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Maize Research in Thailand Past Impacts and Future Prospects

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1. Introduction

This paper has as its objective to examine the contribution of public and private maize research to the economy of Thailand. The first three sections of the paper deal with the trends in maize production and consumption, as well as the nature of maize research in Thailand. The fourth section explores the impacts of maize research on the types of varietal releases, rate of releases, seed production and seed prices, as well as farm-level impacts. Impacts on producers' productivity, income and costs are particularly considered. The fifth, sixth, and seventh sections discuss the nature of public and private linkages and future collaboration. The paper highlights the changing environment, technologically and socio-economically, which will demand a reevaluation of the roles of the public and private sector in maize research in the years to come.

The paper is a product of an ongoing research process focusing on the physical, biological and socio-economic aspects of maize production. The research team has conducted interviews with the public and private sector involved in maize research, production and consumption in Thailand. Past studies on maize research and its impacts were also reviewed.

2. The maize economy of Thailand

The growth of maize production in Thailand has been in the past 30 years the result of intensive research. In terms of research, maize has received high priority relative to other major crops apart from rice. Maize research started in 1966 from the Rockefeller Foundation's Inter Asian Com Program being administered in Suwan Farm in Kasetsart University. Until late 1980's, public sector research, conducted mainly by Kasetsart University and Department of Agriculture, with close collaboration with CIMMYT, developed in Thailand several locally adapted and disease resistant open-pollinated maize varieties (OPV). Breeders from Suwan Farm released Suwan OPVs (Suwan 1 in 1975, Suwan 2 in 1979, Suwan 3 in 1987). The Department of Agriculture developed OPV Nakorn Sawan 1 (NS 1) in 1989. These varieties dominated the market and maize area in Thailand up until 1990. During this period, nearly 2 million ha planted to maize (out of about 4 million ha of planted area under major field crops) and annual production of 4 million ton were testimonies to the success of these public-sector developed OPVs

Today, total output continues to increase steadily, while the acreage planted to maize has fallen somewhat and stabilized around 1.4 million ha per annum in the 1990s.

Beginning around 1990, fundamental shifts took place in the maize seed industry of Thailand. Those who thought they knew what was going on before 1990 say that the industry has entered a really new era. There have been fundamental shifts both in

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production technology and in market outlets. In the 1990s, private sector hybrids have come to dominate farmers' fields, Thailand is no longer a major exporter of maize but a major consumer. Both of these shifts need to be studied carefully. The implications for the balance, roles and characters of public sector versus private sector research will need to be brought to bear for those involved as well as for policy makers.

2.1 Maize-based cropping systems

Maize is grown in Thailand mostly in the upland rain-fed areas. There are two main growing seasons, the first crop being planted during May-September and second crop during August-December. In 1997, 87% of the maize area fell within the first season and 13% in the second season with some variations in different regions (Office of Agricultural Economics, 1997). Forty-nine percent (49%) of the national maize area is located in the North, 27% in the Northeast, 24% in the Central, and a tiny fraction in the South (Table 1). Figure 1 portraits maize growing areas by province. Mono-cropped maize, maize-sorghum, maize-maize, maize-mungbean, maize-legume, maize-sunflower, mungbean-maize, sesame-maize and maize-cotton are common maize-based cropping systems. Competing crops are sugar cane, cassava, cotton, sorghum, groundnut and pasture. Small proportions of the total national maize area are planted to baby corn (29,324 ha) and sweet corn (48,884 ha), mainly in irrigated zones (34,648 ha) in 1997 (Office of Agricultural Economics, 1997). In lowland irrigated areas, maize is grown after rice; this can be done during December-March.

Table 1 Maize growing areas in Thailand, 1996/97.

	Area (‘000 ha)	%
North	677.3	48.8
Northeast	372.2	26.8
Central	333.7	24.1
South	3.2	0.2
Total	1,386.4	100

Source: Office of Agricultural Economics, 1997.

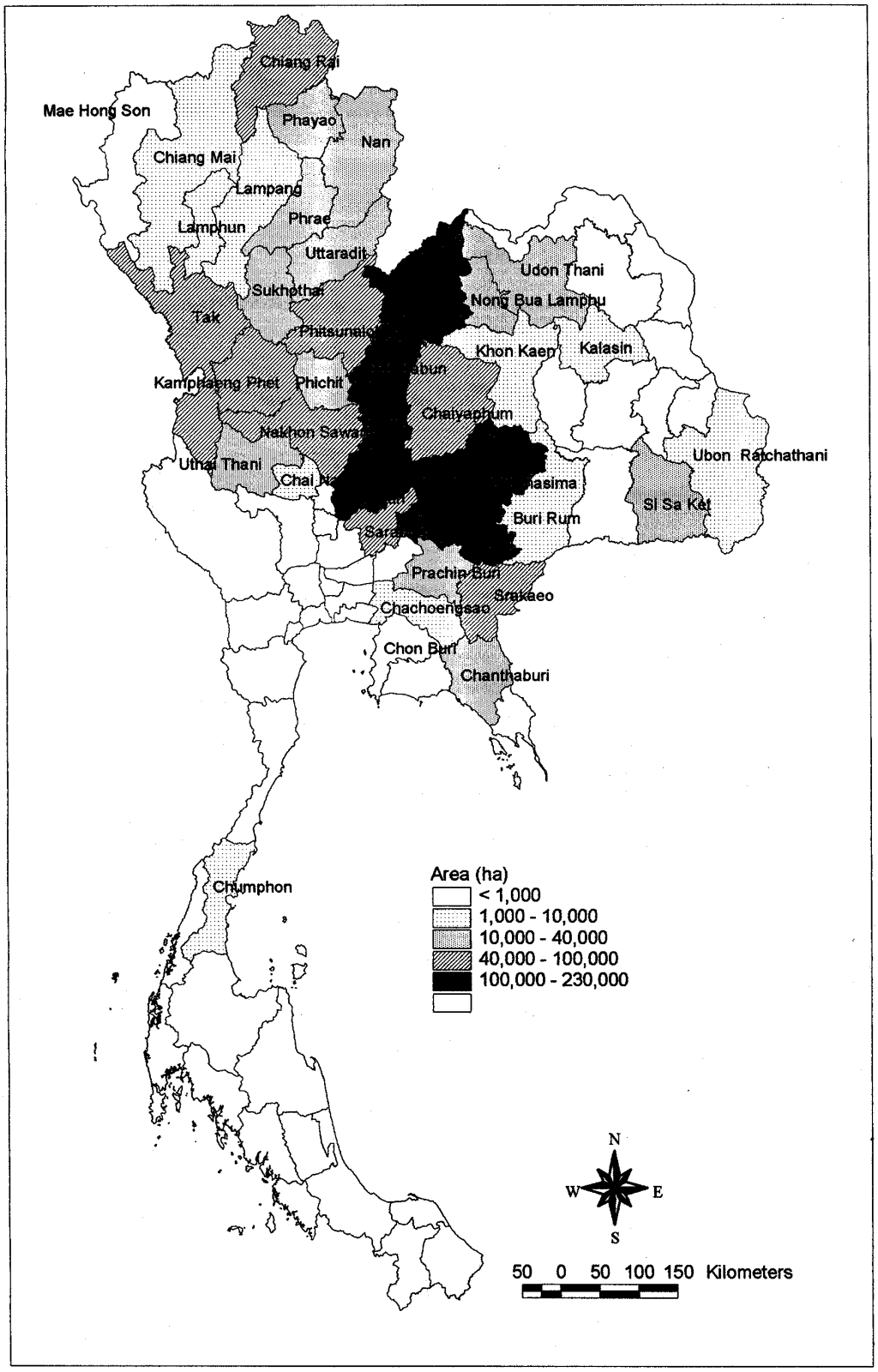

Figure 1 Maize growing areas in Thailand, 1997.

2.2 Maize production trends

Maize production has increased steadily from 1 million ton in 1966 to 4.5 million ton in 1990. Growing areas increased from 0.65 million ha in 1966 to a peak of 1.98 million ha in 1985 (Table 2). The growing areas have reduced somewhat in the past 10 years due to the growth of competing crops and have leveled off around 1.3-1.4 million hectares for the last 5 years (1995-1998). Total production was around 4.0 million ton in 1994-1995 but has rose during 1996-1998 to reach its current level of 4.5 million ton (see Figure 2). Greater use of hybrid seeds and improved management by farmers is contributing to increases in production, given reduced hectares in maize in the past 10 years. Most farmers, through active promotion of both the public and private sector, purchase their new hybrid seeds virtually every year. This practice has become common, and farmers accept it as long as the yield advantage of the new hybrid seeds is worth the increased costs.

During 1994-98, the Department of Agricultural Extension operated a program to subsidize costs of hybrid seed in 128,000 ha (around 10% of total maize area) during 1994-1998. Under this program, farmers paid only 10% of the costs of hybrid seed (8 baht out of the actual cost of 70-80 baht/kg). By rotating areas covered by this program, within five years farmers in at least 640,000 hectares (45% of maize areas in the country) would have had some hybrid seeds introduced to them. After the initial period of hybrid seed subsidization, farmers must purchase their own seeds at market prices. In 1999, the Department will instead subsidize 50% of the seed cost on 240,000 ha. This subsidized seed program has been jointly administered by the private seed companies, which have an interest in introducing their seeds to farmers. The promotion of the use of hybrid seeds has also been done through the work of Bank of Agriculture and Agricultural Cooperatives (BAAC), which grants agricultural loans to farmers, partly in the form of in-kind credit such as seeds and fertilizers.

