided by ethical and safety-oriented principles while respecting the private sector's need to earn a decent return.

In parts of the world, there is also a degree of unease about using biotech/GM products. Thus, in some European countries, 'choice' about whether to plant or eat GM products is exercised. At the same time in the US, GM products are acceptable and readily available to consumers. In fact, plants transformed into biotech crops are not different from those developed through conventional breeding – except that they contain desirable gene/genes. Foods derived from these crop plants have comparative equivalence to those of conventional foods. And, in cases such as 'Golden Rice, there are inherent nutritional benefits that address micronutrient deficiencies. It has been confirmed by many scientific institutions and international agencies that biotechnology utilization would lead to reliable food systems and multiple benefits for poor people. This means that by harnessing the benefits of new technologies in sustainable ways, responsible organizations can aid developing countries around the world in the eradication of hunger and poverty.

6.4 Future Success Depends on Decision.

In the past, Thailand was a regional leader in biotech crop research and development. Because of the lack of decision-making, this development fell behind neighboring countries. In Chapter 4, three choices of National Policy on genetic engineering technology have been described and the “Social Choices”/“Permissive” Policy was recommended. This effective deployment of agricultural biotechnology would enable Thai farmers and the country to be more competitive. It is necessary for the country to decide on adopting this technology for development -- before the situation is irredeemable.

This Study indicates that Thailand has experienced great opportunity losses in terms of biotechnology utilization. Case studies on biotech cotton and papaya have demonstrated that with crop biotechnology and commercialization, there will be significant benefits for farmer income and employment -- plus decreasing chemical usage resulting in environmental conservation. Finally, the most critical opportunity loss may be observed in the low professional moral among researchers. Government initially sent out ‘Thailand’s best and brightest’ who completed studies in this field at top research institutes world-wide. After returning to Thailand and carrying out research in genetic engineering as planned, they were then stopped from completing their research cycles. Many of these research specialists have left their jobs of choice, and are now involved other areas. Such losses can hardly be assessed.

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Appendices

Table 1. Volume and Value of Importation of Individual Chemical Pesticides during B.E. 2537-2548

| Pesticides: Quantity (Ton of active ingredient) and value (million Baht) of pesticides introduced during 1994 and 2005 | | | | | | | | | | |
|---|-------------|-------|-----------|-------|-----------|-------|----------|-------|----------|--------|
| Year | Insecticide | | Fungicide | | Herbicide | | Others | | Total | |
| | Quantity | Value | Quantity | Value | Quantity | Value | Quantity | Value | Quantity | Value |
| 1994 | 5,444 | 1,178 | 5,329 | 544 | 9,543 | 1,700 | 474 | 162 | 20,790 | 3,584 |
| 1995 | 6,602 | 1,655 | 4,824 | 604 | 11,934 | 2,044 | 699 | 399 | 24,059 | 4,702 |
| 1996 | 6,479 | 1,711 | 4,446 | 616 | 14,041 | 2,445 | 576 | 152 | 25,542 | 4,924 |
| 1997 | 7,526 | 2,095 | 4,588 | 817 | 14,403 | 3,285 | 610 | 201 | 27,127 | 6,398 |
| 1998 | 8,488 | 2,774 | 3,424 | 765 | 10,359 | 2,666 | 959 | 197 | 23,230 | 6,402 |
| 1999 | 11,514 | 2,857 | 4,960 | 895 | 16,678 | 3,293 | 817 | 236 | 33,969 | 7,281 |
| 2000 | 7,023 | 2,047 | 4,758 | 1,097 | 17,611 | 3,880 | 1,610 | 283 | 31,002 | 7,307 |
| 2001 | 8,356 | 2,553 | 5,384 | 1,265 | 20,957 | 4,502 | 2,342 | 441 | 37,039 | 8,761 |
| 2002 | 9,046 | 2,931 | 5,681 | 1,444 | 22,670 | 4,349 | 2,237 | 392 | 39,634 | 9,116 |
| 2003 | 9,790 | 3,136 | 6,732 | 1,678 | 31,879 | 6,101 | 1,930 | 426 | 50,331 | 11,341 |
| 2004 | 16,731 | 2,835 | 10,108 | 1,719 | 55,649 | 6,080 | 4,417 | 502 | 86,905 | 11,135 |
| 2005 | 18,529 | 3,322 | 9,052 | 1,716 | 48,841 | 5,806 | 3,744 | 516 | 80,166 | 11,360 |

