Impact of Public- and Private-Sector Maize Breeding Research in Asia, 1966-1997/98

Roberta V. Gerpacio, Technical Editor

CIMMYT

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CIMMYT MR

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Abstract: This book presents results of a study of the impacts of international maize breeding research in seven developing countries of Asia (China, India, Indonesia, Nepal, the Philippines, Thailand, and Vietnam). It provides comprehensive, updated documentation of the status of Asia's national maize seed industries, including information on the roles of the public and private sectors in maize R&D, descriptions of the germplasm products developed by public and private breeding programs, data on the extent of farmers' adoption of modern maize varieties, and analysis of varietal adoption patterns and trends. Information on emerging trends in maize research and maize seed industries is also provided. An introductory chapter on the maize economy of Asia is followed by a chapter synthesizing results of the study for Asia as a whole. More detailed, country-level studies are presented in the remaining six chapters.

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AGROVOC Descriptors: Agricultural development; Economic analysis; Private sector; Public sector; Seed industry; *Zea mays*; Maize; Germplasm; Plant breeding; Research projects; Developing countries; China; India; Indonesia; Nepal; Philippines; Thailand; Viet Nam; Asia

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Foreword

In 1992, the International Maize and Wheat Improvement Center (CIMMYT) began documenting the impacts of international maize breeding research in the developing world. CIMMYT's first global maize impact study, published in 1994, provided detailed information about the extent of adoption of improved maize varieties and discussed how maize could be further improved to better meet the needs of end-users.

In 1997, CIMMYT initiated a project designed to update and extend the results of the earlier global impact study. Separate studies of the impacts of maize research and development (R&D) were conducted in three developing regions: Latin America, sub-Saharan Africa and Asia. This book presents the results of the Asia regional study. It provides comprehensive, updated documentation of the status of Asia's national maize seed industries, including information on the roles of the public and private sectors in maize R&D, descriptions of the germplasm products developed by public and private breeding programs, data on the extent of farmers' adoption of modern maize varieties, and analysis of varietal adoption patterns and trends.

An initial chapter on the maize economy of Asia focuses on the importance of maize in the region, the range of maize production environments, and major trends in maize production and utilization. Chapter 2 describes the objectives of the study, specifies the geographical coverage, and explains the data used as well as their sources. The greater share of the chapter consists of an Asia-wide overview of the impact of maize breeding research. Chapters 3 to 8 are detailed reports from six of the seven countries that participated in the study. These chapters provide in-depth information about the maize economy, maize R&D, the impact of research, and the national maize seed industry in each country.

This study appears at a critical time, when demand for maize in Asia is projected to increase faster than demand for any other cereal, including rice. Rising demand for maize is being spurred by several factors, among which the most important is the region's rapidly expanding livestock industry, which requires an increasing amount of maize for use as feed.

The expanding opportunities in maize production for commercially oriented farmers, and perhaps also for non-commercial farmers in marginal areas where maize traditionally has been grown as a staple food crop, present many challenges for the region's maize seed industries. These challenges come at a time when many national research systems are in transition. Historically, maize research in Asia was built on a strong foundation of public research organizations; for many years, these organizations were the only sources of improved maize varieties and commercial maize seed. In the years since the first CIMMYT impact study was undertaken, many Asian countries have enacted legislation that encourages the private sector to participate more fully in maize breeding research and commercial seed production. With the notable exception of China, where maize R&D and seed production remain the domain of publicly funded organizations, throughout Asia the private sector has come to dominate national seed industries.

This book presents information about the changes that are rapidly transforming national maize seed industries throughout Asia and in seven important maize-producing countries. This information should help policy makers and research managers address vital questions about the consequences of recent policy changes, the answers to which are certain to influence future directions in Asian maize R&D. How effectively has the private sector been able to assume key functions formerly performed by the public sector? What kinds of research are being emphasized by private seed companies, and are these different from the kinds of research that traditionally have been carried out by public organizations? Are there impediments to further increasing participation by the private sector? Is there evidence that more farmers are growing improved varieties as the private sector has increased its presence? What types of farmers have been able to reap the benefits of an increasingly privatized seed industry? Have any types of farmers been bypassed? What role, if any, is being played by international and regional research organizations to facilitate the transition from mainly public to mainly privatized national seed industries? While it may still be too early to answer all of these questions definitively, the information and analysis presented in this volume provide important insights that will be useful in designing strategies for the future.

