Thailand

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Agricultural Development in Thailand

This study includes a survey of private agricultural research and technology transfer in several Asian countries. The purposes of this survey are to: (1) determine the amount and kind of agricultural research is being conducted by the private sector, (2) identify policy constraints and incentives to private research and technology transfer, and (3) assess major effects of private research investments on agricultural productivity. The survey is similar to one conducted by Carl Pray in 1985, and thus provides an update of that earlier work.

The Thailand survey consisted of interviewing 20 companies in Bangkok and other cities during May 1997. The sample was selected to include companies with research and technology transfer activities in the seed, livestock, agricultural chemical, farm machinery, and plantation sectors. These interviews were supplemented with discussions with officials from the Thai government and local universities, U.S Department of Agriculture's Foreign Agricultural Service, and agribusiness associations in Thailand.

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Agriculture in the Thai Economy

Thailand has experienced exceptional economic growth over the past several decades and is rapidly entering the ranks of the newly industrialized countries. While the agricultural sector continues to experience significant growth as well, its relative importance in the overall economy has declined. Between 1965 and 1995, the share of Thailand's gross domestic product (GDP) derived from primary agriculture fell from 35.0 to 10.9 percent, even though agricultural production tripled in real terms over this period (table D-1). In 1995, the value of agricultural GDP was $18.2 billion.

Agriculture provides many raw materials for Thailand's industrial sector. Rubber for latex, sugarcane for refined sugar, cassava for processed livestock feed, and fruit for canning and juices are examples of manufacturing industries that process agricultural commodities into intermediate products or consumer goods for domestic use and exports. A significant share of Thailand's industrial sector is based on processing agricultural commodities.

Table D-1—Trends in Thailand's economy and labor force, selected years

Item	Unit	1965	1980	1990	1995
Gross domestic product	Billion dollars[1]	17.4	52.2	110.5	166.8
Agricultural GDP	Billion dollars[1]	6.1	12.1	13.9	18.2
Agriculture share of total	Percent	35.0	23.2	12.6	10.9
Labor force	Millions	15.4	27.0	32.3	33.0
Agricultural labor force	Millions[2]	12.5	18.4	19.4	17.1
Agriculture share of total	Percent	82.0	68.3	60.1	52.0
Output per non-agriculture worker	Dollars/worker[1]	3,897	4,639	7,488	9,358
Output per agriculture worker	Dollars/worker[1]	488	658	716	1,064
Non-agriculture to agriculture worker	Productivity ratio	8.0:1	7.1:1	10.5:1	8.8:1

[1]Constant 1995 dollars.
[2]Workers whose principal occupation is agriculture. This overstates agriculture's share of total employment since many farmworkers engage in seasonal nonfarm employment. In 1992, 46 percent of farm-household income originated from nonfarm sources (Thailand Development Research Institute, 1995).

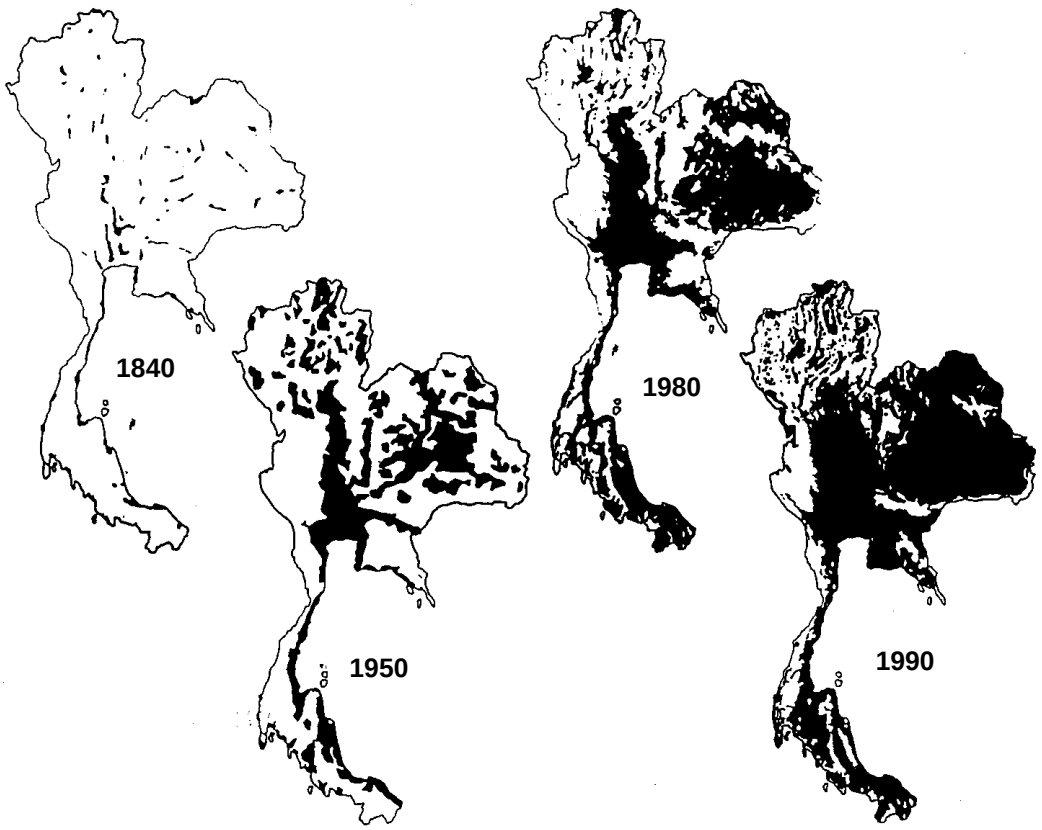
Sources: World Bank; Thailand Development Research Institute, 1997.

In international markets, Thailand continues to possess a strong comparative advantage in producing many agricultural commodities. In 1994, Thailand exported $13.4 billion of agricultural goods and had a positive trade balance in agricultural products of $6.2 billion, despite an overall mercantile trade deficit of $9.3 billion. Major export commodities were shrimp ($1.97 billion), rubber ($1.67 billion), rice ($1.57 billion), tapioca products ($0.75 billion), and sugar ($0.69 billion) (Office of Agricultural Economics, Ministry of Agriculture and Cooperatives, 1996).

Agriculture continues to be the principal source of employment for the majority of the labor force. Even though agriculture in 1998 accounted for only about 10 percent of the nation's GDP, more than 50 percent of the working population resided in agricultural households (table D-1). Availability of new land for settlement and cultivation enabled agriculture to continue to absorb the majority of the rapidly growing labor force up until the 1980s. The absolute size of the agricultural labor force did not begin to decline until the early 1990s, when increasing numbers of farmworkers migrated to urban areas. By 1995, there were 17.1 million workers whose primary occupation was in agriculture, down from 19.4 million in 1990. Furthermore, part-time employment by members of agricultural households in the nonagricultural economy is a significant source of family income. According to one study, nearly half of the income of agricultural households is derived from employment in the industrial and service sectors (Thailand Development Research Institute, 1995). Given the significant wage earnings gap between rural and urban areas, permanent and seasonal rural-to-urban migration is likely to accelerate.

An important implication of rapid economic development for research policy is that the demand for labor-saving technology in agriculture is increasing. Mechanization of agricultural production frees farm labor for the industrial and service sectors. At the same time, mechanization increases the productivity and income of

Figure D-1
Expansion of agricultural cropland, Thailand



Source: Phongpaichit and Baker, 1995

labor that remains in agriculture, thereby helping to close the wage gap between farm and nonfarm employment.

Trends in Commodity Production and Yield

Historically, Thailand's land-abundant economy enabled agricultural growth to be sustained largely through the expansion of cropland. Over the past century, the area planted in rice, rubber, sugarcane, cassava, corn, fruits, and other crops dramatically grew as agriculture expanded into previously forested areas (fig. D-1). By the late 1980s, however, newly settled land was increasingly marginal for agricultural production, and the Thai Government took steps to preserve remaining forestland from further encroachment (Thailand Development Research Institute, 1987; and Fuglie, 1991). Growth in agricultural production will rely increasingly on research and capital investments to increase crop yields and improve production and marketing systems for high-valued commodities.

