泰国玉米生产和遗传改良研究

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摘 要:玉米是泰国一种重要的谷类作物。2000年种植面积估计为1.30百万公顷,籽粒产量约4.48百万吨。杂交种种植面积占到玉米总面积的85.08%,以单交种类型为主,占到杂交种各种类型的74%,其次为三交种。玉米生产主要限制因素为病害(高粱霜霉、南方锈、茎腐、大斑、小斑病)、虫害(亚洲玉米螟)和干旱胁迫。玉米种质发展和品种遗传改良开始于1950年,主要从事单位为农业部农业厅和大学部肯色萨大学。先后育成Suwan 1、Suwan 2、Suwan 3, Nakhon Sawan 1,Suwan 5等改良群体和Suwan Complex、KS 23 broadbase syn.。并从中提取出Ki21、45、Ni1等几十个优良系,组配出Suwan 2301、3851、Nakhon Sawan 72等十多个优良杂交种。分别应用10个群体双列杂交法、顶交法和优良适应品种与外引种质杂交法等,确定了如下几个杂种优势模式:(Suwan 1, Suwan 3) × (Caripeno DMR, KS6); (Suwan 1, Suwan 3, KS6选育系) × (Ki21, Mo17衍生系); [KS 23(S)C_2, Suwan 5(S)C_3] × [Suwan 1(S)C_{11}]。

关键词:玉米 遗传改良 种质发展 杂种优势模式

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Maize Production and Research for Genetic Improvement in Thailand

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Abstract: Maize is one of major cereal crops in Thailand. In the year 2000, it was estimated that the planted area is of 1.30 million hectares and produces about 4.48 million tons. The amount of hybrid seed was 17.76 thousand tons with acquiring 85.08% of total planted area. Production constraints main were biotic and abiotic factors, involving diseases of sorghum Downy Mildew, Southern rust, Southern corn leaf blight, Northern corn leaf blight and Charcoal stalk rot and inset of the Asian corn borer, and drought stress. The maize research for germplasm development and varietal genetic improvement in Thailand was initiated by the Department of Agriculture in 1950 and Kasetsart University in 1958. Several elite populations of Suwan 1, Suwan 2, Suwan 3, Suwan 5, KS6, KS23, and Suwan-Complex were developed. The superior lines of Ki21, Ki 45, Ni1 etc and elite hybrids of Suwan 2301, Suwan 3851, Nakhon Sawan72# etc. were bred. In order to search for heterotic partners, diallel crosses of elite populations with differing in genetic background were performed by the breeding program. The several heterotic partners were determined. i.e. (Suwan 1, Suwan3) × (Caripeno DMR, KS6); (Inbred lines from Suwan 1, Suwan 3, KS6) × (Ki21, a Mol7 derivative line) and [KS 23(S)C_2, Suwan 5(S)C_3] × [Suwan 1(S)C_{11}].

Key words: maize; genetic improvement; germplasm development; heterotic partner

1 Introduction

Maize (*Zea mays* L.) is one of major cereal crops in Thailand with significant contribution to Thailand economy. In the year 2000, it was estimated that Thailand approximately produces about 4.48 million tons with the planted area of 1.30 million hectares (Table 1).

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Thailand used to be one of the major maize exporters to the world market. Approximately, one to three million tons was exported each year. Since 1987, the domestic consumption has increased rapidly due to the expanding livestock industry. Currently, all maize production was domestically used, mainly as animal feed and imports of maize were necessary in recent years. The Office of Agricultural Economics forecasts that the domestic demand will be 4.96 million tons in the year 2001. In order to meet the increasing domestic demand or even to produce for export, Thailand has to make a significant increment of maize production by raising average yield of the nation as well as expanding planted area.