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Acronyms and Abbreviations

AF&F	Agricultural, forestry and fisheries
AIC	Agricultural Inputs Corporation (Nepal)
APP	Agricultural Perspective Plan
ARS	Agricultural Research Station
BAR	Bureau of Agricultural Research (Philippines)
BAS	Bureau of Agricultural Statistics (Philippines)
BBI	Balai Benih Induk (Indonesia)
BBU	Balai Benih Pembantu (Indonesia)
BPS	Badan Pusat Statistik (Indonesia)
CGIAR	Consultative Group on International Agricultural Research
CIMMYT	Centro Internacional de Mejoramiento de Maíz y Trigo (International Maize and Wheat Improvement Center)
CRIFC	Central Research Institute for Food Crops (Indonesia)
DA-BPI	Department of Agriculture–Bureau of Plant Industry (Philippines)
DADO	District Agricultural Development Office (Nepal)
DGFC	Directorate General for Food Crops (Indonesia)
DMR	Directorate of Maize Research (India)
DOA	Department of Agriculture
DOAD	Department of Agricultural Development (Nepal)
DOAE	Department of Agricultural Extension (Thailand)
EIA	Environmental Impact Assessment
FAO	Food and Agriculture Organization of the United Nations
FNRI	Food and Nutrition Research Institute (Philippines)
FTE	Full-time equivalent
FYM	Farm yard manure
GVA	Gross value added
ha	Hectares
HYV	High yielding variety
IAS	Institute for Agricultural Science (Vietnam)
ICAR	Indian Council of Agricultural Research
INGO	International non-governmental organization
IPB	Institute of Plant Breeding (Philippines)
IUCN	World Conservation Union (International Union for the Conservation of Nature)
kg	Kilogram

KUD	Koperasi Unit Desa
MARD	Ministry of Agriculture and Rural Development (Vietnam)
masl	Meters above sea level
m ha	Million hectares
m t	Million tons
MAV	Minimum access volumes
mm	Millimeters
MOA	Ministry of Agriculture
NARC	Nepal Agricultural Research Council
NCSRC	National Corn and Sorghum Research Center (Thailand)
NFA	National Food Authority (Philippines)
NGO	Non-governmental organization
NMDP	National Maize Development Project (Nepal)
NMRI	National Maize Research Institute (Vietnam)
NMRP	National Maize Research Program (Nepal)
NRs	Nepali rupees
NSB	National Seed Board (Indonesia, Nepal)
NSC	National Seed Company (Vietnam)
NSC	National Seeds Corporation (India)
NSIC	National Seed Industry Council (Philippines)
OED	Office of Executive Director
OPV	Open-pollinated variety
PhP	Philippine pesos
PVP	Plant variety protection
R&D	Research and development
RIARCS	Regional Integrated Agricultural Research Centers (Philippines)
RIMOC	Research Institute for Maize and Other Cereals (Indonesia)
Rp	Rupiahs
Rs	Rupees
SAU	State Agricultural University (India)
SCCS	Seed Certification and Control Services (Indonesia)
SEAN	Seed Entrepreneurs' Association of Nepal
SSC	Southern Seed Company (Vietnam)
SSC	State Seed Corporation (India)
SIDA	Seed Industry Development Act (Philippines)
t	tons (metric)
UPOV	International Convention for the Protection of New Varieties of Plants
US$	US dollars
USMARC	University of Southern Mindanao Agricultural Research Center
VAT	Value-added tax
VND	Vietnamese dong
WTO	World Trade Organization
yr	Year

Chapter 1

The Maize Economy of Asia

Roberta V. Gerpacio

Maize has always been a second-priority crop in Asia after rice. Recently however population growth and rising consumption of livestock products (in turn fueled by rising per capita incomes) have led to increased demand for maize. To serve this increased demand, Asian maize farmers are gradually shifting to higher yielding maize varieties and using more modern production technologies. In response, maize research and development (R&D) agencies in the region are aligning their research strategies to better serve the changing production and market requirements.

