ReSAKSS asia
FACILITATED BY IFPRI

WORKING PAPER 04 | NOVEMBER 2014

Maize Seed Industry in Thailand

DEVELOPMENT, CURRENT SITUATION, AND PROSPECTS

Orachos Napasintuwong

ABSTRACT

The seed industry in Thailand is among the advanced and well-developed industries in Asia. Maize contributes to the largest share of seed production and trade. The government and international organizations contributed significantly to the success of the maize seed industry in Thailand by building infrastructure for research and promoting the role of the private sector in the industry during the early years. The private sector also added to the industry's rapid expansion through constant and heavy investment in research and development. Thailand's goal of becoming a seed hub center in this region is bolstered by its suitable geography and weather, numerous highly trained plant scientists, wide diversity of germplasm, and membership in the Association of Southeast Asian Nations (ASEAN) Economic Community (AEC), which will come into effect at the end of 2015. Despite promising motivations, domestic regulations could be prohibitive factors in Thailand's becoming competitive in the regional seed market. This paper provides the history of development; an analysis of the current industry's structure, conduct, and performance; and a review of related regulations of the maize seed industry in Thailand. The lessons learned from the success of the maize seed industry in Thailand could provide implications for the development of the seed industry in other developing countries.

Keywords: *seed, privatization, intellectual property rights, IPR, genetically modified*

INTRODUCTION

The seed industry in Thailand is among the advanced and well-developed industries in Asia. Thailand is the twenty-fourth largest seed exporter in the world, and is the third largest seed exporter in Asia following Japan and China. Among all seed commodities, maize has the highest share in total exports and imports in terms of value. Maize is also one of the most advanced seed industries in Thailand, and has integrated both public and private sectors in research, development, and marketing. After a few decades of privatization, private companies have played a significant role in the maize seed industry development through research and development. Due to several promoting factors, such as suitable geography and weather, availability of highly trained plant scientists, wide diversity of germplasm, good infrastructure, government support, and investments from foreign governments and multinational agencies and companies, Thailand is in position to become the hub for seed production in Asia. As a member of the Association of Southeast Asian Nations (ASEAN) Economic Community (AEC), which will come into effect at the end of 2015, Thailand also has the goal of becoming an ASEAN seed hub center. The National Science and Technology Development Agency (NSTDA), Ministry of Agriculture and Cooperatives (MOA), and Board of Investment (BOI) have several programs to promote seed hub policy. Despite promising motivations, the private sector has expressed concern over domestic regulations that could prohibit the industry's competitiveness in the international seed market. This paper discusses the history of the maize seed industry development; Thailand's current situation with regard to industry structure, conduct, and performance; and related regulations of the seed industry in Thailand. A review of a success model of both public and private contributions to this rapidly maturing industry provides lessons learned for future development of the seed industry in developing countries.Maize Seed Industry Development

The success of the maize seed industry in Thailand is significantly due to the government's promotion of maize as an alternative crop through various programs, international organizations' participation in building infrastructure for research and promoting the role of the private sector in the industry during the early years, and public and private sectors' constant and heavy investment in research and development of improved varieties suitable for the local environment. Furthermore, the public-private partnership (PPP) and the

competition and cooperation among industry stakeholders make maize seed in Thailand one of the most developed seed industries in the developing world. The industry developed rapidly within a few decades after the government's promotion of maize cultivation as an alternative crop to rice to diversify agricultural production in the mid-1950s. Although rice remains the most important crop for consumption and for the economy, maize has become the second most important field crop since the mid-1980s, and currently is one of the most important commodities for feed as the livestock industry became entrenched for exports.

Prior to the 1950s, maize was only consumed for snacks in Thailand, and was not significant in the economy due to limited demand. It became an important commodity when the government promoted maize as an alternative crop to rice to diversify agricultural production. In the mid-1950s, the government promoted maize cultivation by subsidizing the opening of new land specifically for maize production, distributed improved maize seed, and agreed to buy maize grain at a predetermined price (Morris 1998). Even though the demand for maize exports contracted during the late 1980s, the declining demand for field maize seed was partially compensated by the promotion of baby corn for domestic consumption as a vegetable and for value-added export products.

During the early development, the public sector played an important role in maize breeding through the investment of international organizations such as the Rockefeller Foundation and USAID. The Rockefeller Foundation established the headquarters of its Inter-Asian Corn Program in 1966, and to support its regional cooperative efforts, the National Corn and Sorghum Research Center (NCSRC, commonly known as "Suwan Farm") was established as a student training station at Kasetsart University, the largest agricultural public university in Thailand, located in Nakhorn Ratchasima, north of Bangkok (Sriwatanapongse et al. 1993). NCSRC was the research station, featuring suitable field, laboratory, and irrigation facilities to handle three crops per year. The research at NCSRC was conducted by two public institutions, Kasetsart University and the Department of Agriculture (DOA), and also through a strong international collaboration, in terms of germplasm and research results, with the Rockefeller Foundation and the International Maize and Wheat Improvement Center (CIMMYT) (Ekasingh et al. 1999).

In 1975, Suwan-1, the first significantly improved open-pollinated variety (OPV) of maize in Thailand, was released from NCSRC. Suwan-1 was rapidly adopted by farmers due to its superior characteristics, not only yielding more than existing local varieties, but also, most importantly, its resistance to downy mildew disease, the most devastating disease that could reduce yield as much as 80 percent in susceptible maize varieties in Thailand during that time (Sriwatanapongse et al. 1993). The production and distribution of Suwan-1 seed was initially led by the public sector; Kasetsart University and the DOA were responsible for producing breeder seed and the Department of Agricultural Extension (DOAE) for foundation seed, including certified or extension seed (Sriwatanapongse et al. 1993). However, due to a high demand for Suwan-1 seed and the limited supply capacity of the public sector, the private sector participated in the production, distribution, and marketing of maize seed.

Bangkok Seed Industry Co., Ltd. (currently Charoen Pokphand), incorporated with DeKalb AgResearch, initiated a joint research program in maize breeding, and concurrently Bangkok Seed Industry Co., Ltd. was the first to commercialize Suwan-1 seed in 1979. The Board of Investment (BOI) accelerated Thailand's private seed industry by providing investment incentives for domestic and foreign companies entering the seed industry, such as tax holidays for both and assured repatriation of profits for foreign companies (Brown et al. 1985). Subsequently, several other private companies, including Cargill Seeds (Thailand), Ltd., and Pacific Seeds (Thailand), Ltd., started to produce commercial maize seed.

In the late 1970s, the hybrid maize development program was initiated. The national program of hybrid maize development continued to use Suwan-1 as a source for high-yielding and downy mildew–resistant crops. Three other initial OPV releases from NCSRC were Suwan-2 in 1979, Suwan-3 in 1987, and Suwan-5 in 1993, and Nakhon Sawan-1 (NS-1) was released by DOA in 1989. Suwan-2301, the first single cross hybrid, and Suwan-2602, the first three-way cross hybrid, were released from NCSRC in 1982 and 1986, respectively (Ekasingh et al. 1999). The public sector continued to be strong in research, training, and extension during that period in hopes that the private sector would share responsibility for the production and distribution of improved seed (Brown et al. 1985). NCSRC continued to produce foundation seeds, inbred lines, and hybrid seeds for distribution and multiplication by both public and private sectors. Materials developed by the public sector have been used extensively by private companies. For example, CP-1, a top-cross hybrid using Suwan-1 as one parent, was released by Charoen Pokphand, a leading Thai multinational agro-company (Sriwatanapongse et al. 1993).

The first-generation hybrid maize varieties were top-cross, double top-cross, and double-cross hybrid varieties that had unstable characteristics and were not perceived by farmers to be superior because of their unsurpassed productivity over OPVs. The government was reluctant to support the hybrid seed industry because the seeds were expensive and did not perform better than the recommended OPVs. During this time, foreign multinational companies found the maize seed industry in Thailand an attractive business model for developing new hybrid varieties to meet high domestic demand, with Thai farmers potentially adopting modern technology. In 1981 private companies introduced the commercial trials of hybrid maize varieties, and this gave rise to the hybrid maize seed industry

(Pongsroypech 1994). The first large multinational companies to invest in the maize seed business in Thailand included Pacific, Ltd. (Australia-based), Cargill, Ltd. (U.S.-based), Pioneer Hi-Bred, Ltd. (U.S.-based), and Ciba-Geigy (Switzerland-based).

USAID also provided a significant contribution to the maize seed industry development. Seed Development Loan I was started in Thailand in 1975, and as a result, Thai farms using the improved seed experienced an increase in productivity and income. However, this program did not successfully develop a public marketing body for improved seed distribution. Subsequently, Seed Development Loan II started in 1981 with the aim to provide "a comprehensive seed program that efficiently and cost-effectively increases farmers' use of higher quality seed while steadily increasing the role of the private sector to supply this seed" (Brown et al. 1985). This program recognized the role of the private sector in the production and marketing of improved seed and sought to enhance the private sector's performance. It is worth mentioning that prior to the Seed Development Loan projects, USAID had already sponsored education and training in the United States for a significant number of Thai scientists. The skills and knowledge of theses scholars who were engaged in both public, including public universities, and private sectors were important to the development of the seed industry.

At the same time, the DOAE initiated the pilot seed industry scheme in 1975 to provide technical knowledge and training in seed technology to contract growers and production staff at private seed companies. Private companies participated in this pilot scheme with their varietal demonstration and benefited from gaining knowledge and building a network with farmers, extension officers, and public researchers through field trips arranged by provincial extension officers. During 1989/90 and 1993/94, the government implemented the Corn Production Development Program aimed at improving the production efficiency of high-quality maize to maintain export levels and serve the increasing demand from feed and livestock industries. Several strategic plans were used, such as promoting the adoption of high-quality seed and good varieties, promoting appropriate postharvest technology, and inviting private companies to join the program by buying grain from farmers at a guarantee price or higher. Under this program for hybrid maize seed, maize production efficiency improved in medium- to high-productivity areas (>2,187 kg/ha), which include the majority of the corn belt in Thailand.[1] Other projects included local yield trials of hybrid maize on farmers' fields, field trials, yield contests, demonstrations of maize as a substitute for rice in irrigated areas during the dry season, and a national corn and sorghum symposium. Private hybrid seed companies were welcome to participate in all of these projects, and particularly in a pilot project to substitute for rice in irrigated areas, where the companies were contracted to buy grain from farmers at a minimum price, while the DOAE supplied single-cross hybrid seed, chemical fertilizers, and pesticides at no cost to farmers (Pongsroypech 1994). In addition to the pilot seed industry scheme and the corn production development program, the BOI of Thailand's tax exemption for imported equipment has made private companies more engaged in the development of hybrid maize varieties and the maize seed industry.

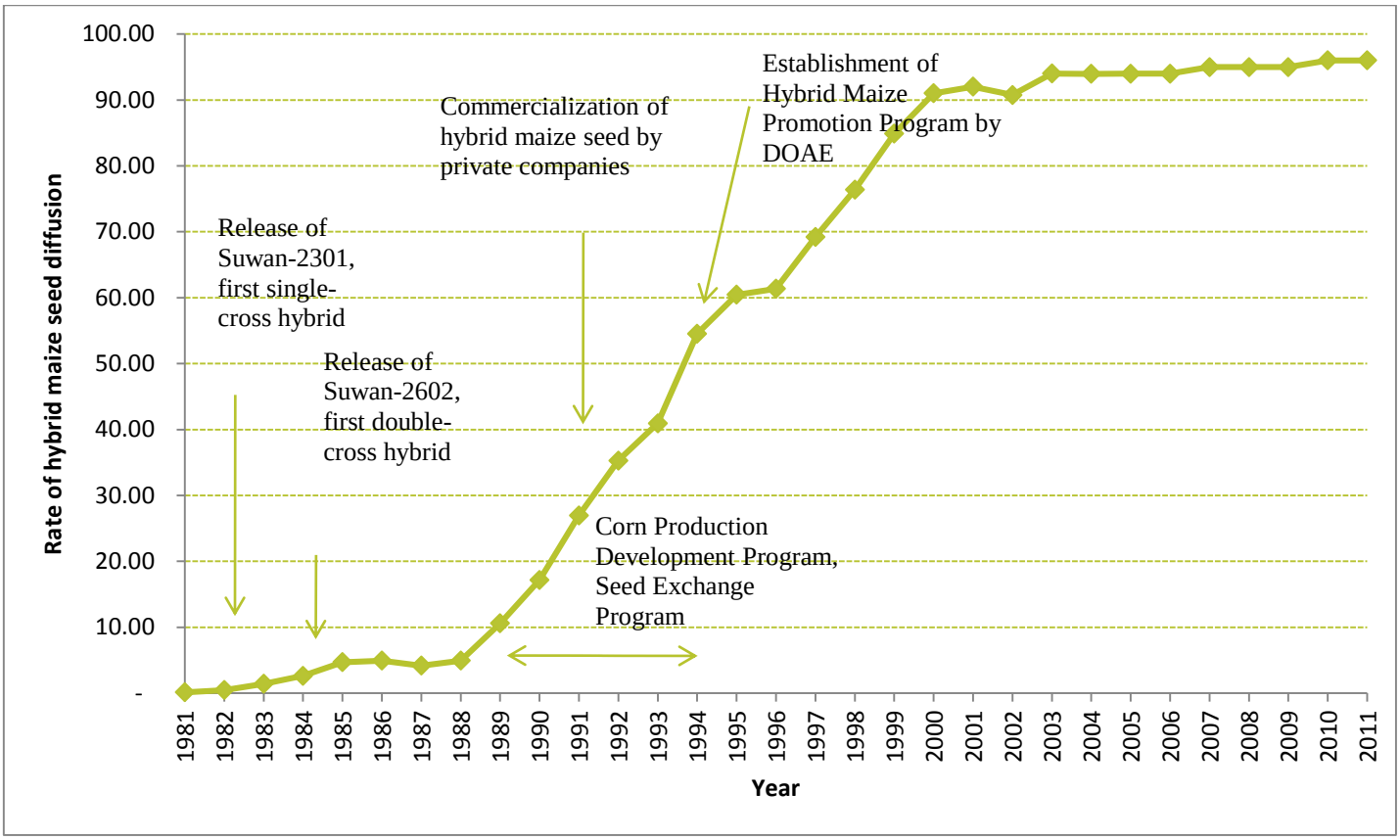
Unlike OPVs, Suwan hybrids require a large-scale seed production area, and the production of hybrid seed is more difficult and costly. During the 1990s, NCSRC and DOA faced a challenge with marketing problems. They sold inbred lines to private companies and were not involved in the private firms' production and marketing activities. Because several companies produced Suwan hybrid seed, there was little incentive for the private sector to expand its production and sale of Suwan hybrids (Ekasingh et al. 1999). In 1998, Kasetsart University used an exclusive licensing policy to sell a new hybrid to only one company in hopes of expanding the production and sale of the seed. However, because of the lack of legal protection for plant breeders' rights and the lack of enforcement for violations, private companies remained hesitant to enter large-scale production of public sector hybrids.

The adoption of maize hybrids increased rapidly during early 1990s. In 1989, the government provided support to maize farmers through the Seed Exchange Program's high-yielding variety rather than through direct subsidies. Occasionally, a limited budget was used to buy grain at a subsidized price from small farmers in poor areas where the grain price was too low. In recognition of the low price of certain commodities, in 1993, MOA set the goal to reduce the planting area of crops with an oversupply, such as rice, cassava, and coffee, and replace them with other crops. Maize was one of the recommended commodities, and farmers requested hybrid maize seed from the Seed Exchange Program. Also contributing to the success of the hybrid seed was the DOAE's single-cross Hybrid Maize Promotion Program, which provided farmers with good-quality hybrid seed. The program started in 1994, covering 39,000 hectares in 18 provinces, and continued to its peak in 1997, covering 144,480 hectares in 38 provinces and 1,165,000 hectares in 40 provinces in 2000 (Suwantaradon 2001). In addition, the Bank for Agriculture and Agricultural Cooperatives encouraged more hybrid maize diffusion through credits for hybrid maize seed and fertilizer. The adoption of maize hybrids increased rapidly after the release of single-cross CP-DK888 by Charoen Pokphand Seeds in 1991 (Suwantaradon 2001). Other hybrid seed companies started breeding their own single-cross hybrids, and the increase in competition among seed firms provided farmers with more alternatives.

[1] The government provided hybrid maize seed to farmers in exchange for grain at the ratio of 2:1 by weight. Farmers were required to apply the recommended fertilizer. The prioritized areas were where hybrid maize was not widely adopted.

Poolsawas and Napasintuwong (2013) found that the adoption of hybrid maize was low during its first introduction to the market, and only at the beginning of the 1990s, when private companies started commercializing hybrid maize seed, did the adoption of hybrid maize increase. This study revealed that farmers' attitudes toward new hybrid maize properties, such as high yield, grain quality, drought tolerance, and rust resistance, influenced the timing of adoption. The private sector, particularly through promotion programs and by providing information on hybrid varieties, played an important role in hybrid maize adoption. The diffusion of hybrid maize was estimated to rise after the privatization of the seed industry in the early 1990s (Figure 1; Table 1).