In 1994, crop production contributed 55 percent of the value of agricultural GDP, followed by fisheries (16.5 percent), livestock (10.1 percent), and other commodities (table D-2). As in other east Asian countries, rice is the dominant crop of Thailand's agriculture. Prior to World War II, rice was the principal export earner for the entire economy (Ingram, 1971). While rice is still the single most important agricultural commodity, occupying more than half of all agricultural land and labor force, its relative importance has declined. Efforts of the Thai Government to promote diversification in the agricultural sector has encouraged the growth of nonrice commodities (Thailand Development Research Institute, 1995). By the early 1990s, rice ranked third in agricultural export value behind shrimp and rubber (table D-3).

Table D-2—Structure of agriculture, Thailand, 1994

Commodity	Value of production	Share of agriculture domestic product
	Million baht	*Percent*
Crops	203,267	55.1
Livestock	37,183	10.1
Fisheries	60,777	16.5
Forestry	4,609	1.2
Other	63,217	17.1
Total agriculture domestic product	369,053	100.0

Source: Ministry of Agriculture and Cooperatives, Center for Agriculture Information, Office of Agricultural Economics, 1996.

Agricultural diversification affected livestock and fisheries as well. Poultry production sustained especially rapid growth in the 1980s and early 1990s (table D-4). Swine, cattle, and dairy production also increased. The number of buffaloes, once the primary source of power in rice production, fell as field cultivation became increasingly mechanized. Aquaculture, especially fresh water shrimp production, has been another growth industry in Thailand's agriculture.

With the closing of Thailand's land frontier, agricultural growth is increasingly dependent on improvements in efficiency and productivity. Between 1978 and 1990, two-thirds of the agricultural growth of 4.01 percent per year was due to increases in labor, capital, and land resources, and one-third was due to improvement in total factor productivity, or the efficiency and quality of input use (table D-5). Agricultural land area grew by only 0.09 percent per year over this period. An important source of productivity growth was diversification of commodity production. By allocating agricultural

Table D-3—Major agricultural exports, Thailand, 1994

Commodity	Production	Exports
	1,000 metric tons	*Million dollars*
Shrimp	NA	1,966
Rubber	1,767	1,663
Rice	21,111	1,558
Sugarcane	37,823	684
Cassava	19,091	664
Poultry	NA	404
Fresh fish	NA	338
Canned pineapple	NA	264

NA = Not available.

Sources: Agrostat database, Food and Agriculture Organization of the United Nations, and Thailand Development Research Institute, 1997.

Table D-4—Number of livestock, Thailand, 1980 and 1995

Commodity	1980	1995	Annual growth rate
	------*1,000 Head*------		*Percent*
Poultry	56,000	80,000	5.01
Swine	3,021	4,507	2.43
Cattle	3,938	7,593	3.67
Dairy	9	120	20.89
Buffalo	5,651	4,807	-2.06

Source: Agrostat database, Food and Agriculture Organization of the United Nations.

resources to commodities with higher value and market potential, Thailand produced more value from a given set of resources and sustained a relatively high rate of growth in its agricultural sector. However, many of the most important agricultural commodities such as rice, cassava, and sugarcane in 1998 had yet to undergo significant technical improvement (Siamwalla, Setboonsarng, and Patamasiriwat, 1991).

Review of Agricultural Policies

Throughout most of the 20th century, Thailand imposed a net tax on agriculture through export taxes levied on its principal export commodities, rice and rubber. Import tariffs on manufactured goods and overvalued exchange rate policies also discriminated against agriculture by increasing the cost of manufactured products to the agricultural sector (Siamwalla and Setboonsarng, 1989). Since about 1980, however, direct and indirect taxation of the agricultural sector has been reduced and direct public support for agriculture increased (Siamwalla, Setboonsarng, and Patamasiriwat, 1991). In 1986, the rice export tax was abolished. In the 1990s, the export levy on rubber was reduced, and the remaining rubber export levy was reinvested in the rubber economy to support research and provide replanting loans to farmers. Increased public support for agriculture has come through price support programs for agricultural commodities, subsidies for irrigation, rural credit, agricultural inputs, and investments in rural infrastructure and agricultural research. Export commodities are generally sold at world prices. Domestic prices of many crops for which Thailand is a net importer are supported through import tariffs or quotas (Siamwalla, Setboonsarng, and Patamasiriwat, 1991).

One form of public subsidy for agriculture is credit for farmers. Public intervention in rural credit markets takes several forms. The Bank for Agriculture and Agricultural Cooperatives is a state-owned financial institution that provides loans to farmers at subsidized rates. In addition, banking regulations require that privately owned banks maintain a minimum lending portfolio to the agricultural and food sectors.

Since the late 1980s, public investment in irrigation projects has been curtailed due to the declining opportunities for low-cost irrigation schemes and rising social and environmental costs associated with creating large reservoirs. Declining prices for rice on the world market also discouraged new investment in irrigation (Siamwalla, Setboonsarng, and Patamasiriwat, 1991).

Policies toward land reform and land registration have occasionally generated rural protests. The rapid expansion of farmland into previously forested areas left a large portion of agricultural land untitled. The lack of formal title to agricultural land serves as a disincentive for farmers to invest in long-term capital improvements and limits access to formal credit institutions for many farmers (Feder et al., 1988).

Table D-5—Sources of agricultural growth, Thailand, 1978-90

Source	Annual growth rate
	Percent
Total output	4.01
Total factor input	2.72
Labor	1.91
Capital	.72
Land	.09
Total factor productivity	1.29

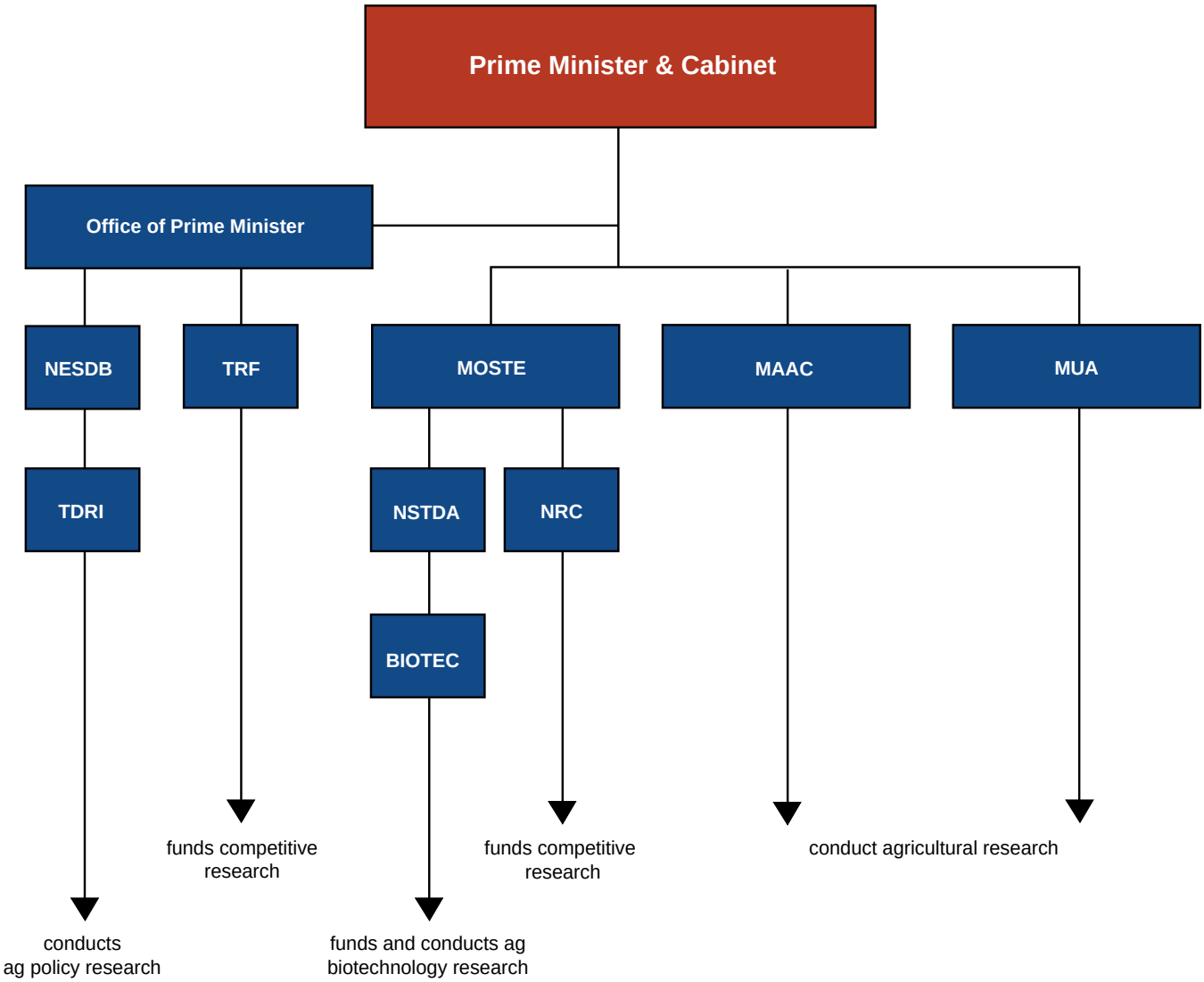
Source: Thailand Development Research Institute, 1997.