2 Maize production trends

Maize production ecologies in Thailand are considered as Tropical lowland with occasionally drought stress in some growing areas. Maize was mainly grown in the rain-fed areas. Two main growing seasons are practised by maize growers. The first crop season is planted during March to July and the second crop season is planted during August to February. It was reported that 85.6% of the total maize area fell in the first crop season and 14.4% of that fell in the second crop season which covered areas that have bimodal distribution of rainfall and irrigated maize areas after the rice crop (Office of agricultural economics, 1998). The national maize growing area is based in the North (48.1%), the Northeast (26.4%), the Central (25.4%), and the South (0.1%), respectively.

During the past 10 years (1989 ~ 1998), Maize production increased at a rate of 1.70% with the production of 4.99 million tons in 1998 (Table 1). Average yields also increased at a rate of 3.96% with the yield of 3 395 kg/ha in 1998. However, the production areas declined at a rate of 2.17% with the planted area of 1.47 million hectares in 1998. The somewhat decreasing trend of growing area is due to the competition of other major crops such as sugar cane and casava. Although the growing area reduced, the production still maintained at the level of 4.0 million tons as the result of greater use of hybrid seeds and improved cultural practices. Between 1989 and 1998, both domestic consumption and maize import increased at the rate of 4.39 and 2.84%, respectively (Table 2). In contrast, maize export reduced at the rate of 28.25%. Given current trends, it is foreseeable that amounts of maize import will be increased in the near future in response to rising livestock consumption if total maize production does not climb up in a greater rate.

Table 1 Maize area, production, and average yield in Thailand from 1989 to 2000

Year	Planted area (1 million ha)	Production (1 million tons)	Yield (kg/ha)
1989	1.79	4.39	2,453
1990	1.75	3.72	2,126
1991	1.48	3.79	2,561
1992	1.35	3.67	2,719
1993	1.34	3.33	2,485
1994	1.41	3.97	2,816
1995	1.34	4.16	3,104
1996	1.39	4.53	3,259
1997	1.40	3.83	2,729
1998	1.47	4.99	3,395
increase rate (%)	-2.17	1.70	3.96
1999*	1.29	4.39	3,403
2000*	1.30	4.48	3,446

Source: Center for Agricultural Information, Office of Agricultural Economics.

* 1999 and 2000 figures are estimated.

Table 2 Domestic use, exports, and imports of maize in Thailand from 1989 to 1999

Year	Domestic use (1 million tons)	Export volume (1 million)	Import volume (1 million tons)
1989	2.900	1.226	-
1990	3.000	1.215	-
1991	3.100	0.849	0.249
1992	3.300	0.179	0.205
1993	3.200	0.125	0.010
1994	3.950	0.117	0.276
1995	4.350	0.090	0.307
1996	3.880	0.054	0.235
1997	3.950	0.074	0.229
1998	4.050	0.144	0.082
increase rate(%)	4.39	-28.25	2.84
1999*	4.00	0.05 - 0.10	0.004

Source: Bureau of Agricultural Economic Research, Office of Agricultural Economics.

* 1999 figures are estimated.

3 Production constraints

According to the Office of Agricultural Economics reports, loss of maize crop is observed every year ranging from 7 to 10%. There are several constraints affecting maize production, involving biotic and abiotic factors. Grudloyma (1998) listed important stress factors responsible for yield reduction of maize in Thailand. Among the biotic factors, Sorghum Downy Mildew, caused by Peronosclerospora sorghi Weston & Uppal, is still a major disease for maize in Thailand. The pathogen generally damages young plants of susceptible varieties and can cause yield losses as much as 80%. In areas where this disease represents a serious problem, resistant varieties or seed treatment of susceptible varieties are recommended. Some

minor foliar diseases such as Southern rust (*Puccinia polysora* Underw.), Southern corn leaf blight (*Helminthosporium maydis* Nisik. & Miyake), and Northern corn leaf blight (*H. turcicum* Pass.) are new threats for maize growers in some areas as the result of extensively growing some popular hybrids which are susceptible to these diseases. Charcoal stalk rot caused by *Macrophomina phaseolina* (Tassi) Goid. showed some economic losses in the north and northeast. For insects, Asian corn borer (*Ostrinia furnacalis*) is an important one and is recently reported causing maize losses in the north and central regions. Among abiotic stresses, drought is a serious one and it occurs frequently throughout maize growing area in Thailand. Low fertility is another abiotic stress which plays an important role in the lowering of national average yields. Farmers know the advantage of chemical fertilizer for boosting their maize yield but they still apply small amounts of fertilizer. High price of fertilizer coupled with frequent drought stress greatly affects farmers' decision for fertilizer use.