Figure 1—Rate of hybrid maize seed diffusion



Source: Rate of diffusion is generated from Suwantaradon et al. 2012.

Table 1—Hybrid maize seed diffusion in Thailand

Year	Maize planted area (1,000 ha)	Total maize seed demand† (ton)	Sales of hybrid maize seed	
			Quantity (ton)	Rate of hybrid seed diffusion (%)
1981	1,567.36	29,388	40	0.14
1982	1,679.04	31,482	145	0.46
1983	1,688.32	31,656	449	1.42
1984	1,816.96	34,068	897	2.63
1985	1,977.76	37,083	1,740	4.69
1986	1,951.20	36,585	1,810	4.95
1987	1,750.56	32,823	1,368	4.17
1988	1,835.36	34,413	1,700	4.94
1989	1,786.40	33,495	3,550	10.60
1990	1,745.60	32,730	5,625	17.19
1991	1,475.04	27,657	7,450	26.94
1992	1,351.36	25,338	8,940	35.28
1993	1,339.20	25,110	10,280	40.94
1994	1,412.64	22,073	12,040	54.55
1995	1,335.36	20,865	12,616	60.46
1996	1,386.40	21,663	13,290	61.35
1997	1,396.64	21,823	15,100	69.19
1998	1,441.28	22,520	17,200	76.38
1999	1,235.04	19,298	16,380	84.88
2000	1,251.68	19,558	17,800	91.01
2001	1,238.72	19,355	17,810	92.02
2002	1,195.84	22,422	20,350	90.76
2003	1,130.72	21,201	19,930	94.00
2004	1,163.52	21,816	20,500	93.97
2005	1,104.96	20,718	19,475	94.00
2006	1,024.80	19,215	18,060	93.99
2007	1,018.24	21,001	19,950	94.99
2008	1,070.72	22,084	20,975	94.98
2009	1,135.84	23,427	22,255	95.00
2010	1,196.96	24,687	23,700	96.00
2011	1,160.96	23,945	22,990	96.01

Source: Adapted from Suwantaradon et al. 2012.
† Based on estimation of 18.75 kg/ha during 1981–1993
15.625 kg/ha during 1994–2001
18.75 kg/ha during 2002–2006
20.625 kg/ha during 2007–2011

In the past few decades, competing crops in dry areas, such as pararubber, sugarcane, and cassava, often have government promotion programs as well, resulting in a significant reduction in the maize cultivation area.[2] However, thanks to high-yielding hybrid maize development, maize could stabilize its production level. About two decades after the privatization of the hybrid maize seed industry, the adoption of hybrid maize is greater than 90 percent, and has nearly completely replaced OPVs today.

Like other seed industries, innovation of new, improved varieties has increased competition in the maize seed industry in Thailand. At first, multinational companies, such as Pioneer Hi-Bred, Pacific Seeds (currently Advanta, and formerly ICI/Zeneca), Syngenta (formerly Ciba-Geigy and then Novartis), and Monsanto (acquired Cargill Seeds and DeKalb Seeds), depended on germplasm from

[2] Average 2013 farm gate prices of cassava sugarcane, non-glutinous rice and maize were 2.13, 965.9, 12,483.63 and 7.9 baht/kg, respectively.

NCSRC, which produced several private hybrids from inbreds. The importance of NCSRC gradually faded, however, when multinational companies relied more on their own germplasm from their mother companies for their breeding programs. Within each company, research results and seed production are shared among regional branches (Ekasingh et al. 1999). The engagement of Thai personnel, including scientists, in these multinational companies has made their breeding program successful, while also marketing with farmers' participation. Thailand's seed industry developed considerably due to healthy competition yet collusion among multinational companies.

Until the late 1990s, there were only a few leading Thai seed companies engaged in maize research: Charoen Pokphand, Uniseeds, and Thai Seed Industry. The first was much larger than the latter ones. Charoen Pokphand has broad access to maize germplasm through collaborative research with DeKalb Seeds. In 1991, Charoen Pokphand released the single-cross hybrid CP-DK888, which dominated the maize hybrid seed in the 1990s (Ekasingh et al. 1999). It still remains on the market today. In contrast, due to their limited resources, Uniseeds and Thai Seed Industry were dependent on germplasm and research from NCSRC and CIMMYT. Other smaller Thai companies did not engage in research and only produced public varieties or varieties owned by other seed companies, or conducted distribution and sales activities. Nevertheless, Thai companies contributed to the seed industry by creating competition and providing alternatives for farmers, as the companies are more interested in OPVs and public sector hybrids. Table 2 shows maize seed developed by private companies sold in Thailand during 1997–1998. After about two decades of privatization of the maize seed market, there was a considerable number of producers and choices of varieties. Table 3 shows the timeline of the maize seed industry development in Thailand.

Table 2—Maize varieties developed by private companies sold in Thailand, 1997–1998

Company	Field maize				Baby corn		Sweet corn
	Three-way cross	Double-cross	Single-cross	Modified single-cross	Three-way cross	Single-cross	Single-cross
Charoen Pokphand	CP-DK822	CP-DK818	CP-DK888 CP-DK999				
Cargill Seeds			C 922 BIG 919 BIG 929	BIG 717 BIG 727		C 501	
Pacific Seeds		Pacific 11	Pacific 328 Pacific 700 Pacific 626 Pacific 848		Pacific 421 Pacific 116 Pacific 129		Hibrix 5 Hibrix 10
Novartis Seeds	Hercules 31 Convoy 93 G 5384		Red Iron 45 Venus 49			G 5414 G 5406 G 5407	
Pioneer Seeds	3248 3006 30A10 3014		3011 3012 3013				
Uniseeds	Uniseeds 38		Uniseeds 89 Uniseeds 90		Uniseeds B-50		Uniseeds SW-1
Royal Seeds			Royal I Royal III				

Source: Ekasingh et al. 1999 and personal interview.

Table 3—Maize seed industry development in Thailand

Year	Major Event
Mid-1950s	Maize was promoted as alternative for rice (for export). Government subsidized opening of new land for maize cultivation. Government distributed improved maize seed and other inputs and agreed to buy grain at predetermined price.
1966	• Rockefeller Foundation established National Corn and Sorghum Research Center (NCSRC) and headquarters of its Inter-Asian Corn Program.
1975	Suwan-1 OPV, resistant to downy mildew, was released from NCSRC. Public sector started the production of Suwan-1 OPV seed.
	• USAID provided Seed Development Loan I targeting to increase productivity and farm income.
	Pilot Seed Industry Scheme: Department of Agricultural Extension (DOAE) provided technical knowledge and training in seed technology to private seed companies. Private companies participated through varietal demonstration.
1977	• Development of maize hybrids by public and private sector.
1979	Private sector (Bangkok Seed Industry with DeKalb) started producing and selling Suwan-1 seed.
1981	• USDA provided Seed Development Loan II targeting to increase usage of higher quality seed and increase private sector's role. • Private companies started commercial trials of hybrids.
1982	Suwan-2301, first single-cross hybrid, was released by NCSRC.
1986	• Suwan-2602, the first three-way cross hybrid, was released by NCSRC.
Late 1980s	Private companies developed hybrids specific to local conditions.
1987	• Public-Private Cooperative Yield Trials Program was initiated.
1990	Private companies successfully developed new hybrid seeds, giving more than 50% higher yield than OPV.
1991	• Charoen Pokphand Seeds released single-cross CP-DK888. • Adoption of maize hybrids started to soar.
1989–1994	Corn Production Development Program targeting to improve production efficiency, promote adoption of high-quality seed and good varieties, and promote appropriate postharvest technology.
	• Seed Exchange Program for hybrid maize: Government provided hybrid seed to farmers in exchange for grains at the ratio of 2:1 by weight.
	Private companies joined the program by buying maize grains at a guaranteed price or higher.
1993	• MOA set the goal of reducing the planting area of crops with oversupply, such as rice, cassava, and coffee, and replacing them with other crops, such as maize. • Hybrid maize seeds were highly requested.
1994	DOAE's Hybrid Maize Promotion Program provided farmers with good-quality hybrid seed.
1998	• Kasetsart University employed an exclusive licensing policy under which a new hybrid is sold to only one company in hopes of expanding the production and sale of Suwan hybrids.

THAILAND'S MAIZE SEED TRADE

The modern seed business in Thailand started in 1921 when Chia Tai Seeds Co., Ltd. (currently an affiliated company of Charoen Pokphand, commonly known as C.P., Group), started importing improved vegetable seed from China. Although the modern seed market of vegetables in Thailand started much earlier than that of field crops, currently maize is the largest exported and imported seed commodity in terms of value. Maize seed exports alone accounted for nearly 35 percent of the total seed export value, and collectively 42 percent when including sweet corn seed (Appendix A). Evidently, there is no seed export of other field crops, except for maize and sweet corn; the rest of exported seed are vegetables and flowers. The production and export of fruit seed is miniscule; it has not made it to the export market. Similarly, maize is the largest imported seed commodity (Appendix B). Although Thailand exports maize seed, the majority of maize seed is imported during off-peak season, when domestic production is insufficient. Maize seed imported by multinational companies is used as germplasm for breeding and as parent seed for commercial seed production. Furthermore, to prevent hybrid seed piracy, some hybrid seeds are produced in other countries and then imported to Thailand.

Table 4 and Table 5 show that Thailand is the net exporter of field maize seed and sweet corn seed, and the trend of trade balance is increasing. Although the imports of field maize seed have fluctuated during recent years, the exports have been continually increasing, in terms of both total export quantity and value. The unit value has also been increasing over time, and it is higher than that of imports. The quantity and value of imports and exports of sweet corn seed are much smaller than that of field maize seed. However, the unit value of sweet corn seed is relatively higher than that of field maize seed, particularly the unit value of sweet corn seed imports.

This is probably because the imports of sweet corn seed are high-quality hybrids, which generally are high-valued products. The rate of seed used per area of sweet corn is also lower than those of field maize and baby corn, so its unit price is generally higher. Similar to field maize seed, the unit value of exports of sweet corn seed has also been increasing over time, but not always higher than that of imports, especially in the past few years, when the unit value of sweet corn seed imports was considerably high.

Table 4—Thailand's import and export quantity and value of maize seed, 2005–2012

Year	Import			Export			Balance of Trade (million USD)
	Quantity (ton)	Value (million USD)	Unit value (USD/kg)	Quantity (ton)	Value (million USD)	Unit value (USD/kg)	
2005	3,125.97	3.119	0.998	9,730.66	15.166	1.559	12.047
2006	2,688.27	3.174	1.181	10,259.77	17.577	1.713	14.403
2007	1,968.26	2.590	1.316	13,423.64	24.237	1.806	21.647
2008	2,414.48	3.304	1.368	15,573.12	32.930	2.115	29.626
2009	5,263.81	9.187	1.745	13,292.29	33.894	2.550	24.707
2010	2,992.01	5.354	1.789	13,595.91	36.928	2.716	31.574
2011	1,216.88	2.667	2.192	19,971.80	45.009	2.254	42.342
2012	3,190.68	7.222	2.264	15,443.98	43.831	2.838	36.609

Source: Calculated from Thai Seed Trade Association 2013b using Bank of Thailand annual average exchange rate.

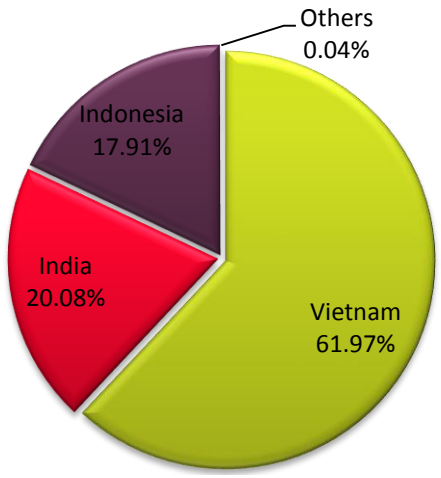
Table 5—Thailand's import and export quantity and value of sweet corn seed, 2005–2012

Year	Import			Export			Balance of Trade (million USD)
	Quantity (ton)	Value (million USD)	Unit value (USD/kg)	Quantity (ton)	Value (million USD)	Unit value (USD/kg)	
2005	18.65	0.060	3.216	191.52	1.418	7.406	1.358
2006	2.61	0.033	12.691	248.75	1.821	7.319	1.788
2007	29.91	0.118	3.949	319.53	2.642	8.269	2.524
2008	62.09	0.194	3.123	315.03	2.937	9.324	2.744
2009	40.37	0.129	3.196	337.56	3.010	8.917	2.881
2010	0.75	0.015	19.955	456.58	3.427	7.506	3.412
2011	1.53	0.043	28.311	931.06	7.597	8.159	7.553
2012	0.58	0.010	17.149	845.43	8.847	10.465	8.837

Source: Calculated from Thai Seed Trade Association 2013b using Bank of Thailand annual average exchange rate.

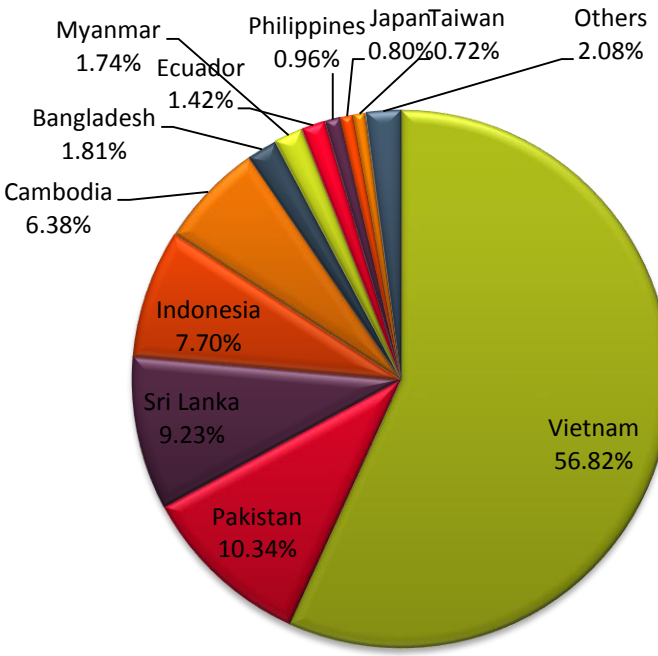
Figure 2 and Figure 3 show the suppliers and export markets of Thailand's maize seed. Vietnam, India, and Indonesia account for nearly all maize seed importation to Thailand. Vietnam alone supplies more than 60 percent of the maize seed, followed by India and Indonesia, respectively. Similarly, Vietnam is also the major importing country of maize seed from Thailand, accounting for more than half of the total maize seed export from Thailand in 2012. Pakistan, Sri Lanka, Indonesia, and Cambodia are also major markets of maize seed export from Thailand. Multinational companies typically develop maize varieties that are suitable for broad countries of similar climate and production environments, and thus their seed can be produced in several locations. Major trade partners of maize seed with Thailand, such as Vietnam, India, and Indonesia, are also production bases of multinational maize seed companies.

Figure 2—Share of countries of origin maize seed imports to Thailand, by quantity, 2012



Source: Thai Seed Trade Association, 2013b.

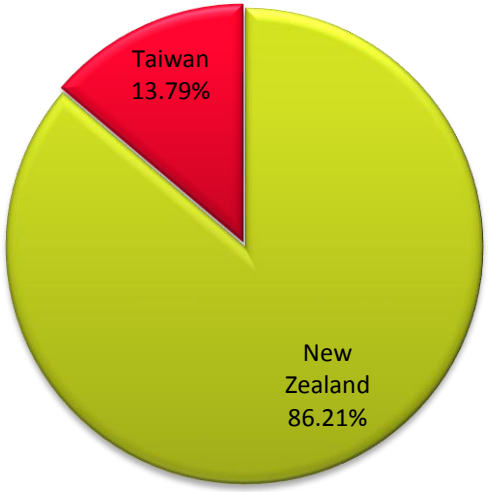
Figure 3—Share of maize seed export market from Thailand, by quantity, 2012



Source: Thai Seed Trade Association 2013b.