The national average yield/ha has increased slowly despite a rapid growth in hybrid variety use, rising from 1.7 t/ha in 1966 to 2.8 t/ha in 1995 (Morris, 1998). In 1997-1998, a yield figure of3.1 t/ha national average was reported by Grudloyma (1997). The Office of Agricultural Economics (1997) reported the national average yield of 3.2 t/ha, with slightly more for hybrid varieties (3.4 t/ha as against 2.3 t/ha for OPV) (Table 2).

2.3 Consumption and international trade trends

Domestic use of maize has increased over the years as a direct result of the expanding livestock industry. Rising urban income, associated increases in the consumption of meat and dairy products, and rising exports of chicken meat to Japanese markets have caused a rapid growth in demand for animal feed such as maize, rice bran, soybean cake, cassava and fish meal. In 1966, virtually all maize produced in the country was exported. In 1996, virtually all maize produced was domestically used, mainly as animal feed, and to a small extent, for home consumption, as vegetables (baby com and sweet com). In some years, imports of maize were necessary. For example, in 1995, net imports reached a high level of around 300,000 ton (Table 3). Moreover, domestic and export demand for baby com and sweet corn products continues to grow.

Table 2 Maize area, production, and yield, Thailand, 1966-1998.

Year	Planted area (m. ha)	Output (m. ton)	Yield (kg/ha)
1966	0.65	1.122	1,718.8
1967	0.66	1.315	1,987.5
1968	0.67	1.508	2,250.0
1969	0.68	1.7	2,500.0
1970	0.83	1.938	2,337.5
1971	1.02	2.3	2,256.3
1972	1.00	1.315	1,318.8
1973	1.15	2.339	2,037.5
1974	1.24	2.5	2,018.8
1975	1.31	2.863	2,181.3
1976	1.28	2.675	2,081.3
1977	1.21	1.677	1,393.8
1978	1.39	2.791	2,012.5
1979	1.52	2.863	1,875.0
1980	1.43	3.00	2,093.8
1981	1.57	3.45	2,200.0
1982	1.68	3.002	2,300.0
1983	1.69	3.552	2,268.8
1984	1.82	4.226	2,431.3
1985	1.98	4.934	2,575.0
1986	1.95	4.309	2,375.0
1987	1.75	2.781	2,050.0
1988	1.84	4.675	2,550.0
1989	1.79	4.393	2,456.3
1990	1.72	3.675	2,131.3
1991	1.48	3.793	2,568.8
1992	1.35	3.672	2,718.8
1993	1.34	3.328	2,487.5
1994	1.41	3.966	2,806.3
1995	1.34	4.155	3,112.5
1996	1.39	4.533	3,268.8
1997	1.39	4.152	2,975.0
1998	1.45	5.018	3,462.5

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Note: 1998 figures are estimates.

Sources: Office of Agricultural Economics, various publications

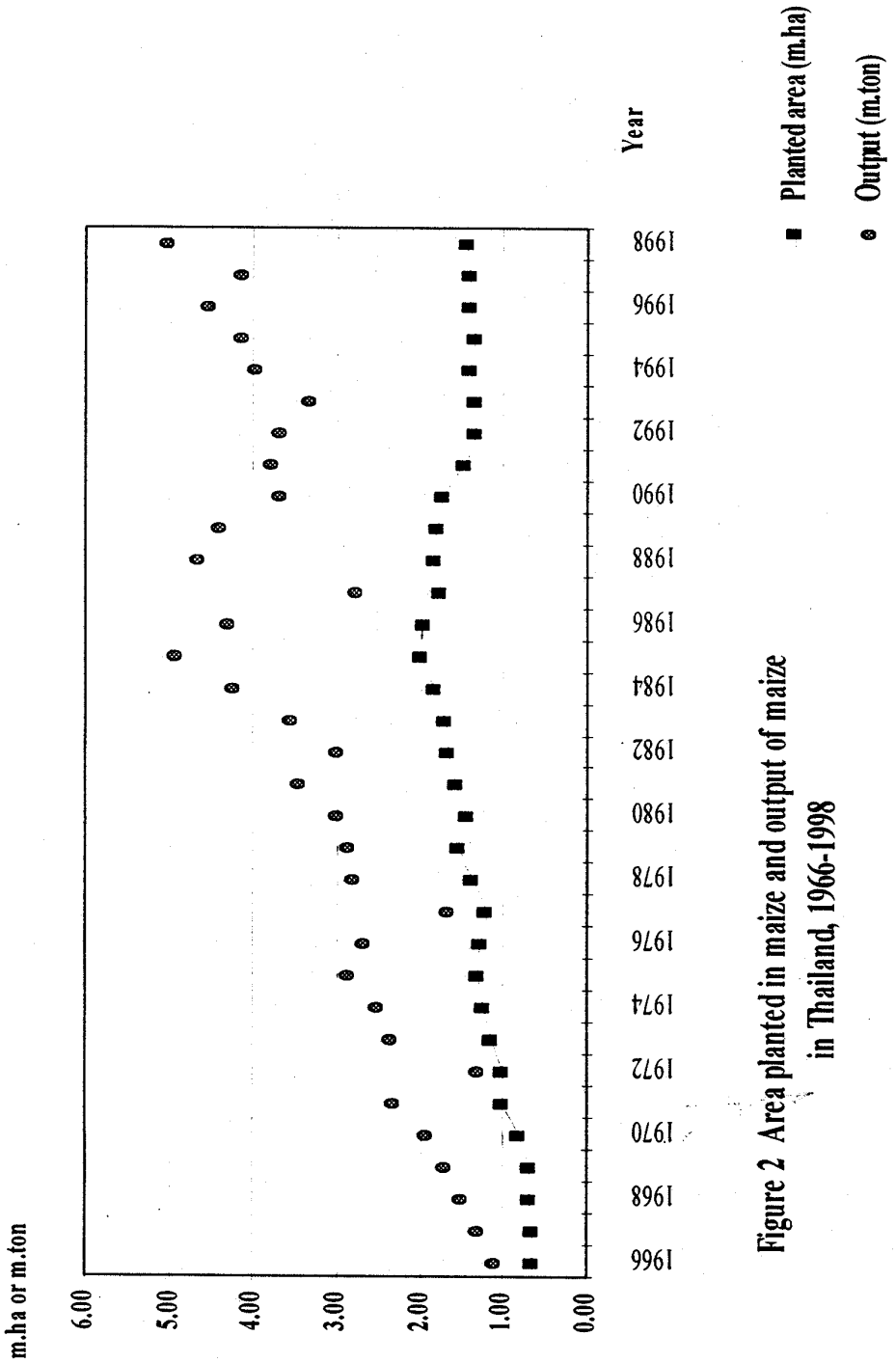

Figure 2 Area planted in maize and output of maize in Thailand, 1966-1998.

Table 3 Domestic use, exports, and imports of maize, Thailand, 1966-97.

Year	Domestic use (m.ton)	Export		Import	
		Volume (m.ton)	Value (m.baht)	Volume (m.ton)	Value (m.baht)
1966	..	1.219	1,519.9	..	..
1967	..	1.091	1,355.4	..	..
1968	..	1.481	1,556.1	..	..
1969	..	1.476	1,674.4	..	..
1970	..	1.52	1,856.9	..	..
1971	..	1.806	2,185.7	..	..
1972	..	1.932	1,980.2	..	..
1973	..	1.456	2,861.2	..	..
1974	..	2.26	5,964.6	..	..
1975	..	2.072	5,615.1	..	..
1976	..	2.388	5,598.1	..	..
1977	0.47	1.518	3,286.5	..	..
1978	0.645	1.955	4,231.0	..	..
1979	0.758	1.988	5,567.4	..	..
1980	0.913	2.175	7,200.8	..	..
1981	0.324	2.547	8,235.8	..	..
1982	0.885	2.801	8,230.9	..	..
1983	0.756	2.63	8,386.8	..	..
1984	1.149	3.116	10,049.8	..	..
1985	1.204	2.752	7,609.0	..	..
1986/87	1.388	3.981	9,176.2	..	..
1987	2.2	1.628	3,866.6	0.5	..
1988	2.7	1.206	3,713.6	0.5	..
1989	2.9	1.179	4,076.8	0.7	..
1990	3	1.215	3,809.0	0.9	..
1991	3.1	0.849	2,745.0	0.249	955
1992	3.3	0.179	579.0	0.205	858
1993	3.2	0.125	452.0	0.01	31
1994	3.95	0.117	444.0	0.103	396
1995	4.35	0.09	415.0	0.389	2,293
1996	4.6	0.054	276.0	0.169	829
1997	N/A	0.054	373.4	N/A.	N/A.

Note: Negligible
Source: Office of Agricultural Economics, various issues.