Table 3 Germplasm assembled in Thai Composite # 1 (Jinahyon, 1973)

Source	Group	Material
Caribbean Islands	Argentino	Cuba Gr.
		Cuba 11J
		Puerto Rico Gr. 1
	Tuson	Cuba 40
	Tuson – Canilla –	Cuba 1J
	Criollo – Tuson	Cuba 59
		Antigua Gr. 1
		Antigua Gr. 2
		Puerto Rico Gr. 2
		Barbados Gr. 1
		Cupurico
		Caribbean Flint Composite
		Flint Comp. Amarillo
		Comp. Caribbean Amarillo
		Tequisate Golden Yellow x Caribbean Comp.
		Tequisate Golden Yellow x Guadalupe 12D – 14D
Mexico and Central America	Tuxpeno	Veracruz 163
		Veracruz 181
		Veracruz Gr. 48
		Tamaulipas 8
	Salvadoreno	Salvadoreno Amarillo
	Argentino – Criollo	Tequisate Golden Yellow
South America	Northern Cateto	Guayana Francesca III
	Cuban Yellow Dent	Bahai III BCO
		Dentado Amarillo
	Argentino – Crillo – Tuson	Narino 330 – Peru 330 DV 103
India	Caribbean – Tuxpeno – India – USA	Composite A1
		Multiple Cross 2
		Multiple Cross 4
		Synthetic A3B
		Synthetic A11
Other	Tuxpeno – Caribbean – USA	Tuxpantigua
		Veracruz 181 x Antigua Gr. 2
		Usatigua
		Florida Synthetic

4 Public and private sector involvement on maize research

4.1 The early development of improved open-pollinated varieties

Maize was brought to Thailand some 400 ~ 500 years ago by Portuguese merchants. For centuries it was grown on a small scale for fresh ear consumption. Commercial production of maize began in 1932 when Prince Sithiporn, then the Director General of the Department of Agriculture, introduced two varieties, Nicholson's Yellow Dent and Mexican June, into Thailand. They were multiplied and subsequently distributed to northeastern of Thailand where commercial production first began. Until the early 1950s, the maize acreage was still negligible (Sriwatanapongse et al., 1993).

Maize research in Thailand was initiated by the Department of Agriculture in 1950 and Kasetsart University in 1958. These two organizations have been a core stone of maize germplasm development for Thailand. In the lack of a suitable maize cultivar for the nation, varieties were introduced from different countries and were tested at many locations. In 1953 USAID staff in Indonesia provided a variety developed in Guatemala from a mixture of two strains of maize of Cuban origin; one was a white semi-dent, and the other a golden yellow flint. This variety was known as "Guatemala" (Tequisate Golden Yellow). It demonstrated broad adaptation in Thailand. The variety Guatemala was released by the Thai Ministry of Agriculture and farmers planted it until 1974 when sorghum downy mildew became a major threat to corn production.