Review of Science Policy

The level of research capacity and scientific manpower in Thailand are low, compared with other dynamic Asian economies such as Korea, Taiwan, and Singapore (National Science Foundation, 1993). However, the Thai Government has recognized since the late 1970s that rapid economic growth could not be sustained without increased investment in science and technology to raise productivity. In 1979, it established the Ministry of Science, Technology, and Energy to coordinate and implement science policy. In 1982-86, the fifth national development plant emphasized investment in science infrastructure and manpower. Subsequent development plans established a goal of increasing the level of science and technology investment from the 1998 level of 0.2 to 0.75 percent of GDP (Ministry of Science, Technology, and Energy, 1997).

Government support for agricultural research precedes recent emphasis given to science and technology investment, and agriculture still accounts for most public expenditures for research. Agricultural research in Thailand dates back to the establishment of the Rangsit Agricultural Experiment Station near Bangkok in 1916. In 1998, agricultural research was supported by a number of government ministries and agencies (fig. D-2). The Ministry of Agriculture and Agricultural Cooperatives is the largest performer of agricultural research, with an annual research budget of $80

Figure D-2
Agencies funding and performing agricultural research, Thailand, 1998

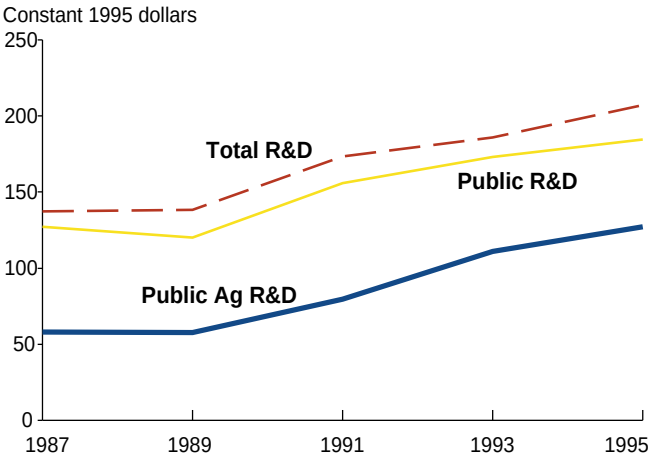


million to $90 million for research on crops, livestock, forestry, and fisheries. Public universities also have significant programs in agricultural research, funded through the Ministry of University Affairs and through grants from the Thailand Research Fund and the National Research Council. A $10-million annual biotechnology research program, most of which is devoted to agriculture, is funded through the National Science and Technology Development Agency, an autonomous public corporation under the Ministry of Science, Technology, and Energy.

The 1998 pattern of public research expenditures indicates the priority given to agriculture. In 1995, of total government research expenditures of $207 million (Ministry of Science, Technology, and Energy, 1997), an estimated $127 million was allocated for agriculture (Poapongsakorn, 1996). Moreover, the share devoted to agriculture appears to have increased over the 1980s, from about 40 percent of the total in 1987 to 60 percent in 1995 (fig. D-3). Within agriculture, the largest share of the research budget is for crop research, with relatively small budgets for livestock, forestry, or fisheries (Poapongsakorn, 1996).

In addition to investing in public research, the Thai Government has also encouraged private investment in research, although these efforts appear to have had only limited success (Thailand Development Research Institute, 1990). Policies to support private research have included tax incentives and subsidized loans, but the overall demand for these subsidies appears to have

Figure D-3
Research expenditures, Thailand, 1987-95



Sources: Total and public agricultural R&D from MOSTE (1997); and public agricultural R&D from Poapongsakorn (1996).

been small. However, public encouragement of the private seed industry does appear to have been an important factor in stimulating private plant breeding in Thailand (see "Private Investment in Agricultural Research" section). Other efforts to promote private research include increasing the availability of science and technology personnel, providing information and consulting services, establishing a science park (opened in 1998), and strengthening protection for intellectual property rights. Under the 1979 patent law, agricultural inventions were explicitly excluded from patent protection. However, a new patent law enacted in 1992 extended coverage to agricultural chemicals, farm machinery, biotechnology processes, and genetic sequences, although the law excluded plant and animal life forms from patent protection. A special patent court to enforce patent laws was established in 1996, and a law enabling *sui generis* plant breeders' rights is being considered.

Structure of Agricultural Input Industries

A principal way in which new technology reaches farmers is through new and improved agricultural inputs, such as better seed, livestock feed, crop protection chemicals, livestock pharmaceuticals, and farm machinery. The private sector can be expected to invest in research to improve agricultural inputs when: (1) the size of the market is sufficiently large, (2) technological improvements can be made relatively quickly and easily, and (3) individual companies can protect their intellectual property from copiers (Pray and Fuglie, 1999).

Table D-6—Market for seed, Thailand, 1996

Source of seed	Quantity	Average price	Value
	Metric tons	*Dollars/ kilogram*	*Million dollars*
Private hybrid corn	15,000	3.00	45
Private sector—vegetable	2,000	NA	15 - 20
Public sector—open-pollinated	59,000	.42	25
Farmers' own seed	633,300	NA	NA
Total seed requirement	>710,000		

NA = Not available.

Source: Private seed sales from own survey; public seed sales and total seed requirement from Annual Report 1995, Ministry of Agriculture and Cooperatives, Department of Agricultural Extension, Seed Division, Thailand.

Seed

Most agricultural seed in Thailand is from farmers' own saved seed from their previous crop. Of the more than 700,000 metric tons of seed needed annually, only about 75,000 to 80,000 tons are provided by seed companies or government agencies, with the rest supplied by farmers (table D-6). The private sector produces hybrid seed for corn and vegetable production and some self-pollinated seed under contract with government agencies. In 1996, private companies sold about 15,000 tons of hybrid corn seed estimated at a market value of $45 million. This was sufficient for about 90 percent of farm demand for corn seed. Estimates of vegetable seed sales are unavailable, but are probably about 2,000 tons worth $15 million to $20 million per year. In addition, the Department of Agricultural Extension (DOAE) maintains 23 seed centers located throughout the country to produce seed. In 1995, the DOAE produced 59,200 tons of seed and earned $25 million in seed sales at subsidized prices.

Thailand is also a net exporter of agricultural seed (table D-7). Several private companies use Thailand as a base for seed production for other markets in southeast Asia and elsewhere. The Asia and Pacific Seed Association reports seed exports of $15.2 million and seed imports of $8.5 million in 1995. Japan and the United States are major import and export markets for Thai seed, especially for vegetables. Australia is a major exporter of seed to Thailand, mainly hybrid sorghum, and Vietnam is a major market for hybrid corn seed produced in Thailand.

Table D-7—Seed trade, Thailand, 1995

Crop	Imports		Exports	
	Quantity	Value	Quantity	Value
	Metric tons	*1,000 dollars*	*Metric tons*	*1,000 dollars*
Tomato	2	122	30	4,305
Corn	180	673	1,347	3,103
Watermelon	49	539	122	2,778
Cabbage	22	1,871	3	383
Kang kong	544	627	1,160	1,739
Sorghum	1,650	1,481	0	0
Pepper (hot and sweet)	3	65	10	1,373
Cucumber	1	65	15	788
Chinese cabbage	79	691	5	63
Onion	8	610	0	0
All seed	3,200	8,462	2,915	15,233

Source: Asia Pacific Seed Association.

There are six seed companies in Thailand with breeding programs in hybrid corn that supply at least 90 percent of hybrid corn sold in Thailand. Four of these companies are wholly owned subsidiaries of foreign seed companies. The remainder of the hybrid corn market is supplied by several small local seed companies that reproduce seed from inbred lines developed by Kasetsart University. Hybrid sorghum seed was previously bred and produced in Thailand, but in 1998 was mostly imported from abroad.