Thailand moved from being net exporter position of maize in 1966 to being a net importer in 1995. Also the Thai export price of maize appears to be higher than U.S. maize exports. Thai maize often has a problem of aflatoxin contamination. Shifting from exporting to domestic consumption has reduced shortens storage times, convincing many buyers that the problem of aflatoxin contamination is no longer there. Nevertheless, to reestablish itself as an exporter, Thailand will have to seriously tackle this problem, and long term planning will be necessary. In 1998, due to the Thai financial crisis starting in 1997, domestic demand for meat, and thus maize, fell substantially, while supply

increased as the result of high farm-gate prices in the previous year. This led to a short-term domestic supply surplus, which in suppressed the farm gate prices in 1998.

While exporting substantial volume of maize is not yet an immediate, realistic possibility, Thailand has a potential for producing and exporting more maize. Achieving an expansion in area planted and a significant increase in average yields will not be difficult as a result of further improvement in adoption, use and management of new hybrid maize varieties.

3. Organization of maize research in Thailand

3.1 Public-sector research

3.1.1 National level

The two organizations which have undertaken substantial maize research in the country are Kasetsart University (KU) and the Department of Agriculture. KU has a 368 ha experiment station in Nakhorn Ratchasima called the National Com and Sorghum Research Center (NCSRC, commonly called "Suwan Farm"), which has been doing maize research --particularly breeding work --since 1966. At Suwan Farm, maize research is conducted jointly among university staff members and NCSRC staff. During the last 30 years, Suwan Farm has released at least 4 OPVs, 9 field com hybrids, 4 sweet com and 2 baby com varieties apart from 46 inbred lines (Table 4). The success of Suwan Farm in maize breeding has laid a productive foundation for locally adapted private sector developed hybrids in the countries. Many breeders in the private sector were originally trained at this university.

The first successful OPV, Suwan 1, was a product of research by KU scientists. It was a variety developed from 36 maize landraces, 16 from the Caribbean Islands, 6 from Mexico and Central America, 5 from South America, 5 from India, and 4 from other areas. Downy mildew resistance was then introduced to the variety through the introduction of 2 Philippine varieties, Philippine DMR 1 and 5. Suwan 1 was very well received by farmers in the 1970s and 1980s and was used in other countries as much as in Thailand. Today Suwan 1 is still used extensively in the country for breeding new hybrid varieties because of its broad genetic base.

Suwan Farm also released many hybrids. Two hybrids were released in the 1980s, and six to seven more were developed by Suwan Farm in the 1990s. Inbred lines from Suwan Farm are especially valuable to breeding work, both in the public and private sector.

The other main body of public sector maize research is the Department of Agriculture. The Department is officially responsible for government research and policies in maize. Maize breeding work in the Department is relatively recent compared to Kasetsart University. In 1989, Nakorn Sawan Field Crops Center, a division within the Department, developed and released NS 1, and there are plans to release a few more hybrids in 1999.

Table 4 Public-sector maize varieties and inbred lines, Thailand, 1975-97.

Organization	OPV	TWC	SC	Sw	BC	Inbred lines
Suwan Farm	Suwan 1	Suwan 2602	Suwan 2301	TSC1 DMR	Suwan 2	Ki 1-46
	Suwan 2	Suwan 3101	Suwan 3501	HSX 27127	TSC1 DMR	
	Suwan 3	Suwan 3602	Suwan 3502	HSX 11476	Kasetsart 1	
	Suwan 5		Suwan 3503	Insee 1		
			Suwan 3504			
			Suwan 3601			
			Suwan 3851			
DOA	NS 1					

Note: OPV = open-pollinated variety, TWC = three-way cross hybrid, SC = single-cross hybrid, BC = baby corn, Sw = sweet corn

Sources: Aekatasanawan (1994a, b, c, 1997); Aekatasanawan, et al. (1997).

3.1.2 International level

The Department of Agriculture and Suwan Farm have had good linkages to international centers since the early days of research in Thailand. International collaboration is essential to successful breeding work, as can be seen from the case of Suwan 1 variety. When Suwan 1 was developed, KU scientists had good back up support (both in terms of germplasm and in terms of research results) from an international network supported by the Rockefeller Foundation, the Inter Asian Corn Program. Later on, the International maize and Wheat Improvement Center (CIMMYT) established an office in Bangkok. CIMMYT staff have collaborated closely with the two public sector research organizations, providing germplasm, training, exchange of information, scientists, development of joint research, etc.

CIMMYT germplasm was used in developing a number of public sector varieties (namely, CIMMYT's POP 28 was used in developing NSI in 1989 and Suwan 5 in 1993). Moreover, since CIMMYT maintains a free distribution policy for germplasm, the private sector also uses CIMMYT materials for research. CIMMYT's germplasm is especially valuable for small national companies and public sector organizations which do not get easy access to other sources of germplasm. As for multinational companies, they get good access to their own companies' germplasm, but even so, many of the multinationals also evaluate CIMMYT germplasm on a routine basis.

Materials developed by public breeding organizations in Thailand are also used extensively by private companies. , In fact, most companies say they use Suwan Farm's germplasm more than CIMMYT's germplasm in their breeding work. This is understandable, as Suwan varieties are better adapted to local conditions and have been

evaluated more extensively at the local level as compared to the CIMMYT's materials. This may be a case to argue for strong national-level research in certain areas in support of private sector research. The role of international research centers will need to be backing up both national level and private sector research for the benefit of a wide circle of clients-producers and consumers especially in developing countries.

3.2 Private-sector research

3.2.1 Multinational companies

Up until 1998, only four multinational seed companies operated in Thailand: Pioneer Hi-Bred, Pacific Seeds (Advanta/lCI/Zeneca), Novartis, and Cargill Seeds. These companies obtain most of the germplasm used for breeding work from their mother companies. Within each company, research results, activities, and output are shared among different regional branches. Three of these companies established offices in Thailand during the late 1970s or early 1980s. With their Thai staff, they were able to operate with adequate research backup and efficient management. After 15-20 years of operation in Thailand, they have acquired experience and skills in working with farmers and have come up with successful breeding programs with strong farmers' participation. Adequate competition has been observed among them and has provided the industry with healthy working environment with many positive performances.

3.2.2 Domestic (Thai) companies

Among the seven private companies operating in Thailand, three are domestic companies. The biggest of these, the Charaen Seeds Group (C.P. Group) is a Thailand-based multinational company involving all lines of agribusiness, including seed. The other two companies (Uniseeds and Royal Seeds) are much smaller. Charaen Seeds, although a Thai-based company, collaborates with a U.S.-based company, DeKalb Seeds. In this way, Charaen Seeds maintains broad access to Dekalb's germplasm and technology. In 1991, the company released the single cross CP-DK888 hybrid, which has been very successful and has dominated the maize hybrid seed market for the last nine years. It is very popular among farmers, who by now have become very knowledgeable about hybrid seeds and often express forcefully their preferred hybrid varieties.

The structure of the Thai seed industry will change in 1999 because the U.S.-based agrochemical company, Monsanto, has acquired both Cargill Seeds (international section) and Dekalb Seeds. .Since C.P .-Dekalb together with Cargill Seeds constitute around 70% of the market share in Thailand, the merger will substantially change the nature of competition as more market concentration takes place.

The smaller domestic companies are more dependent on public-sector germplasm and research, both CIMMYT and KU's Suwan Farm. These smaller domestic companies have some limitations in their research capacity (personnel and budget) compared to multinational companies, but with good coordination with the public sector they can make important contributions. They not only strengthen healthy competition in the industry, but also they provide alternative modes of research and business operations from what multinational companies have to offer. For example, they are more interested than multinational companies in pursuing further research on OPV s and in marketing OPVs and public-sector hybrids.

Table 5 Public and private sector maize cultivars released in Thailand, 1966-97/98.

Indicator	*Public Sector (cultivars released from 1966-97/98)*	*Private Sector (cultivars being sold in 1997/98)*
Number of maize cultivars released, 1966-97	20	36
Improved OPVs	5	-
Hybrids: Single cross	12	21
Double cross	-	2
Three-way cross	3	11
Others	-	2
Numbers of cultivars released by adaptation		
Lowland tropical	20	36
Subtropical/mid-altitude	-	-
Highland	-	-
Numbers of cultivars released by grain color		
White	-	-
Yellow	20	36
Numbers of cultivars released by grain texture		
Flint	5	17
Semi-flint	9	10
Semi-dent	-	4
Dent	-	-
Others (baby, sweet corn)	6	5
Numbers of cultivars released by maturity class		
Extra early (<100 days)	1	1
Early (100-110 days)	2	16
Intermediate (110-120 days)	11	14
Late (120-135 days)	-	-
Extra late (>135 days)	-	-

Table 6 Private-sector maize varieties developed and sold in Thailand, 1997-98.

Table 6. Private-sector maize varieties developed and sold in Thailand, 1997-98.