Others = Miticide, raticide hormones etc

Source:

<http://www.oae.go.th/factor/PestNew.htm>

Table 2. Average yield of rice of major production countries; 2003-2005

| Yield ranking | Country | Yield per rai (Kgs) | | | Average (3 yrs) |
|---------------|-----------------|---------------------|------------|------------|-----------------|
| | | 2003 | 2004 | 2005 | |
| | World ave. | 627 | 646 | 644 | 639 |
| 2 | China | 970 | 1,009 | 1,006 | 995 |
| 9 | India | 492 | 484 | 480 | 485 |
| 4 | Indonesia | 727 | 726 | 732 | 728 |
| 5 | Bangladesh | 578 | 578 | 583 | 580 |
| 3 | Viet Nam | 742 | 771 | 792 | 768 |
| 10 | Thailand | 464 | 457 | 474 | 465 |
| 6 | Myanmar | 567 | 587 | 587 | 580 |
| 7 | Philippines | 539 | 562 | 572 | 558 |
| 8 | Brazil | 520 | 569 | 534 | 541 |
| 1 | Japan | 936 | 1,026 | 1,047 | 1003 |
| | Others | 518 | 539 | 530 | 529 |

Source: Office of Agricultural Economics, 2548 Page 1

Table 3. Average yield of maize of major production countries; 2003-2005

| Yield ranking | Country | Yield per rai (Kgs) | | | Average (3 yrs) |
|---------------|-----------------|---------------------|------------|------------|-----------------|
| | | 2003 | 2004 | 2005 | |
| | World ave. | 714 | 790 | 755 | 753 |
| 1 | U.S.A. | 1,428 | 1,610 | 1,490 | 1509 |
| 5 | China | 770 | 819 | 800 | 796 |
| 7 | Brazil | 596 | 542 | 486 | 541 |
| 10 | Mexico | 404 | 440 | 410 | 418 |
| 4 | Argentina | 1,036 | 1,030 | 1,139 | 1068 |
| 11 | India | 317 | 320 | 314 | 317 |
| 3 | France | 1,139 | 1,437 | 1,296 | 1291 |
| 8 | Indonesia | 519 | 535 | 549 | 534 |
| 9 | South Africa | 425 | 498 | 574 | 499 |
| 2 | Italy | 1,197 | 1,521 | 1,610 | 1443 |
| 6 | Thailand | 617 | 619 | 602 | 613 |
| | Others | 406 | 463 | 444 | 438 |

Source: Office of Agricultural Economics, 2548 Page 9

Table 4. Average yield of cassava of major production countries, 2003-2005

| Yield ranking | Country | Yield per rai (Kgs) | | | Average (3 yrs) |
|---------------|-----------------|---------------------|--------------|--------------|-----------------|
| | | 2003 | 2004 | 2005 | |
| | World ave. | 1,747 | 1,763 | 1,751 | 1754 |
| 8 | Nigeria | 1,509 | 1,483 | 1,483 | 1492 |
| 4 | Brazil | 2,151 | 2,173 | 2,205 | 2176 |
| 3 | Indonesia | 2,381 | 2,475 | 2,544 | 2467 |
| 2 | Thailand | 3,087 | 3,244 | 2,749 | 3027 |
| 9 | Congo | 1,298 | 1,298 | 1,298 | 1298 |
| 5 | Ghana | 2,030 | 1,988 | 1,988 | 2002 |
| 7 | Angola | 1,416 | 1,533 | 1,839 | 1596 |
| 6 | Tanzania | 1,670 | 1,670 | 1,672 | 1671 |
| 1 | India | 4,667 | 4,467 | 4,467 | 4534 |
| 10 | Mozambique | 941 | 960 | 937 | 946 |
| | Others | 1,543 | 1,581 | 1,573 | 1566 |