For Kasetsart University, during 1958 ~ 1959, its varietal genetic improvement research aimed at hybrid development. With the help from USAID under a Kasetsart-Oregon State University contract, many US hybrids were evaluated under Thailand production conditions and none proved to be adapted. The concept of utilizing hybrids was discontinued. In 1960, Kasetsart University intensively reviewed a maize breeding program and began to concentrate on devel-

oping improved, open-pollinated maize varieties with orange yellow flint kernels. In 1966, the Inter-Asian Corn Program moved the headquarters from India to Thailand. Farm Suwan, National Corn and Sorghum Research Center, was developed as a first class research station for the region and this established a deep root of corn and sorghum research to the nation. Many tropical varieties, and collections from the Caribbeans and composites from the Philippines, Taiwan, and Indonesia were introduced for testing. Many composites, germplasm complexes and varieties were formed and several recurrent selection methods were used. The search for heterosis from varietal crosses was also made. None of these approaches were produced the superior varieties. In 1969, another review of breeding program was made and breeding staffs concluded that the limitation of genetic diversity would make it difficult to capitalize the heterotic effects among varietal crosses (Jinahyon, 1979). Most utilized germplasm been working were from the Caribbeans. They agreed that racial complexes should be developed and used as genetic resources for yield improvement. By applying the following criteria: good performance as reported by other workers, relative adaptability to Thailand, and diversity of materials by origin, 36 germplasm sources were chosen to form a population designed "Thai Composite # 1" (Table 3).

Table 4 Kasetsart inbred lines released from 1982 ~ 1997

Inbred	Release year	Pedigree
Ki 1[1]	1982	Suwan 1(S)C_4 – S_8 – 1 – 5(2001)
Ki 2	1982	Suwan 1(S)C_4 – S_8 – 1 – 7(2002)
Ki 3	1982	Suwan 1(S)C_4 – S_8 – 5 – 3(2007)