	Field corn				Baby corn		Sweet corn
	TWC	DC	SC	MSC	TWC	SC	SC
Charaen Seeds (C.P.)	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		
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				

Note: OPV=Open-pollinated varieties, TWC= Three-way cross varieties, DC= Double-cross varieties,

SC= Single-cross varieties, MSC= Modified single-cross varieties, BC =Baby corn varieties, SwC= Sweet corn varieties *Released in 1998

4. Impacts of maize research

4.1 Varietal releases

4.1.1 Rate of releases

The famous variety Suwan 1 was released in 1975. Suwan 2 was released in 1979, Suwan 3 in 1987 and Suwan 5 in 1993. All four of these OPVs were developed at Suwan Farm. NS 1 (released in 1989) was the only OPV released by the Department of Agriculture. Suwan Farm released the first two hybrids, a single cross, KSX2301 (released in 1982) and a three-way cross, KTX2602 (released in 1986). Today, maize research is oriented largely towards hybrids, both in the public and private sector. Single cross hybrids are now preferred due to their yield advantage. On the other hand, since they are products of only two inbred lines, they are more susceptible to be copied by other breeders. While this did not pose problems early on, problems have increased in recent years.

From 1991 to 1997, Suwan Farm has released eight hybrids, six of which were single crosses. Unlike the OPV Suwan 1, the Suwan hybrids need large-scale seed production plots. Hybrid seed is difficult and costly to produce, so once the seed has been produced, seed organizations have an interest in finding ways to make sure that it is purchased by farmers. In this context, public sector research organizations like Suwan Farm and Department of Agriculture will need to find ways to overcome marketing problems if they want to be successful in promoting their hybrid seeds. Currently, Suwan Farm sells their inbred lines to private companies, and the companies take care of production and marketing activities. One problem with this arrangement is that seed of the Suwan hybrids is being produced by many companies, so individual companies have little incentive to expand production and sales of the Suwan hybrids. In 1998, Kasetsart University introduced an exclusive licensing policy, under which a new hybrid is sold to only one company. Hopefully this will encourage companies to produce and sell Suwan hybrids on a much broader scale than in the past. Nevertheless, in the absence of national legislation on plant breeders' rights, this type of licensing agreement must involve a contractual arrangement based on contract laws. Practically speaking, any violation by non-party members is not enforceable by law. For this reason, private companies appear reluctant to enter into large-scale production of public-sector hybrids. By 1997, despite all of the hybrids produced by Suwan, only 4.7% of the national maize area was under public sector hybrids (Office of Agricultural Economics, 1997).

As far as maize production is concerned, the 1990s have been the decade of the private sector. A survey conducted in 1998 revealed that some of the hybrids being sold in 1997 were released as far back as 1988 (e.g., the three-way cross Hercules 31 sold by Novartis Seeds). In 1990, Pacific Seeds released its double cross hybrid PAC11, which was still in use in 1998. In 1991, when the famous single cross CP-DK888 was released by Charaen Seeds (C.P. Group), a three way cross (Uniseeds 38) and a double cross (CP-DK818) were also released in the same year. During 1991-93, hybrids were released at the rate of about three new hybrids/year by different companies. During 1994-96, the rate of releases accelerated to about five new varieties a year. In 1997, there was a record release of eight private sector new hybrid varieties, six of which were single crosses. During 1988-1997, there were altogether not fewer than 36 private sector hybrids released and

sold in Thailand. Five of these were baby corns or sweet corns. These hybrids were suitable for different ecozones. Thanks to active promotion by the companies and the Department of Agricultural Extension, adoption has been rapid. Most Thai maize farmers are more of less active users of hybrids. They are segmented in their preferences of hybrid varieties by their relative association with different private companies. A few of the more advanced farmers have become hybrid maize seed producers themselves.

4.1.2 Types of materials

In 1997, approximately 70% of all hybrid maize seed sold in Thailand consisted of single cross hybrids. Twenty-one of the hybrids being sold by the private sector in 1997-1998 were single cross hybrids, two were modified single crosses, two were double-crosses, and eleven were three-way crosses. Out of 20 cultivars, whose seed was being produced by Kasetsart University's Suwan Farm, twelve were single-cross hybrids, three were three-way-cross hybrids, five were OPVs, four were sweet corn varieties, and three were baby corn varieties (Table 4). The Department of Agriculture varieties included one OPV, as well as several forthcoming single cross hybrids.

In addition to producing finished cultivars, Suwan Farm produced up to 46 inbred lines over a period of20 years (1978-98). These inbred lines were sold to the private sector for the development of hybrids. Single cross hybrids are more preferable in later years because of their yield advantage. Experimental plots can give as high as 8 t/ha for a good single-cross hybrid (Yodsaporn et aI, 1998). Different hybrids have relative advantage in yields, prices and agroecozones.

4.2 Seed production

4.2.1 Production of improved seeds

As the adoption of improved varieties is widespread in Thailand, the production of improved seed is becoming a major activity for both public agencies and private companies. In the public sector, seed production is done by the agencies own staff, including hired workers. In contrast, private companies work mostly with contract farmers, who receive close supervision from company personnel. With an estimated 15,000 ton of hybrid seed produced and sold in 1997 (Kriangsak, 1997), the number of farmers involved in seed production included around 6,000 farm households distributed over 12,000 ha [2] (65% of maize area). Some farmers were reported to use F2 seeds. In 1998-99, the percentage, of farmers planting some form of hybrid seed undoubtedly equaled 90% or more.

In some years, there have been shortages of improved seed, but generally farmers have been able to buy hybrid seeds with no difficulty. The seed promotion and marketing programs of the various companies function reasonably well. Moreover, during the past five years, seed promotion and marketing activities have been assisted by some government programs which subsidized hybrid seed use. Thanks largely to these programs, most farmers have now switched to hybrids. Even so, use of OPVs has not died out completely. For example, in 1997 some small private companies such as

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[2] Using a 1.25 t/ha yield and 2 ha per household.

Uniseeds were still producing and selling seed of the Suwan OPV's. However, sales of OPV seed now account for a small percentage of total sales of improved seed Some small local companies buy Suwan hybrids such as Suwan 3504 and Suwan 3601, hire some technical assistants, and produce Fl hybrid seeds for sale under their own brand names. These companies do not do any research and do not produce new hybrids; they just produce and sell seed of the Suwan hybrids. These small companies are essentially producers and marketing agents for Suwan seeds, both OPVs and hybrids.

Suwan Farm encourages these small companies to operate in this way, and it sells regularly inbred lines for the production of these hybrids. Suwan Farm's inbred lines are actually what the private companies value and want to buy. Smaller companies buy the inbred lines and produce hybrid seed according to Suwan Farm's instructions. Larger companies buy the inbred lines for further research and crossing with their companies' materials. The work conducted by Suwan Farm is seen as very valuable by all.

A controversy arose in 1997 when several small domestic companies were accused to have "stolen,,3 Fl seed produced by seed growers working under contract with a private company. The seeds were allegedly repackaged and sold to customers under the small companies' brand names. In the absence of plant variety protection laws and a rigorous test of variety identification, further incidents of this nature are likely to create distrust and lead to unproductive follow up and litigation costs. Calls for both plant variety protection laws and DNA fingerprinting are coming from private companies and from the Association of Plant Breeders, who claim such measures are needed to protect their investment in developing new plant varieties. The government is responding to these calls, but when it comes to plant variety protection, other issues come into play. For example, groups supporting farmers' rights are demanding the farmers be compensated for the use of landraces and traditional varieties. The process for plant variety protection laws is currently undergoing scrutiny by the members of the parliament.

4.2.2 Seed prices

In 1997, OPV seed was sold by private companies for about 20 baht/kg. The price of seed for double cross hybrids averaged about 45 baht/kg, for three way cross hybrids about 60 baht/kg, and for single cross hybrids about 80 baht/kg. For purposes of comparison, at the time the price of ordinary maize grain averaged about 4.0 baht/kg. Seed-to-grain 3 Illegally bought from farmers the other company's contracted F 1 seeds.price ratios thus averaged about 5: 1 for OPV s, 11: 1 for double cross hybrids, 15: 1 for three way cross hybrids, and 20: 1 for single cross hybrids (Table 7). In times of shortage, hybrid prices can be higher, but adequate competition exists among the companies in relation to their yield performance. Retail prices and prices of hybrid seed being sold in remote settings can be higher according to distances and the profits merchants charge. Sometimes, single cross hybrid seed prices can rise as high as 120 baht/kg. Here, there is a need to investigate the level of seed prices bought by farmers in relation to the degree of competition among different companies and traders in an area.

4.3 Varietal adoption and diffusion

Maize farmers adopted improved OPVs extensively during 1970s and 1980s. During the 1990s, more and more farmers have switched to hybrids. In 1997, the Office of Agricultural Economics estimated that 81% of the national maize area was planted to

hybrid seed sold by the private sector, 4.7 % was planted to hybrid seeds produced by the public sector, 13.9% was planted to OPVs, and a tiny 0.3% was planted to traditional varieties (Table 7). OPVs were used more in the Northeast region of Thailand. In 1998, the estimates of area under hybrid maize varieties was expected to increase even further; it is projected that 90% of the total national maize area will be planted to hybrids. Table 8 shows the rate of increase in the adoption of hybrid seed in Thailand since 1990. Notice that the implied proportion of the hybrids in total maize planted areas derived from Suwantaradon's estimates was 72% in 1997 (Table 8), while the Office of Agricultural Office estimated the percentage to be 85% in the same year (Table 7). The discrepancy may be due to the fact that Suwantaradon's estimate did not include areas under recycled hybrid seed.