Source: Office of Agricultural Economics, 2548 Page 17

Table 5. Average yield of sugarcane of major production countries, 2003-2005

| Yield ranking | Country | Yield per rai (Kgs) | | | Average (3 yrs) |
|---------------|-----------------|---------------------|--------------|--------------|-----------------|
| | | 2003 | 2004 | 2005 | |
| | World ave. | 10,448 | 10,410 | 10,467 | 10442 |
| 4 | Brazil | 11,797 | 11,820 | 11,655 | 11757 |
| 8 | India | 9,779 | 9,447 | 9,912 | 9713 |
| 7 | China | 10,273 | 10,457 | 10,425 | 10385 |
| 9 | Thailand | 10,429 | 9,269 | 7,434 | 9044 |
| 10 | Pakistan | 7,575 | 7,954 | 7,823 | 7784 |
| 6 | Mexico | 11,298 | 11,298 | 11,298 | 11298 |
| 1 | Colombia | 14,734 | 14,831 | 14,766 | 14777 |
| 2 | Australia | 13,213 | 13,212 | 14,570 | 13665 |
| 3 | Philippines | 12,273 | 13,165 | 13,053 | 12830 |
| 5 | U.S.A. | 12,212 | 11,092 | 10,661 | 11322 |
| | Others | 9,265 | 9,325 | 9,565 | 9385 |

Source: Office of Agricultural Economics, 2548 Page 20

Table 6. Average yield of soybeans of major production countries, 2003-2005

| Yield ranking | Country | Yield per rai (Kgs) | | | Average (3 yrs) |
|---------------|-----------------|---------------------|------------|------------|-----------------|
| | | 2003 | 2004 | 2005 | |
| | World ave. | 363 | 358 | 367 | 363 |
| 1 | U.S.A. | 364 | 454 | 459 | 426 |
| 4 | Brazil | 449 | 370 | 351 | 390 |
| 2 | Argentina | 448 | 352 | 437 | 412 |
| 7 | China | 264 | 290 | 285 | 280 |
| 11 | India | 169 | 122 | 137 | 143 |
| 5 | Paraguay | 456 | 307 | 290 | 351 |
| 3 | Canada | 347 | 414 | 414 | 392 |
| 6 | Bolivia | 380 | 300 | 300 | 327 |
| 9 | Indonesia | 204 | 205 | 209 | 206 |
| 10 | Russian | 158 | 160 | 172 | 163 |
| 8 | Thailand | 246 | 238 | 238 | 241 |
| | Others | 215 | 234 | 234 | 228 |

Source: Office of Agricultural Economics, 2548 Page 23

Table 7. Average yield of cotton of major production countries; 2003-2005

| Yield ranking | Country | Yield per rai (Kgs) | | | Average (3 yrs) |
|---------------|-----------------|---------------------|------------|------------|-----------------|
| | | 2003 | 2004 | 2005 | |
| | World ave. | 279 | 317 | 303 | 300 |
| 4 | China | 456 | 533 | 512 | 500 |
| 8 | U.S.A. | 330 | 380 | 364 | 358 |
| 11 | India | 145 | 137 | 132 | 138 |
| 9 | Pakistan | 274 | 365 | 365 | 335 |
| 7 | Uzbekistan | 324 | 389 | 434 | 382 |
| 5 | Brazil | 491 | 526 | 476 | 498 |
| 3 | Turkey | 589 | 592 | 611 | 597 |
| 2 | Australia | 681 | 776 | 661 | 706 |
| 6 | Greece | 462 | 500 | 469 | 477 |
| 1 | Syria | 627 | 761 | 751 | 713 |
| 10 | Thailand | 235 | 224 | 212 | 224 |
| | Others | 180 | 200 | 195 | 192 |

