Development and Concentration of Maize Seed Market in Thailand

Orachos Napasintuwong

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ABSTRACT

Today Thailand is the second largest field crop seed exporter in Asia with maize contributing the highest value to seed exports. Hybrid maize is considerably adopted in Thailand mainly due to the demand from feed industry and development of livestock and poultry industry. The success of varietal development of commercial maize hybrids is owed to the investments of international donors during the 1980s and continuous breeding efforts of multinational seed companies even as public institutions played a key role in maintaining genetic resources conservation and pre-commercial lines research. This paper reviews the history of research and development in maize and maize seed market development in Thailand. Furthermore, expert elicitation method is used to reveal the adoption of commercial maize varieties in 2013/2014 cropping seasons. The results of adopted maize varieties were used to estimate market shares and suggested that maize seed market in Thailand is moderately concentrated with tendencies towards oligopolistic competition.

***Keywords**:* seed industry, maize, market structure, agricultural research

JEL: Q16, Q13, L1

Introduction

In 2013, Thailand ranked 29th among the maize producers in the world (FAOSTAT 2016). In that year maize was cultivated in 1.179 million hectares producing 5.09 million tons or 4.317 tons/ha. In 1983 when the first hybrid maize was introduced by the National Corn and Sorghum Research Center (NCSRC), the cultivation area was 1.69 million hectares producing 3.55 million tons or 2.113 tons/ha. This remarkable increase (40%) in production and a doubling of yields in three decades is due to investments in research and development that have made Thailand one of the most important countries for maize production in Southeast Asia. About a decade after hybrids became available, the same time as the release of single-cross hybrids by private companies in the early 1980s, the adoption of hybrid maize dramatically increased. Today more than 98% of the maize cultivation area is planted to hybrid varieties.

The success of commercial maize hybrid varietal development is owed to the investments of international donors during the 1980s and continuous breeding efforts of multinational seed companies even as public institutes played the significant role of maintaining genetic resources collection and basic research. The majority of maize varieties used in Thailand are commercialized by a few large multinational companies. The small local companies rely primarily on a few improved varieties from public research programs.

Thailand is the 31st largest field crop seed exporter in the world and the 2nd largest in Asia after China (International Seed Federation, 2016). In 2013, Thailand used about 24,133 tons of maize seed (FAOSTAT, 2016) and exported about 20,800 tons of maize seed valued at 70.14 million USD, beating out seed of all other crops (Thai Seed Trade Association, 2015). Thailand's is also one of the most advanced seed industries in Southeast Asia having integrated both public and private sectors in research, development and marketing. Building on this success, the Thai government aspires to become the region's premier "Seed Hub". The National Center for Genetic Engineering and Biotechnology, Ministry of Agriculture and Cooperatives, and Thai Seed Trade Association are central to this effort, channeling investments in R&D and strengthening public private partnership to maintain Thailand's leadership in the regional seed market.

In order to understand the success of the advanced commercialization, the history of maize varietal development in Thailand is reviewed. It is important to accurately describe and explain the structure of the seed industry in order to imply appropriate policy measures aligning the "Seed Hub" policy. The collection of maize germplasm and its adoption may imply the competitiveness of the seed companies from their breeding efforts, and since farmers generally replace hybrid seeds every cropping season, the adoption of hybrid varieties may also be used to imply the market share of individual seed company. The main objective is to use expert elicitation method to reveal the adoption of commercial maize varieties available in the market. This method is relatively easy to implement, low-cost, and can be used to regularly update the estimate of varietal adoption (Maredia & Reyes, 2014). Earlier study found that the maize seed industry in Thailand is oligopolistic and moderately concentrated (Napasintuwong, 2014). In her study, the data from estimated sales of the five largest maize seed companies in Thailand were used to calculate the market shares, which in turn are used to calculate the four firms' concentration ratio (CR_4) and the Herfindahl-Hirschman Index (HHI). Because the market share

calculated from sales may not completely reflect the market concentration as most of multinational seed companies are highly integrated with agbiotech and agchemical companies (Spielman et al., 2014), this study provides an alternative measurement of market shares from the resulting collection of most adopted maize varieties from expert elicitation.

Maize varietal development in Thailand

Maize was introduced into Thailand by Portuguese during the 16th century (Morris, 1998). Only after the introduction of two yellow dent varieties from North America, "Nicholson's Yellow Dent" and "Mexican June", in 1932, the commercial production of maize has started in the Northeast Thailand (Sriwatanaponge et al., 1993). Maize was only consumed as snack during that time, and constrained by limited demand and cultivation. There was no maize variety improvement research in Thailand until the early 1950s by the Department of Agriculture (DOA), and Kasetsart University, the largest and oldest agricultural school in Thailand. Several organizations were involved in the early development of maize breeding program, but mainly international organizations and public institutes. Variety improvement research during the early period focused on hybrid development. Under Kasetsart University-Oregon State University collaboration with the aid from U.S. International Cooperation Administration (ICA) (presently USAID) under U.S. Oversea Mission (USOM), several U.S. hybrids were tested during 1958-1959 (Sriwatanaponge, 2014). Unfortunately none was adaptable to Thailand's production condition and because the seed of parental lines could not be reproduced, the research was discontinued. In 1951, the DOA brought a maize variety developed in Guatemala from a composite of Caribbean collections known as "Guatemala" (Tequisate Golden Yellow Flint) by the late I.E. Melhus, Professor Emeritus at Iowa State University by USAID staff in Indonesia. "Guatemala" was tolerant to some diseases and insects, had good grain texture (flint), acceptable color (orange yellow), and showed broad adaptation in Thailand (Sriwatanaponge, et al., 1993). During 1953-1954, "Guatemala" was promoted to farmers by the DOA, and had been widely adopted. Phra Phutthabat Research Station in Saraburi Province was the main research station for breeding of the DOA. It was built in 1955, but the research practically started in 1959. In 1961, the DOA's maize breeding program continued using this variety as a base for stratified mass selection at Phra Phutthabat Research Station. Between 1961 and 1974, there were 12 "Phra Puttabat" varieties developed at this station, but one of the most successful ones due to its high yielding quality "Phra Puttabat-5" was developed in 1966. In 1969 "Phra Puttabat-5" was promoted to farmers and was well-accepted until the devastation of sorghum downy mildew disease around 1971 (National Corn and Sorghum Research Center, 1993). Subsequent varieties to "Phra Puttabat-5" continued to use the name "Phra Puttabat-5" for ease of farmers' promotion.