Importance of Maize

Worldwide, maize ranks first in terms of production among cereals, just ahead of wheat and significantly ahead of paddy rice. In developing economies, maize ranks first in Latin America and Africa, but only third in Asia after rice and wheat (FAO 2001). Globally, 561 million tons (m t) of maize were harvested in 1995-97 from just under 140 million hectares (m ha). Seventy-six percent of this area was located in developing countries (CIMMYT 1999). During the same period, around 151 m t of maize grain (27% of world production) were harvested in Asian countries from 42 m ha (30% of global maize area) (Table 1). This level of production represented a significant increase from 1983-85, when 94 m t of maize were produced annually from 35 m ha. Asia's contribution to worldwide harvested maize area and maize production also increased markedly between the two periods (Table 1).

It is projected that by 2020 demand for maize in developing countries will surpass the demand for both wheat and rice. Globally, maize demand is projected to increase by 50% from its 1995 level of

Table 1. Average annual maize area, yield and production, Asia and the world, 1983-85 and 1995-97

	1983-85			1995-97		
	Area (m ha)	Yield (t / ha)	Production (m t)	Area (m ha)	Yield (t / ha)	Production (m t)
Asia	35.6	2.7	96.6	41.9	3.6	151.7
South	7.5	1.3	10.0	8.0	1.5	12.3
Southeast	8.2	1.6	13.4	8.5	2.2	19.1
East	18.9	3.7	70.8	24.3	4.8	117.0
West[a]	1.0	2.3	2.4	1.1	3.1	3.3
World	126.7	3.4	429.9	136.7	4.1	561.5
Asia as percentage of world	28.1	79.4	22.5	30.7	87.8	27.0

Source: CIMMYT (1987, 1999).
[a] Data for West Asia, 1983-85, computed from FAOSTAT database, Production Domain, May 2000.

558 m t to 837 m t by 2020 (IFPRI 2000). In developing countries, rising incomes and the consequent growth in meat and poultry consumption have resulted in a rapid increase in the demand for maize as livestock feed. This trend is particularly evident in East and Southeast Asia, where maize demand is projected to increase from 150 m t in 1995 to 280 m t in 2020 (IFPRI 2000). Unabated population growth and the persistence of poverty have also kept food maize demand high in poor countries, as in some parts of South Asia.

Environmental, technological and institutional factors have led to differentiation in maize production systems across Asia. In the intensive production systems of East Asia, maize is grown mainly in favorable environments by commercial farmers who plant high-yielding varieties (HYVs), apply high levels of purchased inputs and make extensive use of machinery. By contrast, in the more extensive production systems of South Asia, maize is grown mainly in marginal environments by subsistence-oriented farmers who rely heavily on manual labor or animal power.

The major maize producers in Asia are China and Korea (D.P.R.) in East Asia; Indonesia, Thailand and Philippines in Southeast Asia; India, Nepal and Pakistan in South Asia; and Turkey, Iran and Afghanistan in West Asia. The major maize consumers in the region are Jordan, Lebanon, Sri Lanka, Malaysia and the Republic of Korea (see Annex 1, p.10).

Principal Maize Production Environments

Maize (*Zea mays L.*) is a versatile crop that adapts easily to a wide range of production environments. Maize grows at latitudes ranging from the equator to slightly above 50° North and South, from sea level to over 3,000 meters above sea level (masl), under heavy rainfall and in semi-arid conditions, and in temperate and tropical climates. The growing cycle can range from three months to more than a year (Dowswell *et al.* 1996). Maximum grain yields have been recorded in locations where temperatures reach 30-32ºC during the day and drop to 11-18ºC at night, but the crop can tolerate wide deviations from this ideal range (Dayanand 1998).