Source: Office of Agricultural Economics, 2548 Page 36

Table 8. Labor cost: Lowest labor cost rate (Baht/day) during 1973-2006

| Year | Labor cost rate | Year | Labor cost rate |
|-------------|------------------------|-------------|------------------------|
| 1973 | 12 | 1990 | 74-90 |
| 1974 | 16-18 | 1991 | 82-100 |
| 1975 | 25 | 1992 | 94-115 |
| 1976 | 25 | 1993 | 102-125 |
| 1977 | 19-28 | 1994 | 102-135 |
| 1978 | 25-35 | 1995 | 118-145 |
| 1979 | 35-45 | 1996 | 128-157 |
| 1980 | 44-54 | 1997 | 128-157 |
| 1981 | 52-61 | 1998 | 130-162 |
| 1982 | 52-64 | 1999 | 130-162 |
| 1983 | 56-66 | 2000 | 130-162 |
| 1984 | 56-66 | 2001 | 133-165 |
| 1985 | 59-70 | 2002 | 133-168 |
| 1986 | 59-70 | 2003 | 133-169 |
| 1987 | 61-73 | 2004 | 133-170 |
| 1988 | 61-73 | 2005 | 137-175 |
| 1989 | 63-78 | 2006 | 137-175 |

Source: http://www.mol.go.th/download/past_wages.xls

Figure 1. Benefits from using Biotech Crops (Resistant to Plant Pests): Decrease of Chemical Use in the Control of Plant Pests