Following an intensive review in 1960, Kasetsart University began to focus its efforts on developing open-pollinated varieties (OPVs). Many tropical varieties and collections of International Maize and Wheat Improvement Center (CIMMYT) and Rockefeller Foundation precedence were received from Mexico and India, and composites were obtained from the Philippines, Taiwan and Indonesia (Sriwatanaponge, et al., 1993). In 1960, by the invitation from Director of the DOA, the Rockefeller Foundation sent Dr. E.J. Wellhausen and Dr. E.W.

Sprague who had maize breeding experience in Latin American and other developing countries to develop a maize program in Thailand (Sriwatanaponge, 2014). In 1962, Ministry of Agriculture, Kasetsart University and Rockefeller Foundation established "Coordinated Project for Corn Improvement Program". The research under this program was conducted at Kasetsart University's research station in Nakhon Ratchasima province and the DOA's Phra Phutthabat Research Station. The Rockefeller Foundation whose office was in India at that time made it official to support the maize breeding program in Thailand by emphasizing on supporting university research. Under the Rockefeller Foundation's support, the National Corn and Sorghum Research Program was initiated in 1963. In 1966, the Rockefeller Foundation established the headquarters of its Inter-Asian Corn Program (IACP) in Thailand (Morris, 1998). The IACP was a regional collaborative research involving the exchange of germplasm, conferences, and training of experts in Asia. Under IACP, Kasetsart University research station in Nakhon Ratchasima province covering 368 hectares, commonly known as "Suwan Farm" was transformed into a suitable field with irrigation facilities to hand three crops per year, including laboratory, dormitory, staff housing, and offices. In 1969, the National Corn and Sorghum Research Center (NCSRC) was established at Suwan Farm of Kasetsart University to be the research center for both the Thailand National Corn and Sorghum Program and the IACP. The effort of NCSRC was to develop improved varieties using "Guatemala", but turned out to be unsuccessful due to limited genetic diversity. As a result, NCSRC gathered maize varieties and cultivars from around the world during the 1960s, and resulted in Thai Composite #1, a population comprising 36 germplasm sources from maize varieties and cultivars: 16 from the Caribbean Islands, six from Mexico and Central America, five from South America, and four from other areas (Sriwatanapongse et al., 1993). The research continued to improve Thai Composite #1 for yield and other agronomic characteristics during the early 1970s.

During those years, there was a devastation of sorghum downy mildew disease caused by fungus *Peronosclerospora sorghi*, a disease that could reduce susceptible varieties to 80-100% (Morris, 1998; Sriwatanaponge, et al., 1993). The disease continued rapidly and severely throughout the early 1970s. This threat for maize production resulted in a focus on the development germplasm resistant to sorghum downy mildew disease. In 1970, the DOA brought "Tainan #10" from Taiwan and "Bogor Syn 2" from Indonesia to solve the sorghum downy mildew problem; however, due to their weak resistance to the disease, the varieties did not continue (National Corn and Sorghum Research Center, 1993). In 1974, NCSRC successfully developed "Suwan-1" also known as Thai Composite #1 DMR BC3 (S) C2, the first improved downy mildew resistant OPV, the first official maize variety developed by Thai scientists (Sriwatanapongse et al., 1993), and the only registered variety under the cooperative effort by Kasetsart University, the DOA, and the Rockefeller Foundation. Suwan-1 was developed from a cross between Thai Composite #1, and downy mildew-resistant (DMR) sources from the Philippines: Philippines DMR #1 and Philippines DMR #5 (Ekasingh et al., 1999). During the early years, the production of breeder seed of Suwan-1 was led by Kasetsart University and the DOA while the Department of Agricultural Extension (DOAE) was responsible for foundation seed, certified or extension seed production. Suwan-1 was rapidly adopted by farmers due to its high yielding characteristic, and most importantly downy mildew resistance. It is well-documented that Suwan-1 has been introduced in the breeding programs in Thailand and by

CIMMYT and other collaborators in Southeast Asia and many other countries as a source of high yielding and downy mildew resistance (Ekasingh et al., 1999; Lopez-Pereira & Morris, 1994; National Corn and Sorghum Research Center, 1993; Sriwatanapongse et al., 1993; Sriyisoon et al., 1998). The NCSRC used Suwan-1 to create several inbred lines under the name "Kasetsart Inbred or Ki". The Ki inbreds were released to seed companies for commercial purposes. Thailand maize program continued to use Suwan-1 in developing composites and hybrids such as early public OPV releases including Suwan-2 in 1979, Suwan-3 in 1987, and Suwan-5 in 1993 by NCSRC, and Nakhon Sawan-1 (NS-1) in 1989 by the DOA. These varieties have dominated the market until 1990 (Ekasingh et al., 1999).