The diverse environments in which maize is grown in Asia reflect the crop's adaptability to a wide range of production conditions, as well as its suitability for many different types of cropping systems. Maize can be grown as a monocrop, as an intercrop or as a relay crop; it can be harvested green (fodder) or when fully mature (grain and stover).

In India, maize is cultivated in locations where temperatures range from as low as 10ºC to as high as 45ºC and where rainfall ranges from as little as 200 millimeters per year (mm/yr) to as much as 2,500 mm/yr. Indian maize production has traditionally been concentrated in the southern "Corn Belt" states of Karnataka and Andra Pradesh, where the main maize crop is grown during the summer (*kharif*) season. In recent years, introduction of cold-tolerant varieties has led to the emergence of an irrigated winter (*rabi*) maize crop in the northern states of Bihar and Uttar Pradesh.

In Nepal, maize is grown in three of the country's four ecological zones. In the Terai (1,000 masl), an intensively cultivated flood plain, maize is the third most important crop after paddy and wheat. In the mid-hills (1,000-3,000 masl), a zone of steeply sloping land and many small river valleys, maize is the most important cereal crop, followed by millet and paddy. In the mountain zone (>3,000 masl), where only about 4% of the steeply sloping land surface is cultivated, maize covers about 30% of the total cropped area.

In Indonesia, maize production systems are distributed in a mosaic across the country. Maize is grown in *tegalan* (rainfed dryland) and in *sawah* (floodable wetland). There is also the specialized tidal swamp maize production system, called *surjan*, found mainly in newly opened land outside Java, where rice is grown in standing water in sunken beds and maize is grown on raised beds (Subandi 1998).

In China, maize is grown in every province. Approximately two-thirds of the maize in China is grown in temperate production environments in the north; the rest is grown in the subtropical and tropical environments of the south (Dowswell *et al.* 1996, Pray *et al*. 1998).

No universally recognized system exists for classifying maize production environments. CIMMYT, which holds a global mandate for maize improvement in developing countries, has developed a classification system based on the concept of *mega-environments* (CIMMYT Maize Program 1988, Hartkamp *et al*. 2000).[1] CIMMYT maize breeders commonly distinguish four major maize mega-environments: the lowland tropics, tropical highlands, subtropics/mid-altitude zones and temperate zones (Table 2).

In Asia, maize is grown mainly in tropical lowland and temperate environments (Table 3). While tropical lowland production environments are found in all Asian countries, temperate production environments are found mostly in northern China (Vasal 1998). Within a given country, maize production may be concentrated within a single mega-environment (as in Thailand and Indonesia, where maize is grown mainly in lowland tropical zones), or it may be distributed across several different mega-environments (as in China, where maize is grown in lowland tropical, subtropical/mid-altitude, tropical highland and temperate zones).

Cropping patterns adopted by maize farmers reflect a confluence of factors. On the supply side, these include climatic conditions, land type, soil characteristics and water availability. On the

Table 2. Major maize mega-environments

Mega-environment	Latitude	Elevation (masl)
Lowland tropics	0–25° North and South	<1,000
Tropical highlands	0–25° North and South	>1,800
Subtropics/mid-altitude zones	26°–36° North and South	1,000–1,500
Temperate zones	>36° North and South	All elevations

Source: S. Pandey (personal communication).

Table 3. Maize area by mega-environment, all developing countries of Asia, late 1990s

	Including China		Excluding China	
Mega-environment	Area (000 ha)	Proportion of total area	Area (000 ha)	Proportion of total area
Lowland tropics	13,456	35.4	13,456	53.6
Tropical highlands	958	2.5	958	3.8
Subtropics/mid-altitude zones	4,254	11.2	4,254	16.9
Temperate zones	19,300	50.8	6,433	25.6
Total	37,968	100.0	25,101	100.0

Source: Vasal (1998).