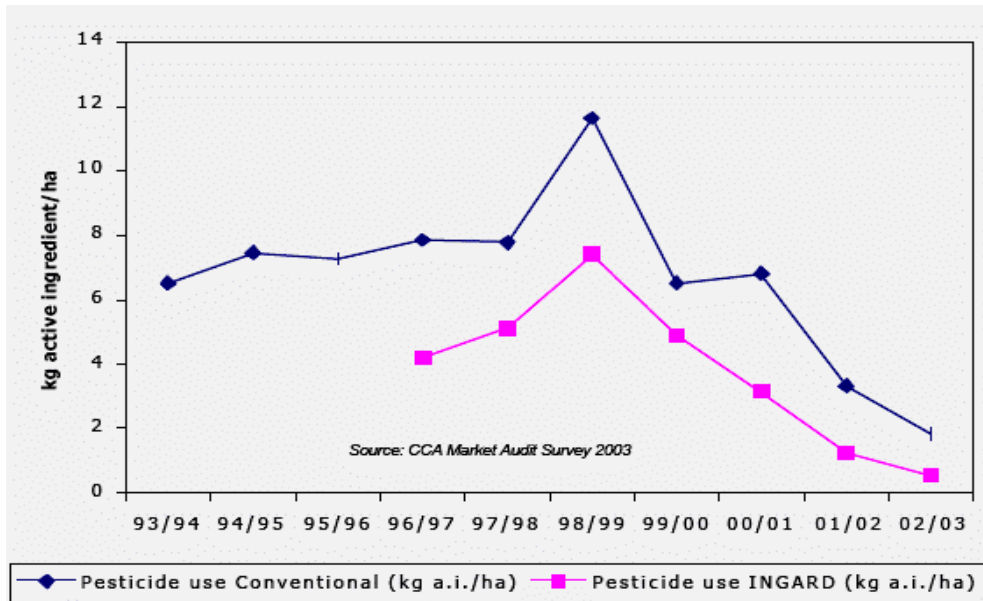
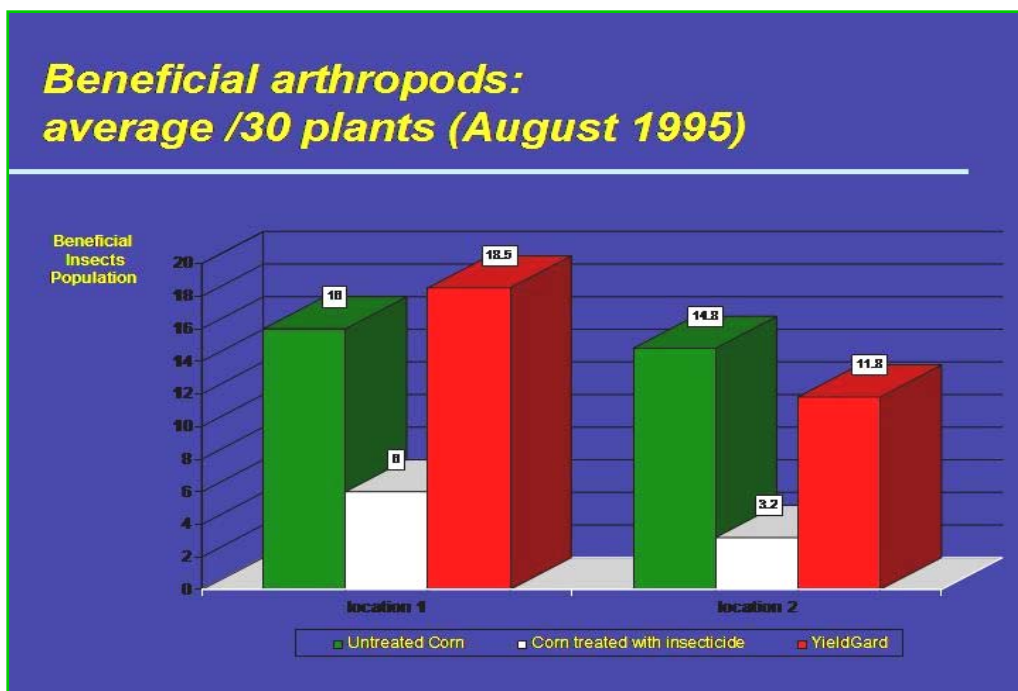
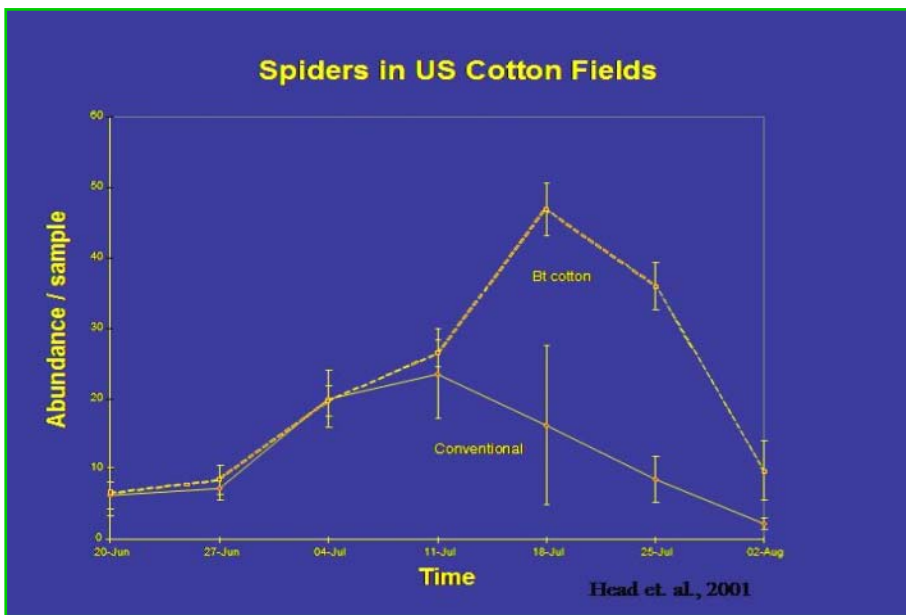


Figure 2. Conservation of Beneficial Insects: Arthropods



Source: Tom Nickson, Ecological Technology Center, (Slide presentation)

Figure 3. Conservation of Beneficial Insects: Spiders in US Cotton Fields



Source: Tom Nickson, Ecological Technology Center, (Slide presentation)