The hybrid maize breeding program in Thailand started in the late 1970s. The NCSRC's hybrid maize breeding program of Kasetsart University was initiated in 1978, and private seed companies started their hybrid breeding programs a few years later (Ekasingh et al., 1999). 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). Suwan-2301 a cross between two inbred lines: Ki 3 and Ki 11, was the first hybrid that has high-yielding, drought tolerant and good adaptation characteristics. CIMMYT also used Suwan-2301 as germplasm for drought tolerant during that time (National Corn and Sorghum Research Center, 1993).

During the late 1970s to 1980s, the demand for maize increased dramatically due to increased demand for feed in the domestic poultry and livestock industry. Bangkok Seed Industry, the leading agricultural company, under Charoen Pokphand Group, the largest livestock and feed industry in Thailand and a joint venture with Dekalb AgResearch, had planned to backward integrate to maize production and hybrid maize seed production. Due to high demand of Suwan-1 seed and limited capacity of the public sector for seed production and distribution, prior to the release of hybrid maize seed, Bangkok Seed Industry started commercializing Suwan-1 seeds in 1979 in hope to educate farmers the differences between seed and grain, and benefits of certified seeds compared to saved seeds. This marked the R&D of hybrid maize by private sector. Charoen Seeds was responsible for R&D of hybrid maize while Bangkok Seeds Industry was responsible for production, marketing and distribution (Sriwatanaponge, 2014). Charoen Pokphand Group released its first commercial hybrid maize, CP-1, from Suwan-1 germplasm in the early 1980s.

Several multinational companies such as Pacific Seeds, Cargill Seeds, Pioneer Hi-Bred, and Uniseeds had established their subsidiaries in Thailand in the late 1970s and early 1980s (Suwantaradon, 1989). In 1981 private companies started commercial trials of hybrid maize varieties (Pongsroypech, 1994). The adoption of hybrid varieties was slow during the early years due to unsurpassed yield benefits to the existing OPVs and much higher seed price. The adoption of hybrid maize dramatically increased after the release of single-cross CP-DK888 by C.P. Seeds (Charoen Pokphand Group) in 1991 (Suwantaradon, 2001). Due to its uniformity and high yielding, CP-DK888 was popular among farmers since its release and is still in use today. CP-DK888 was preferred by Charoen Pokphand Feed Industry due to its orange-yellow color and less vulnerable to ear rod problem. It was noted that during its peak of adoption, Charoen Pokphand Feed Industry offered price premium for CP-DK888 due to its intense color. Other

companies also released single-cross hybrids, and the increase in competition among seed firms provided farmers with more alternatives. In 1990, Pacific Seeds released PAC11, a double cross hybrid. In 1991, C.P. Seeds and Uniseeds released CP-DK818, a double cross, and Uniseeds38, a three way cross, respectively. From the mid-1990s, single-cross hybrids became important due to its higher yield potential and promotion efforts by the seed companies, Kasetsart University, and the DOAE. Single-cross hybrid seed demand was about 79% of total hybrid seed demand and about 56% of total maize seed demand in 1996 (Aekatasanawan et al., 1998). As the opportunity to make profit arises from adoption of hybrid varieties, several private companies focus their research on hybrid variety improvement.

Two public institutes that have played important role in maize breeding research are Kasetsart University (through National Corn and Sorghum Research Program) and Nakhon Sawan Field Crop Research Center (under the DOA) which became more active in maize breeding research than Phra Phutthabat Research Station after 1984 (P. Grudloyma, personal communication, May 28, 2015). After the establishment of IACP in Thailand, the support of Rockefeller Foundation via IACP was prominent during the 1960s. However after Dr. E.W. Sprague, who was the Director of corn program of the Rockefeller Foundation in Thailand, left to join CIMMYT in Mexico in 1969, the support of the Rockefeller Foundation in maize breeding was through CIMMYT (S. Sriwatanaponge, personal communication, May 14, 2015). Until the 1980s, Kasetsart University and the DOA have had a close collaboration with CIMMYT. However, after 1984 when CIMMYT moved the office from Suwan Farm to the DOA, the role of CIMMYT in Kasetsart University's research program became less important, but continued to a good extent with DOA. Aside from Suwan-1, public maize breeding research extensively use of germplasm obtained various other sources outside the country such as CIMMYT. The CIMMYT germplasm was used in developing several public varieties, namely CIMMYT's POP 28 in developing DOA's NS-1 hybrid in 1989, and NCSRC's Suwan-5 in 1993 (Ekasingh, 1999). Lopez-Pereira and Morris (1994) noted that since the Rockefeller Foundation breeding program essentially was transformed into CIMMYT in 1966, it was reasonable to classify those materials developed prior to the establishment of CIMMYT as CIMMYT materials. Thus, materials developed during the 1960s by the Rockefeller Foundation-supported scientists, particularly Suwan-1 materials in Thailand, were classified as public materials using some CIMMYT germplasm (Lopez-Pereira and Morris, 1994). Given this classification, it was reported that between 1966 and 1990, 60% of varieties released by private companies contained CIMMYT germplasm. Because CIMMYT materials essentially were not well-adapted to local conditions, by the 1990s, CIMMYT materials were used less by private companies in Thailand while Suwan-1 was still used extensively for breeding (Ekasingh et al., 1999). In 1990, maize planted areas under public materials were 92% while 8% were of private materials (Lopez-Pereira and Morris, 1994). Recently, there is no official report of local varieties or OPVs adoption, but about 6,000 hectares of pubic hybrid varieties (0.5%) and 1.157 million hectares of private hybrid varieties (99.5%) (Office of Agricultural Economics, 2013). The role of CIMMYT in Thailand became negligible after it moved the office from Thailand to Nepal in 2000 and eventually to India (S. Sriwatanaponge, personal communication, May 14, 2015; P. Grudloyma, personal communication, May 28, 2015).