1 A mega-environment is a broad, not necessarily contiguous production zone, delineated by certain ecological conditions (e.g., temperature, rainfall, soils), crop characteristics (e.g., maturity cycle, grain color, grain texture), biotic and abiotic constraints and socio-economic factors (e.g., production systems, cropping patterns, consumer preferences). A recent GIS-based approach by CIMMYT to defining mega-environments for maize research may be seen in Hartkamp *et al.* (2000).

demand side, utilization patterns play an important role. Maize-millet cropping systems are most common in South Asia, whereas rice-maize and maize-vegetable cropping systems predominate in Southeast Asia.

In Nepal, the maize-millet rotation is the most important rotation among farmers of the hill regions, covering about 45% of the cultivated area in the eastern hills. In some Terai districts served by good roads, high-value vegetable crops, such as cabbage, cauliflower and tomato, are grown after maize (Chaudhary *et al.* 1996).

In Indonesia, maize cropping systems can be classified into high-productivity and low-productivity systems. High-productivity systems are characterized by abundant water supply and receive adequate fertilizer. Where these systems are common, farmers grow two to three maize crops in succession or rotate maize with cash crops, such as cassava. Low-productivity systems are located in less developed or remote areas and cover 69% of Indonesia's total maize area (Subandi 1998). In these systems, farmers apply less fertilizer and plant early maturing white or yellow local varieties that are mostly consumed directly by the household.

In the Philippines, traditional distinctions among maize production systems are based not on agro-ecological characteristics, but on grain color. The distinction is quite stark, because white-colored varieties are grown in low-productivity areas where maize is a staple, while yellow-colored varieties are grown in high-productivity areas where it is used as livestock feed.

More generally, throughout Asia white maize is grown mainly in marginal environments and used for home consumption. In these environments, which occupy several million hectares in the various ecological zones, use of improved varieties is uncommon, and application of fertilizer, pesticides and herbicides is inadequate. Subsistence farmers, who make up the majority of farmers in marginal areas, use few purchased inputs either because they lack capital needed to pay for them or because the inputs are simply not available. Improving the productivity of marginal environments through dissemination of improved production technologies remains a fundamental challenge for maize R&D, especially given that suitable early maturing genotypes are still lacking (Vasal 1998).

In Asia as in other regions of the developing world, there is a positive relationship between the share of white maize in total maize production and the importance of maize as a component of human diets (FAO and CIMMYT 1997).

Long-Term Production Trends

In 1996-98, China led Asia[2] in maize production. Chinese farmers produced 122 m t of maize on about 25 m ha, achieving average yields of 5 tons per hectare (t/ha) (Table 4). India was second after China in maize area harvested and production, followed by Indonesia and Thailand. Of the seven countries included in the CIMMYT study, Nepal was the smallest maize producer. Nepalese farmers produced 1.3 m t of maize on about 800,000 ha, achieving average yields of 1.6 t/ha.

The area planted to maize in Asia increased from 27 m ha during the 1960s to 38 m ha during the 1990s (1% average annual growth). During the same period, average maize yields rose from 1.4 t/ha to 3.7 t/ha (3.6% average annual growth). Due to the combined effects of area expansion and yield gains, maize production almost tripled from 35 m t to around 120 m t (4.6% average annual growth) (Tables 4 and 5). Figure 1 shows the relative contributions of area and yield to growth in maize production in Asia between 1961 and 1998.

2 Throughout this report, unless otherwise stated, "Asia" refers to the seven countries included in this study: China (the southern provinces), India, Indonesia, Nepal, the Philippines, Thailand and Vietnam.