Figure 4. Decrease of Fungal Attack and Toxic Contamination

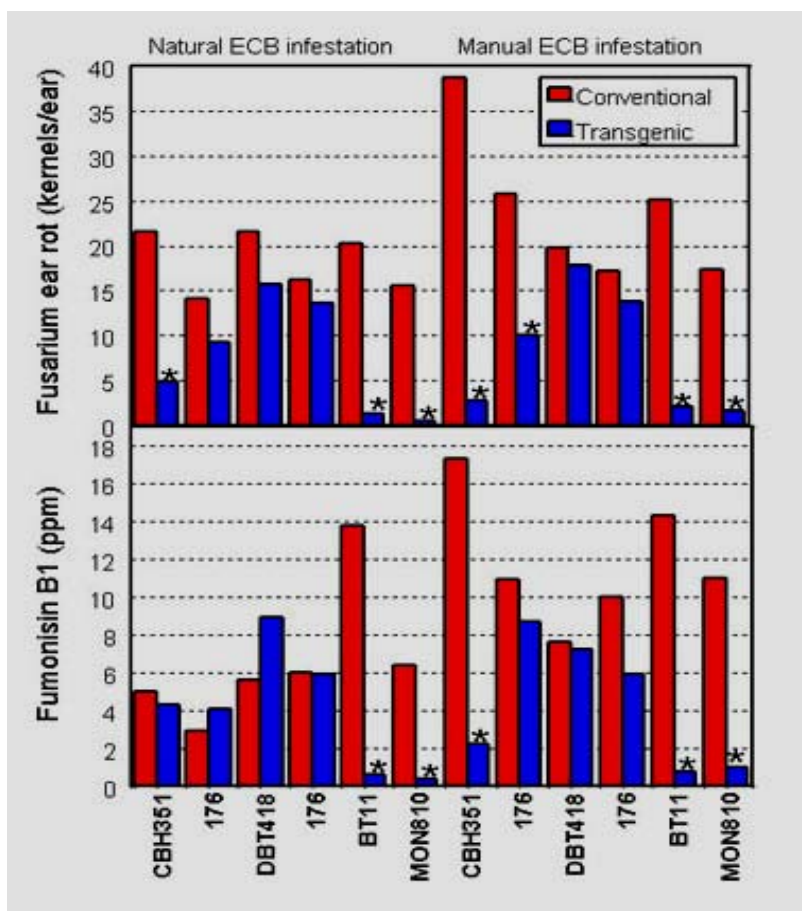


Figure 5. Total welfare assuming increased production will be consumed in the Thai domestic market (closed economy model)

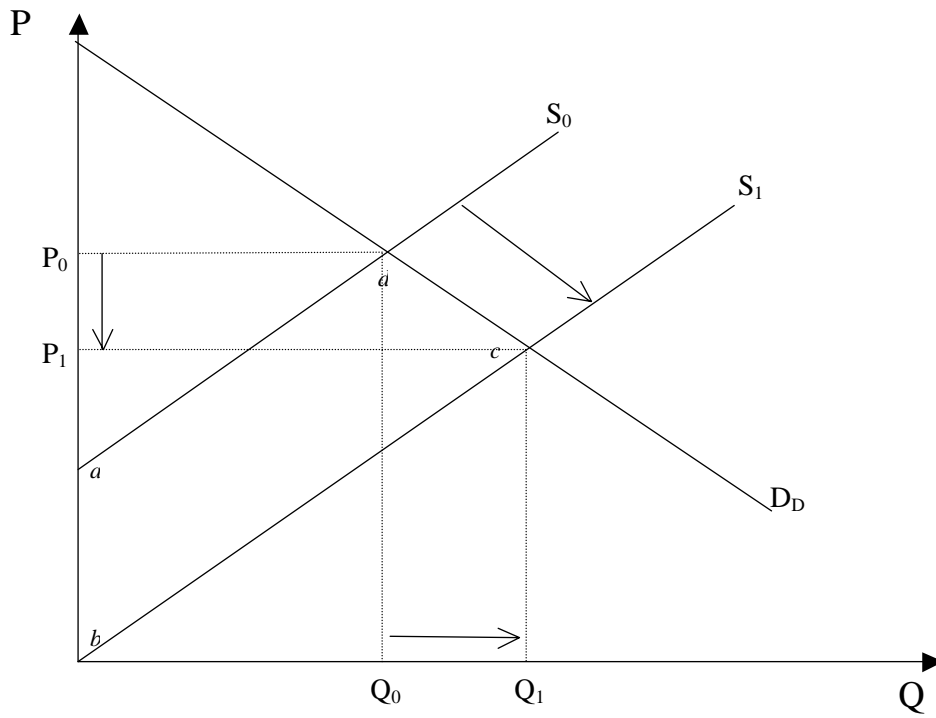
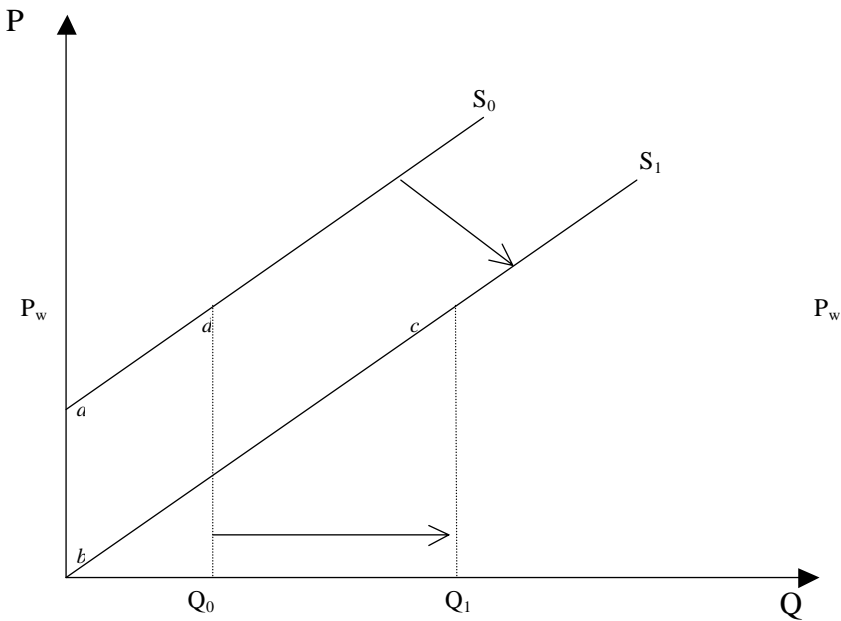