In 1997, Kasetsart University announced the policy for private seed companies to access Ki inbred lines and parental lines of maize developed by the NCSRC. The announcement addressed the royalty fee of the use of germplasm for commercial purposes (Aekatasanawan et al., 1998). The licensing of NCSRC has been non-exclusive, except for a short period of time during 1998-1999 that it granted one exclusive licensing to a private company. Since the exclusively licensed variety did not perform well in the market, it was discontinued in a few years. Commercial hybrids were also used as source materials from which inbred lines can be extracted (Morris, 1998) including the development of Ki21 which was developed from Pacific 9 hybrid (Aekatasanawan et al., 1998) and the development of NS-3, the only public hybrid variety significantly adopted today. Until now NCSRC has released 60 Ki inbred lines for large multinational companies and SMEs, including foreign and domestic companies, and several "Kasetsart elite index or Kei" were released to SMEs who have lower capacity for R&D at lower prices (S. Jampatong, personal communication, July 15, 2015). On the contrary, the DOA released inbred lines of the approved hybrid varieties only. As of today, the DOA only released inbred lines of approved hybrid varieties: Takfa-1, Takfa-2, and Takfa-3, the parental lines Nakhon Sawan 2 (NS-2) and Nakhon Sawan 3 (NS-3) single-cross hybrids. This implies that non-exclusive licensing of public hybrid varieties would create reluctance to the large companies, particularly those who have high research capacity, to produce and sell public hybrid seeds while small companies with limited research capacity will gain the access to produce the non-exclusive licensed public hybrid seeds.

One important success of hybrid maize development in Thailand is the collaborative research between public and private sectors through the Cooperative Hybrid Corn Yield Trial, also known as Public-Private Yield Trial, which has been carrying out since 1987 until today. The program aims at evaluating the progress of yield improvement of the elite maize hybrids through the support of the NCSRC and the DOA (Aekatasanawan et al., 1998). The multi-station yield trials were organized to compare hybrids or elite lines of the NCSRC, the DOA and private companies who have research stations in Thailand. The trials are conducted at Suwan Farm, Nakhon Sawan Field Crop Research Center, Chiangmai University, Maejo University, and the rest are at the research stations of each company who submitted hybrids or elite lines throughout the country. The results of yield trials revealed potential and progress of hybrid maize breeding in Thailand. In addition, the DOA also accommodates the trials of hybrids at no charge. The DOA's trials are conducted at Suwan Farm and three DOA's research centers: Nakhon Sawan Field Crop Research Center, Phetchabun Field Crop Research Center, Lop Buri Agricultural R&D Center. The submission of elite lines for yield trials to DOA does not limit to the companies who have research stations in Thailand.

Napasintuwong (2014) found that the maize seed industry in Thailand is moderately concentrated by a few large multinational firms with access to proprietary breeding lines and advanced technologies developed in their global operations, and operate alongside several small- and medium-sized enterprises (SMEs). Thus, to prevent the monopoly power of large multinational firms, recently there are a few public programs aiming at promoting the use and production of public hybrid variety, namely NS-3, so that SMEs and local communities could provide public variety seed at lower price. Except for developing public hybrid variety such as

NS-3, today the role of the public sector does no longer focus on releasing new hybrid varieties, but providing inbred lines to the small and medium private seed companies.

Expert elicitation of maize varietal adoption

This study follows the Guidelines for Collecting Varietal Release and Adoption Data (Maredia & Reyes, 2014) built on methods used to compile information on varieties by the DIIVA and TRIVSA projects to collect perceived varietal adoption at the national level of maize in Thailand using expert elicitation method. Prior to the expert elicitation meeting, the information on maize cultivation areas was collected to classify agroclimatic cultivation regions (domains). Individual experts were consulted for accuracy of current situation of commercial maize cultivation practice.

Ekasingh et al. (2004) classified the agro-ecology of maize production in Thailand into two main agro-ecozones, namely rainfed upland and rice-based irrigated. Maize cultivation areas are concentrated in the North, Northeast and parts of the Central Plains while the South is not suitable for maize cultivation due to high rainfall. Figure 1 shows the area of maize cultivation by region. A significant share of maize cultivation Northern region is attributable to upland while the majority of Northeast and Central regions are lowland; thus, it is assumed that maize cultivation in the latter two regions do not differ due to altitudes. In this study, the area of maize cultivation in Northern region is divided into upland and lowland since high and low altitudes require different suitable traits, and could affect variety development and adoption. Because there is no data on maize cultivation area by altitudes, the share of area by altitude in each Northern Province is used to estimate the cultivation area for maize in each altitude group. The rainfed upland areas cover the uplands, lower mountain slopes, foothills, and highlands with altitudes greater than 500 masl.