Table 4. Maize production and net imports, selected Asian countries, 1996-98

	Area harvested (t / ha)	Yield (m t)	Production (000 t)	Net imports (m ha)
China (all)	24.6	5.0	121.9	-1,956.2
India	6.2	1.7	10.8	41.6
Indonesia	3.6	2.6	9.4	-469.3
Nepal	0.8	1.7	1.3	-0.2
Philippines	2.6	1.6	4.2	-421.9
Thailand	1.2	3.6	4.3	-177.2
Vietnam	0.6	2.5	1.6	56.4
Asia	39.7	3.9	153.6	-2,926.8

Source: Basic data from FAOSTAT database, Production Domain, April 2001.
Note: Some columns do not sum due to rounding.

Table 5. Growth (%) in maize area, yield and production, selected Asian countries and region, 1961-98

Country / period	Area	Yield	Production	Country / period	Area	Yield	Production
China (all)				Philippines			
1961-70	1.4	6.0	7.4	1961-70	2.8	3.0	5.8
1971-80	2.7	4.4	7.1	1971-80	3.4	2.3	5.7
1981-90	1.3	3.1	4.4	1981-90	2.0	2.9	5.0
1991-98	2.7	1.2	3.9	1991-98	-5.5	3.1	-2.4
1961-98	1.3	3.9	5.1	1961-98	1.3	2.5	3.8
India				Thailand			
1961-70	3.5	1.7	5.1	1961-70	9.8	2.5	2.3
1971-80	0.0	1.4	1.4	1971-80	4.2	0.3	4.5
1981-90	0.0	2.5	2.6	1981-90	1.3	0.7	2.0
1991-98	0.8	2.6	3.4	1991-98	-1.2	4.3	3.1
1961-98	0.6	1.6	2.2	1961-98	3.4	1.4	4.8
Indonesia				Vietnam			
1961-70	0.1	-0.1	0.0	1961-70	-1.6	-0.2	-1.8
1971-80	0.4	4.1	4.6	1971-80	7.2	-0.7	6.5
1981-90	2.1	3.8	5.9	1981-90	2.9	4.1	6.9
1991-98	2.9	3.2	6.1	1991-98	5.9	8.2	14.0
1961-98	0.6	3.1	3.9	1961-98	2.7	2.1	4.5
Nepal				Asia			
1961-70	0.0	-0.9	-0.9	1961-70	1.9	3.4	5.3
1971-80	0.0	-2.1	-2.1	1971-80	2.1	3.7	5.9
1981-90	5.6	0.5	6.1	1981-90	1.3	3.0	4.3
1991-98	0.8	0.7	1.5	1991-98	1.7	2.2	3.8
1961-98	2.1	-0.6	1.5	1961-98	1.2	3.4	4.6

Source: Basic data from FAOSTAT database, Utilization Domain, April 2001.

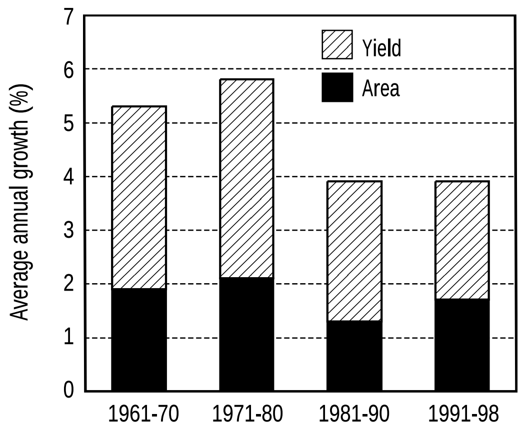

Figure 1. Area and yield contribution to maize production growth in Asia, 1961-98.
Source: FAOSTAT database, Production Domain, April 2001.

The aggregate regional figures conceal considerable variation in country-level trends, however. During the last four decades, Indonesia and Vietnam have experienced accelerating growth in maize area and yields, resulting in rapid growth in production. The most notable improvement came from Vietnam, where maize production declined by 1.8% per year during the 1960s because of the war, recovered after the liberalization of agricultural production in the late 1980s, and grew at a rate of 14% per year during the 1990s. In China and the Philippines, maize production has continued to increase, although annual rates of growth have slowed in recent years. Maize production in the Philippines increased by nearly 6% per year during the 1960s, but during the 1990s it declined at a rate of 2.4% per year.