Several dozen companies multiply and sell vegetable seed, but only three or four have research programs in Thailand. The dominant company in the vegetable seed market is Chia Tai Seed Company, the oldest seed company in Thailand and part of the Charoen Pokphand conglomerate. Other important suppliers include companies based in Taiwan, Korea, Japan, and the United States with subsidiaries in Thailand, in addition to Thai-owned seed companies.

Table D-8—Agricultural chemical use, Thailand, 1996

Commodity use	Quantity	Value
	Metric tons	*Million dollars*
Herbicides	33,000	145
Insecticides	20,000	100
Fungicides	6,000	35
Others[1]	2,000	10
Total	61,000	280

[1]Others include rodenticides, acaricides, fumigants, and plant growth regulators.

Source: Agricultural Statistics of Thailand and own survey.

Agricultural Chemicals

Annual sales of chemical pesticides and plant growth regulators are estimated at $280 million to $300 million (table D-8). The largest and fastest growing agrichemical market is for herbicides, valued at around $145 million in 1995/96. The rising cost of farm labor for weeding crops is one factor leading to an increase in demand for herbicides as chemical weed control. Field crops (rice, cassava, and corn) and plantation crops (rubber) are the principal users of herbicides. Insecticide sales are estimated at around $100 million annually. Rice and horticultural crops are the largest users of insecticides. More than 90 percent of fungicides are used on horticultural crops.

Companies that produce and distribute agricultural pesticides in Thailand are in two categories. The first group are R&D-based multinational corporations. These companies are based in the United States, Europe, and Japan. They synthesize new chemical compounds, develop chemical manufacturing and formulation procedures, and test their products in markets throughout the world. Many of these companies were in Thailand in 1998, including Agrevo (Germany), American Cyanamid (United States), Bayer AG (Germany), DuPont (United States), Monsanto (United States), Novartis (Switzerland), Rhone-Poulenc (France), and Zeneca (United Kingdom). In Thailand, they probably supplied 70 to 75 percent of the agrochemical market. The second group of companies were manufacturers of generic products, usually of chemicals with expired patents. These companies do not develop new products and, therefore, do not conduct much research, except for the toxicology and other tests necessary to fulfill regula-

tory requirements for registering products for sale in Thailand or other countries.

In Thailand, most chemical companies import active ingredients and formulate products locally, import formulations for local packaging, or import finished products. Only one company synthesizes active ingredients at its manufacturing plant in Thailand (Zeneca, for the herbicide paraquat). Unlike other countries in southeast Asia, Thailand levies no import duties on agricultural chemical ingredients, formulations, or finished products, so there is no tariff advantage obtained from locally manufacturing products.

Pesticide regulations in Thailand for registration and use follow the standards established in Europe and North America, although they are less rigorously enforced. Thailand did not establish a patent law covering agricultural chemicals until 1992 and does not recognize international patents granted before this date. Thus, any company may produce and distribute chemicals in Thailand, even if that chemical is protected by a patent awarded prior to 1992 in another country.

Farm Machinery

Rising wages in the Thai economy have sharply increased the demand for labor-saving farm machinery. The number of water pumps, power tillers, riding tractors, harvester-threshers, and mechanical sprayers in use by Thai farmers rose from 140 to 300 percent between 1980 and 1993 (table D-9). Farm machines are both imported and manufactured locally by a large number of domestic and multinational firms. The Bank of Agriculture and Agricultural Cooperatives (BAAC) is the principal source of financing farm machinery purchases by farmers. The BAAC is a government-owned bank that provides long-term loans to farmers. Commercial banks are also required to maintain a minimum portfolio of agricultural lending.

Livestock, Poultry, and Aquaculture

The principal purchased inputs for the animal and aquaculture sectors are compound feed, veterinary pharmaceuticals, and animal housing units. In poultry, purchased feed constitutes more than 60 percent of variable production costs (Narrod and Pray, 1995). Over 80 percent of broiler production is managed by large, integrated operations. These companies provide chicks, feed, and other inputs to contract growers, buy back adult fowl at predetermined prices, then process and market finished poultry products. An estimated 15 to 20 percent of swine production is also conducted by integrators. Poultry layers (eggs), cattle, dairy, and aquaculture farms are owned and managed mostly by independent producers.

Table D-9—Use of farm machinery, Thailand, 1980 and 1993

Machinery	1980	1993	Growth
	---1,000 units---		*Percent*
Water pumps	518	1,577	204
Two-wheel power tillers	281	1,136	304
Sprayer machines	132	318	141
Large riding tractors	37	98	165
Harvester-threshers	18	55	205
Minimum wage (baht/day)	44	102	132

Wages are in nominal terms.
Sources: Farm machinery numbers are from Ministry of Agriculture and Cooperatives, Center for Agricultural Information, Office of Agricultural Economics; minimum wage rates are for poor, rural provinces reported in Thailand Development Research Institute. 1997.

Table D-10—Market for manufactured animal feed, Thailand, 1996

Subsector	Annual demand
	Million tons
Chickens (broilers and layers)	5.0
Pigs	3.7
Aquaculture	.6
Ducks	.4
Cattle, dairy, and small ruminants	.4
Total	10.0

Source: Thai Feed Mill Association.

The annual demand for compound livestock feed in Thailand is about 10 million metric tons (table D-10). About 6.5 million tons are produced and marketed by feed millers, and the remaining 3.5 million tons are from producers. About half of the demand for compound feed is for poultry production. The other large market is for swine production (3.7 million tons). Aquaculture, cattle, dairy, ducks, and small ruminants make up the remaining demand for processed livestock feed.

There are a large number of feed millers in Thailand, although the top six companies provide more than half of total feed mill capacity. Charoen Pokphand and Betagro Agro are the two largest feed millers. About half of their feed mill production is provided to their own integrated poultry and swine operations, and half

are sold to other producers. Other large millers include Krungthai, Lee Pattana, Ramtong, and Centra-Agro.

Other principal livestock inputs such as breeding stock and pharmaceuticals are provided through imports. Poultry grandparent stock and swine parent stock are imported by several of the large integrated operations and locally multiplied for sale and distribution.

Private Investment in Agricultural Research

Plant Breeding

The private sector has been actively involved in plant breeding in Thailand since the late 1970s. Private research is concentrated on developing hybrid seed for field crops (mainly corn, with some sorghum and sunflower) and vegetables. A relatively small amount of research is devoted to self-pollinated seed, mainly in vegetable seed markets.

Companies with plant breeding programs in Thailand are listed in table D-11. Six companies have breeding programs for field crops and together spend about $3.5 million annually in breeding, nearly all of which is for hybrid corn. An additional $2.1 million is spent on vegetable breeding by three or four other companies. Hybrid and self-pollinated seed varieties have been developed for more than 30 species of vegetables. Pray (1987) estimated private plant breeding expenditures to be about $1.1 million in 1985, or about $1.3 million in 1995 dollars. Thus, it appears that private plant breeding has increased by more than 150 percent in real terms over the past decade.

Private-sector investment in corn breeding began in the late 1970s and early 1980s, following the successful development of corn varieties resistant to downy mildew by Kasetsart University. Kasetsart's effort to develop resistant varieties began in 1966, with support from the Rockefeller Foundation. Based on germplasm from the Philippines, Latin America, India, and local sources, Suwan 1 was released in 1974, followed by Suwan 2 (1975), Suwan 3 (1978), Suwan 4 (1982), Suwan 5 (1988), and others. Prior to the availability of Suwan germplasm, downy mildew had been a major constraint to corn production in southeast Asia. The Suwan varieties became very popular throughout Thailand and southeast Asia and helped to significantly expand corn area and production. Hybrid corn varieties developed by private companies are based largely on crosses between Suwan varieties and superior inbred lines imported from the United States and Europe. Foreign multinational companies play a significant role in the Thai corn seed industry, either through wholly owned subsidiaries or through joint ventures with local seed companies.