Ki 4	1982	Suwan 1(S)C_4 – S_8 – 5 – 5(2008)
Ki 5	1982	Suwan 1(S)C_4 – S_8 – 5 – 6(2009)
Ki 6	1982	Suwan 1(S)C_4 – S_8 – 5 – 9(2011)
Ki 7	1982	Suwan 1(S)C_4 – S_8 – 7 – 3(2012)
Ki 8	1982	Suwan 1(S)C_4 – S_8 – 14 – 9(2019)
Ki 9	1982	Suwan 1(S)C_4 – S_8 – 16 – 7(2021)
Ki 10	1982	Suwan 1(S)C_4 – S_8 – 17 – 3(2022)
Ki 11	1982	Suwan 1(S)C_4 – S_8 – 18 – 7(2025)
Ki 12	1982	Suwan 1(S)C_4 – S_8 – 18 – 8(2026)
Ki 13	1982	Suwan 1(S)C_4 – S_8 – 18 – 9(2027)
Ki 14	1982	Suwan 1(S)C_4 – S_8 – 19 – 5(2028)
Ki 15	1982	Suwan 1(S)C_4 – S_8 – 20 – 2(2029)
Ki 16	1982	Suwan 1(S)C_4 – S_8 – 20 – 5(2031)
Ki 17	1982	Suwan 1(S)C_4 – S_8 – 20 – 8(2032)
Ki 18	1982	Suwan 1(S)C_4 – S_8 – 22 – 4(2034)
Ki 19	1982	Suwan 1(S)C_4 – S_8 – 22 – 9(2035)
Ki 20	1984	Caripeno DMR (S)C_4 – S_8 – 125 – 5 – 3
Ki 21	1986	Pacific 9 – S_8 – 45
Ki 22	1986	{Pacific 11 x Suwan 1 (S)C6} – S_8 – 30
Ki 23	1987	{Ki 11 x Suwan 1 (S)C_7 – S6 – 6 – 2 – 2}S_8 – 152 – 1 – 3
Ki 24	1987	Suwan 1 (S)C_7 – S_8 – 2 – 2 – 3 – 3
Ki 25	1987	Suwan 1 (S)C_8 – S_8 – 84 – 1
Ki 26	1987	Suwan 1 (S)C_8 – S_8 – 84 – 2
Ki 27	1987	Suwan 1 (S)C_8 – S_8 – 220 – 2
Ki 28	1987	Suwan 1 (S)C_8 – S_8 – 233 – 1
Ki 29	1987	Suwan 1 (S)C_8 – S_8 – 322 – 5
Ki 30	1987	Caripeno DMR (S)C_4 – S_8 – 114 – 1 – 1
Ki 31	1992	Suwan 1 (S)C_9 – S_8 – 329 – 1 (Kei2 8901)
Ki 32	1992	Suwan 1 (S)C_9 – S_8 – 346 – 2 (Kei 8902)
Ki 33	1992	Suwan 1 (S)C_9 – S_8 – 385 – 1 (Kei 8903)
Ki 34	1992	Suwan 1 (S)C_9 (L)(S)C_4 – S_8 – 163 – 3 – 2 – 1 – 2 (Kei 9001)
Ki 35	1992	Suwan 3 (S)C_4 – S_8 – 140 – 2 – 2 – 1 – 2 (Kei 9002)
Ki 36	1992	Suwan 3 (S)C_2 – S_8 – 102 – 1 – 1 – 4 – 3 (Kei 9003)
Ki 37	1992	Suwan 3 (S)C_2 – S_8 – 194 – 1 – 1 – 1 – 1 (Kei 9004)
Ki 38	1992	Suwan 3 (S)C_2 – S_8 – 302 – 3 – 1 – 1 – 1 (Kei 9005)
Ki 39	1992	RS 1(H)C_4 – S_8 – 5
Ki 40	1992	Suwan 2(S)C_7 – S_8 – 2 – 4
Ki 41	1992	AHO – S_8 – 1 – 4
Ki 42	1992	AHO – S_8 – 3 – 4
Ki 43	1992	Suwan 3 (S)C3 – S_8 – 138 (Kei 9101)
Ki 44	1992	KS 6(S)C_2 – S_8 – 366 (Kei 9102)
Ki 45	1995	{(Ki21 x Tzi15)S2 x Ki21} – S_8 – 36 – 2 – 2 – 2(Kei9304)
Ki 46	1997	Suwan 1(S)$C_4$0(HLT)C_4 – F2 – S_8 – 159 – 1 – 1 – 1 – 1(Kei9405)