The cultivation of maize in Thailand can be divided into three seasons as follows:

i) Early rainy season. Land preparation and sowing in early rainy season usually starts in late-March to May after the first rain, planting is between April and before mid-June, and harvesting ranges from August to September.
ii) Late rainy season. This cropping season usually faces more risk from drought as famers wait after harvesting previous crops and until enough soil moisture content for planting. Planting starts between July and before mid-August while harvesting is usually for dry (long standing) crop between November and February.
iii) Dry season (after paddy). Planting is between October and February after rice harvest. The cultivation during this season is only possible in irrigated areas of paddy fields, and frequently fetches higher price.

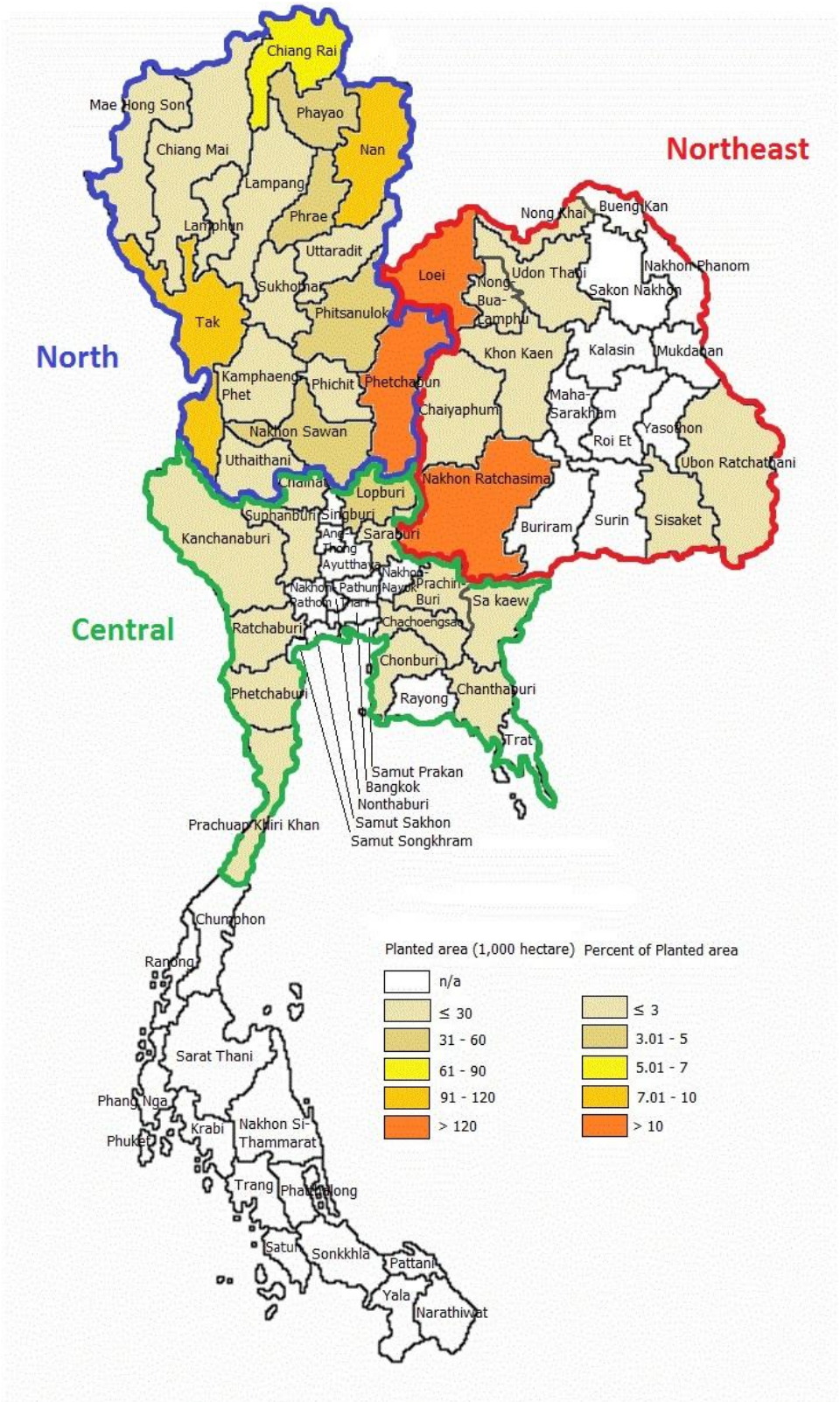

Figure 1. Thailand's maize cultivation area by region, 2012

Source: generated from Office of Agricultural Economics, 2014

Table 1 describes planted area, output and yield of maize in Thailand in 2012. About 95% of planted area and output were cultivated during the rainy season, including early and late rainy seasons. About 66% of planted area and output are located in the Northern region while the Northeast and Central regions account for 24% and 10%, respectively.