Two vegetable companies, Chia Tai and East-West Seeds, have had vegetable breeding programs in Thailand for more than a decade. Recently, Seminis Seeds, a subsidiary of Empresas La Moderna, a Mexican-

Table D-11—Private plant breeding, Thailand, 1998

Seed company	Country of parent company	Field crop breeding	Vegetable and others
Charoen Seeds (CP/DeKalb)[1]	Thai/United States	Corn, sorghum	Orchids
Pioneer Hi-Bred	United States	Corn	Baby corn
Cargill Siam	United States	Corn	
Novartis[2]	Swiss	Corn	
Pacific Seeds (Advanta)[3]	United Kingdom	Corn, sorghum	Baby corn, sweet corn
Uniseeds	Thai	Corn	Okra, mungbean
Chia Tai (CP)[1]	Thai		More than 20 species
East-West Seeds	Thai		More than 10 species
Seminis Seeds (ELM)[4]	Mexico		5 species
Known-You	Taiwan		
Total annual research		$3.5 million	$2.0 million

[1] Part of Charoen Pokphand (CP) group of companies.
[2] Norvartis was recently formed by the merger of two Swiss companies, Ciba-Geigy and Sandoz.
[3] Advanta was recently formed by the merger of the United Kingdom-based Zeneca Seeds (parent company of Pacific Seeds) and Van der Haver, a Dutch seed company.
[4]Includes Petoseed, Royal Sluis, and Asgrow operations in Thailand, which were merging with Seminis. All of these companies were subsidiaries of Empresas La Moderna.

Source: Author's survey.

based multinational seed company, began conducting vegetable breeding in Thailand. Vegetable companies from Taiwan, South Korea, and Japan, along with several smaller locally owned companies, are also active in importing, multiplying, and marketing vegetable seed, although their investment in crop research in Thailand is believed to be small.

Plant breeding research conducted by multinational companies tends to be organized and managed on a global scale. A company is likely to have research facilities and staff in several countries who regularly exchange germplasm and scientific resources. Research stations in Thailand are likely to develop and multiply seed not only for the Thai market, but for other markets in southeast Asia with similar ecological conditions. For example, most if not all of the companies that had developed hybrid corn varieties in Thailand also market these varieties in Burma and Vietnam.

In addition to plant breeding research, private seed companies also promote improved agronomic practices to farmers through their marketing divisions. For farmers to realize the higher yield potential of improved varieties, they often need to adopt other new practices, such as higher seeding rates, increased fertilizer use, and improved pest and weed control. Several companies, especially the major hybrid corn companies, have established agronomy services to conduct field trials and work with customers to promote new practices along with the adoption of improved seed. This investment is not included in the estimate of research expenditures but may be as large as the research expenditure itself.

The major source of germplasm for the private-sector breeding programs is the companies' own elite lines. The multinational seed companies are continuously collecting and screening cultivated varieties from public and private sources around the world, but invest few resources in testing or adapting unimproved landraces. Developing new elite germplasm from unimproved landraces and wild relatives of cultivated crops is primarily undertaken by the public sector. Seed companies in Thailand screen elite germplasm provided by national and international institutions. Kasetsart University is the most important public-sector partner of the Thai hybrid corn industry. In addition to providing elite germplasm for private breeding programs, Kasetsart provides trained scientific staff through its teaching and training programs and technical services such as electropholisis for DNA fingerprinting. Private seed companies also test germplasm provided by international research centers, namely, corn germplasm from the International Maize and Wheat Improvement Center (CIMMYT), vegetable germplasm from the Asian Vegetables Research and Development Center, and sorghum germplasm from the International Crops Research Institute for the Semi-Arid Tropics. Kasetsart University and CIMMYT have also provided training for technical staff from private seed companies.

In 1995, Kasetsart University initiated a royalty payment scheme for its elite corn lines. Previously, corn germplasm was sold to private seed companies for a fixed fee. Under the royalty scheme, private companies will pay Kasetsart University a share of their seed sales from varieties that use Kasetsart parent material. As of 1998, the royalty scheme had not been applied because none of the current commercial corn hybrids use post-1995 Kasetsart germplasm.

Agricultural Biotechnology

Biotechnology, along with materials science and computer technology, has been identified by the Government of Thailand as a priority for science and technology investment to develop domestic capacity in these industries. In 1983, the Thai Ministry for Science, Technology and Energy established the National Center for Genetic Engineering and Biotechnology (BIOTEC) to develop research capacity in biotechnology and induce commercial development of new biotechnology products. In 1991, BIOTEC was transferred to the National Science and Technology Development Agency (NSTDA), an autonomous public corporation that has the authority and flexibility to conduct and fund research, license technology to the private sector, and invest in joint ventures to commercialize emerging technology. About 80 percent of BIOTEC's annual

Table D-12—R&D funded by BIOTEC, Thailand, 1984-96

Research application area	Funds provided
	1,000 dollars
Plants	3,337
Animals	3,289
Rural development	701
Sustainable development	2,788
Industrial products & processes	3,477
Human health	3,282
Total	16,874

Source: National Center for Genetic Engineering and Biotechnology.

research and development (R&D) budget of $10 million is devoted to agricultural biotechnology, with the balance in biodiversity conservation and tropical disease research. In addition to in-house activities, BIOTEC has provided nearly $17 million for competitive grants for biotechnology research to universities and other institutions since 1984 (table D-12).

BIOTEC has already established several joint initiatives with the private sector to commercialize agricultural biotechnology. The most significant of these is in aquaculture. In 1996, BIOTEC invested $1 million in a joint venture with several private-sector partners to form the Shrimp Culture Research and Development Company, Ltd. This consortium is conducting R&D in shrimp domestication and breeding, disease prevention and control, and production and environmental management. Revenues generated from product sales are shared by consortium members, including BIOTEC. In addition to aquaculture, BIOTEC has developed joint projects or granted exclusive licenses with private companies to commercialize other technologies, including blue-green algae for shrimp feed, biofungal pesticide for vegetables, viral pesticide for insect control, and micropropagation of disease-free plantlets for strawberries, onions, and potatoes.

Other tools—besides joint ventures and exclusive licensing—used by the National Science and Technology Development Agency to promote technology commercialization are: providing grants, subsidized loans, and consulting services to companies; providing technical training and information services; and establishing a science park, which was scheduled to open in 1998. While BIOTEC has made considerable gains in establishing a base for a biotechnology industry in Thailand and has developed several promising biotechnology applications, it appears to have been unable to induce much new private-sector research in biotechnology.

While most biotechnology research in Thailand as of 1998 had been funded and conducted by the public sector, private seed companies have made significant investments in testing transgenic crop varieties in Thailand. Thailand has adopted a biosafety protocol for testing transgenic crop varieties modeled on that of the United States and Australia. Applications for conducting field tests of transgenic varieties are reviewed by the National Biosafety Committee. Approved tests have included material that had already been field-tested in an industrialized country. The first field test of a transgenic variety was conducted in 1994, with a delayed-ripening tomato variety developed by Calgene. Since then, field tests have been approved for Bt-cotton, Bt-corn, and viral-resistant melons. Additional field tests of herbicide-resistant corn, herbicide-resistant soybean, quality-enhanced corn, and viral-resistant papaya and chili peppers are anticipated for the near future. Private biotechnology research, however, is limited to field testing. Actual gene transfers are made at the companies' research laboratories in North America or Europe. Private-sector expenditures for testing transgenic cotton varieties in Thailand were about $1 million in 1997.

Crop Protection

Research by agricultural chemical companies in Thailand is principally to fulfill the regulatory requirements for product registration and develop recommendations for timing and application rates for targeted crops. Only one company, Novartis, maintains its research station in Thailand. Other companies conduct trials in farmers' fields or at public facilities. New chemicals and chemical manufacturing processes are developed entirely in company laboratories located in the United States, Europe, and Japan.

Because research activity is often integrated with market development and promotion, many companies find it difficult to quantify their research investment. Survey estimates of research expenditures as a percentage of product sales in Thailand ranged from 0 to 3 percent, for an average of 2.3 percent, among four agricultural chemical companies interviewed. If that average is applied to total product sales by the R&D-based companies, it would imply an annual research investment of $5.23 million.

In addition to research and market promotion, the agricultural chemical industry has also taken steps to promote safe-use practices, partly in response to the growing concern regarding pesticide poisonings, contaminated food, and environmental hazards caused by pesticide use. In 1991, the Thai Crop Protection Association (whose members include the R&D-based agricultural chemical companies) began a collaborative effort to extend safe-use practices to farmers at a cost of $1.33 million per year. The Safe Use Project is one of three pilot projects worldwide, undertaken by the Brussels-based International Group of National Associations of Agrochemical Product Manufacturers. Besides Thailand, other pilot projects are in progress in Guatemala and Kenya. In addition to training farm-

ers, product distributors, and agricultural extension workers, in appropriate practices, the project seeks to increase the availability of protective clothing for chemical applicators, provide information to medical professionals on the diagnosis and treatment of pesticide poisoning, and promote industry standards in product quality.