[1] Ki = Kasetsart inbred [2] Kei = Kasetsart experimental inbred

In 1968, sorghum downy mildew caused by P. sorghi (Weston & Uppal) was identified as a new threat to maize production in Thailand. During the early 1970s, the disease reached epiphytotic proportions and it intensively devastated maize production. In 1971, Thai Composite # 1(S) C1 was crossed to two high yielding, downy mildew resistant varieties: Philippine DMR 1 and 5. Three backcrosses were made to recent selection cycles of Thai Composite # 1. After the third backcross, the downy-mildew-resistant version of Thai Composite # 1 was improved by S1 recurrent selection for two cycles. Then it was approved by the Ministry of Agriculture and was released as a standard variety naming "Suwan 1" in 1975. After the release of Suwan 1, three improved open-pollinated varieties were subsequently released to farmers. These were Suwan 2 in 1979, an early, downy-mildew-resistant variety; Suwan 3 in 1987, a medium-maturing, rust- and downy-mildew-resistant variety; and Suwan 5 in 1993, a high-yielding, medium-maturing, downy- mildew-resistant variety (plate Ic). The

Department of Agriculture also released Nakhon Sawan 1 in 1989, a medium-maturing, downy- mildew-resistant variety.

4.2 Research and development of hybrid maize in Thailand

Kasetsart University established hybrid maize breeding in 1978. At the beginning, germplasm sources were from the improved open-pollinated variety program and Suwan 1 was a major source of inbred line development. Most inbred lines were developed from the consequence of S1 recurrent selection. In 1982, 19 inbred lines from Suwan 1(S) C4 were released to the public. Among the first group of released inbred lines, Suwan 2301, the first single cross hybrid in Thailand, was identified and released for commercial. In order to search for heterotic partners, the ten-elite-population diallel was performed by the breeding program. It demonstrated that Suwan 1 and Suwan 3 combined well with Caripeno DMR, KS 6, and Suwan 5 (Jampatong, 1989, unpublished). Another approach for finding heterotic partners is to cross elite adapted varieties to exotic germplasm. Between 1978 and 1981, many tropical, subtropical, and temperate germplasm were topcrossed to Suwan 1. The results indicated that some temperate germplasm especially germplasm from Iowa State University displaying an excellent heterosis with Suwan 1 but the heterosis expressed only in the optimum environment. During this period, the breeding project began to convert temperate germplasm for tropical adaptation. In 1985, Ki 21, a Mo17 derivative, was released. Later it was found that Ki 21 and its derivative showed high combing with lines from Suwan 1, Suwan 3, and KS 6. In 1987, KS 23, a broadbase synthetic with containing some temperate germplasm, was formed. The synthetic was designed to be a counterpart of Suwan 1 for inter-population improvement. Grudloyma et al. (1993) conducted a population diallel among ten elite populations. The results indicated that KS 23(S)C2, Suwan 5 (S) C3, and Suwan 1(S) C11 gave significantly high general combining ability effect. From 1982 to 1997, Kasetsart University released all together 46 inbred lines and 10 hybrids as shown in Table 4 and 5, plate I$_{A,B}$ (Source: Sriwantaradon Jinahyon et al., 1993) respectively.

The Department of Agriculture established hybrid breeding in 1980s. Elite germplasm sources for line development were from Suwan -complex, Suwan 1, Population 28(Amarillo Dentado from CIMMYT), Population 24 (Antigua Veracruz 181 from CIMMYT), and NSDR (Nakhon Sawan Drought Synthetic). Reciprocal recurrent selection is underway in Suwan 1 and Population 28. The research efforts for line development employ 90% for recurrent selection method and 10% for pedigree selection method. In 2000, the Department of Agriculture officially released a single-cross hybrid naming "Nakhon Sawan 72" and its inbred parents were Ni 1 and Ni 2. Ni 1 (Nei 9008) was developed from Suwan-complex and Ni 2 (Nei 9202) was developed from population 28.

The role of private sectors in the development of maize hybrid, started in the late 1970s, Thai government had policy to encourage the private sector to participate in crop improvement and in the production of good quality seed for farmers. Between 1978 and 1981, five multinational seed companies decided to establish maize breeding program in Thailand. Elite germplasm was provided by the national program such as Kasetsart University and the Department of Agriculture, and with international organization such as Asian Regional Maize Program of CIMMYT. Besides providing elite germplasm, Kasetsart University has provided trained staff and training for technical staff. For germplasm movement in private breeding, interviews conducted with six private companies revealed that 56% is materials selected by the organization in this country (Ekasingh et al., 1999). Materials obtained from public breeding programs in this or any other country and materials obtained from foreign office of the organization account for 12 and 10%, respectively. CIMMYT materials were used about 9%. Among utilized germplasm, Suwan 1 is still used extensively for breeding work. Tuxpeno germplasm and its derivative, and the temperate x tropical germplasm are generally mentioned as counterparts of Suwan 1 (Jampatong, personal communication).

5 The adoption of maize hybrids in Thailand.

Maize hybrids were first planted by Thai farmers with the total seed amounts of 40 tons in 1981.

From 1981 to 1985, the amount of hybrid seed sold doubled every year and substantially increased in later years (Table 6). In the 1980s, most hybrid seed sold were double crosses and three-way crosses. During that period, there was an argument on the yield advantage of hybrids over improved open-pollinated varieties. Farmers were reluctant to buy hybrid seeds due to the small difference in yield as compared to higher price of hybrid seed. After private sectors introduced high, stable yields of single cross hybrids to farmers in the early 1990s, the adoption of hybrid varieties in-