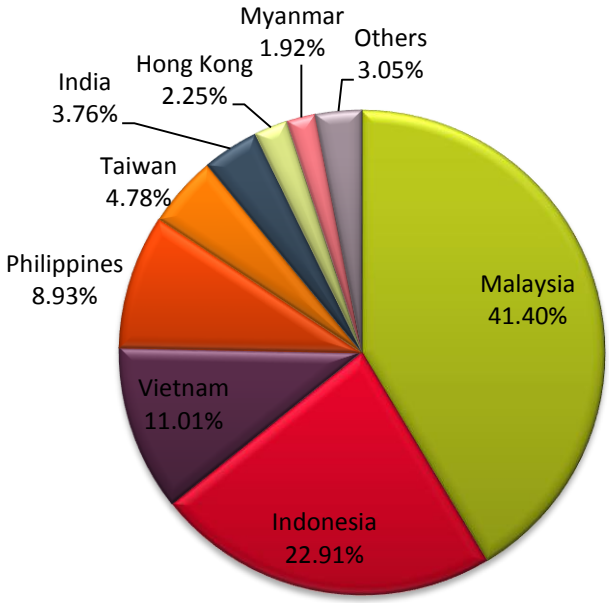
The domestic market of sweet corn seed is much less significant than that of maize, as seen from trade volume. New Zealand and Taiwan are two countries that export sweet corn seed to Thailand (Figure 4). Sweet corn seed imports from New Zealand account for nearly 90 percent of the total sweet corn seed imported to Thailand in 2012. New Zealand and Taiwan notably produce quality sweet corn seed, and the unit value of this seed from these countries is significantly higher than the unit value of sweet corn seed exports. Malaysia is the largest market for sweet corn seed from Thailand, followed by Indonesia, Vietnam, and Philippines, respectively (Figure 5). Again, these markets have similar climatic and production environment to Thailand.

Figure 4—Countries of origin of sweet corn seed imports to Thailand, 2012



Source: Thai Seed Trade Association 2013b.

Figure 5—Export markets of sweet corn seed from Thailand, 2012



Source: Thai Seed Trade Association 2013b.

CURRENT MAIZE SEED INDUSTRY ENVIRONMENT

Today maize is an important economic crop that supplies the feed industry. The extraordinary growth of Thailand's feed and livestock industry over the past few decades is largely attributed to the success of the hybrid maize seed industry. Table 6 and Table 7 show recent production of maize and sweet corn in Thailand. Major production areas are in the north and northeast of Thailand (Appendix C). Recently, the domestic demand for maize seed has increased slightly as the cultivation area of maize expands, except for the last year due to drought problems. In some areas of the northeast region, maize is grown on pararubber plantations; as rubber trees become larger, the cultivation of maize is reduced, hence the contraction of the cultivated area. Sweet corn production, on the other hand, is much smaller than that of field maize, and the cultivation area fluctuated somewhat over recent years though the expansion of the cultivated area did not change much. Sweet corn is consumed fresh in the domestic market, and there is a substantial demand from the canned industry, largely for exports.

Table 6—Cultivated area of maize in Thailand by region, 2008–2012

Region	Planted area (ha)					Average annual growth rate
	2008	2009	2010	2011	2012	
Whole kingdom	1,070,689	1,135,820	1,159,741	1,186,498	1,178,719	2.52
Northern	669,116	709,529	735,599	757,318	754,549	3.19
Northeastern	248,336	268,492	278,903	302,239	299,070	5.11
Central plain	153,237	157,799	145,240	126,941	125,100	-4.59

Source: Office of Agricultural Economics 2013a.

Table 7—Cultivated area of sweet corn in Thailand by region, 2009–2012

Region	Planted area (ha)				Average annual growth rate
	2009	2010	2011	2012	
Whole kingdom	35,949	36,466	37,402	36,392	0.41
Northern	12,657	13,760	13,535	13,928	3.35
Northeastern	6,684	7,080	7,605	6,604	-0.40
Central plain	13,452	12,472	12,846	12,624	-2.05
Southern	3,156	3,153	3,415	3,236	0.85

Source: Office of Agricultural Economics 2013a.

There was no rigorous information on the demand for maize seed, but it can be calculated by the cultivated areas. The interview with private sectors revealed that farmers generally used about 18.75 kg/hectare of field maize seed, 9.375 kg/hectare of sweet corn seed, and 31.25–37.5 kg/hectare of baby corn seed. In 2012, it was estimated that domestic demand for field maize seed was about 22,000 tons, and about 340 and 1,000 tons for sweet corn seed and baby corn seed, respectively. Compared to the trade quantity of seed, assuming that the demand for field maize seed includes both baby corn seed and field maize production (Table 8), the total demand for domestic use of field maize seed is about 65 percent of its net export volume demand (Table 8). However, the domestic demand for sweet corn seed is less than 30 percent of its net export volume. Thus the demand for maize seed and sweet corn seed estimated in Table 8 is slightly different than the estimation of Suwantaradon et al. (2010).

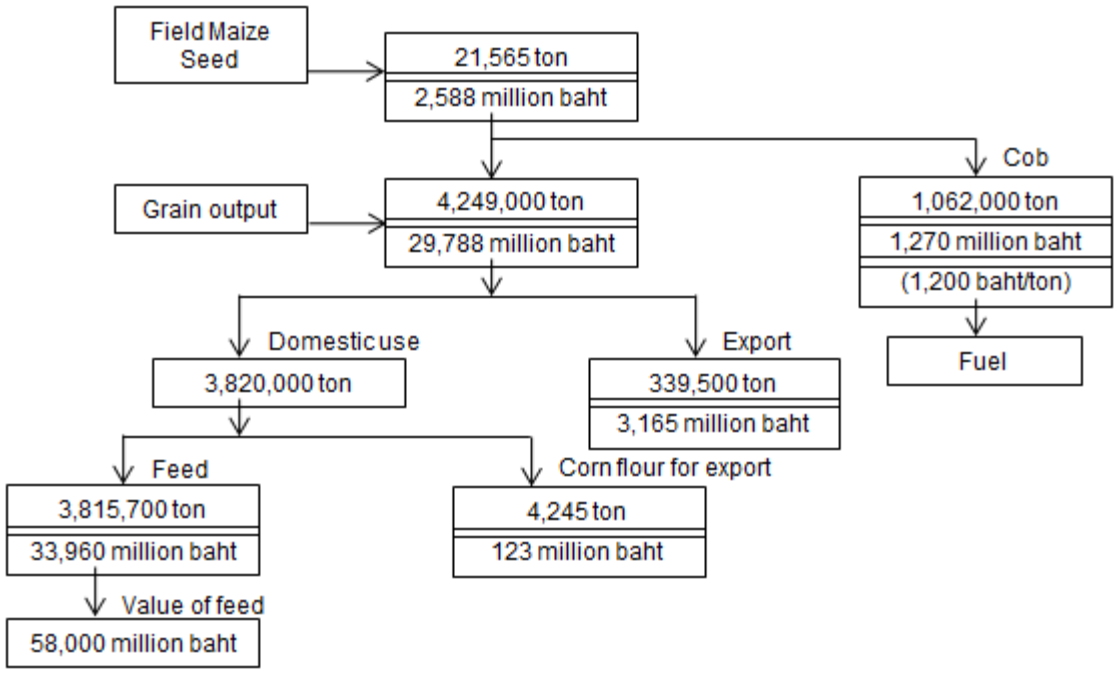
Table 8—Estimation of maize seed demand in Thailand, 2012

Type of maize	Planted area (ha)	Seed use per area (kg/ha)	Seed demand (ton)
Field maize	1,178,719	18.75	22,100.99
Sweet corn	36,392	9.375	341.17
Baby corn	30,072*	34.375	1,033.73

Source: Author's calculation

Figure 6 shows that the domestic demand for field maize seed in 2008 was about 21,565 tons, slightly lower than that of 2012. The production of maize was primarily for the feed industry. This estimation does not include the production of seed for export. The by-product of seed production could be supplied to the fuel industry.

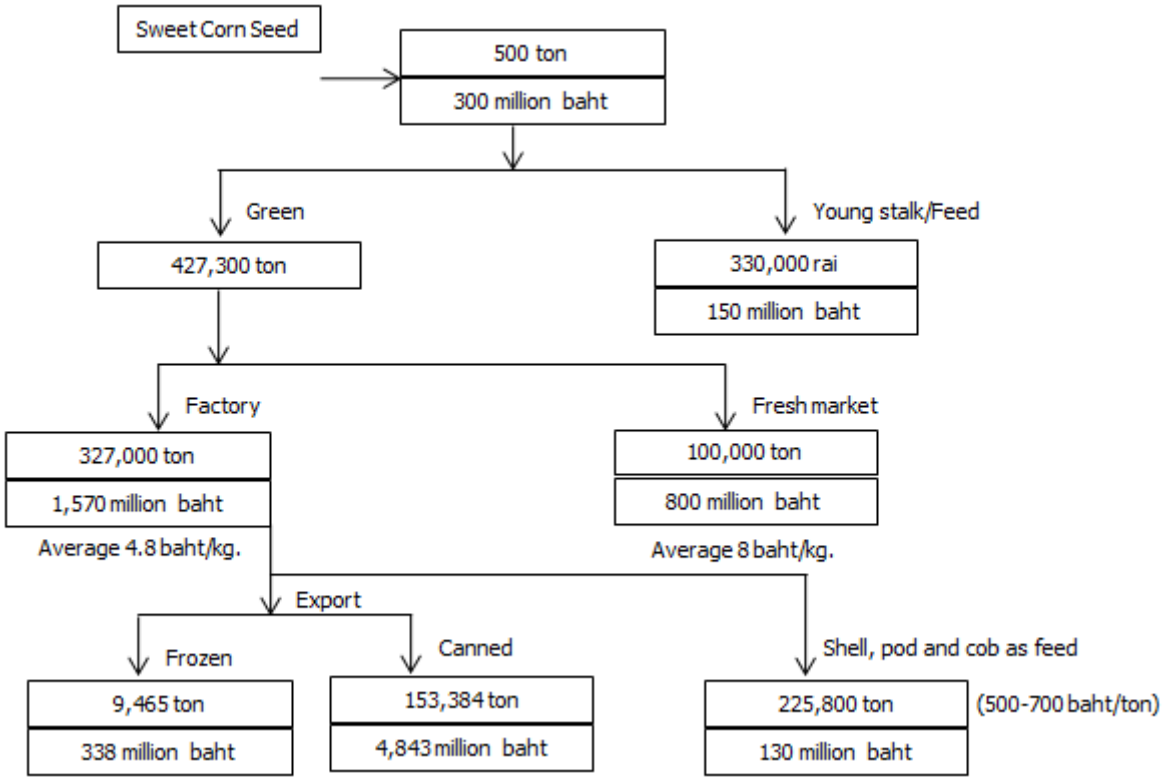
Figure 6—Estimation of quantity and added value in maize-related industries, 2008



Source: Suwantaradon et al. 2010.

Figure 7 shows the demand for sweet corn seed. In the Suwantaradon et al. (2010) estimation, production of sweet corn required about 500 tons of seed, about 1.46 times that required in 2012. Sweet corn is used for human consumption, to produce canned and frozen corn for export and also as a fresh product for the domestic market. The by-product of sweet corn production is used for feed as well.

Figure 7—Estimation of quantity and added value in sweet corn–related industries, 2008



Source: Suwantaradon et al. 2010.

CURRENT MAIZE SEED INDUSTRY STRUCTURE

Figure 8 illustrates the value chain of the maize seed industry in Thailand. This figure shows the links among stakeholders at different levels along the value chain. Large multinational companies generally integrate at all levels of the value chain, including importing and exporting of seed and germplasm. Local companies are mainly seed producers contracted by farmers. Farmers themselves are the buyers of seed and at the same time can also be producers through contracts with private companies or as local producers themselves using public varieties.

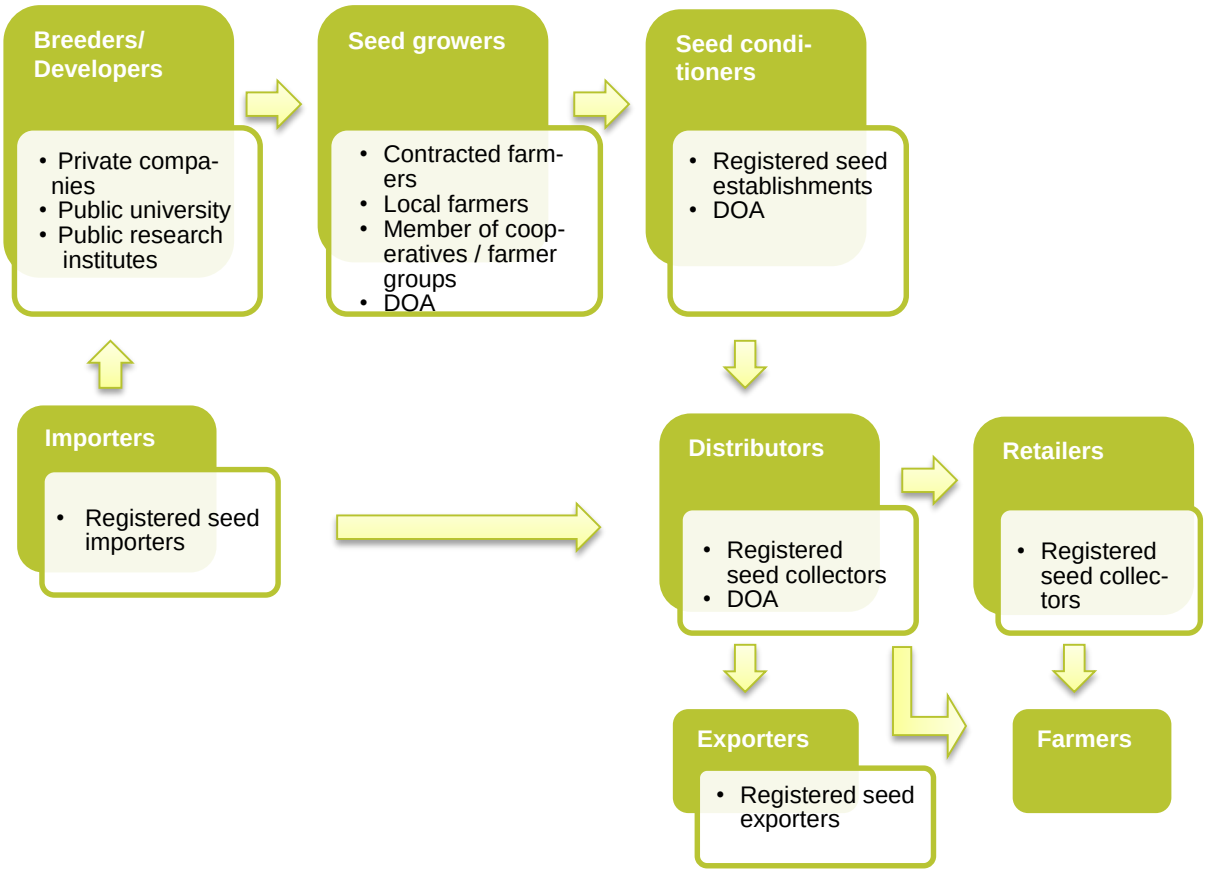
There are three main categories of maize seed suppliers: developers, producers, and distributors.

i. Developers are generally those who invest in varietal improvement research and new varieties development. They not only sell licenses but also engage in production and marketing along the value chain. Most of the large multinational companies that have advantages in accessing a broad spectrum of germplasm and long-term investment in research and development are in this category. The developers have exclusive rights to their own registered varieties and have their own brand name products.

ii. Producers are companies that import or buy inbred varieties (or parental lines) from other seed companies or from public institutions to produce hybrid seeds. They engage in seed multiplication, seed conditioning, and seed storage, but are not involved in research and development of new varieties. For public hybrid varieties developed by DOA, such as Nakhon Sawan-3, the producers can buy inbred lines from DOA without paying a royalty fee, and they do not own exclusive rights to produce public hybrid seed. These producers include small farmers, members of agricultural cooperatives, and small and medium enterprises (SMEs). Public hybrid seed can be registered under their own brand names, and the DOA certifies the commercial seed. Most suppliers in this category are small local companies.

iii. Distributors are those who collect seed from authorized producers, from either domestic suppliers or importers. A significant amount of them are retailers who generally buy and sell seed, using marketing and promotion activities, under their own brand names, and they also need to be registered with DOA.