Table 7 Area planted, yield, and seed prices of hybrids vs. improved OPVs, 1996/97.

	Traditional varieties	Improved OPV	Hybrid varieties	Total
Area planted	4.3	192.3	1,189.8	1,386.4
-('000 ha)				
-(%)	0.3	13.9	85.8	100
Yield (t/ha)	1.98	2.33	3.42	3.27
(index)	85	100	146	
Seed prices	small	10-20	35-55 DC	
(baht per kg)			50-75 TWC	
			75-90 SC	
Grain prices	-	4.0	4.0	
Seed:grain price		2.6-5.3	9.2-23.7	

Sources: Area and yield: Office of Agricultural Economics, 1997
Seed and grain prices: interviews.
Note: DC=double-cross, TWC=three-way cross, SC=single-cross hybrids

Table 8 Rate of hybrid maize adoption, Thailand, 1988-97.

Year	Hybrid seed sales (ton)	Planted area in hybrid seeds (1,000 ha)	% of maize planted area in the country
1988	1,700	108.8	5.9
1989	3,550	227.2	12.7
1990	5,625	360.0	20.1
1991	7,450	476.8	32.2
1992	8,940	572.2	42.4
1993	10,280	657.9	49.1
1994	12,040	770.6	54.7
1995	12,616	807.4	60.2
1996	14,440	924.2	66.5
1997	15,680	1,003.5	72.2

Source: Derived from Kriangsak, 1997.

4.4 Farm-level impacts

4.4.1 Profitability of adopting improved varieties.

Improved varieties have substantial yield advantage, and they are also disease resistant. The incremental value of yield offset the incremental value of costs which involve higher seed prices and fertilizer costs. Chokechai (1997, 1997a) reported the progress of yield improvement in the Cooperative Hybrid Yield Trials during 1987-1996. The yield for Suwan Farm single cross (Suwan 3851, Suwan 3853) reached 9.5-9.9 t/ha in 1995-1996, while for other hybrids were in the range of 8.7-9.5 t/ha during 1991-1995 (Table 9). However, the national average yield still lagged behind at 2.7-2.9 t/ha during 1991-1996 despite increasing adoption of maize hybrids in the country.

Sanit and Saran (1993) analyzed farmers' maize cultivation and profit for 1992-1993 crop year for Sa Kaeo province and found out that an average yield for single-cross hybrids could reach 4.85 t/ha with a profit of 8,063 baht/ha. An average yield for other hybrids was 4.4 t/ha with an average profit of 7,330 baht/ha while an average yield for the OPV Suwan 3 was 3.58 t/ha yielding a profit of5,654 baht/ha to farmers (Table 10).

Sanit and Saran (1993) also identified that while seed costs for single cross hybrid were higher than those of OPV and other hybrids by 3.83 and 1.6 times respectively but other costs of production were not much different. Narong, et al (1993) compared farmers' practices and problems, and yields in export areas, special intensive area and general area in 1993 to find out that the average yield was 3.87 t/ha, 2.85 t/ha and 2.5 t/ha respectively (Table 11). Both studies identified drought as the major problem in most area affecting about 60% of farmers growing maize.

Kriangsak (1989) asserted that all other costs of maize production, apart from seed costs, were the same for OPV and for hybrids. In such cases, farmers would need to

have an increase in yield of hybrid over OPV s of about 9%-21% depending on the original yield level. According to Kriangsak, adopting hybrid seeds could be profitable at all levels of yields provided that farmers obtained a sufficiently high increase in yield for hybrid maize. Nevertheless, farmers who obtained the lower the original yield would need to have a higher percentage increase in yield compared to those who obtained higher original yield level. For an original level of yield of2.5 t/ha, this increase in yield can be only 9-11% to break-even. A similar conclusion was also reiterated by Byerlee, Morris and Lopez-Pereira {1993) and Heisey, et al (1998). Byerlee, Morris and Lopez-Pereira displayed a graph showing the set of minimum percentage yield increases, computed across a range of yield levels, a hybrid must generate to compensate farmers for the higher seed cost and increased risk. This break even yield curve falls as farmers current yields rise and a high seed-to-grain price ratio, the break-even yield advantage must be also large to compensate farmers of such increased seed costs. These relationships illustrated why farmers producing maize under better growing conditions and with good management are likely to adopt hybrids more readily than those producing maize under marginal growing conditions with poor management.

Despite the proven superiority in yield of maize hybrids over traditional OPVs by various field testing and in farmers' fields, there have been relatively few studies in Thailand which clearly confirmed farm-level impact, particularly profitability and farmers' income. Although some studies were carried out in selected sites, many of these studies are now outdated. Most of the studies were conducted during 1992/1993 when the adoption of hybrid maize was just starting. For example, Thipatorn, et al (1994) studied maize production in 1993/94 in 3 provinces in Northern Thailand covering three provinces, namely Phayao, Chiang Rai and Phrae. They found that the average yield of OPVs was 3.2 t/ha with a profit of 255 baht/ha while the average yield of hybrid maize was 4.2 t/ha with a profit of2,556 baht/ha. They found that while there was a statistically significant yield advantage of hybrid, there was no statistical differences in variable costs or prices between OPV and hybrids. The study seemed to confirm that adoption of hybrid maize was profitable for farmers in those areas. Benjawan (1996), conducting a survey in 1994 among 200 maize farmers in Nakorn Sawan, found out that farmers who adopted hybrids enjoyed a 32% increase in yield, 36% increase in net return, 29% increase in profit per kg and a 69% increase in profit per ha, despite higher materials costs (85% increase) and labor costs (13% increase) (Table 11, Figure 3).

Nevertheless, given a rapid change in hybrid maize adoption in the country and an increasing domination of single-cross hybrids, the conclusion that there is no change in the cost structure of farmers may no longer be true. Data obtained from the Office of Agricultural Economics (Table 12, Table 14, Figure 4) seem to suggest that variable costs increased rapidly (40% increased during 1992, 1994 to 1997/98). There is still a need for a study which looks specifically at farm level impact differentiating different types of hybrids according to its potential and seed prices.

Some studies suggested that maize production in upland areas as well as in paddy fields would be profitable only when maize yields exceed 3.0-3.3 t/ha (Mullika and Bumpen, 1997 and the Office of Agricultural Economics, 1994, Sanit and Saran, 1996, 1997, Table 12-13). A cause for concern lies in the fact that Kriangsak's and Byerlee et al's argument which asserted that hybrid maize can be profitable at all levels of original yield,

given a sufficiently high yield advantage need to be investigated again. Policy makers need to know why despite widespread adoption of hybrid varieties, a meaningful increase in the national average yield has still not been achieved. Given the potential of the new hybrids, many experts feel that national average yield should be as high as 5.0 t/ha, but the national average is only 3.4 t/ha, with some areas significantly lower than this level.

Also, studies are needed to establish the level of profitability of maize production in comparison with the production of other crops. There is a need to study the relative profitability of different upland crops under different agro-ecological systems and under different technological packages. Relative profitability rankings can help guide policy makers to formulate appropriate policy measures.

Table 9 Average yields and comparative yields of superio hybrids and Suwan 1

Year	Superior hybrid	Type	Average yield (kg/ha)		
			Superior hybrid	Suwan 1	National
1987	CGX 14423	TWC	7,113	5,081	2,050
1988	CARG 333	TWC	7,768	5,756	2,619
1989	DK 888	SC	8,434	6,582	2,569
1990	CARG 733B	MSC	8,240	6,336	2,406
1991	Suwan 3504	SC	8,726	6,547	2,713
1992	CARG 922	SC	8,824	6,366	2,969
1993	Suwan 3601	SC	9,081	5,855	2,731
1994	KSX 3751	SC	9,598	6,774	2,938
1995	Suwan 3851	SC	9,532	5,920	3,288
1996	Suwan 3853	SC	9,990	7,040	-
Mean			8,731	6,226	2,698

Notes: TWC=three-way cross hybrid, SC=single cross hybrid, MSC= modified single-cross hybrids.
Source: Chokechai, et al, 1997.

Table 10 Comparison of cost and return (baht)/ha from maize cultivation classified by varieties in Sa Kaeo

Item	Suwan 3	Hybrid	Single Cross
	----------baht/ha----------		
Fixed cost	1,132	1,063	1,355
Variable cost	3,387	3,843	4,083
Total cost	4,520	4,906	5,437
Cash cost	3,088	3,582	3,819
Yield (kg/ha)	3,583	4,401	4,850
Maize price (baht/kg)	2.44	2.48	2.45
Gross revenue	8,741	11,882	11,882
Net return	5,354	7,068.6	7,799
Net profit	4,222	6,006	6,445
Net profit over cash cost	5,654	7,330	8,063

Source: Sanit and Saran, 1993.

Table 11 Returns to production of OPVs vs. hybrids, Nakorn Sawan Province, 1994.