Table 5 Kasetsart maize hybrids released from 1982 ~ 1997

Hybrid	Type[1]	Release year	Pedigree
Suwan 2301	SC	1982	Ki 3 × Ki 11
Suwan 2602	TC	1986	(Ki 3 × Ki 11) × Ki20
Suwan 3101	TC	1991	(Ki 27 × KI28) × Ki 21
Suwan 3501	SC	1993	Ki 32 × Ki 21
Suwan 3502	SC	1993	Ki 36 × Ki 21
Suwan 3503	SC	1993	Ki 43 × Ki 21
Suwan 3504	SC	1993	Ki 44 × Ki 21
Suwan 3601	SC	1995	Ki 44 × Ki 45
Suwan 3851	SC	1997	Ki 46 × Ki 45

[1] SC = Single cross, TC = Three – way cross.

creased rapidly. There was estimated that the amount of hybrid seed required for the year 2000 was 17,760 tons with acquiring 85.08% of total planted area (Table 6). In the 2000, there were twenty-seven hybrids being sold in Thailand by seven seed companies (Table 7). Approximately 74% of all hybrids were single cross hybrids. No double cross hybrids were sold.

6 Conclusions

Overall, Thailand has successfully switched from planting improved open-pollinated varieties to hybrids, resulting in gradually increasing average yield of the nation and maintaining total maize production in spite of declining trends of planted area. With the adoption of hybrid varieties, few popular hybrids were grown widely by farmers. The sign of genetic vulnerability is developing due to the reduction of genetic diversity in the farmer field and the expansion of genetic uniformity. Some minor diseases such as southern rust and southern leaf blight have been observed as new threats in some growing areas. To tackle this problem, the collaborative research and information exchange between public and private sectors are crucial. For given maize production trends, in order for Thailand to produce maize grain enough for domestic demand or even to reposition as an exporter, accelerating national average yield and expansion of planted area are immediately undertaken.

Table 6 Growth of hybrid maize in Thailand, 1981 ~ 2000 (Suwantaradon, 1997)

Year	Hybrid seed Sale (tons)	Planted area for hybrid (1000 ha)	% of total planted area
1981	40	2.50	0.16
1982	145	9.06	0.54
1983	449	28.06	1.66
1984	897	56.06	3.09
1985	1 740	108.75	5.49
1986	1 810	113.13	5.80
1987	1 370	85.63	4.89
1988	1 700	106.25	5.79
1989	3 550	221.88	12.42
1990	5 625	351.56	20.14
1991	7 450	465.63	31.57
1992	8 940	558.75	41.35
1993	10 280	642.50	47.98
1994	12 040	752.50	53.27
1995	12 616	788.50	59.05
1996	14 440	902.50	65.10
1997	15 680	980.00	70.17
1998	16 300	1 018.75	72.12
1999	16 920	1 057.50	82.08
2000	17 760	1 110.00	85.08

Note: Average sowing rate of hybrid seed is 16 kg/ha.

Table 7 Commercial hybrid seed sold for the year 2000 from seven seed companies

Organization	Variety name	Type of hybrid[1]
Pacific Seeds	PAC 626	SC
	PAC 983	SC
	PAC 988	SC
	PAC 328	TC
	PAC 11	TC
Monsanto	Big 919	SC
	Big 939	SC
	Big 949	SC
	Big 717	Modi – SC
	Big 727	Modi – SC
Novartis	Red Iron 45	SC
	Venus 49	SC
	Convoy 93	TC
Pioneer	3012	SC
	3013	SC
	30A97	SC
	30A65	SC
	30A55	SC
	30A10	TC
Charoen Seeds (CP)	DK 888	SC
	DK 989	SC
Uniseeds	NS 72	SC
	UNI 2000	SC
	UNI 90	SC
Royal Seeds	Royal 1	SC
	Royal 3	SC
	Royal 5	TC

Source: Information from Pacific Seeds (Thailand) Ltd.

1 SC = Single cross, TC = Three – way cross, and Modi – SC = Modified single cross.

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