Figure 6. Change in total welfare assuming increased production will be exported at world market price (small, open economy model)



Box 1

Benefits in Using Biotech Crops (Herbicide Tolerance)

1. Excellent control of weeds, therefore, increasing yields
2. Easy in planting crops. It is possible to control weeds after the growth of crop plants.
3. Decrease number of herbicide spray in each crop season.
4. Decrease fuel use due to decreasing number of plowing (due to herbicide use with minimum tillage)
5. Decrease soil compaction (due to less number of tillage and herbicide usages)
6. Use of low toxic level of chemicals and low residue in soil.
7. Enabling the use of minimum tillage which will result in good soil structure and conserving beneficial microbes in the soil.

Result of Minimum Tillage

1. Saving of fuel usage at around 234 million gallons a year and
2. Decrease soil erosion saving top soil around 247 million tons

Case Example of Biotech Crop Planting in Spain

1. In year B.E. 2544/45 Spain has total area of 485,000 hectare corn crop and 90% under irrigation.
2. Biotech crop accounts for about 20,000-25,000 hectares of total area.
3. Majority of normal corn areas have medium to high infestation of corn borers.
4. Planting areas of 6-20 % need chemical protection of insect pests.
5. It results in the cost of spray about 18-24 Euro/hectare when applying through irrigation and 36-42 Euro/hectare if spraying is applied
6. The chemical spray should be made before egg hatching and in period of 3 weeks of effective chemical usage.
7. Chemical use will not be effective if borers already got into the stalks.
8. Corn borers could cause yield reduction of about 10-15 % varying fro location to location.
9. In areas where insect infestation is high, the use of Biotech Bt. crop will result in 10% yield increase for the areas used to use chemicals and 15% increase in area without previous chemical use.
10. Though the cost of Biotech crop seeds is about 18.5 Euro/hectare, the cost of chemical spray of about 24-102 Euro/hectare is saved. Besides, the cost of labor is saved together with time saving in applying with irrigation.
11. Net profit in using biotech crops in heavy insect infestation is about 67-329.5 Euro/ hectare.

Other benefits that farmers received

1. Decrease risk in corn borer destruction
2. Saving time in chemical spraying.
3. Obtaining good quality grains with low level of toxin contamination.
4. Farmers' health improving with decreasing accidental risk in using chemicals.
5. Improving environment from decreasing chemical usage.
6. Enabling biotech crop grains sold in same manner as normal maize grains for animal feed.