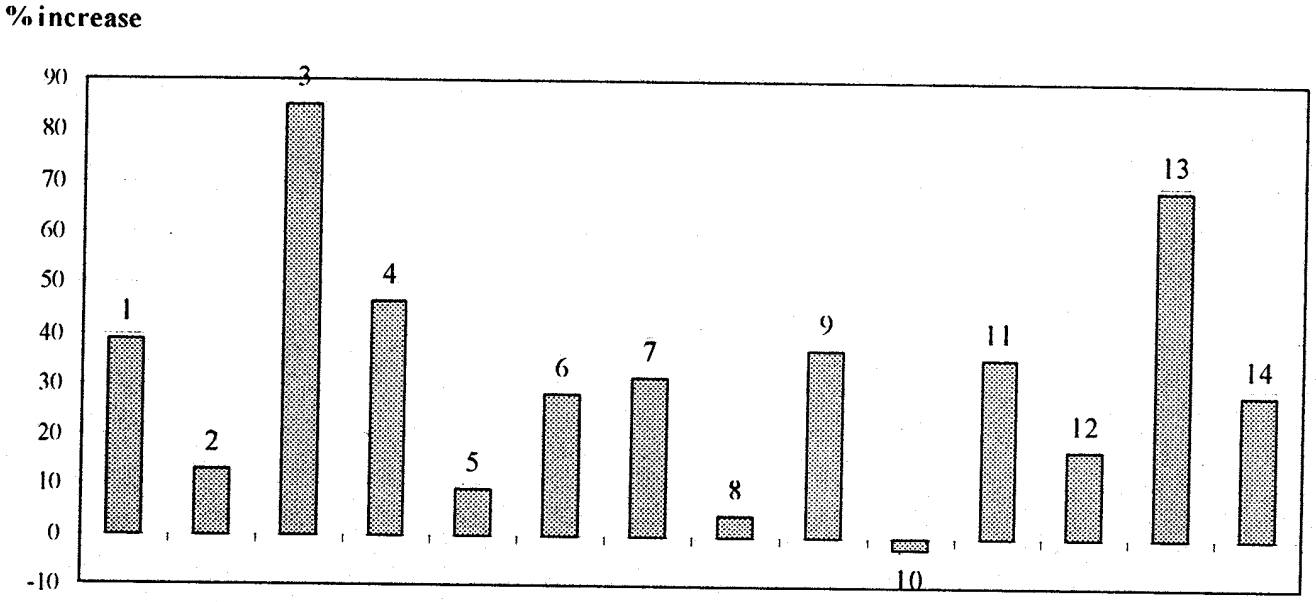
	OPVs (baht/ha)	Hybrid (baht/ha)	% increase (decrease)
Total variable cost	3,686	5,102	38.7
- Labor cost	2,189	2,478	13.2
- Material cost	1,249	2,309	84.9
- Others	248	364	46.6
Total fixed cost	1,934	2,109	9.0
Total Cost	5,619	7,210	28.3
Yield (t/ha)	2.79	3.67	31.5
Selling price (baht/kg)	2.57	2.68	4.2
Total revenue	7,173	9,834	37.1
Total cost (baht/kg.)	2.01	1.96	(2.5)
Net return	3,488	4,733	35.7
Net return over cash cost	4,548	5,336	17.3
Profit per ha (baht/ha)	1,554	2,624	68.9
Profit per kg (baht/kg).	0.56	0.72	28.6

Source: derived from Benjawan, 1996

Table 12 Returns to production of hybrid maize, Thailand, selected years.

	Nakhon Rachseema 1995/96 [1/]	Supunburi 1994/95 [2/]	Srisaket 1991/92 [3/]	Whole country 1992/93 [3/]	Whole country 1997/98 [3/]
No. of sample	78				
Type of planted area	Paddy	Paddy	Upland	Upland	Upland
Type of materials	HV	HV	HV	HV	HV
Total variable cash cost	7,800	10,202	6,143	5,629	8,194
Total fixed cost	481	1,651	315	1,046	975
Total Cost	8,280	11,853	6,458	6,674	9,169
Yield (t/ha)	1.65	2.7	6.25	4.79	3.27
Selling price (Bht/kg)	4.16	3.27	2.0	2.53	2.8
Total revenue	6,873	8,817	12,500	12,128	9,153
Total cost/kg.	5.01	4.40	1.03	1.39	2.80
Net return/ha	-927	-1,385	6,357	6,499	959
Net return over cash cost	3,535	4,654	6,686	-	-
Profit/ha	-1,407	-3,036	6,042	5,454	-16

Source : [1/] Saran and Sanit, 1997, [2/] Saran and Sanit, 1996,
[3/] Office of Agricultural Economics



1=TVC, 2=Labor cost, 3=Material cost, 9=total revenue 10=total cost per kg,
4=other cost, 5=fixed cost, 11=net return per ha, 12= net return over cash cost/ha,
6=total cost, 7=yield, 8=output price, 13=profit per ha, 14=profit per kg

Figure 3 Comparison of hybrid over OPV maize varieties in 1994 among 200 farmers in Nakorn Sawan.

Table 13 Returns to production of single cross hybrid maize in paddy fields, 1996/97.

	Phetchabun	Chiang Rai	Chaiyaphum	Average
Total variable cash cost	7,518	7,334	6,839	7,263
Yield (t/ha)	5.27	4.89	4.11	4.76
Selling price (Bht/kg)	3.33	4.10	4.00	3.85
Total revenue	17,541	20,063	16,404	18,342
Net return over cash cost	10,023	12,729	9,565	11,079
Net return over cash cost/kg	1.90	2.60	2.32	2.33

Source: Mullika and Bumpen, 1997.

Table 14 Indicators of maize production costs, Thailand, 1988-97.

Year	Variable cost (baht/ha)	Fixed cost (baht/ha)	Total cost (baht/ha)	Yield (kg/ha)	Cost/kg (baht)
1988/89	3,906	683	4,589	2,550	1.80
1989/90	3,903	689	4,593	2,456	1.87
1990/91	4,068	689	4,757	2,131	2.23
1991/92	4,311	706	5,017	2,569	1.95
1992/93	4,376	706	5,082	2,719	1.87
1993/94	6,315	706	7,021	2,488	2.82
1994/95	6,555	706	7,261	2,806	2.59
1995/96	6,904	706	7,610	3,113	2.45
1996/97	8,194	975	9,169	3,269	2.80
1997/98	9,116	975	10,091	2,763	3.65

Source: calculated from Office of Agricultural Economics. 1998. Information on important commodities' production and marketing.

4.4.2 Farmers' acceptance of improved varieties

Farmers adopt improved varieties easily because of the increased profitability. Over time, they become more and more particular about the improved varieties they would like to use. Their preference for a variety is well expressed. Companies, through the working of BAAC and DOAE, thus need to convince farmers that the hybrid they are currently using are already the best for them.

Benjavan (1996) showed that hybrid maize farmers enjoy more than 100% increase in income (Table 15). According to the farmers that were interviewed during this study, the most important reason for selecting hybrids is the yield advantage. A smaller proportion of farmers cited drought tolerance as the reason for their adoption. Those farmers who were still using OPV were concerned about seed prices and pest resistance quality (Table 16).

In her sample of farmers in Nakorn Sawan, Benjawan (1996) found that a large amount of information about hybrid maize came from the public sector --as much information as came from the seed companies (Table 17). Thus one can conclude that the success achieved in promoting adoption of hybrid maize can be attributed to effective collaboration between the public and private sectors. The private sector does research and sells hybrid seed, while the public sector deals with back-up research, promotion, and extension activities.

Table 15 Distribution of income earned by maize farmers (baht/person), Nakorn Sawan,1995.

	Years of experience growing hybrids			
Source of Income	**0-2 years**	**3-5 years**	**>5 years**	**OPV**
Maize	64,624	71,924	62,615	30,471
Other crops	35,859	24,932	22,283	26,783
Off-farm	2,125	1,589	2,867	1,350
Total	102,608	98,446	87,765	58,603

Source: Benjawan, 1996.

Table 16 Reasons for maize variety selection, Nakorn Sawan, 1995.

Reasons	Years of experience growing hybrids			
	0-2 years	**3-5 years**	**>5 years**	**OPV**
	-------1st rank answer as % of each group of households ----------			
High yield	68	78	90	0
Drought tolerance	25	15	7.5	10
Pest resistance	5	4	-	35
Seed price	0	3	-	65
Others	2	0	2.5	10

Note: More than one answer can be selected by a household.
Source : Benjawan, 1996.

Table 17 Sources of information about hybrid maize (% of farmers).

Sources	0-2 years	3-5 years	>5 years
Self learning	8	17	5
Other farmers or neighbors	18	6	8
Seed companies	39	38	45
Public sector	35	53	63
Local input merchants	8	6	3
BAAC	5	1	3

Source: Benjawan, 1996.

5. Public-private sector linkages

The close working relationship and effective linkages between the public sector (including CIMMYT) and the private sector has been critical to the success of maize varietal development in Thailand. The private sector has established many relationships with the public sector, and these relationships have been very fruitful. Those collaborations will be elaborated below.