Table 1. Thailand's maize cultivation area, output, and yield, 2012

Region	Rainy season			Dry season			All seasons		
	Cultivation area (ha)	Output (ton)	Yield (ton/ha)	Cultivation area (ha)	Output (ton)	Yield (ton/ha)	Cultivation area (ha)	Output (ton)	Yield (ton/ha)
North									
Upland*	290,140.89	n/a	n/a	18,712.99	n/a	n/a	308,853.88	n/a	n/a
Lowland**	465,473.19	n/a	n/a	37,949.73	n/a	n/a	503,422.92	n/a	n/a
Total North	755,614.08	3,095,177	4.10	56,662.72	260,725	4.60	812,276.80	3,355,902	4.13
Northeast	271,637.76	1,094,936	4.03	6,172.16	26,247	4.25	277,809.92	1,121,183	4.04
Central	113,942.08	468,843	4.11	329.28	1,602	4.87	114,271.36	470,445	4.12
Total	1,141,193.92	4,658,956	4.08	63,164.16	288,574	4.57	1,204,358.08	4,947,530	4.09

Source: Office of Agricultural Economics, 2014

Note: Rainy season includes early rainy and late rainy season

* > 500 masl estimated from the percentage of upland area in each Northern province

** =< 500 masl estimated from the lowland area in each Northern province

The sub domains are classified based on region, altitude, and growing season. There are three regions (North, Northeast, and Central), two altitudes (upland and lowland, but applied only in the Northern region), and three growing seasons (early-rainy, late-rainy and dry). Since there are no data of planted area by early- and late-rainy season, but rainy season as a whole. The shares of production areas by geographical region are estimated from planted areas by region in 2012, the latest approved data (Office of Agricultural Economics, 2013). The area in the Northern region is then divided into upland and lowland areas based on the estimated area of total provincial areas above and below 500 masl in Northern provinces. Table 2 shows the shares of each subdomain.

In the second stage, twelve maize experts were invited to the elicitation group meeting: three from public research institutes, eight from private seed companies, and one independent consultant (formerly affiliated with a private company). Among the experts from private seed companies, six are from subsidiaries of foreign multinational firms, one from a Thai multinational firm, and one from a Thai medium sized local company[1]. On average, the experts have had 26 years of experience in the maize industry and about 16 years of work experience with their current affiliations. Experts were presented with the latest available secondary data on cultivation areas of maize by region, season and altitude, and are asked to agree on shares of cultivation areas by subdomains (Table 2). The coverage of adopted varieties includes those that have been developed by breeders in the formal system including the national and/or international

[1] Office of small and medium enterprises promotion (2002) classified small, medium, large enterprises as those with fixed asset < 50 million THB, 50-200 million THB, and > 200 million THB, respectively.

public and private sector research. The experts were individually asked to provide the commercial names of adopted maize varieties, and their perceptions of varietal adoption.

In the third stage, each expert was individually asked to list all the improved maize varieties he/she perceives farmers are growing in each region- season combinations per 2013/2014 cropping year. In the final stage, the experts were equally divided into two groups randomly. They were then asked to go over the results of the third stage, discuss and jointly agree on the adoption of varieties by sub-domains, and then aggregated at the national level.

Table 2. Shares of maize production area by subdomain, 2013/2014

	Season[3]			
Geographical area[1]	Early-rainy	Late-rainy	Dry	Total
North				
Upland (> 500 masl)[2]	18.716	5.640	1.282	25.638
Lowland (<= 500 masl)[2]	30.525	9.199	2.091	41.815
Total North	49.241	14.840	3.373	67.453
Northeast	16.835	5.073	1.153	23.061
Central	6.925	2.087	0.474	9.486
Total	73.000	22.000	5.000	100.000

Note: [1]Calculated from Office of Agricultural Economics, 2013

[2]Calculated from Office of Agricultural Economics, 2014 and Highland Research and Development Institute, 2015

[3]The shares of early-rainy, late-rainy and dry seasons of whole country are provided by the experts

Seed market concentration

Market concentration

The concentration of the maize seed industry could be represented by the four firms' concentration ratio (CR_4), a measurement of total market share of the four largest companies, and the Herfindahl-Hirschman Index (HHI), a measurement of the size of the firms in relation to the industry (Dunning & Lundan, 2008). These two indicators are commonly used to analyze market concentration (Spielman & Kennedy, 2016). The information collected on adopted commercial maize varieties can be used to describe the seed market concentration. The share of sales and production of each company can be estimated from the area of adoption provided that the price and seed rate of hybrid maize are comparable across adopted varieties. The average seed rates of hybrid maize in Thailand is 18.75 kg/ha (Napasintuwong, 2014), and seed price is between 120 and180 baht/kg. As the industry consists of multinational firms, the concentration ratio reflects the shares of production and sales in Thailand only. It does not take into account the competition from producers for the export market.

$$CR_4 = \sum_{i=1}^{4} S_i$$

$$HHI = \sum_{i=1}^{N} {S_i}^2$$

where S_i is the company *i*'s market share of the industry total sales revenue

N is the number of companies in the market

The larger the concentration ratio of four largest firms, the more concentrated is the industry. If the market is concentrated toward a monopoly, the concentration ratio will approach 100%. If the market consists of a large number of small firms, the concentration ratio will approach zero. The U.S. Department of Justice guidelines for antitrust considers HHI below 1000 as unconcentrated, between 1,000 and 1,800 points to be moderately concentrated, and considers markets in which the HHI is greater than 1,800 points to be highly concentrated (U.S. Department of Justice, 2015).