Farm Mechanization

The increasing demand for farm machinery in Thailand is met through direct imports of machinery from abroad and local manufacture. Local machinery manufacturing companies often modify equipment design and manufacturing processes in order to reduce costs and to make machinery more suitable for local conditions. However, none of these companies maintains a formal research division, and the companies interviewed were unable to provide precise estimates of staff or expenditures that could be classified as R&D. Through our survey, however, we collected information on some farm machinery advances made in Thailand and traced the source of these innovations.

In the 1970s and 1980s, local manufacturers modified the designs of Japanese power tillers and threshing machines developed by the International Rice Research Institute (IRRI) for rice production (Pray, 1987). These innovations resulted in more suitable and lower cost machinery than imported machinery. The adoption of these machines rapidly spread throughout Thailand. More recently, new innovations have developed mechanized harvesting equipment for rice, sugarcane, pineapples, cassava, soybeans, corn, and potatoes. Kaset Pattana, a machinery manufacturer based at Phisanulok in central Thailand, developed a mobile combine harvester-thresher for rice by combining elements from IRRI's rice thresher and John Deere's corn harvester. The result was a design very different from the main competing Japanese import and one more suited to Thai conditions. Chao Chalarinchai, a company located at Ayuttaya, developed a new small riding tractor, but efforts to commercialize it were unsuccessful due to competition from imports of second-hand tractors from Japan. Despite the limited quantitative information on private-sector farm machinery research, based on the evidence above of a few companies innovating their own machinery designs, a conservative estimate of private machinery R&D is $200,000 per year.

Many major innovations in farm machinery have come mainly from the public sector. The Agricultural and Mechanical Engineering Departments at the Department of Agriculture, IRRI, Asian Institute of Technology, Chulalongkorn University, Kasetsart University, and other Thai universities have contributed important innovations to Thai farm machinery manufacturers. Improvements continue to be made in tillage equipment as well. Research funded by the Ministry of Science, Technology, and Environment and conducted at Chulalongkorn University developed an improved transmission for power tillers that was adopted by at least three local manufacturing companies.

The lack of patent protection may be one reason why the Thai farm machinery industry has tended to rely on the public sector or foreign sources for major machinery innovations. Patenting of agricultural machinery was specifically excluded from the first Thai patent law passed in 1979. However, a new patent law passed in 1992 removed this exclusion (Subhadpholsiri, 1993). The new patent law allows for both invention patents and design patents. Design patents do not have the non-obvious criterion required of invention patents and are for a shorter period (10 years, instead of 20 years for invention patents). For example, a patent was obtained by the inventor of the modified power tiller transmission. However, because the research was funded by MOSTE, that company owns the patent and allowed manufacturers free access to it. Nevertheless, the new patent system, which includes a special patent court established in 1996 may encourage more explicit research and development by the local farm machinery industry.

Livestock, Poultry, and Aquaculture

Investment in technology development and transfer by the Thai animal industry can probably trace its origin to 1970, when Charoen Pokphand (CP) established a joint venture with a U.S. poultry breeding firm, Arbor Acres, to introduce grandparent broiler chicks to Thailand. CP developed its feed and integrated poultry business simultaneously. CP later expanded its poultry business to other countries in southeast Asia, China, and the United States. CP investment in animal technology was further enhanced through its purchase of the U.S. poultry genetics firm, Avian Farms. Other companies also established grandparent and parent poultry farms in Thailand, using imported chicks, mainly from the United States. However, no private company maintains pureline poultry in Thailand for commercial breeding. Swine production has relied primarily on importing parent lines from abroad, principally from Europe and Taiwan. CP also established a swine genetics program in the mid-1990s to develop its own breeds.

Private animal research in Thailand concentrates on poultry and swine, with a principal goal of improving feed efficiency. There are also efforts to improve poultry housing and animal disease management. Feed milling technology is based on foreign designs, and the rapid rate of expansion by the Thai feed mill industry implies that, on average, feed milling systems in Thailand are newer and more advanced than those in the United States and Europe. Because of the close link between feed efficiency and genetics, the major feed milling companies maintain feed and nutrition research units to find the lowest cost feed sources and mixes. Total private-sector livestock research in Thailand (including aquaculture, which is linked to feed and nutrition research) is probably at least $2.0 million annually.

Plantations and Food Processing

Private companies have played a significant role in developing plantation crops, especially fruit production for export. For example, Dole maintained agronomic and production research activities for its large pineapple production and canning operations and developed a forcing technique to stimulate year-round flowering and fruit growth in pineapple plants (Pray, 1987). However, Dole has since moved all of its food agricultural research programs for southeast Asia to the Philippines. There has also been some private research in oil palm, another plantation crop, although most new technology and varieties for oil palm originate from Malaysia. Our survey, however, of private research did not adequately cover the food processing and product development sectors. Instead, estimates of research by this sector were derived from a survey of private research conducted by Thai National Research Council. This survey reported total private research expenditures of 561 million baht in 1995 by private companies or nonprofit private organizations, with about 15 percent of that being food related (Ministry of Science, Technology, and Energy, 1997). This implies that about $3.4 million of total private research of $22.4 million was conducted in the food industry. This estimate is probably conservative.

Public and Private Investments in Agricultural Research

A summary of public and private agricultural research expenditures for Thailand is provided in table D-13.

Table D-13—Agricultural research expenditures, Thailand, 1985 and 1996

Private research by input sector	1985 companies	1985 research	1996 companies	1996 research
	Number	*US$1,000*	*Number*	*US$1,000*
Seed—field crop	5	1,500	6	3,500
Seed—vegetable	NA	NA	4	2,100
Biotechnology	0	0	3	1,000
Agricultural chemical	7	2,100	9	5,200
Poultry & livestock	2	2,400	6	2,000
Farm machinery	3	NA	5	200
Plantations & processing	6	4,600	NA	3,400
Total private agricultural research	23	10,600	33	17,400
Total public agricultural research		67,200		127,000
Total agricultural research		77,800		144,400
Agricultural GDP		9,350,000		18,120,000
			Percent	*Percent*
Private agriculture research intensity			0.113	0.096
Public agriculture research intensity			.719	.691
Private agriculture research			13.6	12.0

NA = Not available. Research and development and gross domestic product figures are in constant 1995 dollars. Results are based partly on extrapolating the research intensity (research as a percentage of market sales) of interviewed companies to other companies with research activities in Thailand. The extrapolations were done for the agricultural chemical and animal sectors. The estimates for private seed and biotechnology research are likely fairly complete. The estimates for the food sector are drawn from Ministry of Science, Technology, and Energy (1997) and are probably low. Thus, there is a significant margin of error in many of the estimates.

Sources: Private agricultural research for 1985 from Pray (1987); for 1995 from author's survey, except plantations and food processing, from Ministry of Science, Technology, and Energy (1997). Agricultural gross domestic produce from Thailand Development Research Institute (1997). Public agricultural research from Poapongsakorn (1996).

Private investment in food and agricultural research appears to have increased by two and a half times in nominal terms between 1985 and 1996. By 1996, total private agricultural research approached $19 million. Seed and biotechnology research increased most rapidly, with private-sector research reaching $6.6 million. The private sector was responsible for about 13 percent of total agricultural research in Thailand.

Public agricultural research increased at about the same rate as private research over this period, so that its share of total agricultural research remained about the same over the decade, at 87 percent. Despite the rapid growth in both public and private research investment, research intensity (R&D expenditure as a percentage of agricultural gross domestic product) may have declined slightly due to the even faster rate of growth in agricultural output. Together, public and private agricultural research were equivalent to about 0.80 percent of agricultural GDP in 1996, compared with 0.83 percent in 1985. But given the uncertainty in some of the estimates of private research, it is fair to say that research intensity did not change appreciably over this time period.

Effect of Private Agricultural Research

Three areas in which private investment in private agricultural research and technology transfer had significant effects on agricultural productivity in Thailand are: increasing yields for corn and horticultural crops, improving poultry and swine feed efficiency, and raising labor productivity through farm mechanization. However, many of the original improvements in farm machinery originated from the public sector or imported designs.