5.1 Germplasm exchange

5.1.2 Free distribution

The first important linkage between the private and public sector involved flows of improved germplasm. The private sector can obtain breeding materials from the public sector, especially from CIMMYT, which has in its maize germplasm bank some 13,000 accessions collected from all around the world. CIMMYT has been very open and helpful in distributing this germplasm, which is always provided free of charge. The national research organizations rely heavily on CIMMYT germplasm. Strong breeding programs at the national public agencies such as Kasetsart University and DOA in turn provide research support to the private sector, both for multinational and domestic companies. Private companies can also gain ready access to CIMMYT germplasm, which they evaluate on a regular basis.

The impact of CIMMYT germplasm is more pronounced among small domestic companies and national research organizations than among large multinational companies and national companies with partnership with multinational companies. These latter groups of companies have access to germplasm developed by their own mother or overseas branch companies. They reportedly use a small proportion of CYMMYT materials for breeding work (around 16%) while obtaining the bulk of their breeding materials from elsewhere.

Table 18 Origin of breeding materials used in -private sector maize breeding programs.

Germplasm source	% of this type of germplasm in the public sector breeding program
Materials selected by the organization in this country (two or more local cycles of selection)	56 %
Materials obtained from a foreign office of the organization	10 %
Materials obtained from foreign companies with which the organization has an alliance	1 %
Materials obtained from public breeding programs in this or any other country	12 %
Materials obtained directly from CIMMYT (populations, pools, inbred lines)	9 %
Materials obtained from CIMMYT's germplasm bank, but which are not considered germplasm developed by CIMMYT	7 %
Materials obtained from other organizations in this or any other country	6 %
Other (specify):	0 %
Total	100 %

Source : From private companies' interviews.

Interviews conducted with six private companies revealed that Suwan 1 is still used extensively for breeding work, while CIMMYT materials are used less. Often it was reported that CIMMYT materials are not well adapted to local conditions. On the other hand, inbred lines, OPV, and hybrid varieties from Suwan Farm have been used extensively by the private companies for further varietal development. Rather than distributing them free of charge, Suwan Farm sells these materials to recover some costs of research.

Table 19 Sale prices of inbred and parent lines, Suwan Farm.

Material	Sale prices
Ki 1 – Ki 30	US$400 per unit (100 grams), if used for hybrid variety development, no further payment is necessary.
Ki 31 (1992) onwards	US$200 per unit (100 grams) and if used for developing hybrid variety, additional payment is necessary.
	US$400 in the first year of hybrid production,
	US$1,600 in the second year of production,
	and US$8,000 for three or more year of production exceeding 100 ton, if production is less than 100 ton, US$1,600 for each year.
Parent lines for producing the NCSRC's hybrids	US$12/kg a minimum of 75 kg.
Any Inbred lines, in	US$10/kg a minimum of 500 kg
Addition to the above	US$8/kg a minimum of 1,000 kg

5.1.2 Selling of inbred lines

Suwan Farm has a policy of selling its inbred lines. Before 1999, it sold inbred lines to whomever wanted to buy. Prices differed according to the number as follows. More recently, Suwan Farm initiated a new scheme for selling inbred lines. It now grants an "exclusive right" by selling each line to only one company, which must satisfy certain conditions set forth by Kasetsart University's administrators. One of the conditions is a guaranteed minimum production level. This is to ensure that the winning company will disseminate Suwan Farm's hybrids through its production, marketing and distribution outlets. The contract is a three-year renewable contract. , With the help of this new distribution scheme, KU officials hope that Suwan Farm's hybrids will be able to compete in popularity with the private sector's hybrids. The ultimate goal is to ensure the healthy competition in the domestic maize seed market.

5.2 Varietal testing and evaluation

Suwan Farm, DOA, and the private sector join together for regular varietal testing and evaluation. The Department of Agricultural Extension has also established a seed quality testing program. The varietal testing and evaluation program provides a mechanism for comparing and contrasting materials produced by the private sector and materials produced by the public sector. Through comparative testing and evaluation, private companies can use the results as reference points for working with farmers and with government agencies. CIMMYT also provides venues for varietal testing and evaluation across countries. In the Southeast Asian Region, CIMMYT and FAD have

helped to establish the Tropical Asian Maize Network (T AMNET) for this kind of service. Trials conducted through these networks show that many of the latest hybrids have potential yields of around 8-9 t/ha (Chantachume, et a11998, Vasal, 1998, Aekatasanawan, 1997).

5.3 Seed quality testing

There are currently no requirements for the certification of new maize varieties in Thailand, unless they are public sector varieties. The private sector can release new varieties and sell them essentially without restrictions. Nevertheless, in order to meet formal tender requirements for government purchases of seed, seed must be subjected to quality testing. Not only field testing is required, but following a recent scandal involving falsely labeled seed, DNA fingerprinting will also be required also for such purchases. DNA fingerprinting services are now available through the National Center for Genetic Engineering and Biotechnology, National Science and Technology Development Agency in collaboration with Kasetsart University. The cost is around 20,000-30,000 baht per hybrid. The Department of Agriculture is also in the process of acquiring the necessary equipment for such a service, which is regarded as priority for future seed testing work. This rigorous testing should end disputes over "stealing" of new varieties. Nevertheless, legislation establishing plant variety protection will also be needed to back up claims over plant variety rights.

In collaboration with the Department of Agricultural Extension, the private companies also conduct a seed quality testing program, as well as a seed promotion program. The DOAE set up a system of acreage allocation among different companies, which allows the companies to concentrate their work in different regions. Through the mediation of DOAE and BAAC, all seed companies get their share of business according to their relative strengths and potentials. A transparent system of performance evaluation and mutually agreed criteria for competition on the part of the government sector helps the private companies in their quest to expand market share.

5.4 Human capital development

Another important public-private linkage is evident in the area of human capital development. Universities provide degree and short-term training for private sector personnel. CIMMYT also regularly trains both public and private sector researchers. The researchers and workers in the private sector have their background one way or another in public universities. They relate with each other on a personal basis, either as friends, alumni of the same institutions, or through friends of friends, junior-senior, ex-students and teachers, etc. In this way, the human capital in maize research in the public and private sector has been well functioning, highly qualified, motivated and committed to their work. The frequent personal contact between public and private sector researchers helps make maize research more interesting and competitive and has clearly contributed to the success of the maize research system in Thailand.

5.5 Information exchange

5.5.1 Workshops and conferences

There are regular workshops and conferences on maize research, focusing both on breeding and on agronomic work. There is an annual conference on National Corn and

Sorghum Research, each year attended by a large number of people both from the public and private sector. There are also regular workshops on plant breeding. Workshops in other topics such as biotechnology and farming systems also involve maize research in different aspects.

There are also regular regional and international conferences conducted by CIMMYT which are attended by national scientists. These are important venues for exchanges between the public and private sector researchers.

5.5.2 Publications

National and international publications are important means of linkages between the public and private sector. Public organizations regularly publish research papers, journal articles, books, etc. In the private sector, these kinds of publications are more limited. The mode of operation is very different in the public and private sectors. The former is more open, while the latter is more closed. In the private sector, knowledge is abundant, but because of confidentiality requirements, it tends to remain inaccessible to the public. As more and more knowledge is accumulated in the private sector, there is a danger that public knowledge will become more limited and that learning will be inhibited. It is the role of the public sector to diffuse and disseminate knowledge. This can counteract the private sector in their "closed" form of knowledge.

5.6 Policy-related matters

The Thai government has been very supportive of the research and development work carried out in the private sector. It has appropriately built up policies which support and expand the work of private companies. By working with these companies, the government has made possible the rapid expansion of hybrid maize. Coupled with its expenditures on public-sector research, extension, and infrastructure development, maize farmers have been well serviced either by the public or the private sector. Increased international trade has expanded the demand for maize in domestic and foreign markets. Livestock and maize production are among the list of activities promoted by the Ministry of Agriculture and Agricultural Cooperatives (MOAC). Apart from seed subsidization, the government has pledged to continue to promote public and private collaboration in maize production. Credit provision is provided through credit programs of BAAC. Plant breeders' rights are also high in the agenda although the particular form of implementation will not concentrate only on plant breeders' rights per se. This issue will be discussed in Section 6.3.1 below.

One important policy-related maize production issue relates to environmental concerns. Numerous criticisms have been made that government policies are accelerating the process of deforestation and environmental degradation. Since maize is often produced in upland areas, many maize farmers have land disputes with the government, particularly with the Royal Forest Department. Land tenure is an important policy issue, which has not yet been resolved. Maize (also cassava and sugar cane) producers are viewed by some sectors of the public and the media as being environmentally destructive and are frequently blamed for causing deforestation and soil erosion. Mechanization of maize production is especially criticized because of its alleged contribution to environmental problems. While these issues cannot be characterized as specifically maize-related, policies designed to deal with environmental issues (including policies

relating to land rights) will directly affect many maize farmers in the uplands. As far as the private companies are concerned, environmental-related government policies will have both direct and indirect effects on their activities.