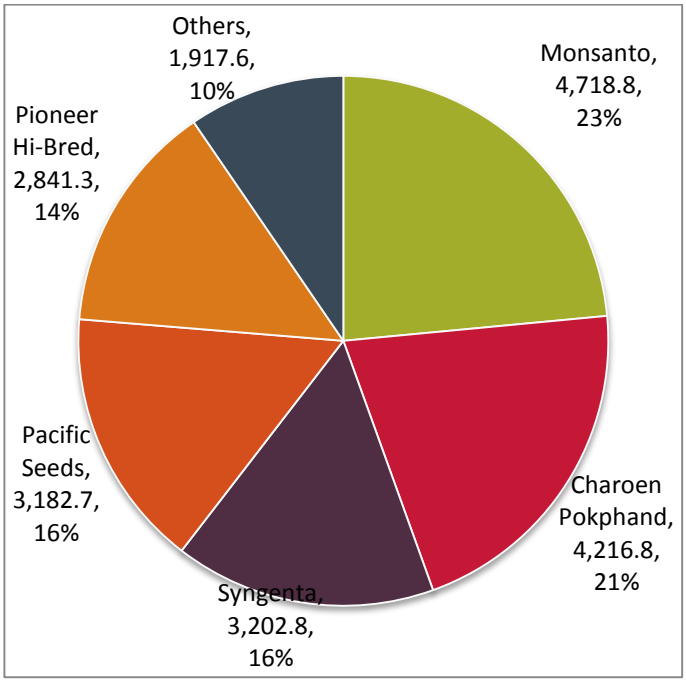
Figure 8—Maize seed industry in Thailand



Number of Suppliers

At present, there are five leading multinational companies in the maize seed industry. Four of them, Monsanto, Syngenta, Pacific Seeds, and Pioneer Hi-Bred, are foreign companies that have operated in the global seed market for a substantial amount of time; only one of them, Charoen Pokphand, is a Thai multinational. Monsanto, Charoen Pokphand, Syngenta, and Pacific Seeds cover about 76 percent of the field maize seed market in Thailand (Figure 9). The concentration and competition in the maize seed industry could be represented by the four firms' concentration ratio (CR_4)[3] and the Herfindahl-Hirschman Index (HHI).[4] From the market shares presented in Figure 9, the CR_4 equals 76 percent while the HHI is approximately 1,700, suggesting that the market is oligopoly and moderately concentrated. These few large companies have integrated businesses and constantly do research and development for new hybrid varieties. In addition to large private companies, there are numerous small enterprises that do not engage in research and development. Many of them produce public variety hybrid seed, and some may have reproduced hybrid seed illegally from the inbred seed of large companies. A small share of maize seed is also sold by the public sector, namely DOA and NCSRC.

Figure 9 Sales (ton/year) and market shares of top five field maize seed companies in Thailand, 2011



Source: Aungsuratana et al. 2012, cited by Department of Business Development.

Only a few private companies contribute significant shares in the market. Because maize contributes to the highest share of exports and imports of total seed, and the data on maize seed alone are not available, Appendix D and Appendix E provide a rough picture of the major exporting and importing seed companies of controlled seed.[5] Obviously, major multinational maize seed companies—such as Monsanto Thailand, Ltd.; Pacific Seeds, Ltd.; Pioneer Hi-Bred Co., Ltd.; and Syngenta Seeds, Ltd.—also play a major role in seed trade. Furthermore, Thai companies, particularly the large multinational Charoen Pokphand Group (which includes Charoen Pokphand Produce Co., Ltd.; C.P. Intertrade Co., Ltd.; and Chia Tai Seeds Co., Ltd.) are engaged in the seed trade.

Barriers to Entry

Seed companies engaging in research and development of new varieties require a large initial investment; thus, the competitiveness of small companies remains limited. By comparing the initial investment of the first seven companies entering the maize seed industry in Thailand during the 1980s, Table 9 explains why the entry into the maize seed industry has been cumbersome for small Thai companies. The interviews with large multinational companies revealed that recently the annual research budget is approximately 10 to 15 percent

[3] CR_4 measures total market share of the four largest companies; $CR_4 = \Sigma^4_{i=1} s_i$, where s_i is the market share of company i.

[4] HHI measures the size of the firms in relation to the industry; $HHI = \Sigma^N_{i=1} s_i^2$, where s_i is the market share of company i in the market, and N is the number of companies.

[5] There is a list of 37 controlled species under Notification of Ministry of Agriculture and Cooperatives on Types and Varieties of Controlled Seeds B.E. 2549, including 9 field crops and 28 vegetable crops.

of their global sales. The research investment of a company in Thailand alone ranges from 20 to 50 million bahts, or about US$0.6 to 1.5 million. For multinational companies, this research budget implies developing varieties that could be adapted in other similar climatic markets. Furthermore, large multinational companies have a long history of breeding research and multilocation branches in several countries. This implies that they have more access to a broad spectrum of germplasm from which to develop new varieties, and they are also more advantageous in their testing capacity of pre-commercial lines. Research capacity requires not only a large investment in facilities but also skilled researchers. At present, the number of skilled scientists, including plant breeders, plant pathologists, and soil scientists, is very scarce. Given current available technology, industry experts tend to agree that the future of Thailand's seed industry rests in the application of increasingly sophisticated research and development tools for trait identification, breeding, and multiplication. This includes tools of biotechnology and bioinformatics, though not at the exclusion of conventional breeding approaches. The research and development of new varieties require a large initial investment for cutting-edge innovation; thus, small seed companies with financial constraints have a limited capacity for product improvement and competitiveness.

Table 9—Initial investment of maize seed companies in Thailand

Company	Year of R&D establishment	Research station investment (million baht)	Annual budget† (million baht)	R&D staff (person)				Other permanent staff (person)	Hired labor (person/day)	Research coverage
				Ph.D.	Master's	Bachelor's	Below college			
Pacific Seeds	1978	20.0	3.5	0	3	0	1	3	12	maize, sorghum, sunflowers, feed crops
Charoen Pokphand	1978	30.0	9	2	1	6	3	5	60	maize, sorghum, sunflowers, feed crops, soybeans, rice
Cargill Seeds	1979	10.0	6	1	3	2	8	4	24	maize, sorghum, soybeans, rice
Pioneer Hi-Bred	1980	10.0	7	1	4	0	5	10	20	maize, sorghum
Ciba-Geigy	1981	20.0	8	1	2	5	1	8	60	maize, sorghum
Thai Seed Industry	1982	3.7	2	0	1	1	4	0	10	maize, sorghum
Uniseeds	1984	n/a	4	1	1	2	2	2	10	maize, sorghum, soybeans, mung beans, vegetables

Source: Suwantaradon 1989.

† including cost of breeder seeds and foundation seeds production

Product Differentiation/Similarity

The majority of field maize and sweet corn seeds available in Thailand's market are hybrid varieties; OPVs are still being sold in the market, but much less. Table 10 summarizes the number of registered dealers, the number of registered varieties, and their sources of seed. There are a significant number of sellers of hybrid and OPV seeds; however, the majority of them are collectors and distributors, and only some are developers of new varieties. Based on this information, farmers have a wide range of product selections under different brand names and trademarks, but the range of product differentiation is much narrower, principally due to the marketing of the same or similar products under different brand names (some are also unlicensed seed) by small merchants. In Thailand, where the Plant Variety Protection Law (PVP) protects varieties that have been developed only after the law came into effect in 1999 (*Office* of the Council of State, 1999) and which is not fully enforced, pirate hybrid seed is unavoidable. It is estimated that about 10 percent of hybrid maize seed in the market are reproduced from non-licensed inbred seed and some are from public varieties that do not protect their proprietary rights. Large companies, namely Charoen Pokphand, Monstanto, Pacific Seeds, and Syngenta, diversify their products to various types of maize, except for Pioneer Hi-Bred Co., Ltd., which only engages in field maize, and Chia Tai Seeds Co., Ltd. (a subsidiary of Charoen Pokphand Group), and East-West Seed International, Ltd., which emphasize their products in sweet and waxy corn (Appendix F). Compared to Table 6 about two decades later, available commercial seed varieties have been drastically multiplicative.

Table 10—Registered maize and sweet corn seed varieties in Thailand, 2013

Field maize				
Type of variety	**Number of supplier**	**Number of variety**	**Number of trademark**	**Source of seed**
Hybrid	74	354	143	Thailand, India, Indonesia, Vietnam, Philippines, China, Pakistan, Myanmar
Inbred	5	33	8	Thailand, Indonesia, India, United States, Brazil, Pakistan, Philippines, Mexico, Egypt
OPV	41	56	59	Thailand
Total	**120***	**443**	**210**	
Sweet corn				
Type of variety	**Number of trader**	**Number of variety**	**Number of trademark**	**Source of seed**
Hybrid	36	122	43	Thailand, United States, Taiwan, Indonesia, India, New Zealand, Philippines
OPV	23	23	30	Thailand
Total	**59***	**145**	**73**	

Source: Thai Seed Trade Association 2013a.

* Multiple counting because traders have activity more than once

Table 11 and Table 12 compare characteristics of pre-commercial and commercial varieties in multilocation hybrid maize yield trials. These varieties are selected by participating companies as the best hybrids nearly ready to be released to the market, and will eventually be registered under the Plant Variety Protection Law. The variations in yield and performance of each variety will definitely affect farmers' adoption. Furthermore, each variety has special characteristics that are suitable to specific locations, such as drought-tolerant, downy mildew–tolerant (most private varieties are vulnerable to this diseases), and maturity period, while size of seed also affect farmers' choices when planting machinery is used. Generally, private varieties perform better than the public varieties; however, the public varieties are more resistant to downy mildew disease.

Table 11—Yield and performance comparison of pre-commercial and commercial hybrid maize varieties from DOA's trials, 2010

Origin	Name of variety	Yield (kg/ha)	Yield/average yield (%)	Damaged stalk (%)		Ear/stalk (%)	Harvested ears (%)	
				Fallen	Broken		Full	Damaged
Private								
Charoen Pokphand	TSM0704	9292	112.91	6.25	7.07	115.18	58.63	9.75
	TSM0702	9168	111.41	5.19	6.26	111.91	57.25	10.50
	CP-DK 888	7350	89.32	8.34	4.46	116.57	58.88	16.77
Fertiliser and Bioseeds Co.	Narai 5	8224	99.94	3.50	2.77	98.68	44.13	9.11
	Narai 3- plus	7230	87.86	3.49	1.18	97.82	46.69	9.95
Monsanto	Big 919	7310	88.84	10.43	7.12	98.77	49.63	14.31
Pacific	Pac.999	9264	112.57	2.08	1.22	96.35	47.50	7.07
	Pac.339	9206	111.87	1.88	2.04	96.07	47.06	5.33
Seed Asia	SH0907	8244	100.18	6.14	4.38	99.83	49.25	12.37
	SH1001	8030	97.59	9.64	9.68	104.59	52.44	19.43
Syngenta	NT 7328	9222	112.07	0.87	1.33	101.48	50.63	13.05
	NT 6346	8892	108.05	3.22	6.08	97.59	49.38	9.39
	NK 48	8763	106.49	7.74	1.47	99.01	50.25	7.37
Uniseeds	Uni H 5108	8107	98.52	0.61	1.44	103.13	51.81	5.79
	Max 08	7980	96.97	0.00	0.36	98.82	49.31	5.26
Private varieties' average		8419	102.31	4.63	3.79	102.39	50.85	10.36
Public								
Department of Agriculture	Nakhon Sawan-2	7998	97.19	5.44	1.96	94.75	48.19	7.02
	Nakhon Sawan-3	7820	95.03	1.09	5.68	102.49	51.94	5.57
	NSX 042013	7936	96.44	1.09	1.93	112.34	56.94	10.79
	NSX 062006	7463	90.69	2.94	11.92	101.39	51.44	7.52
	NSX 042022	7567	91.96	0.72	8.19	102.45	52.63	6.90
	NSX 052014	7985	97.04	7.15	10.82	100.02	50.94	10.13
Kasetsart University	Suwan 4452	8274	100.55	10.50	4.67	96.66	48.88	12.26
	KSX 5318	8099	98.42	7.34	3.29	93.90	46.19	11.60
	KSX 5319	8077	98.15	2.78	2.53	97.82	50.25	19.08
Public varieties' average		7913	96.16	4.34	5.67	100.20	50.82	10.10
Overall average		**8229**	**99.98**	**4.52**	**4.49**	**101.57**	**51.00**	**10.26**

Note: Results are from DOA's yield trials in 4 public research centers: Nakhon Sawan Field Crop Research Center, Phetchabun Field Crop Research Center, Lop Buri Agricultural R&D Center, and National Corn and Sorghum Research Center.

Source: Department of Agriculture 2013a.

Table 12—Yield and performance comparison of pre-commercial and commercial hybrid maize varieties from Public-Private Yield Trial (PPYT) program, 2013

Origin	Name of Variety	Grain yield (kg/ha)	Yield/average yield (%)	Lodging		Poor husk cover	Rotten ear	Ear/stalk (%)
				Root	Stalk			
Private								
Bioseed	SB65	10150	106.87	3.71	1.77	9.11	2.60	98.77
	SB81163	9469	99.71	1.06	0.40	8.10	2.81	97.87
Charoen Pokphand	TSF1203	10417	109.69	3.86	2.81	9.26	4.38	98.08
	TSF1103	10352	109.01	0.58	0.87	8.12	2.93	97.78
	TSF1261	9683	101.96	0.46	2.10	8.09	2.65	96.99
	CP888	8719	91.80	9.63	6.57	9.14	2.68	113.89
Monsanto	DK6818	10264	108.08	3.81	2.34	11.25	2.35	104.82
	DK9955	10153	106.91	3.36	2.46	11.00	3.87	101.92
Northern Seed	NTSX632	7395	77.87	7.91	2.31	12.66	4.87	98.43
	NTSX321	6079	64.00	22.10	7.04	16.15	17.14	96.59
Pacific	PAC022	11002	115.85	0.82	1.22	8.00	1.62	97.75
	PAC339	10806	113.79	1.29	0.85	8.40	2.13	96.83
	PAC403	10426	109.78	0.25	0.45	9.01	1.25	97.19
Pioneer	P4181	10604	111.66	1.21	1.61	14.89	5.64	109.56
	P4546	10561	111.21	0.64	0.85	8.03	3.22	101.71

Table 12—Continued.

Origin	Name of Variety	Grain yield (kg/ha)	Yield/average yield (%)	Lodging		Poor husk cover	Rotten ear	Ear/stalk (%)
				Root	Stalk			
Private								
Seed Asia	SH121208	9766	102.83	1.93	1.68	10.81	2.33	102.09
	SH111212	9718	102.33	0.99	0.93	9.00	2.54	99.15
Syngenta	ST6181	10662	112.26	2.65	0.72	8.32	2.63	107.49
	S6248	10548	111.06	3.78	0.66	8.41	1.28	98.84
Thai Seed Research	TS2620	9317	98.11	2.16	1.35	8.12	2.64	98.04
	TS2401	7979	84.02	0.86	0.95	8.48	6.27	96.02
Private varieties' average		9718	102.32	3.48	1.90	9.73	3.71	100.47
Public								
Department of Agriculture	NSX052014	9861	103.84	4.47	5.26	8.05	2.55	99.57
	NSX112011	9237	97.26	6.21	7.04	8.92	2.24	99.66
	Nakhon Sawan-3	8902	93.74	0.92	2.40	8.47	1.61	98.65
Kasetsart University	KSX5612	9450	99.51	0.65	1.10	12.71	4.99	96.66
	KSX5602	8750	92.13	1.29	2.30	12.28	3.16	92.89
	Suwan1(S)C15	6305	66.39	5.40	3.81	11.41	5.78	89.62
	Suwan 4452	9340	98.35	7.48	4.76	8.00	3.00	96.30
Public varieties' average		8835	93.03	3.77	3.81	9.98	3.33	96.19
Overall average		**9497**	**100.00**	**3.55**	**2.38**	**9.79**	**3.61**	**99.40**

Note: Results are from PPYT's yield trials in 13 locations:
Wang Thong, Phitsanulok province, Monsanto; Wang Muang, Saraburi province, Charoen Pokphand; Takhli, Nakhon Sawan province, Syngenta; Phraphutthabat, Saraburi province, Pacific; Pattananikom, Lopburi province, Pioneer Hi-Bred Seeds; Sanpatong, Chiang Mai province, Northern Seed; Phraphutthabat, Saraburi province, Thai Seed Research; Phraphutthabat, Saraburi province, Thai Seed Research; Chatujak, Bangkok province, Shriram Bioseed; Muang Chiang Mai, Chiang Mai province, Chiang Mai University; San Sai, Chiang Mai province, Maejo University; Pak Chong, Nakhon Ratchasima province, NCSRC; Takfa, Nakhon Sawan province, Nakhon Sawan Field Crops Research Center.

Table 13 shows the development of varieties over time. It can be observed that maize production using local and OPVs has nearly vanished within the past 15 years. The use of public hybrid seed dramatically declined while the use of private seed remains about the same. The yields of public hybrid varieties have been much lower than that of private ones, but the difference has become smaller in recent years. It may suggest that the majority of hybrid maize seeds sold in the market are differentiated in terms of traits, and not much by yield.