Crop Yield

One measure of the effect of private research in Thailand is the gain in crop yield. As documented earlier in this chapter, private plant breeding has concentrated almost exclusively on hybrid corn and vegetables, with minor investment in hybrid sorghum, sunflower, and soybeans. For corn, the public sector reduced varietal development research as private-sector capacity increased. Public breeding efforts for horticultural crops has never been large. Breeding and crop improvement research on other important crops such as rice, cassava, and sugarcane (the three principal crops of Thailand) are almost exclusively conducted by the public sector.

Table D-14 shows the rates of yield growth for selected crops between 1981 and 1995, during which time the private sector made important contributions to new varieties for corn and vegetable crops. Yield growth of corn exceeded the growth in yield of self-pollinated or clonal crops such as rice, cassava, and sugarcane. Corn yield increased by 1.75 percent per annum, or by more than 0.6 ton for each hectare over the 14-year period, compared with 1.2 percent for rice and 0.85 percent for sugarcane. Cassava yield declined by 0.94 percent per year.

The first Suwan variety, developed by Kasetsart University, was released to farmers in 1974. Suwan 1 is an open-pollinated variety with resistance to the most important corn disease in southeast Asia, downy mildew. Improved open-pollinated varieties rapidly spread to farmers in the 1970s. The first hybrid corn

Table D-14—Area, yield, and production for major crops, Thailand, 1981-95

Crop	Area	Yield	Production	Average annual growth		
				Area	Yield	Production
	1,000 hectares	*Tons/ hectare*	*1,000 hectares*	*Percent*		
Rice	9,248	2.10	19,449	-0.40	1.20	0.79
Cassava	1,352	14.56	19,558	1.62	-.94	.67
Sugarcane	674	47.73	32,382	4.84	.85	5.74
Soybean	302	1.27	392	9.33	1.60	11.07
Corn	1,522	2.54	3,851	-1.32	1.75	.41
Vegetables	250	14.00	3,500	NA	NA	NA

NA = Not available.

Source: Agrostat database, Food and Agriculture Organization, except for vegetable production, which was industry estimates of production in 1995 (published estimates of vegetable production are unreliable).

varieties were introduced by CP/DeKalb, Pioneer Hi-Bred, and Pacific Seeds in 1981 (Suwantaradon, 1989). These first hybrids were top-crosses and double-crosses and had a significant yield advantage over open-pollinated varieties when grown with appropriate agronomic practices. In 1987, the private sector released the first locally developed triple-cross hybrids, followed by single-cross hybrids in 1991. By 1996, almost all private hybrid corn varieties sold in Thailand were single-crosses, and hybrid seed supplied 70 to 75 percent of all corn seed planted. The change from open-pollinated to hybrid corn varieties is estimated to have increased the average corn yield in Thailand by 25 to 30 percent, and the switch from top-crosses, double-crosses, and triple-crosses to single-crosses increased it another 10 to 15 percent. From an average annual corn yield of around 2 tons per hectare in 1980, this implies a total yield gain of between 0.75 to 1 ton per hectare by 1996. By the mid-1990s, corn yields averaged 2.5 to 3 tons per hectare, with corn farmers in the corn-producing areas of Thailand's central plain regularly obtaining 4 to 5 tons per hectare with hybrid seed. Research station results have shown that 1998 varieties had a yield potential of 8 to 10 tons hectare.

The sustained increase in corn yield achieved in the 1980s and 1990s is due not only to the introduction of new classes of seed (i.e., double-cross, triple-cross, and single-cross hybrids), but also to a steady stream of new and improved corn varieties within each class. Since the first hybrid corn varieties were released in 1981, the private sector had introduced more than 90 new varieties of corn by 1998. Breeding efforts in 1998 promised continued improvements in single-cross hybrids.

One consequence of the yield advantage of hybrid corn over open-pollinated corn is that most indigenous corn seed companies were forced out of the corn seed industry during the 1980s and early 1990s (Morris, 1997). Only a handful of companies with access to enough capital and scientific resources necessary to maintain a viable hybrid breeding program survived. Corn breeding companies in Thailand spent more than $500,000 annually for research, on average. Indigenous companies specializing in multiplying open-pollinated Suwan varieties failed because of the competition from the superior hybrids.

Published data on the production of major vegetable crops are not very reliable, so it is difficult to examine trends. Nevertheless, hybrid seed varieties have made major contributions to yield and quality improvements since 1990. Seed companies typically found yield increases of 50 to 100 percent between hybrid and open-pollinated varieties (Groot, 1997). For many vegetables, hybrid varieties can also be planted in the off-season when prices are higher and provide more uniform quality than traditional varieties. Moreoever, there remains considerable potential for more yield increases as the use of hybrid vegetable seed expands.

Soybean yield growth (1.6 percent per year) was comparable to the high rates achieved by hybrid corn, despite the lack of private-sector interest. Soybean seed is exclusively self-pollinated, and most private companies have been unwilling to invest in soybean breeding without plant breeders' rights to protect their varieties. Nevertheless, Thailand's Department of Agriculture made a major commitment to increasing soybean production in order to reduce the demand for oilseed imports. The data indicate that with adequate support, a public breeding program can be as successful as private breeding in improving crop yield. The advantage for Thailand in having a private seed industry is that scarce public research resources can be concentrated on important national priorities.

Animal Feed Efficiency

Private investment in research and technology transfer has achieved significant productivity gains in poultry production and, to a lesser extent, in pig production. Locally adaptive research on poultry production systems multiplied imported hybrid crosses, developed better and lower cost feed rations, and improved the design of poultry housing units to significantly reduce production costs and expand output. Partly as a result, frozen poultry emerged as a major export commodity for Thailand.

From interviews with private animal scientists, the feed conversion ratio (FCR) for poultry (kilogram (kg) of feed for each kg of meat) improved by 10.0 to 12.0 percent in 1988 to 1998. FCR achieved on research farms improved from 2.2 to 1.7 percent, while that achieved in commercial farms was about 2.05 percent. In addition, the length of time needed to produce a fully grown bird was reduced by 10 to 15 days, and the size of a finished bird was increased to 1.5 kg for each bird, an increase of about 0.5 kg. The demand for larger birds increased with the growth of household income in Thailand. Since most birds are sold fresh and whole, bird size determines the purchase unit by food shoppers, and the purchase unit generally increases with income. Producing larger birds in the

tropics, however, requires use of closed poultry houses. Local adaptations in poultry houses, based on evaporative cooling, plastic sheeting, and ventilation fans, significantly reduced the cost of closed poultry housing units and encouraged their use by farmers. Improvements were also made in feed efficiency for poultry layer (egg) and duck production.

In pig production, large commercial operations achieved FCR of 3 to 3.5 percent, using imported breeds and compound feeds, compared with 5 to 7 percent on small farms (Pray, 1987). Small farms still dominated the pig sector, however, accounting for 80 to 85 percent of total production in 1998.

These advances were almost entirely attributable to the private sector. Public expenditures for animal research were only around $4 million for each year in the early 1990s (Poapongsakorn, 1996, table 5). Public animal research also deals with a wider range of commodities, including cattle and dairy, commodities where private research is believed not to be large.

Farm Mechanization

A first wave of farm mechanization occurred in the 1970s and 1980s, with the diffusion of mechanized land cultivation and rice threshing. Power-tillers, or two-wheeled walking tractors, were introduced in rice production. Larger, four-wheeled riding tractors where widely adopted to facilitate the rapid expansion of area planted to nonrice crops, especially cassava and sugarcane. In the late 1980s and 1990s, a second wave of mechanization was underway to mechanize crop harvesting. The role of the private sector in machinery development is limited to minor modifications to design and manufacturing processes. Major design improvements originate mainly from imported machines and the public sector.

Policies and Private Agricultural Research

Government Investments in Research and Extension

Agricultural research policy in Thailand has explicitly sought to encourage private investment in agricultural research and technology transfer by focusing public resources on activities to complement, rather than compete with, the private sector. This is clearly evident in the seed sector, where the public sector maintains a large seed production capacity but avoids producing for markets where private seed companies are active. In corn seed production, for example, the public sector withdrew from seed multiplication as the availability and use of private hybrid seed expanded. In 1995, the public seed division of the Department of Agricultural Extension produced only 5 tons of corn seed, down from more than 2,000 tons annually during the 1980s (Department of Agricultural Extension, Ministry of Agriculture and Cooperatives, 1995).