6. Looking ahead

6.1 Future demand and supply

Given current trends, it is foreseeable that demand for maize will increase in the near future in response to rising livestock consumption and trade. At the same time, the potential to increase production is great due to the introduction of hybrid seeds and their associated yield advantage. With modern technology, maize has great potential to increase farmers' income. However, the yield gap between farmers' fields and public and private experimental stations is of particular concern. Farmers' yield performances will be critical to the future of maize supply. Together with the private sector, the public sector will have to pay much more attention to what really happens on the ground. Do hybrids perform badly among resource-poor farmers, or under erratic rainfall, or under particular biological and physical conditions? The fact that many farmers are now using private sector hybrids is not a good reason why policy makers should ignore what is really happening to farmers, especially resource poor farmers. On the other hand, the profit motive should not be the only criterion of success for private seed companies, especially not to the extent of making them overlook the "real" impacts of the new hybrids on farmers' income and welfare. The "real" impacts of new varieties must be measured not in terms of adoption rates, but rather in terms of what farmers (and consumers) are receiving in the incremental benefits to their lives.

6.2 Emerging 1g technologies

On the production technology side, advances in biotechnology for maize will be substantial in the near future, particularly advances in molecular genetics and genetic engineering. These advances will set a new stage for the maize seed industry, both for the public and the private sector. Issues relating to biosafety, health-related problems, cost-related concerns, and competitiveness of the industry will have to be addressed, however. Also, there are urgent human capital development needs for the new technologies. The roles of the public and private sector in the new technological advances will have to be seriously evaluated in the context of new technology. What can international centers like CIMMYT contribute to such a balance? Finally, the need for good impact studies resulting from such technologies will also be substantial.

6.3 The evolving legal environment

6.3.1 Plant breeders' rights, plant varietal protection

On the legal side, there will also be a shift in paradigm concerning rights and variety protection. In the past, all new varieties were not protected by law, but the private companies used forms of breeders' "secrets" to protect their varieties while relying on "contract laws" to enforce business deals. Because secrets were sometimes revealed and/or "stolen," private companies see the need to protect their varieties through legal means. In the next few years, new forms of plant breeders' rights, together with the technical means to enforce these rights (e.g. DNA fingerprinting) will become the order of the day.

In compliance with WTO's TRIPS agreement, Thailand is now drafting a Plant Varietal Protection Bill which contains elements not only of plant breeders' rights, but also of farmers' rights. This very innovative *sui generis* bill will require plant breeders to pay royalties to holders of traditional variety rights. The bill will not affect maize breeders much, however, because practically all maize varieties grown in Thailand are not traditional land races. Nevertheless, the bill will allow plant breeders and/or seed companies to register their new varieties for protection. Once the bill is passed, any violation of the breeder's rights will be protected by law. No doubt the new bill will raise many enforcement issues, because there are many potential implementation problems that could render it ineffective. For example, the bill does not prevent biopiracy, because it is powerless once a plant variety is taken out of the country. Moreover, new varieties and traditional varieties are lumped together in the same bill, even though they are very different.

While the proposed legislation is attempting to break new ground in plant variety rights, it has a number of fundamental weaknesses when it deals with issues of research and development, especially agricultural research. It can safely be predicted that if the bill is passed, there will be a rush to register and claim rights to all plant varieties. Disputes on plant variety rights will be so overwhelming that they could discourage all kinds of research and development. In all likelihood, the costs of administering those rights and disputes will far exceed all benefits derived from having them. The United Nations Food and Agriculture Organization (F AO) and Consultative Group of International Agricultural Research (CGIAR) are exploring alternative means of administering farmers' rights which might imply lower costs than those implied by the Thai Plant Variety Bill. The F AO/CGIAR approach needs to be considered by the Thai government before passing the Plant Variety Protection Bill as it stands.

6.3.2 Biosafety regulations

Alongside plant varietal protection rights, issues related to biosafety have arisen as a result of the appearance of genetically modified varieties. Regulations dealing with these biosafety issues will become increasingly important in the years to come. Genetically modified cotton varieties (Bt cotton) are currently being tested by DOA, although none of these varieties has passed DOA's tests for disease resistance. Moreover, patent costs are still to be negotiated between DOA and Monsanto. The National Center for Genetic Engineering and Biotechnology within the National Science and Technology Development Agency is setting up regulations concerning biosafety.

6.4 Changes in the organization of research

Maize research in Thailand, like research on other crops, will not be the same in the future. As private research becomes increasingly protected by patents and/or plant variety protection laws, public sector researchers on the one hand and farmers on the other will be less willing to share information, research results, and germplasm.. Remuneration will be demanded in many cases. As government funding for research becomes more limited, more and more public research is being funded by the private sector. In this context, research results will increasingly be sold for profit, rather than distributed freely. Some products of public sector research will need to be patented, similar to research results from the private sector.' Private sector knowledge will be

available only for a price. Research will be more expensive in the future as patent costs rise. Thus, the overall environment in which research takes place will change in the near future. Public research institutions will soon act as like private companies in order to generate income. Beginning in the year 2000, all universities in Thailand will be financed by the government through block grants, and they will become more independent from government financial rules and regulations. This will force them to substantially revise how research is conducted. Suwan Farm itself aims to become more financially independent. Public research institutions will be more income-oriented and cost-effective than in the past.

6.5 Ecoregional research

Maize research in the future will need to be more location specific, giving more attention to agroecological characteristics. A greater number of locally-adapted varieties will need to be developed to suit different agroecological zones. Geographic information systems (GIS) will become invaluable as a research tool to guide maize research. Finally, it will be necessary to establish closer links between countries in the same ecoregional zones in order to exploit economies of scale in research and maximize the benefits of potential research spillovers. Public sector research will need to be more strategic in orientation as the structure of research changes.

7. Role of public research organizations

In the years to come, the private sector will come to dominate research in maize due to its comparative advantage in new lines of technology, such as biotechnology (particularly genetic engineering). The roles of public research organizations such as the Department of Agriculture, universities, and even CIMMYT, will need to be reevaluated. Public organizations will likely not to have the same level of research funding and personnel capacity as multinational companies, which have a tendency to be bigger, larger, and more integrated in their line of business. Seed companies are now merging with agrochemical and food products companies. Research is more and more private sector research with legal protection. As the large multinational companies continue collecting and keeping their own germplasm, more research will be patented and privatized. On the other hand, smaller companies will lose out in the process without the support from the public sector. Unless public research organizations are well placed in the new technological and legal environment, they will be driven out of the market due to strong winds of competition. Together with the public sector, the private sector will need to work out complementary roles, as it is in the best interest of all concerned to ensure a healthy economy in which everybody can enjoy the fruits of technological advances.

The Thai maize sector has performed well in the past. Will it continue to perform as well in the future? The following section discusses possible new and expanded roles of public sector organizations in the Thai context. In other words, the public sector will need to be more of a moderator, mediator, monitor, and regulation setter, rather than direct producer of hybrid seed.

7.1 Role of the Department of Agriculture

7.1.1 Administering plant breeders' rights, plant varietal protection laws

a. Registration of new varieties, plant breeders' rights

b. Enforcing plant breeders' rights
c. Regulation of new varieties
d. Testing of new varieties using DNA tests

7.1.2 Research

a. Developing of improved OPV varieties for certain environmental conditions.
b. Developing of inbred lines
c. Varietal testing
d. Agronomic research
e. Cost-effective biotechnology research

7.1.3 Agronomic Impact assessment

a. Biosafety monitoring

7; 2 Role of other government departments

7.2.1 Department of Agricultural Extension

a. Hybrid variety promotion and extension work
b. Seed quality testing

7.2.2 National Center for Genetic Engineering and Biotechnology

a. Biosafety regulations
b. Human capital development

7.2.3 Office of Agricultural Economics

a. Comparative advantage
b. Profitability studies

7.2.4 Land Development Department

a. Land use
b. Land evaluation

7.3 Role of universities

a. Inbred line development
b. Agronomic research
c. Impact assessment
d. Supply and demand projections
e. Adoption, yield gap studies
f. Policy analysis

7.4 Role of regional networks

a. Germplasm exchange
b. Information exchange
c. Varietal testing

7.5 Role of international centers (CIMMYT)

a. Germplasm exchange
b. Germplasm evaluation
c. Information exchange
d. Varietal testing
e. Human capital development
f. Cost effective biotechnology research

g. Policy analysis

8 Summary and conclusions

The current success of the Thai maize seed industry can be traced back many years, specifically to the 1970s and 1980s, when public breeding of open-pollinated varieties laid a firm foundation for private breeding of hybrids in the 1990s. Nevertheless, gains in average productivity per unit area have not been realized as rapidly in farmers' fields as might have expected. Gains in farmers' incomes have been observed in selected study areas, but additional data are needed before it will be possible to assess aggregate impacts of hybrids and thus of maize research in Thailand. Substantial yield gaps are observed to exist between experimental stations and farmers' fields. More research is needed to determine constraints to production at the farm levels especially for resource poor farmers in marginal environment.

During the next decade, maize research will again be very different in approach and impacts than in the past due to rapid changes not only in technology, but also in the legal and political environment surrounding research organizations and products. As research becomes privatized and increasingly concentrated, it is time to rethink roles of the public and private sectors to identify gaps of knowledge that will exist given the context of strong private sector research and development. Those gaps will need to be filled by public sector research organizations, both at the national and international level.

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