Table 13—Maize harvested area, output, and yield comparison in farmers' fields, 1996–2010

Varieties	1996			2000			2005			2010		
	Harvested area (thousand ha)	Total output (ton)	Yield (ton/ha)	Harvested area (thousand ha)	Total output (ton)	Yield (ton/ha)	Harvested area (thousand ha)	Total output (ton)	Yield (ton/ha)	Harvested area (thousand ha)	Total out-put (ton)	Yield (ton/ha)
Local	3.88	8,445	2.17	0.13	378	2.90	n/a	n/a	n/a	n/a	n/a	n/a
Nakhon Sawan	5.70	13,623	2.39	0.74	2,579	3.51	n/a	n/a	n/a	n/a	n/a	n/a
OPVs	178.66	435,875	2.44	16.16	37,614	2.33	n/a	n/a	n/a	n/a	n/a	n/a
Public hybrids	60.65	199,329	3.29	6.59	19,444	2.95	8.71	28,470	3.27	6	23,678	3.71
Private hybrids	1,065.77	3,875,338	3.64	1,191.40	4,401,701	3.69	1,020.98	3,914,721	3.83	1,157	4,837,068	4.18
Total/average	**1,314.66**	**4,532,610**	**3.45**	**1,215.01**	**4,461,716**	**3.67**	**1,029.69**	**3,943,191**	**3.83**	**1,163**	**4,860,746**	**4.18**

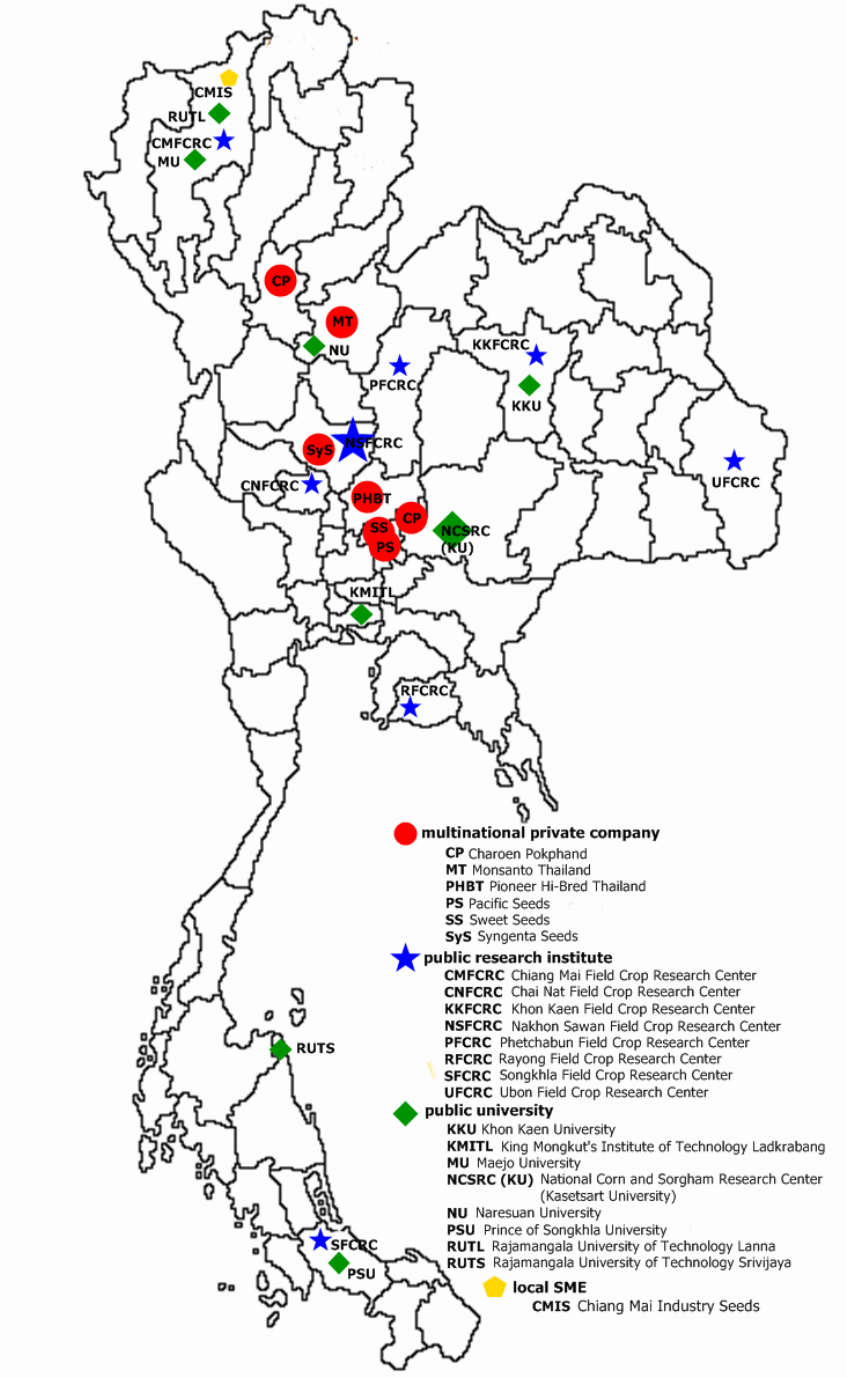
Source: Office of Agricultural Economics 2013b.

BUSINESS CONDUCT

Product Research and Development

At present, public research institutes play a small role in the development of new varieties and produce a very small amount of seed for sale. They include public universities, public research institutions such as the National Center for Genetic Engineering and Biotechnology (BIOTEC) under the National Science and Technology Development Agency (NSTDA), and various field crop research centers under DOA. Figure 10 illustrates the locations of organizations involved in maize research in 2013, except for BIOTEC, which mainly does research in Pathum Thani laboratory, north of Bangkok.

Figure 10—Locations of maize research and experimental stations in Thailand



Large multinational companies, namely Charoen Pokphand, Monsanto, Pacific Seeds, Pioneer Hi-Bred, and Syngenta, contribute to a great deal of progressive development in hybrid maize and sweet corn research. In conventional breeding programs, the process of screening germplasm, making selections, combining materials, and evaluating progeny is labor-intensive; a concentrated seed industry may not benefit much from economies of scale and scope. However, large multinational companies are increasingly dependent on having access to a wide range of superior germplasm and on being able to test experimental materials in various locations (Morris 2002). Multinational companies that engage in international networks of research stations and testing facilities have an advantage over small national and local companies in accessing wider genetic materials and evaluating them in different locales.

This constraint on small national and local companies explains the decreasing number of public institutes engaging in maize breeding research and the increasing size of existing private breeding programs.

Despite much less capital and resources, small local and regional companies do conduct research and development, including Seed Asia Co. and Bio Seeds Co. These small companies are greatly dependent on public germplasm. Table 14 shows the number of inbred lines sold to private companies by NCSRC. This implies that even though public research institutes may not be actively involved in research and development as much as the private sector is, public genetic materials that have been developed over time are still valuable for current maize breeding in Thailand, particularly for small companies. To develop new varieties using public inbred varieties owned by NCSRC, and under Kasetsart University's material transfer agreement, developers essentially buy inbred lines; if the inbred lines are used for commercial production of hybrid varieties, they must pay a small royalty fee. Large companies also buy licenses from other developers to produce hybrid seed and to broaden their germplasm already developed by other companies. Large companies with smaller capital and limited global trial stations still depend on licensed hybrids for much of their sales. More than 70 percent of Charoen Pokphand's commercial varieties, for example, are bought from other large multinational companies. Furthermore, Sweet Seeds Co., an affiliated company of Thai Seed Research Co., is one significant developer that focuses on the research and development of sweet corn and its licensing. At present, Sweet Seeds Co. is the major supplier of genetic materials of sweet corn in the tropics.

Table 14—Material transfers from National Corn and Sorghum Research Center, 1999–2012

Year	Number of inbreds	Number of companies		
		Large multinational foreign companies†	Foreign companies	Domestic companies
1999	2	-	-	1
2000	-	-	-	-
2001	-	-	-	-
2002	-	-	-	-
2003	-	-	-	-
2004	28	-	2	-
2005	2	-	1	-
2006	-	-	-	-
2007	10	-	3	1
2008	34	-	4	6
2009	19	-	3	10
2010	24	-	2	-
2011	10	1	5	9
2012	79	1	7	7

Source: National Corn and Sorghum Research Center 2013.

† Pacific, Pioneer Hi-Bred, Monsanto, Syngenta

Table 15 shows the number of new maize variety petitions filed for protection under the Plant Variety Protection Law from 2003 to 2013. These include field maize, baby corn, sweet corn, and waxy corn, yet the majority of them are field maize varieties. Monsanto has the largest number of new varieties, followed by Pacific Seeds. With respect to the market share of field maize in Figure 9, Monsanto and Pacific Seeds are the first and fourth largest companies. Perhaps their capacity to innovate and provide farmers with diverse new products is one of the main reasons these two large multinational companies can take up large market shares. Although Charoen Pokphand Group (including Bangkok Seed Industry) and Syngenta (previously Novartis Crop Protection) are also leading companies in the field maize market, their capacity to innovate appears to be much less than the first two companies. However, the market share and market power of firms also depend on other factors, such as the ability to access unprotected varieties (i.e., public varieties) at a lower cost of production, particularly when exclusive licensing of all commercial varieties is not fully realized. Other factors include marginal costs of production, the production pipeline, and marketing and sales strategies. The protection of new plant varieties that are not native to Thailand, such as maize, can be complicated under the PVP law because the benefit sharing of germplasm that has been developed over time by various parties is not easily achieved. The example of the maize seed market may also suggest that despite their dependence on the technology invented by other large companies, small companies can still perform well in the market when the exclusive licensing of public varieties is not fully protected.

Table 15—Number of corn varieties† petitions filed for Plant Varieties Protection, 2003–2013

Name	Approved	Pending	Trial stage	Withdrew	Total
Monsanto (Thailand) Co., Ltd.	19	0	28	1	48
Pacific Seeds Co., Ltd.	12	13	7	3	35

Khon Kaen University	0	10	4	0	14
Khon Kaen University and NSTDA	0	0	7	0	7
East-West Seed Co., Ltd.	6	1	0	0	7
Seed Asia Co., Ltd.*	1	4	0	2	7
Novartis Crop Protection Co., Ltd.	0	5	2	0	7
Bangkok Seeds Industry Co., Ltd.	0	1	2	0	3
Charoen Pokphand Produce Co., Ltd.	0	0	2	0	2
Chia Tai Seeds Co., Ltd.	0	0	3	0	3
Sweet Seed Co., Ltd.	0	0	1	0	1
Total	**38**	**34**	**56**	**6**	**134**

Source: Extracted from Plant Varieties Protection Division, Department of Agriculture 2013b.
† including field maize, baby corn, sweet corn, and waxy corn
* including corporate-owner registration

Furthermore, some research collaborations exist among international organizations, mainly CIMMYT, and public and private sectors. For instance, the DOA and CIMMYT continue to collaborate in terms of germplasm exchange, field trials, and personnel training; the Chinese and South Korean governments collaborate with DOA in terms of training and seed villages mentioned above; NCSRC and DOA collaborate with BIOTEC on molecular research; and DOA collaborates on research projects with two private companies, Charoen Pokphand and Sweet Seeds Co., to develop disease- and drought-resistant varieties of field maize and sweet corn, respectively. After the establishment of private maize seed companies in the early 1980s, several plant breeders who previously worked at NCSRC have joined the private sector. The majority of them were friends during the time when NCSRC was very active in maize research or during their study program at Kasetsart University.

This relationship among plant breeders in the maize industry is extraordinary. An example of collaborative management and technical support is the Public-Private Cooperative Yield Trials Program of maize varieties (PPYT) that has been carried out by NSCRC since 1987. Each year private companies in Thailand and those from abroad that have research facilities in Thailand are invited to send their pre-commercial and commercial elite hybrids for yield trials at multiple geographical locations. The purpose of this program is to provide a low-cost, voluntary, and unbiased method for evaluating and comparing maize seed hybrids available in Thailand (Richmond 2013). The trials are conducted mainly at research stations of the NSCRC, at collaborative public universities such as Chiang Mai University and Maejo University, at DOA's Nakhon Sawan field crop research centers, and at each participating company. This collaborative research is partly due to a strong bond among senior plant breeders who work in the public and private sectors. The genetic resources pooled from NCSRC and the private sector have contributed to better hybrids that are better adapted to geographical areas over the years. In addition, DOA has been conducting field trials of public and private maize varieties at its various field crop research centers throughout the country at no cost. Each year, private companies may send two of their pre-commercial and commercial hybrids for yield trials. The results are shared among research units of participating companies.

The investment in biotechnology research is also a key factor in developing new varieties. The initial investment in biotechnology, such as the cost of equipping laboratories and training scientists, can be prohibitively high for small and medium-size companies. Only large multinational companies with large capital are capable of reaping benefits from cutting-edge technologies, such as genetically modified (GM) hybrid seed. Prior to 2001, there were 10 approved importations of GM maize seed for trials (Table 16). However, on April 3, 2001, the government cabinet prohibited farm-scale trials of GM crops in response to a request made by anti-GM NGOs concerned with the environmental impact of GM crops. On December 25, 2007, the Thai government reinstituted permission for field trials of GM crops, but restricted it to public fields. The request of GM field trials has to be approved by the government cabinet on a case-by-case basis with no objection from the local community. At present, Thailand does not deregulate any commercialization of GM crops, and the research on GM crops remains in confinement. The main reason for slowing down the research and development of GM crops is due to a new Biosafety Law that was enacted, although the draft of biosafety guidelines for laboratory and field tests was released in 1992. The importation of GM seed is also prohibited except for research purposes, and it needs to be approved by the DOA.

Table 16—Approved GM maize seed importation to Thailand, 1996–1999

Date	Company	Variety of GM maize seed	Area of requested trials
October 8, 1996	Novartis (Thailand) Co., Ltd.	Bt-maize	confined greenhouse
May 27, 1997	Pioneer (Thailand) Co., Ltd.	Bt-maize	confined greenhouse
February 19, 1998	Monsanto (Thailand) Co., Ltd.	Roundup-Ready maize	confined greenhouse
May 1, 1998	Monsanto (Thailand) Co., Ltd.	Bt-maize	confined greenhouse
August 24, 1998	Cargill Co., Ltd.	Bt-maize	confined greenhouse

August 24, 1998	Novartis (Thailand) Co., Ltd.	Bt-maize	confined greenhouse
August 24, 1998	Novartis (Thailand) Co., Ltd.	Bt-hybrid maize	small experimental field (isolated area)
January 28, 1999	Cargill Co., Ltd.	Roundup-Ready maize	confined greenhouse
January 29, 1999	Monsanto (Thailand) Co., Ltd.	Roundup-Ready maize	confined greenhouse
June 10, 1999	Monsanto (Thailand) Co., Ltd.	Bt-maize (Mon-810)	small experimental field (isolated area)

Source: Biosafety Committee, Department of Agriculture 2007.

Still, there is a strong demand by the private sector, particularly multinational companies, to legalize GM crops. However, to date the only request for GM maize field trials was made by Monsanto for the Roundup-Ready NK603 variety in early 2013. The DOA is reviewing the request. The project is proposed in cooperation with Naresuan University, a public university in northern Thailand. The field trials are expected to start in late 2013 or 2014. In addition, Syngenta and Pioneer also requested to import GM maize seed for greenhouse trials in 2013 (Preechajarn 2013). Both are still being reviewed the DOA. The survey of 24 seed (including maize) companies by Suwantaradon et al. (2010) shows that several large companies have already used molecular marker technology, DNA fingerprinting, dihaploid/double haploid technology, and cell and tissue cultures; none is using recombinant DNA or genetically engineered technology. This does not mean that large multinational companies, including Charoen Pokphand, do not conduct GM maize research, but they have instead conducted their GM research in other countries.

The research and development of maize varieties in Thailand has several advantages for the region. The firm foundation of multinational companies in establishing research facilities and access to genetic materials, the well-known reputation of NCSRC for corn research, and the investment promotion of biotechnology research have made Thailand attractive for potential future breeding programs. However, there are some prohibitive regulations for advanced development, such as the stringent regulations of GM field research, particularly in open field trials, and the prohibition of GM maize seed imports except for research purposes. Such imported maize seed generally has to be tested for contamination of Cry 9 C DNA sequence or materials of Starlink Corn, which will incur some cost and time for researchers. The current more stringent Plant Quarantine Act that requires Pest Risk Analysis from country of origin further burdens the importation of maize seed. Furthermore, the protection of new varieties under plant variety property rights and plant breeder rights is complicated because maize is not native to Thailand, and the agreement on benefit sharing of germplasm that has been mutually developed in the past by public and international organizations can be cumbersome.

Advertisement/Product Promotion

There are several promotion campaigns used by large private companies. Common practices are demonstration plots in local communities where sales and extension staff of private companies rent small farm plots to demonstrate their new varieties with their input and technical supports. Some large companies also provide technical training programs to disseminate their technology to local communities. Others provide exhibitions to demonstrate their products at agricultural fairs and local farmer trade shows. The most common marketing strategy among large companies is a large-volume discount or sales incentives by organized annual gratis tours to wholesalers and distributors who sell at their target volume.