Economic Benefit if Biotech Bt. Cotton Planted in Thailand Farmers' benefit

1. Yield per unit area increased higher that that of Sri-samrong 60 about 59-122 Kg/rai.
2. Cost of product decreased resulting from decreasing chemical use in controlling cotton boll worm insect.
3. When consider benefit to farmers, if cotton yield is 250 kg/rai, net profit will be 1,000-1,050 Baht increase per rai. It is certain that this will result in foreign exchange saving regardless any variety. If there is 200,000 rai of cotton planting, it would save around 771 million Baht of foreign exchange.

Case Example of Biotech Maize Tolerance to Herbicides

1. Survey information made by North Carolina University indicated that net benefit received by farmers planting to biotech corn, cotton and soybean is about 9.30 USD/ acre/year

2. Benefit in term of conservation, the planting of biotech herbicide tolerance will vary from 43.67 USD for planting to corn to 48.22 USD for cotton planting.

3. Considering the inclusion of minimum tillage together with the use of herbicide tolerance, net benefit will be about 53.54 USD /acre.

4. The seed cost is higher in using biotech crop, e.g. biotech cotton seed is 9.50 USD higher than normal seeds and 6.30 USD higher for biotech soybean seed per acre.

5. Because of its convenience in practices, it is popular among farmers in using biotech crops. This includes time saving in weed management and flexibility in applying herbicides.

6. Time saving could be transformed into about 10-12 USD /acre.

7. In term of farm equipment saving, farmers could save about 5.50 USD per acre.

8. Farmers who plant to biotech cotton could save about 8.50 USD /acre.

9. Farmers who plant to biotech soybean could save about 7.00 USD /acre.

10. In term of human health safety, its value may be equivalent to 3.65 USD / acre.

11. And finally, environmental safety could be valued at 3.80 USD /acre in case of planting to biotech herbicide tolerance crops.

Box 2:

Welfare Calculation

In economics, welfare of the society is used to measure the well-being of consumers, producers, and government. Economic surplus is the measurement of how much each party benefits from participating in the market compared to what they are willing to buy or sell the commodity. A consumer surplus is the difference between the price consumers are willing to pay and the market price, and a producer surplus is the difference between the market price and the price they are willing to sell. Changes in the amount and distribution of economic surplus are the results of changes in market conditions, specifically the market price. A decrease in price creates an increase in consumer surplus and a decrease in producer surplus. On the same token, an increase in price increases producer surplus and decreases consumer surplus.

Because new technology reduces the cost of production, farmers will increase production through a combination of higher yields and possibly by increasing area. To calculate welfare, this is modeled as a downward shift in the supply curve in Appendix Figures 5. The model represented in Appendix Figure 5 assumes that the commodity is produced and only consumed domestically. A downward shift in the supply curve results in a lower market price. As a result, the consumer surplus increases by area P_0P_1cd , whereas the producer surplus changes by area $P_1bc - P_0ad$.

In Thailand, cotton and papaya are traded in international markets, and the country's increased production is not large enough to affect the world price. The country has open trade policies, so that domestic prices and world prices are equal. Any increased output will either be exported at the world price, or will substitute for imports that would otherwise occur at the world price. Because the country is small relative to total world production, new production does not affect output price and no consumer surplus is produced. Total change in annual surplus is equal to producer surplus represented by trapezoidal area $abcd$ in Appendix Figure 6.

Welfare change calculations

Calculation of economic benefits requires that the farm level costs and returns of the new technology be compared with alternative practices (Alston, et al., 1998, Falck-Zepeda, et al., 2000). The estimated reduction in the cost of production is then used to estimate the size of the shift in the supply curve and the total surplus produced by the new technology.

The economic surplus corresponding to the areas depicted in Figure 6 can be calculated using the following formula (Alston, et al., 1998): $\Delta \text{Total Surplus} = P_w Q_0 K (1+0.5K\epsilon)$. Where P_w is the world price, Q_0 is output, K is the percent cost savings from GM technology multiplied by the percent adoption, and ϵ is the elasticity of supply.