The public sector plays an important role in encouraging farmers to adopt improved agricultural technology, including new crops and crop varieties, and improved agronomic practices, agricultural chemicals, and compound animal feeds. The Department of Agricultural Extension and the Bank for Agriculture and Agricultural Cooperatives distribute samples of new agricultural inputs to farmers at free or subsidized rates to encourage trial and adoption. These institutions were instrumental in promoting the use of hybrid corn seed, for example (Morris, 1997). The private sector sees these efforts as complementary to its own agronomy services and marketing operations.

From the public's perspective, encouraging private companies to develop new agricultural technology frees public resources for other priorities. The annual revenues of $45 million that private companies earn through the sale of hybrid corn seed provides the resources for $3.5 million in their corn breeding research. This allowed public-sector breeders to devote more resources to other crops such as rice and soybeans. In 1995, only about $250,000 was spent on public corn breeding, and the program was largely self-sufficient through its sales of elite germplasm to the private sector.

The close working relationship between the hybrid corn seed industry and government crop research and regulatory agencies resulted from a combination of close personal ties and a well-organized seed association. Seed companies recruited scientific and management staff from university and government offices, helping to solidify good working relationships between the public and private sectors. The hybrid corn companies organized the Seed Association of Thailand to promote their interests. In 1994, the Asia Pacific Seed Association (APSA) was formed with assistance from the Food and Agriculture Organization of the United Nations to promote the seed industry and improve seed supply in the region. APSA's headquarters is located

within the Department of Agricultural Extension in Bangkok. The vegetable seed sector has been somewhat less successful in organization and promoting its own interests. Most vegetable seed companies remained outside the seed association (although the largest companies are members), and government research and extension policies have not significantly invested in this sector.

Tax, Credit, and Investment Incentives for Private Research

The Thai Government has established tax incentives and a subsidized loan program for private research (Thailand Economic Information Kit, 1990). However, none of the companies interviewed in this survey were aware of these programs or, if they were, saw them as little inducement for private research. Nevertheless, a special package of incentives introduced by the Central Bank's Board on Investment (BOI) for the private seed sector is seen by the private sector as instrumental in encouraging the development of the seed industry in Thailand. The BOI package included investment support and a 10-year tax holiday for new seed companies, a waiver of import duties on research equipment and materials, and permission for foreign companies to own agricultural land for research purposes.

Regulatory Environment for Seeds, Agrichemicals, and Biotechnology

Thailand's relatively lax regulatory environment has generally been favorable to private business. A low regulatory burden on private companies reduces business costs and encourages increased investment, including in research. However, at the same time, it imposes little incentive to develop technologies that conserve environmental resources or produce other nonmarket goods (Fuglie et al., 1996).

Regulations governing seed are stipulated in Thailand's Seed Act. This law describes seed labeling requirements and minimum allowable germination requirements for 20 species of seed. In contrast to many other countries, Thailand does not have a compulsory varietal registration program. Companies are free to introduce new varieties at their choosing. Market forces, through company reputation and brand-name recognition, provide incentives for companies to limit new introductions to the most promising lines. The lack of compulsory seed registration increases the speed at which new varieties can be introduced. Indonesia, by comparison, has a seed registration scheme in which each new variety must pass through two or three seasons of yield trials and be evaluated by a government committee before it may be legally sold. This process can add several years to product development time. In addition to the Seed Act, Thailand has a Plant Quarantine Act to control the importation of plant pests and diseases in planting materials.

The establishment of a biosafety protocol for biotechnology field testing has encouraged the private sector to develop and introduce transgenic varieties to Thailand. Nevertheless, the system is new and not yet entirely predictable. Several companies expressed concern over delays in obtaining permission to conduct field trials, although this did not appear to be a significant constraint to biotechnology development and transfer thus far.

For chemical production, government authorities require a series of environmental and toxicological tests before any new product may be sold and distributed in the country. Thai chemical registration regulations generally follow North American and European standards. Several agricultural chemical companies expressed concern over the lack of enforcement of truth-in-labeling laws for chemical products. Some companies, particularly generic producers, are thought to have poor quality control in product manufacture and formulation. As a result, many products sold on the market may be diluted or otherwise mislabeled. From a consumer's perspective, there is growing concern over the misuse of agricultural chemicals resulting in high levels of chemical residues on food products, chemical poisonings, and environmental contamination. In 1998, some shipments of exported agricultural products were reportedly rejected because of high levels of chemical residues detected. This has increased efforts to promote safer practices, at least for export-oriented commodities. A private sector response to this problem is the Safe Use Project initiated by the Thai Crop Protection Association to promote proper handling and application of chemical pesticides (see the "Farm Mechanization" section).

Conclusions

Investment in agricultural research by the private sector increased from $7.5 million to $17.4 million between 1985 and 1996, or by 130 percent. Despite this rapid rate of growth, overall private research intensity (research expenditures as a percentage of agricultural gross domestic product) remained about the same

due to a similar rate of growth in agricultural production. About a third of private agricultural research is for plant breeding and biotechnology. Plant breeding by the private sector is heavily concentrated on hybrid varieties for corn and vegetables. Little or no private research is being devoted to Thailand's major crops of rice, cassava, and sugarcane, due to the difficulty in protecting intellectual property in open-pollinated or clonally propagated seed.

Government policy toward agricultural research and extension has generally been supportive of private research. Public breeding and seed multiplication programs have concentrated on commodities where the private sector is not present in order to avoid public-private competition. As private capacity in a seed market developed, the public sector gradually reduced its seed multiplication in that crop. This has most clearly been the case with corn seed. In addition, public extension and credit programs promote the diffusion of new agricultural technology, whether it originates from the public or private sector. A special package of investment incentives was instrumental in encouraging local and foreign companies to participate in the Thai seed industry.

Future trends facing Thailand's agriculture are likely to accelerate the demand for improved agricultural technology. The closing of the land frontier has shifted the principal source of agricultural growth to new technology that raises crop yields and develops higher-valued products. The rise in wages due to the rapid industrialization of the Thai economy has increased the demand for labor-saving technology, especially agricultural harvesting machinery and chemical weed control.

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Appendix D:

SURVEY OF PRIVATE-SECTOR CROP IMPROVEMENT RESEARCH IN THAILAND, May, 1997

sponsored by

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New Brunswick, NJ

1. Company name and address:

Your name and position	
Company name	
Address in Thailand	
Telephone number	
Fax number	
E-mail	

2. In what year did your company begin selling seed in Thailand?: _____
When did your company begin conducting crop improvement research in Thailand?: _____

Definition of crop improvement research: any activity to improve varieties, agronomy, and pest control of crops, especially plant breeding.

3. What was your company's revenue from seed sales (all types) in 1996? : _____ baht.

4. How many people does your company employ in crop improvement research? Please indicate the number by university degree. If an employee works part-time on research, please include only the fraction of his time devoted to research. How many new crop varieties has your company developed and released in Thailand since 1990?

Crop	Number of full-time staff for crop improvement research				Number of new varieties developed and released in Thailand since 1990
	Ph.D.	M.S.	B.S.	technicians	
Corn					
Sorghum					
Soybeans					
Other field crops (name)					
Vegetable crops					
Fruit crops					
Oil palm or rubber					
Flowers or ornamentals					
Others (name)					
Total					

5. What were your company's expenditures for crop improvement research in 1996?

Annual (recurring) research expenditure, including salaries	baht
Capital (non-recurring) research expenditure	baht
Fees paid for research contracted out	baht
Total research expenditure for 1996	baht

6. Has you company had any technical collaboration in crop improvement research with any of the following organizations in the last five (5) years? Please check (✓) all that apply.

Type of collaboration	government institute or university	international research center	other private company
Joint technology development			
Technology licensing			
Contract research			
Training			
Testing			
Crop germplasm supply			

7. Do the following government policies encourage, discourage, or have no effect on your company's willingness to investment in crop improvement research? Please check (✓) the appropriate column.

Policy	Encourage	Discourage	No effect
Tax deduction for research expenses			
Low-interest loans for research expenses			
Seed certification regulations			
Seed phytosanitary and biosafety regulations			
Seed sales and distribution by government agencies			
Crop improvement research by government agencies			
Agricultural extension by government agencies			
Policy toward foreign participation in the seed industry			
Policy toward plant breeders rights			

Comments:

Thank you very much for your cooperation.

List of Tables and Figures

Figures