Large companies generally benefit from capturing economies of scale and scope in seed distribution, particularly those with diversified products and services. As large companies establish brand loyalty and farmers recognize their brand and products (seed products of the same company are usually named similarly, see Appendix F), more profits from investment in advertising and marketing campaigns can be expected. Evidently, marketing activities are prominently observed among large companies.

Collusion

The maize seed industry in Thailand has distinguished cooperative oligopolistic behavior. Without much government regulation, the profit-driven seed companies have well-established efforts to collude. The collusion is observed by cooperative pricing, which has observed a similar continual increasing trend at comparable rates in the past decade. Morris (1998) explained that two factors contribute to a laissez-faire attitude of the maize seed industry. First is that the industry is small and most industry participants, particularly senior maize breeders, know each other personally. These relationships provide a close personal network wherein opportunistic or unethical behavior, such as stealing inbred lines from competitors, comes at a prohibitive cost, because such behavior would be severely punished through formal and informal sanctions. Second, most large, well-established multinational companies have invested considerably in building reputations for quality and service. The unethical behaviors that jeopardize their reputations are too risky.

Furthermore, the Thai Seed Trade Association (THASTA) established in 2002 plays a significant role in collaborative activities of the seed industry. At present, most maize seed developers, producers, and distributers are members of THASTA. THASTA actively and successfully engages in core industry activities, such as promoting breeding activities among members, coordinating the promotion of quality seed use and seed dissemination, coordinating with public institutes on seed evaluation and recommendation,

cooperating with international organizations in seed trade, facilitating seed registration and a standardization database, and providing seed industry information. This actuality creates the necessary conditions for successful collusion, so that the industry shares information among its members and follows the moves of other companies. The association of maize seed companies agreeing to coordinate its activities, although pricing is not a formal agreement, behaves like a cartel, and raising the market price is possible. Despite a potential loss of profit, commercial maize seed is differentiated and farmers appear to be somewhat brand loyalty; thus, the demand for maize seed is relatively inelastic. The role of THASTA as a trade association, in addition to a small number of large companies and a concentrated market, keeps organizational costs low, thus making cooperative activities possible.

It is also worth mentioning the Seed Association of Thailand (SAT), established under the name Crop Seed Association of Thailand in 1990. Prior to that, in a joint effort the government and the private sector established the Seed Club in 1982 to serve as an official center for the coordination of various government agencies, the private sector, and international organizations for seed industry development and quality seed supply. The main differences between the roles of SAT and THASTA are that SAT serves as a center for the exchange of information, expertise, and experience in seed technology and related fields; provides technical assistance on seed technology; and provides managerial advice on the seed business and services related to the government's rules and regulations (Seed Association of Thailand 2013), while THASTA engages more in business-oriented activities.

Pricing

A survey of prices of hybrid maize seed in Thailand shows that large companies sell at a much higher price than small local companies, and the public sector's varieties (Nakhon Sawan-3, in particular) are sold at only half the price of the private sector's varieties (Table 17). Excluding the cost of research and development and other management and marketing costs, it is estimated that the cost of DOA seed production is about 60 baht/kg. This is consistent with the gross profit margin indicated by large private companies at about 50 percent of the selling price. Evidently, new varieties that are better adapted to local and current environments are generally sold at a higher price. Some old varieties that remain popular in the market, such as CP-DK888, are sold at a slightly lower price. The lower quality varieties produced by small companies, such as Fertiliser and Bioseeds Co., are usually much cheaper. Note that the farm gate price of maize is 7.9 baht/kg while the average private maize seed is about 149 baht/kg, nearly 19 times greater. The survey of maize seed retailers suggests that farmers are generally willing to pay for superior quality seeds that are suitable to their production environment because the cost of seed is only about 10 to 20 percent of the cost of maize production,[6] while the output depends heavily on the varieties. Price competitiveness of seed, therefore, is not a good market strategy. The development of varieties with high-quality traits is much more important.

[6] Approximated from the Office of Agricultural Economics 2013 survey of maize production cost based on current maize seed market prices and seed use.

Table 17—Hybrid field maize seed price in Thailand, 2013

Company	Variety	Price (baht/kg)
Charoen Pokphand	CP KKK Super	144.0
	CP888	122.5
	CP888 New	146.0
	CP888 Super	138.5
	CP801	154.0
	CP101	154.0
	CP301	152.0
Monsanto	DK979	150.0
	DK9901	146.0
	DK9955	151.3
	DK6919	149.0
	DK7979	153.3
Pacific Seeds	Pacific 777	160.0
	Pacific 339	163.8
	Pacific 999	158.3
Pioneer	B80	159.0
	Y87	148.0
	T60	153.0
	P4181	153.0
	P4296	148.0
	P4546	159.0
	P4311	153.0
	P4199	145.0
	P4196	150.0
Syngenta	NK48	152.7
	S7328	156.8
	NK58	147.0
	NK20	136.3
	S6248	154.0
Fertiliser and Bioseeds Co.	Narai 3- plus	125.0
	Narai 5	125.0
Average price of private maize seed		148.6
DOA	Nakhon Sawan-2	70.0
	Nakhon Sawan-3	70.0
Average price of public maize seed		70.0

Note: Not all varieties are available in all selected stores.
Inbred lines for hybrid seed production sold by DOA is 200 baht/kg
Average farm gate price of maize at 14.5% humidity is 7.9 baht/kg.

Source: Average from corporate website and retail stores in Saraburi, Nakhon Ratchasima, and Nan provinces

Industry Performance

The performance of industry as a consequence of market structure and its conduct may be measured by the profitability of the firms. It may be assumed that the smaller the number of firms and the less competitive the industry, the higher market power and profitability of the firms. And vice versa, the performance of the industry also could lead to a change in conduct and structure. Interviews with large private companies reveal that most of them have a similar gross profit margin at about 50 percent of the selling price. Although the Lerner index is a measure of monopoly power, it is not possible to obtain marginal cost data from financial reports. Alternatively, price-cost margin and accounting rates of profit can be used to measure profitability of the companies (Lipczynski and Wilson 2001), and current asset turnover ratio implies the efficiency, or how well a company generates sales revenue from its current assets. The current asset turnover ratio is calculated by revenue over current assets.

Price-Cost Margin

To measure monopoly power, the Lerner index, specified as $L = \frac{P-MC}{P}$, is commonly used. When the average costs are constant, the price-cost margin (PCM) is equal to the Lerner index. The price-cost margin is defined as the ratio of profit to sales revenue and can be expressed as (Lipczynski and Wilson 2001)

$$(1) PCM = \frac{P - AC}{P} = \frac{P \cdot Q - AC \cdot Q}{P \cdot Q}$$

where *P* denotes price, *Q* quantity ,and *AC* average cost. The larger the price-cost margin, the greater the company's ability to raise prices above average costs, which implies higher monopoly power.

Accounting Rate of Profit

When the data to calculate the economic rates of return are limited, despite some limitations of the methods used in accounting measures, the accounting rate of profit may be used as a proxy for profitability. The accounting rate of profit is defined follows (Scherer and Ross 1990):

- Accounting rate of profit on capital = $(Accounting\ profit + interest\ payments)/Total\ assets$
- Accounting rate of profit on equity = $Accounting\ profits/Shareholders'equity$
- Accounting rate of profit on sales = $Accounting\ profits/Sales\ revenue$

Table 18 shows the profit to sales, accounting rate of profit, and current asset turnover of selected maize seed companies, including the five largest field maize seed producers (Charoen Pokphand Seed, Monsanto, Pacific, Pioneer Hi-Bred, and Syngenta) and four SMEs (C.M. Seed Asia Co., Ltd.; Fertiliser and Bioseeds Co., Ltd.; Sweet Seed Co., Ltd.; and Thai Seed Research Co., Ltd.). Novartis Crop Protection and Sweet Seed Co., Ltd., are primarily developers that focus on breeding and licensing.

Table 18—Thailand's maize seed industry performance, 2012

Company	Price-cost margin	Accounting rate of profit on capital	Accounting rate of profit on equity	Accounting rate of profit on sales	Current asset turnover
Sweet Seed Co., Ltd.	0.5631	0.1880	0.2034	0.5631	0.3948
Monsanto Thailand	0.1502	0.1935	1.4633	0.1502	1.6191
Syngenta	0.1447	0.1644	0.2530	0.1447	1.2114
Pacific Seed	0.1264	0.1281	0.1650	0.1264	1.1746
Novartis Crop Protection	0.0752	0.0952	0.1279	0.0752	2.2214
Thai Seed Research Co., Ltd.	0.0714	0.1217	0.4952	0.0714	2.0686
Pioneer Hi-Bred	0.0586	0.0603	0.2875	0.0586	1.2620
C.M. Seed Asia	0.0313	0.0701	0.5195	0.0313	2.2307
Charoen Pokphand Seed	-0.2645	-0.0292	0.2613	-0.2645	0.5501
Bangkok Industry Seed	-1.9340	-0.4194	-2.1088	-1.9340	0.2976
Fertiliser and Bioseeds	-2.1837	-1.1864	0.0414	-2.1837	n/a

Source: Calculated from Department of Business Development 2012.

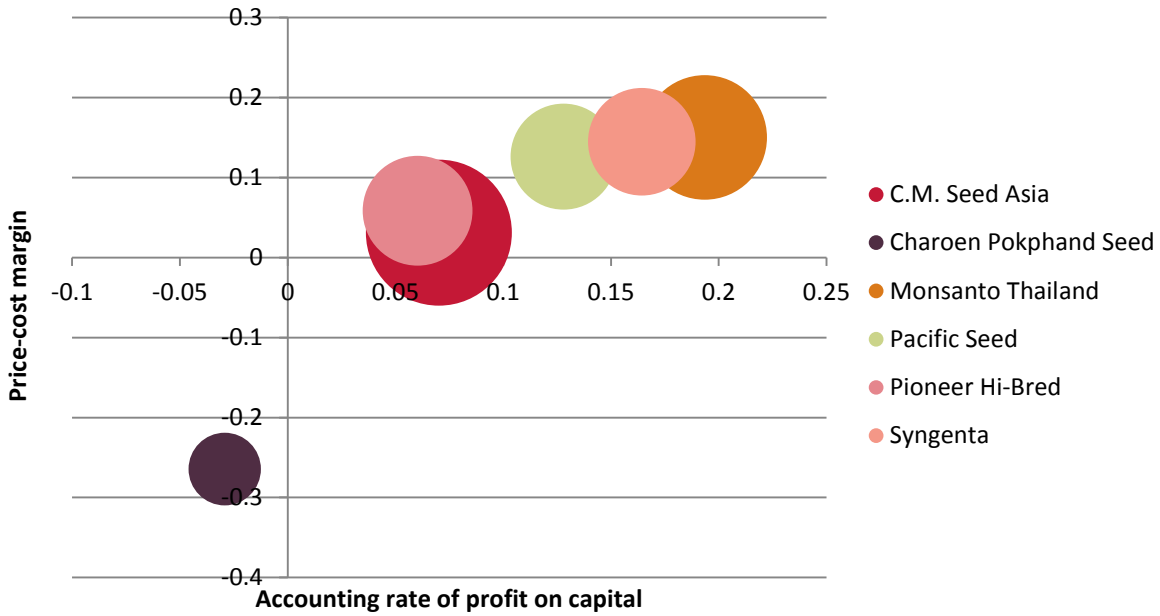
In 2012, three companies, Charoen Pokphand Seed, Bangkok Industry Seed (a subsidiary of Charoen Pokphand Company), and Fertiliser and Bioseeds had negative PCMs. All three are Thai-owned companies. Sweet Seeds Co., Ltd., had the highest PMC, while Novartis Crop Protection ranked fifth for PCM. Both are primarily developers. This implies that licensing and innovative firms appear to have relatively high profitability and high market power. Similarly, based on three indices of the accounting rate of profit, Sweet Seed Co., Ltd., appeared to perform well while Charoen Pokphand Seed, Bangkok Industry Seed, and Fertiliser and Bioseeds also showed negative profitability.

Monsanto has the highest accounting rate of profit on capital and accounting rate of profit on equity. This may imply that it has the highest profitability based on its asset. Other multinational large companies, namely Syngenta, Pioneer Hi-Bred, and Pacific Seed, also have moderate profitability based on three indices of the accounting rate of profit. C.M. Seed Asia is a relatively new company started in 2009. It is an SME that separated from Chiangmai Seed Industries Co., Ltd., a seed producer that does not develop its own varieties. C.M. Seed Asia Co., Ltd., is an example of an SME that benefits from BOI promotions and at present depends on parental lines from the DOA to produce Narai-3, the public variety that appears to be competitive with CP-DK888 in several areas. It is not surprising that Charoen Pokphand Seed did not perform well, although it has a large market share. This could be because Charoen Pokphand Seed depends on much of its sales from well-known varieties licensed from DeKalb Seed and Monsanto, such as CP-DK888, but its profit from these varieties may be deteriorating, as can be observed from a price lower than that of new

competitive varieties; SMEs like C.M. Seed Asia Co., Ltd., are becoming more price competitive and gaining a larger market share. Based on current asset turnover, C.M. Seed Asia Co., Ltd., is most effective in generating sales from its current assets compared to other large multinational companies. Except for Sweet Seed Co., Ltd., which is the sweet corn developer, Thai Seed Research Co., Ltd., the only SME sweet corn seed producer in this group, also has high current asset turnover.

Figure 11 compares the PCM and accounting rate of profit on capital among field maize seed companies in Thailand. Evidently, large multinational companies, except for Charoen Pokphand Seed, which is a Thai-owned company, have higher profitability given that Monsanto has the largest profitability, followed by Syngenta, Pacific Seed, and Pioneer Hi-Bred. C.M. Seed Asia, the only SME in this figure, also has comparable profitability to Pioneer Hi-Bred, but has the largest current asset turnover. This may suggest that although SMEs may not have as great a market power as other large companies, they may be effective in generating sales revenue. At present, BOI promotion and support of parental lines from public institutions may be important in promoting new entries and young businesses, but for them to remain competitive in the long run, investment in research and development to generate innovative varieties is necessary. As we can see from the example of Charoen Pokphand Seed, when compared to other large multinational companies such as Monsanto, profitability and capacity to utilize market power is not as great as expected, even though the company has a large market share. This may be due to Charoen Pokphand Seed's lower and later development of new competitive varieties compared to large multinational companies.

Figure 11—Field maize seed companies' profitability



Note: Size of circle represents relative current asset turnover.

REGULATIONS AND SEED HUB POLICY

Plant Variety Protection Act (PVP)

In Thailand, the PVP, which aims to protect newly developed varieties, came into effect in 1999 (*Office* of the Council of State 1999). The PVP gives the rights-holders of new plant varieties the sole right to produce, sell or distribute, import, export, or possess them for the abovementioned purposes; however, it only protects varieties that have been developed after 1999 and has not been fully enforced. Thus, pirate seed problems are unavoidable. It is estimated that about 10 percent of hybrid maize seed in the market is reproduced from non-licensed inbreds and some from public varieties that do not have proprietary right protection. The principles of new plant variety protection follow the distinctness, uniformity, and stability or DUS testing under the International Union for the Protection of New Varieties of Plants (UPOV). The PVP requires the applicants to actually grow the subject plant variety in Thailand for the purposes of examination. This implies that foreign companies will face difficulty in importing seed because in order to be granted protection, not only must the subject plant fulfill the requirements under the PVP, but for a foreign applicant developing or breeding the variety outside Thailand, the subject variety must also meet the requirements of the Plant Variety Act and the Plant Quarantine Act (Naboriboon 2007). The import of seed for the purposes of registering a new plant variety, however, is not considered research and development. Importation of seeds for trials still requires a permit, and due to the bureaucratic administration and the lack of close cooperation between the authorities, obtaining the permit has been a major obstacle.

Plant Variety Act (PVA)

The PVA was enacted in 1975. Its first goal was to protect farmers from low-quality seed resulting in low-yielding production. Prior to 1975, seed was subject to controlled commercialization, production, and international trade, even though there was a significant quantity of seed imports. To ensure the quality of seed production, MOA controls nearly all stages of the production, sales, and distribution, including imports and exports. The PVA controls the quality of listed controlled plant varieties[7] along the supply chain, including seed certification and registration of plant varieties, collectors, wholesalers, and retailers. Maize, sweet corn, rice, and sorghum are included in the list of controlled plant varieties. The production and sale of controlled seed must meet the requirements of minimum standards. The PVA specifies the purity and germination rates (98 percent and 75 percent for maize and 98 percent and 80 percent for rice, respectively) of seed from registered sellers and regulates the standards of seed storage (Ministry of Agriculture and Cooperatives 2006). The penalties for substandard seed sellers are one year of confinement or a 2,000 baht fine or both. Despite the PVA regulation, the enforcement is non-stringent. Furthermore, PVA complies with the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) for the protection of endangered wild plant varieties. The protection of new plant varieties that are not native to Thailand, such as maize, can be complicated under PVP because the benefit-sharing of germplasm that has been developed over time by various parties is not easy to achieve.