Results and Discussion

The results of expert elicitation reveal 20 most adopted maize varieties during 2013/2014 cropping season (Table 3). The only variety registered in this list is Nakhon Sawan 3 developed by DOA, and the rest have not been registered for plant variety protection nor as approved variety. Based on these results, the varieties were grouped by companies and the shares of maize seed production and sales, by company, were estimated from the area of adoption provided that the price and seed rate of hybrid maize are comparable across adopted varieties. The average seed rate of hybrid maize in Thailand is 18.75 kg/ha (Napasintuwong, 2014), and seed price of major seed companies rages between 120 and180 baht/kg; thus, it is assumed that the price is not significantly different. The estimated shares of seed sales by company are presented in Figure 2.

The largest shares of most adopted varieties belong to five companies: Charoen Pokphand (CP), Monsanto, Pacific Seeds, and Syngenta, and Pioneer Hi-Bred, covering about 75% of the market. Although CP takes the largest share of sales, it is observed that these varieties were exclusively licensed from Monsanto which imply that the sales of CP may be overestimated while Monsanto's sales is most likely underestimated. The 6th largest share of adopted variety belongs to Seed Asia, a medium-sized local company that has about 3% of the market share. The DOA has the 7th largest share of adopted variety. Although the DOA owns the property right of Nakhon Sawan 3 variety, it is a public variety and the government does not collect any royalty fee. The DOA sells parental lines of NS-3 on a limited supply, and the production and distribution of Nakhon Sawan 3 are operated by numerous small- and medium-sized local companies, including agricultural cooperatives and farmer groups.

Table 3. Top 20 adopted maize varieties in Thailand identified in expert elicitation, 2013/14

Modern Variety (MV) as identified in expert elicitation	Company	Total sown area (ha)	% Area adopted under the variety by expert elicitation
C.P.888*‡	CP	105,260.90	8.74
DK9901	Monsanto	102,852.18	8.54
S7328	Syngenta	100,925.21	8.38
30B80	Pioneer Hi-Bred	86,593.35	7.19
Pacific 339	Pacific Seeds	86,111.60	7.15
C.P.888 New*	CP	61,301.83	5.09
C.P.801*	CP	60,338.34	5.01
DK7979	Monsanto	56,363.96	4.68
Pacific 999	Pacific Seeds	41,911.66	3.48
Pioneer 4546 (P4546)	Pioneer Hi-Bred	39,623.38	3.29
DK9955	Monsanto	39,141.64	3.25
TF222	Seed Asia	38,900.77	3.23
S6248	Syngenta	31,313.31	2.60
Nakhon Sawan 3†	DOA	26,977.62	2.24
Pacific 777	Pacific Seeds	24,207.60	2.01
DK6919	Monsanto	22,641.93	1.88
NK48	Syngenta	18,787.99	1.56
DK6818	Monsanto	14,693.17	1.22
C.P.301*	CP	12,404.89	1.03
P4311	Pioneer Hi-Bred	5,901.35	0.49
Other modern varieties	-	221,601.89	18.40
Local Varieties	-	6,021.79	0.50
Total	-	1,204,358.08	100.00

*Exclusively licensed by Monsanto
‡ Previously called CP-DK888
† DOA sells parental lines to local companies without royalty fee

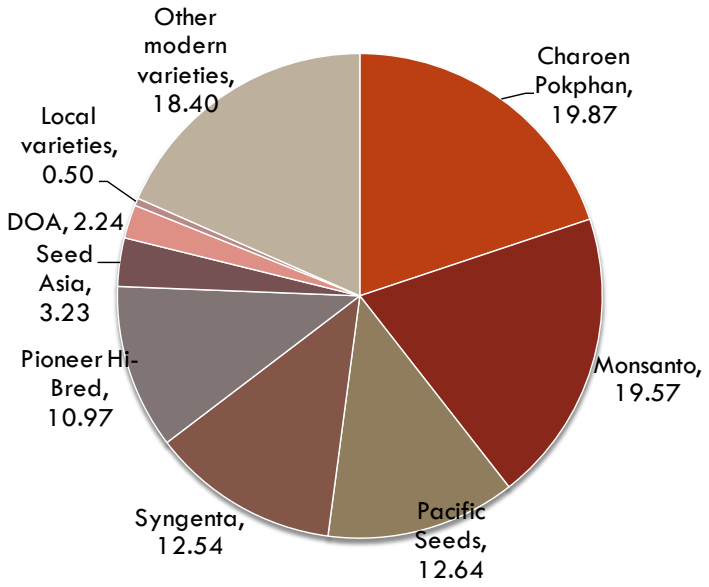

Figure 2. Share of top 20 adopted commercial maize varieties in Thailand by company, 2013/2014

The estimates of CR_4 and HHI from the top 20 adopted varieties are approximately equal to 65%, and 1,230, respectively. It is most likely that the rest of 18.4% of other adopted varieties belong to four largest firms; thus, the estimated CR_4 and HHI values from this method probably underestimate the concentration of the market. Nevertheless, the results suggest that the maize seed market in Thailand is oligopolistic and moderately concentrated. Similar results of market concentration of Thailand's maize seed industry were reported by Napasintuwong (2014). Her results show the estimates of CR_4 and HHI i.e. 76% and 1,700, respectively, and also suggested that the industry is oligopolistic and moderately concentrated.