Plant Quarantine Act (PQA)

The PQA of 1964 mainly provides the sanitary and phytosanitary standards for importation, transit, and exportation of controlled plants and their parts, including seeds. The PQA aims to prevent the spread of unsafe foreign pests and diseases of controlled plants (Office of the Council of State 1964). The current more stringent PQA requires Pest Risk Analysis from the country of origin, which puts a greater burden on the importation of seed for research and commercial purposes.

Seed Hub Policy

Thailand aims to become the seed hub of Asia, particularly in preparing for the Association of Southeast Asian Nations (ASEAN) Economic Community (AEC) that will come into effected at the end of 2015. Several related public agencies are involved in promoting the Seed Hub Policy. The National Center for Genetic Engineering and Biotechnology (BIOTEC) under the National Science and Technology Development Agency (NSTDA) of the Ministry of Science and Technology has set the strategic plans in the Seed Cluster Program with the aim of using science and technology (S&T) in supporting the seed industry. The strategic plans were set for two phases: 2007–2011 and 2012–2016. The first phase emphasized the importance of S&T in promoting higher valued seed production. The SWOT and TOWS analysis by NSTDA suggested that the Thailand seed industry has a high potential to become a leader in the region. However, presently most of the seed companies are traders and contract producers of large multinational companies, and even fewer of them produce brand-name seed. This is due to insufficient investment in cutting-edge seed technology, particularly in the variety improvement and breeding technology of local companies. The goals of this program are (1) to provide farmers with good-quality seed, (2) to increase the number and income of seed-producing farmers, and (3) to promote the seed industry's role in developing and exporting Thai-owned brand-name seeds (National Science and Technology Development Agency 2006). In the current phase, the program aims to support the use of S&T to elevate the seed industry's competency. The target is to increase seed export value to 5,000 million baht (about US$160 million) by 2016. Major plans include (1) generating sustainable germplasm management, (2) using biotechnology (particularly molecular breeding) for crop improvement through a cooperation with the private sector, (3) developing disease diagnostics and providing support to small seed producers for high-value seed production, and (4) developing seed coating technology from natural products (National Science and Technology Development Agency 2011). The focused crops in the Seed Cluster Program are maize, chile, tomato, and melon.

In 2013–14, MOA set up flagship projects to improve the standards of agricultural products. The seed hub project, in preparing for the inauguration of AEC, is determined to place Thailand as the hub of research and production for tropical plant seed. The seed hub project also aims to produce sufficient quality seed, particularly for field crops and vegetables, for domestic use and exports, and to supply sufficient certified rice seed because the current capacity of production by the Rice Department is much less than the demand (Office of Agricultural Economics 2013).

NSTDA and MOA's projects to promote the seed industry as a seed hub include several activities. The PPP and public supports to farmer groups and local SMEs, such as maize seed village and rice seed village projects, are important factors in making the seed hub policy successful. Under BIOTEC's Seed Cluster Program, for example, joint research projects have been set up with private companies and public universities involved in plant breeding. The germplasm network engages private companies, public universities, DOA, and NCSRC in the collection, characterization, and evaluation of genotype and phenotype and multiplication of seed.

[7] The Notification of Ministry of Agriculture and Cooperatives on Types and Varieties of Controlled Seeds B.E. 2556 (2013) listed 33 controlled plant varieties.

Other PPP activities supported by the public sector include multilocation field testing of maize varieties that involves public institutions, such as DOA, and private companies (Richmond 2013); village seed programs for maize and rice so that the local community can estimate the demand and produce its own rice and maize seed for local use (Dailynews 2012); and support by DOA and NCSRC in providing the parental lines without a royalty fee to SMEs that have limited research capacity.

The seed business is currently one of the promoted industries in Thailand. The BOI has promoted incentives for businesses involved in plant propagation and development and seed production using biotechnology. Furthermore, for SMEs that have limited capital to invest in research and development, BOI also provides incentives to engage in plant propagation and development (Table 19). This provides more opportunities for both small and large companies to enter the seed industry, and will make the industry more competitive.

Table 19—Recent promotion measures for seed business investment

Business category	Benefits	Conditions
1. Biotechnology: Classified as a priority activity that has special importance and benefits to the country 1.1. Research and Development (R&D) activity and/or manufacturing of seed industry, plant and animal improvement industry using biotechnology 1.2. R&D activity and/or manufacturing of biomolecule and bioactive compounds using microorganisms, plant cells, and animal cells 1.3. Manufacture of raw materials and/or essential materials used in molecular biological experiment or test 1.4. Biological substances analysis and/or synthesis services	1. Exemption of import duties on machinery, regardless of zone 2. Eight-year corporate income tax exemption, regardless of zone NOT subject to the corporate income tax exemption cap 3. Other rights and benefits shall be granted according to BOI Announcement No. 1/2543 dated August 1, 2000 4. Projects that are located in science and technology parks shall receive a five-year additional 50% corporate income tax reduction for net profits after the end of corporate income tax exemption period	1. Projects must use modern biotechnology as approved by the National Science and Technology Development Agency (NSTDA) or the Thailand Centre of Excellence for Life Sciences (TCELS) 2. Letter of intention must be submitted to the Office of the Board of Investment by December 30, 2009
2. Plant propagation and development: Classified as a priority activity	1. Exemption of import duty on machinery, regardless of zone 2. Eight-year corporate income tax exemption, regardless of zone 3. Other rights and benefits shall be granted according to BOI Announcement No. 1/2543 dated August 1, 2000	1. Project must have plant research and development process 2. Letter of intention must be submitted to the Office of the Board of Investment by December 30, 2009
3. Plant propagation and development: Classified as small and medium enterprises	1. Exemption of import duty on machinery, regardless of zone 2. Eight-year corporate income tax subject to a cap at 100% of land and working capital 3. Other rights and benefits shall be granted according to BOI Announcement No. 1/2543 dated August 1, 2000	1. Unconditional on plant research and development process 2. The size of investment shall not be less than 200 million baht (exclusive of land prices and working capital) Thai shareholders shall hold no less than 51% of registered capital 3. The ratio of liability to capital shall not exceed 3:1 4. Letter of intention must be submitted to the Office of the Board of Investment by December 31, 2014

Source: Board of Investment 2009, Board of Investment 2013.

Finally, to provide alternative inexpensive sources of seed, the DOA of Thailand and the Rural Development Administration of South Korea initiated a "Maize Seed Village in Thailand" under the ASEAN Food and Agriculture Cooperation Institute (AFACI) project during 2010–2013. Up to 2012, there were 175 farmers participating in 52 villages of five northern provinces—Nakhon Sawan, Tak, Chiang Mai, Sukhothai, and Phetchabun—covering 95 hectares. Farmers were trained to produce a hybrid public variety, Nakhon Sawan 3, which is a cross between two public inbreds, Tak Fa1 and Tak Fa3. There were 80 tons of Nakhon Sawan 3 seed produced during the first three seasons, and the seed was distributed over 6,400 hectares of maize cultivation area (Dailynews 2012). Under this project, hybrid seed production knowledge is disseminated to local communities where local demand can facilitate local production plans. Furthermore, the varieties developed by the public sector can be produced without a piracy issue. The project is now being continued under the support of DOA until 2015. This project provides new opportunities for small and medium enterprises, including agricultural cooperatives that have limited capital for research and development. Although the production of hybrid seed requires a suitable climate and skilled farmers, and the entry into the hybrid seed business may remain limited, it is expected that the number of hybrid maize seed producers will expand in the near future.

CONCLUSION

The maize seed industry has developed successfully in Thailand due to privatization, which allows for more competitors in the market. This is not solely due to the declining role of public research, but also to the limited capacity of seed production and marketing by public institutions, providing opportunities for the private sector to take more important roles in the industry. With continuous research and development of new, higher yielding varieties appropriate to the local environment, the share of private varieties has nearly fully replaced public ones. Although an oligopoly market structure usually implies a higher margin and less competitive products and prices, the industry is relatively competitive.

Technological advancement in crop improvement is one important factor for a successful seed industry. The business environment of the maize seed industry in Thailand has several advantages in the region. Examples that have made Thailand attractive for maize seed industry include a strong foundation in establishing research facilities, access to genetic materials by multinational companies, NCSRC's internationally recognized research and performance, the government's investment promotion for biotechnology research, and an increasing demand for maize seed in similar-climate countries. However, there are some prohibitive regulations for advancement in industry development, such as the stringent regulations of genetically modified (GM) crop research.

To reach the goal of becoming the seed hub in the region, it is essential to have more investment in research and development for new competitive varieties. Promotion from the BOI for research and development using biotechnology and for SMEs is one of the key policies for the seed companies, particularly the new entries and small companies. However, these companies are far behind large multinational companies that have larger capital and access to a broader diversity of germplasm. The government should put more emphasis on promoting basic research infrastructure, such as education and training of scientists, public research facilities, and collaborative research with other national and multinational institutes to gain access to broader field trials and germplasm for national companies to become well established in the business.

The success of the maize seed industry suggests that the private sector's significant contribution improves not only the production of the commodity—maize, in this case—but also its related industries, such as feed and seed for export. Because maize is an important cash crop in Thailand, the country's regulations and policies should be further analyzed and revised so that maize seed industry can remain competitive in the international marketplace.

APPENDIX A

Export quantity and value of controlled seed from Thailand by commodity, 2012

Crop	Quantity		Value	
	(ton)	percent	(million baht)	percent
Maize	15,443.98	84.01	1,362.49	34.90
Tomato	44.46	0.24	638.43	16.35
Watermelon	139.14	0.76	381.58	9.77
Pepper	87.55	0.48	319.77	8.19
Sweet corn	845.43	4.60	275.01	7.04
Cucumber	87.82	0.48	260.19	6.66
Cantaloupe	47.53	0.26	137.06	3.51
Bitter gourd	47.12	0.26	103.22	2.64
Pumpkin	43.38	0.24	95.95	2.46
Swamp morning glory	1,074.80	5.85	70.50	1.81
Cabbage	11.84	0.06	44.52	1.14
Eggplant	12.17	0.07	40.96	1.05
Cauliflower	4.65	0.03	34.61	0.89
Cowpea	114.22	0.62	30.62	0.78
Angled gourd	16.25	0.09	29.80	0.76
Flowering cabbage	160.14	0.87	19.76	0.51
Okra	20.98	0.11	16.95	0.43
Coriander	85.14	0.46	9.45	0.24
Chinese radish	36.05	0.20	7.53	0.19
Gourd	1.78	0.01	6.59	0.17
Chinese cabbage	17.97	0.10	5.06	0.13
Broccoli	0.46	0.003	3.48	0.09
Chinese mustard	24.92	0.14	3.39	0.09
Lettuce	5.83	0.03	3.28	0.08
Kale	3.50	0.02	1.88	0.05
Small eggplant	0.26	0.001	1.30	0.03
Pea	3.68	0.02	0.75	0.02
Sunflower	1.47	0.01	0.35	0.01
Green bean	0.38	0.002	0.02	0.00
Total	**18,382.90**	**100.00**	**3,904.49**	**100.00**

Note: Based on a list of 37 controlled species under Notification of Ministry of Agriculture and Cooperatives on Types and Varieties of Controlled Seeds B.E. 2549. Cooperatives

Source: Thai Seed Trade Association 2013b.

APPENDIX B

Import quantity and value of controlled seed to Thailand by commodity, 2012

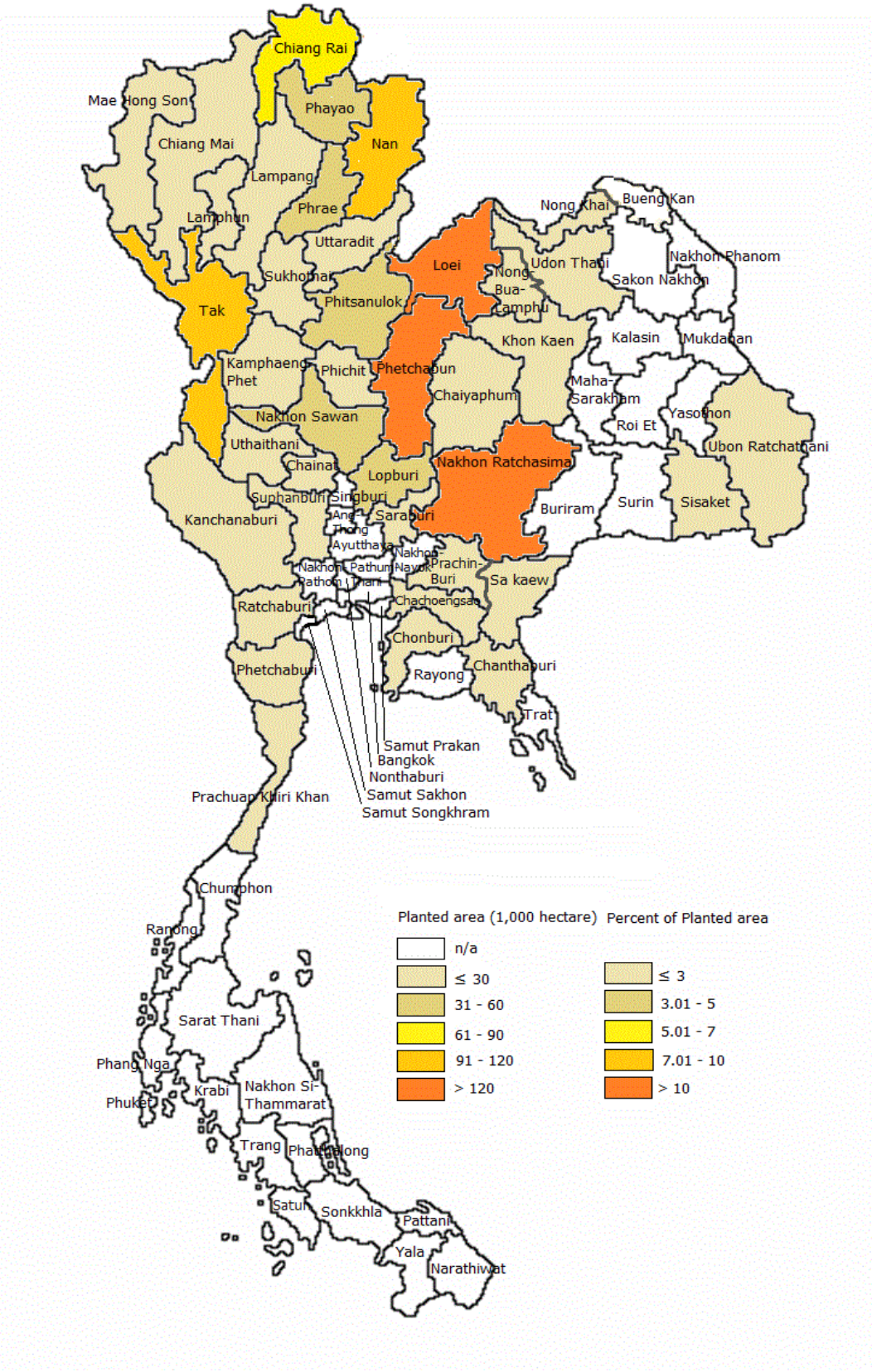
Crop	Quantity		Value	
	(ton)	percent	(million baht)	percent
Maize	3,190.68	52.69	224.50	26.13
Cilantro	1,137.96	18.79	65.87	7.67
Cabbage	20.19	0.33	61.76	7.19
Tomato	4.59	0.08	53.74	6.25
Flowering cabbage	491.61	8.12	49.08	5.71
Cucumber	23.41	0.39	40.46	4.71
Cauliflower	8.48	0.14	40.37	4.70
Bitter gourd	32.66	0.54	39.85	4.64
Pepper	10.60	0.17	37.20	4.33
Sunflower	229.35	3.79	36.76	4.28
Kale	300.93	4.97	35.83	4.17
Chinese cabbage	38.64	0.64	18.32	2.13
Lettuce	28.40	0.47	18.16	2.11
Angled gourd	18.16	0.30	17.77	2.07
Onion	3.20	0.05	16.55	1.93
Watermelon	14.24	0.24	15.37	1.79
Chinese radish	82.09	1.36	14.96	1.74
Pumpkin	14.07	0.23	13.46	1.57
Soybean	78.00	1.29	9.51	1.11
Swamp morning glory	143.12	2.36	8.32	0.97
Okra	14.32	0.24	8.19	0.95
Chinese mustard	80.30	1.33	8.18	0.95
Broccoli	1.11	0.02	6.36	0.74
Eggplant	2.82	0.05	6.21	0.72
Cantaloupe	0.41	0.01	4.30	0.50
Sorghum	62.03	1.02	3.87	0.45
Small eggplant	0.85	0.01	1.20	0.14
Pea	17.93	0.30	1.18	0.14
Cowpea	4.50	0.07	1.04	0.12
Sweet corn	0.58	0.01	0.31	0.04
Gourd	0.16	0.003	0.30	0.03
Green Bean	0.30	0.005	0.22	0.03
Total	6,055.67	100.00	859.19	100.00

Note: Based on a list of 37 controlled species under Notification of Ministry of Agriculture and Cooperatives on Types and Varieties of Controlled Seeds B.E. 2549.