Conclusion

The review of development in maize seed market in Thailand explains the history of germplasm collection and development of commercial maize varieties. Expert elicitation method was used to reveal adopted maize varieties during 2013/2014 cropping seasons. Given that the area of hybrid maize adoption in Thailand covers nearly all the production area, and farmers replace hybrid seeds every cropping season, the adopted areas were used to make implicit estimates of market shares of seed companies. The maize seed market concentration was estimated from the shares of sales of most adopted varieties which are used to estimate the HHI and CR_4. Although this method depends largely on the experts' opinion and requires that the seed rate and seed price of the top varieties are nearly the same, it is less costly than a farm survey and could reflect the market concentration more precisely when the sales of integrated seed companies are difficult to identified. It is found that maize seed market is moderately concentrated and has oligopolistic behavior. This result is consistent with the earlier study that uses sales of seed companies to calculate the same indices. The information about adopted varieties i.e. similarity and differentiation of seed characteristics and prices, and number of

suppliers of other varieties not on the top list may further be analyzed to comprehensively reveal the market competition.

References

Aekatasanawan ,C., Jampatong, S., Aekatasanawan, C., Chulchoho, N., & Balla, C. (1998). Supporting the Hybrid Maize Breeding Research in Thailand. In S. K. Vasal, G. Gonzalez Ceniceros, & F. Xingming (Eds.), *Proceeding of the 7th Asian Regional Maize Workshop,* Los Banos, Philippines, February 23-27, 1998 (pp. 82-91).

Dunning, J. H., & Lundan, S.M. (2008). Multinational enterprises and the global economy (2nd ed). Cheltenham: Edward Elgar.

Ekasingh, B., Gypmantasiri, P., Thong-ngam, K., & Grudloyma, P. (2004). Maize in Thailand: Production systems, constraints, and research priorities. Mexico D.F.: CIMMYT.

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

FAOSTAT. (2016). Maize production statistics. Food and Agriculture Organization of the United Nations. Statistics Division. Retrieved from http://faostat3.fao.org

Highland Research and Development Institute. (2015). Provincial areas above and below 500 masl. Un-published data (in Thai)

International Seed Federation. (2016). Field seeds exports 2013. Retrieved from http://www.worldseed.org/resources/seed-statistics/

Lopez-Pereira, M.A., & Morris, M.L. (1994). Impacts of international maize breeding research in the developing world, 1966-1990. Mexico D.F.: CIMMYT.

Maredia, M., & Reyes, B. (2014). Guidelines for collecting varietal release and adoption data**.** Objective 2.1 Organizing the collection of crop germplasm improvement research related direct outcomes. Strengthening Impact Assessment in the CGIAR (SIAC), 2013-2016. Retrieved from http:// impact.cgiar.org/sites/default/files//docs/Guidelines-SIAC21-Activity_v7-4-25-14.pdf

Morris, M.L. (1998). Thailand country case study. In M.L. Morris (Ed.), *Maize seed industries in developing countries* (pp. 269–283). Colorado: Lynne Rienner Publishers, Inc.

Napasintuwong, O. (2014). Maize seed industry in Thailand, development, current situation, and prospect. ResAKSS Asia (Facilitated by IFPRI), Working Paper o4, November 2014. Retrieved from http://ebrary.ifpri.org/cdm/singleitem/collection/p15738coll2/id/128923/rec/16

National Corn and Sorghum Research Center. (1993). Suwan 1: Outstanding maize variety of Thailand. Bangkok: Kasetsart University. (in Thai)

Office of Agricultural Economics. (2014). Maize production data. (in Thai) Retrieved from http://www.oae.go.th

Office of Agricultural Economics. (2013). Maize planted area, harvested area, output, and yield, 2010-2012. Bangkok: Center for Agricultural Information. Un-published data (in Thai)

Pongsroypech, C. (1994). Hybrid maize and sorghum development in Thailand. In R.S. Paroda, & M. Rai (Eds.), *Hybrid research and development needs in major cereals in the Asia-Pacific region* (pp. 193-209). FAP RAPA Publication: 1994/21. Bangkok: FAO Regional Office.

Spielman, D. J., & Kennedy, A. (2016). Towards better metrics and policymaking for seed system development: Insight from Asia's seed industry. *Agricultural Systems*, 147, 111-122.

Spielman, D. J., Koladay, D. E., Cavaliera, A., & Chandrasekhara Rao, N. (2014). The seed and agricultural biotechnology industries in India: An analysis of industry structure, competition, and policy options. *Food Policy*, 45, 88-100.

Sriwatanapongse, S. (2014). Maize in Thailand: Origin and development. Kasetsart University Knowledge Repository E-book. Office of the University Library, Kasetsart University (in Thai). Retrieved from http://kukr.lib.ku.ac.th/db/kukr/search_detail/result/285721

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

Siryisoon, W., Pulam, T., Prasatsrisupab, T., & Suwantaradon, K. (1998). Public and private partnership in hybrid maize research: Issues and concerns. In S.K. Vasal, G. Gonzalez Ceniceros, & F. Xingming (Eds.), *Proceeding of the 7th Asian Regional Maize Workshop*. Los Banos, Philippines. February 23-27, 1998, 78-81.

Thai Seed Trade Association. (2015). Quantity and value of controlled seed exports 2015 (in Thai). Retrieved from http://www.thasta.com/web/

U.S. Department of Justice. (2015). Concentration and market shares. Retrieve from https://www.justice.gov/atr/15-concentration-and-market-shares

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