Source: Thai Seed Trade Association 2013b.

APPENDIX C

Maize planted area in Thailand by province, 2012



Source: Generated from Office of Agricultural Economics 2013c.

APPENDIX D

Export quantity and value of controlled seeds for trade by major companies, 2012

Company	Quantity		Value	
	(ton)	percent	(million baht)	percent
Monsanto Thailand Ltd.	4,126.61	22.45	869.31	22.26
Syngenta Seeds Ltd.	6,241.32	33.95	635.51	16.28
Chia Tai Seeds Co., Ltd.	317.02	1.72	555.52	14.23
East-West Seed International Ltd.	498.80	2.71	322.20	8.25
Hsin Seeds Co., Ltd.	92.74	0.50	264.38	6.77
Pacific seeds Ltd.	2,631.40	14.31	200.58	5.14
C.P. Intertrade Co., Ltd.	1,793.31	9.76	195.09	5.00
Adams Enterprises Ltd.	14.03	0.08	153.14	3.92
Charoen Pokphand Produce Co., Ltd.	735.78	4.00	102.65	2.63
Thai Seed & Agriculture Co., Ltd.	25.02	0.14	85.65	2.19
Others	1,906.86	10.38	14,998.86	13.33
Total	**18,382.89**	**100.00**	**3,904.48**	**100.00**

Source: Thai Seed Trade Association 2013a.

APPENDIX E

Import quantity and value of controlled seed for trade by major companies, 2012

Company	Quantity		Value	
	(ton)	percent	(million baht)	percent
East-West Seed International Ltd.	309.67	5.11	138.57	16.13
Charoen Pokphand Produce Co., Ltd.	1,921.80	31.74	129.29	15.05
Chia Tai Seeds Co., Ltd.	377.56	6.23	105.04	12.23
Monsanto Thailand Ltd.	253.76	4.19	98.72	11.49
East-West Seed Co., Ltd.	393.54	6.50	54.76	6.37
Pioneer Hi-Bred (Thailand) Co., Ltd.	472.48	7.80	48.12	5.60
Chua Yong Seng Plant Variety Co., Ltd.	486.67	8.04	36.31	4.23
Seng Heng Huat Seed Co., Ltd.	40.30	0.67	33.23	3.87
Kam Lai Tong Agriculture Co., Ltd.	334.09	5.52	32.98	3.84
Pacific Seeds Ltd.	259.32	4.28	25.53	2.97
Syngenta Seeds Co., Ltd.	287.39	4.75	24.39	2.84
Others	919.10	15.17	132.23	15.38
Total	**6,055.68**	**100.00**	**859.17**	**100.00**

Source: Thai Seed Trade Association 2013b.

APPENDIX F

Registered maize varieties developed by private companies sold in Thailand, 2013

Company	Field maize	Baby corn	Sweet corn	Waxy corn
Charoen Pokphand Produce Co., Ltd., and Bangkok Seeds Industry Co., Ltd.	C.P.101	C.P.B468	C.P.511	Hneawsawan
	C.P.201		Wanthong Super	Victory
	C.P.301			
	C.P.511			
	C.P.801			
	C.P.808			
	C.P.818			
	C.P.838			
	C.P.858			
	C.P.888			
	C.P.888 New			
	C.P.888 Super			
	C.P.909			
	C.P.989			
	C.P.999			
	C.P.AAA Super			
	C.P.KKK Super			
	C.P.QQQ			
	C.P.QQQ Super			
Pacific Seeds, Ltd.	823017/823011	Pacific 271	827064	Fancy Purple Color 111
	823110	Pacific 283	827090	Fancy Purple White 212
	823173	Pacific 321	Bonanza	Max One
	Hycorn 984	Pacific 521	Fancy Sweet	
	MA0392		Hi-brix 10	
	Pac 224 (F224)		Hi-brix 49	
	Pac 224 (M224)		Hi-brix 51	
	Pacific 105 Super		Hi-brix 9	
	Pacific 133		Hi-brix3	
	Pacific 147		Hi-brix39	
	Pacific 224		Hi-brix53	
	Pacific 259		M2549	
	Pacific 313		MZT 052	
	Pacific 339			
	Pacific 414			
	Pacific 555			
	Pacific 759			
	Pacific 777			
	Pacific 984			
	Pacific 999			
	Pacific 999 Super			
	Pacific 999 Super			
	Pacific Super 984			
	Pacific Super 999			
	Super Champ			
	Thaigold			

(Continued)

Company	Field maize	Baby corn	Sweet corn	Waxy corn
Syngenta Seeds Co., Ltd.	Cyclone	SG16 Super	BSS5805	Wax 22
	G5414	SG17	GSS4644	Wax 44
	JET 999	SG17 Super	SK8841	Wax 48
	Jumbo	SG18	Sugar Star	Wax 50
	Kanokkarn 108	SG22	Sugar73	Wax 55
	MPX52037		Sugar75	Wax 88
	MPX55015		Sugar 75 Star	Hneaw Num 74
	MPX57077		Sugar77	Hneaw Moung Tam
	NK20		Sugar79	
	NK22		Sugar 84	
	NK31		Sugar 85	
	NK38		Sugar Max	
	NK40		Summer Sweet 55	
	NK40 Super Jumbo		Summer Sweet 12	
	NK4300		Magnum	
	NK48		Winter Sweet	
	NK50		Songsi 58	
	NK51		Songsi 59	
	NK58		Songsi Sweety	
	NK6326			
	NK6346			
	NK6385			
	NK6654			
	NK67			
	NK72			
	NK7328			
	NP5063			
	NT5549			
	NT6326			
	NT6654			
	NT6661			
	RAMBO			
	S6248			
	S6628			
	S7259			
	S7328			
	Tapeevenus 49			
Monsanto Thailand, Ltd.	717		Golden Sweeter 93	Milky 36
	919		Shimmer	XC 4985
	BIG 717		SV7058SN	
	BIG 919		SYY 093-678	
	C919		Win 99	
	DK6789		XC4985	
	DK6818			
	DK6919			
	DK717			
	DK7979			
	DK85			

(Continued)

Company	Field maize	Baby corn	Sweet corn	Waxy corn
	DK8868			
	DK919			
	DK95			
	DK959			
	DK979			
	DK9901			
	DK9905			
	DK9955			
	M959			
	Tender 58			
Pioneer Hi-Bred (Thailand) Co., Ltd.	3013 10 MW			
	3013CE			
	30A33			
	30B80			
	30D70			
	30K95			
	30N11			
	30N34			
	30T60			
	30Y87			
	3BT			
	69B			
	84R			
	CC-02			
	Cornberry			
	Inbred			
	Mahanchan			
	P3110WE			
	P3577			
	P4094			
	P4097			
	P4181			
	P4199			
	P4296			
	P4311			
	P4546			
	P4644			
	PH12HR			
	PH698			
	PH9TJ			
	PHC2M			
	PHD1A			
	PHDMK			
	PHM6T			
	SG2			
	SKV			
	SKV			
	TM-030			
	Triton			
	X40B108			
	X40B111			
	X6A241			
	X7A316			

(Continued)

Company	Field maize	Baby corn	Sweet corn	Waxy corn
Sweet Seed Co., Ltd., and Thai Seed Research Co., Ltd.	Dr.PEK'S Tab-TimSiam		Dr.PEK'S Wan54	SweetWax254
	TS1004		Wan55	SweetWax274
	TP45		Wan88	
	TP8208			
Seed Asia Co., Ltd.	SA 326		SA 10	
	SA 333		SA 20	
	SA 345		SA 40	
	SA 399			
	SA 501			
	TF 222			
Chia Tai Seeds Co., Ltd.		Gakraphat 802	Bisi Sweet-4	Big 366
		Sweet Dew 1127	Chaiyo	Hneaw Moung Wan 09
			Delight SC 084	Kaopodkow
			Deluxe SC 092	Kow Tubtim 366
			Deluxe SC 382	Kow Wan 1
			Gondola 021	Pansumlee
			Mini Corn	Petpailyn 366
			Polaris	Phadtaw
			SC 1320	Supreme
			SC 1543	Supreme 1565
			SC 7335	Top White 365
			SC 8583	White Green
			Series 7	White Perfect
			Songsi Mini	White Pumpui 004
			Songsi Sweet corn	
			Super Sweet Argo	
			SWC 101	
			Sweet Cho-rus	
			Top Sweet 801	
			Wanampan	
East-West Seed International, Ltd.			Honey Sweet	Big White 852
			Magic Sweet	Big White 854
			Sweet Bi-color	Green Pearl
				Rainy White
				Sweet Green Pearl
				Sweet Violet
				Sweet White 25
				Violet White 926

Source: Thai Seed Trade Association 2013a.

REFERENCES

Aungsuratana, A., C. Jompuk, K. Vijitsrikamol, and S. Pookngam. 2012. *Potential of maize production economics towards dynamics of feed and energy future.* Report submitted to Thailand Research Fund, Bangkok. (in Thai).

Board of Investment of Thailand. 2009. *Board of Investment Announcement No. 10/2552: Types, Sizes and Conditions of Activities Eligible for Promotion*. www.boi.go.th/english/download/law_regulations/606/Por10_2552_eng.pdf.

Board of Investment of Thailand. 2013. *Board of Investment Announcement No. 7/2556: Measures for Capacity Building of Small and Medium Enterprises (SMEs)*. www.boi.go.th/upload/content/7_2556_45790.pdf.

Brown, L., W. Underwood, and S. Tongpan. 1985. *Private sector development in the Thai seed industry.* USAID Special Study No. 23. Washington, DC: U.S. Agency for International Development.

Chummee, C. 2013. *Keeping an eye on Thailand's seed business in ASEAN*. Economic and Business Intelligence Center, Siam Commercial Bank. www.scbeic.com/ENG/document/note_20130514_seed_en.

Dailynews. 2012. *"Maize seed village" cost reduction alternative for farmers*. October 16, 2012. www.dailynews.co.th/Content/agriculture.

Department of Agriculture. 2013a. *Yield comparison of public and private hybrid maize varieties.* Unpublished data.

Department of Agriculture. 2013b. *Petitions filed for plant varieties protection database.* Plant Varieties Protection Division. www.doa.go.th/pvp/index.php?option=com_content&view=article&id=129&Itemid=125.

Department of Business Development. 2012. *Business data warehouse.* http://datawarehouse.dbd.go.th/bdw/search/search1.html.

Ekasingh, B., P. Gypmantasiri, and K. Thong-ngam. 1999. *Maize research in Thailand: Past impacts and future prospects.* Agricultural Systems Working Paper No. 125. Chiang Mai University.

International Seed Federation. 2012. *Exports of seed for sowing by country—calendar year 2011*. www.worldseed.org/isf/seed_statistics.html.

Kasetsart University Research and Development Institute. 2009. *Plant Varieties Developed by Kasetsart University*. Bangkok, KURDI.

Lipczynski, J., and J. Wilson. 2001. *Industrial organization: an analysis of competitive markets.* Essex: Pearson Education Limited.

Ministry of Agriculture and Cooperatives. 2006. *Notification of Standards, Quality and Methods of Storage for Controlled Seeds following Plant Variety Act B.S. 2518*.

Morris, M. L. 2002. "The development of the seed industry under globalization." In *Globalization and the Developing Countries: Emerging Strategies for Rural Development and Poverty Alleviation*, edited by D. Bigman, 201–217. Wallingford: CABI International.

Morris, M. L. 1998. "Thailand country case study." In *Maize Seed Industries in Developing Countries*, edited by M. L. Morris, 269–83. Colorado: Lynne Rienner Publishers, Inc.

National Corn and Sorghum Research Center. 2013. *Inbred varieties transfer statistics, 1999–2012*. Unpublished data.

Office of Agricultural Economics. 2013a. *Agricultural products forecast, 2012/13 crop year.* www2.oae.go.th/mis/Forecast/02_journal/forecast3-2555.pdf.

Office of Agricultural Economics. 2013b. *Maize area, outputs, and yield, 1996–2010.* Bangkok: Center for Agricultural Information. Unpublished data.

Office of Agricultural Economics. 2013c. *Maize production area by provinces 2013.* Bangkok: Center for Agricultural Information.

Office of the Council of State. 1999. *Plant Protection Law B.S. 2542*.

Office of the Council of State. 1964. *Plant Quarantine Act B.S. 2507*.

Pongsroypech, C. 1994. "Hybrid maize and sorghum development in Thailand." In *Hybrid Research and Development Needs in Major Cereals in the Asia-Pacific Region*, edited by R. S. Paroda and M. Rai, 193–209. Bangkok: FAO Regional Office, FAP RAPA Publication.

Poolsawas, S., and O. Napasintuwong. 2013. "Farmer innovativeness and hybrid maize diffusion in Thailand." *Journal of International Agricultural and Extension Education*. 20 (2): 51–65.

Preechajarn, S. 2013. *Thailand Agricultural Biotechnology Annual, 2013*. GAIN Report Number: TH3062. USDA Foreign Agricultural Service.

Richmond, D. D. 2013. *Agribusiness public-private partnerships: A country report of Thailand.* Country case studies—Asia. Rome: Food and Agriculture Organization.

Sangwansupyakor, C., M. Thongjium, M. Pileuk, and S. Sukprakarn. 2003. *The seed industry in Thailand*. Asia and Pacific Seed Association Country Report No. 28. Report presented at Asian Seed 2003, Bangkok, Thailand, November.

Scherer, F. M., and D. Ross. 1990. *Industrial market structures and economic performance*. Boston: Houghton Mifflin.

Seed Association of Thailand. 2013. *Roles of SAT.* www.seed.or.th/english/eng_intro.htm.

Seed Association of Thailand. 2007. *Seed industry in Thailand: 2004–2006.* www.seed.or.th/english/eng_index.html.

Sriwatanapongse, S., S. Jinahyon, and S. K. Vasal. 1993. *Suwan-1: Maize from Thailand to the world*. Mexico, D.F.: CIMMYT.

Suwantaradon, K. 2001. *Two Decades of Hybrid Maize Seed Business in Thailand.* Proceedings of the 30th National Corn and Sorghum Research Conference, Ubon Ratchathani, Thailand. (in Thai).

Suwantaradon, K. 1989. *Maize and Sorghum Seed Business.* Proceedings of the 20th National Corn and Sorghum Research Conference, Bangkok, Thailand, August 23-25. (in Thai).

Suwantaradon, K., P. Pongpanich, S. and Jampatong. 2012. "Three decades of maize hybrid seed business in Thailand." *Khong Kaen Agriculture Journal.* 40 (4): 16–30. (in Thai).

Suwantaradon, K., P. Saraisawas, P. Kaewplug, O. Distaporn, and S. Waiyavute. 2010. *Seed industry situation in Thailand*. Report submitted to National Science and Technology Development Agency. Seed Association of Thailand. (in Thai).

Thai Seed Trade Association. 2013a. *Database of traded seeds registered at Agricultural Regulatory Office, Department of Agriculture.* www.thasta.com/product/search.asp. (in Thai).

Thai Seed Trade Association. 2013b. *Quantity and value of controlled seed exports for trade—calendar year 2012.* www.thasta.com/statistics.asp. (in Thai).

About the Author

Orachos Napasintuwong is a faculty member of Economics in the Department of Agricultural and Resource Economics at the Kasetsart University, Bangkok, Thailand. [Email: Orachos.n@ku.ac.th]

Acknowledgment

This paper is based on research supported by the International Food Policy Research Institute's facilitation of ReSAKSS's "Initiative on the Role of Fertilizer and Seeds in Transforming Agriculture in Asia" project. Special thanks go to Dr. Sutat Sriwatanaponge, Dr. Kriangsak Suwantaradon, Dr. Taweesak Pulam, Dr. Pichet Krudloyma, Dr. Sansern Jampatong, Associate Professor Sanit Kaoian, and all maize seed companies for their invaluable information. I would also like to thank Dr. David Spielman for his suggestions for the analysis of the paper.

INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE
A member of the CGIAR Consortium | A world free of hunger and malnutrition
2033 K Street, NW | Washington, DC 20006-1002 USA
T: +1.202.862.5600 | F: +1.202.467.4439
Email: ifpri@cgiar.org | www.ifpri.org
www.ReSAKSS-Asia.org

This publication has been prepared as an output of the ReSAKSS Asia, which is facilitated by IFPRI. It has not been peer reviewed. Any opinions stated herein are those of the author(s) and are not necessarily representative of or endorsed by the IFPRI.