Long-Term Utilization Trends

Maize has four principal uses: human food, livestock feed, industrial input, seed.[3] At the global level, growth in demand for maize has been driven mainly by rapidly increasing demand for livestock feed. Use of maize as an industrial input to produce food and non-food products has also increased, although less dramatically. Direct human consumption of maize has actually declined as per capita incomes have risen, enabling consumers to replace maize with more preferred foods (Table 6).

Maize utilization trends in Asia have paralleled those taking place at the global level. Food use of maize in Asia rose from 22 m t per year during the 1960s to 38 m t per year during the 1980s before declining to 32 m t per year during the 1990s. Meanwhile, feed use of maize grew explosively from about 10 m t per year

Table 6. Per capita income, maize net imports and per capita utilization, Asia and the world, 1982-84 and 1994-96

	1982-84			1994-96		
	Per capita income (US$)	Maize net imports (000 t)	Per capita utilization (kg / yr)	Per capita income (US$)	Maize net imports (000 t)	Per capita utilization (kg / yr)
Asia						
South	256	-24	10	382	-20	10
Southeast	853	-1,075	30	1,335	3,311	49
East	382	7,338	71	1,219	12,871	99
West[a]	-	286	29	2,152	3,345	29
World	2,650	-317	91	5,260	na	98

Source: CIMMYT (1984, 1999).
Note: na = not available.
[a] Averages for 1982-84 computed from the FAOSTAT database, June 2001.

3 In this report, "utilization" refers to all major uses of maize, whereas "consumption" refers specifically to the use of maize for human food.

during the 1960s to 89 m t per year during the 1990s (Figure 2). Across the entire period, food use grew at barely 1% per year, well below the 8% average annual growth in feed use. Seed use meanwhile remained constant at around 2% of total annual maize supply.

Until quite recently, maize in Asia was a subsistence crop grown mainly for home consumption or for use in small-scale backyard pig and poultry operations. Today, it has become a leading cash crop produced as an input into large-scale commercial feed enterprises. For Asia as a whole, currently about 67% of total maize supply is used to feed livestock, about 20% is used as human food and the rest goes to other uses (industrial input, seed). Not surprisingly given its enormous size, China uses more maize than any other Asian country. Maize in China is used mainly to feed livestock, although a significant proportion of total supply is consumed directly by humans (Table 7). Among the countries included in the study, feed use of maize is highest in Thailand, where livestock producers use 96% of maize supply. Food use is highest in Nepal, where 70% of maize supply is consumed directly by humans. Consistent with these differences in country-level utilization figures, per capita consumption of maize is highest in Nepal (42 kg) and lowest in Thailand (0.5 kg) (Table 7).

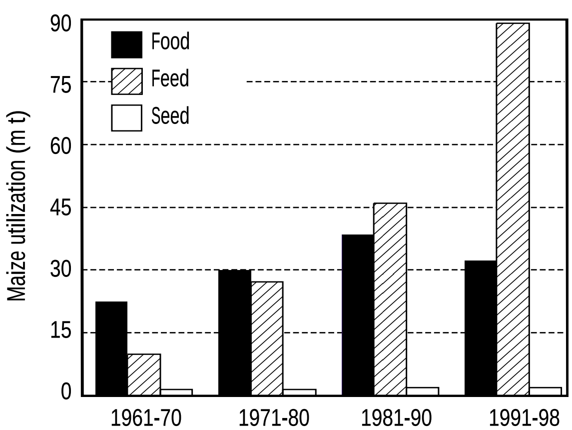

Figure 2. Average maize utilization as human food, livestock feed and seed, Asia, 1961-98.
Source: FAOSTAT database, Utilization Domain, April 2001.

As in the case of production, aggregate regional utilization trends conceal considerable variability at the country level. During the 1990s, average annual growth in maize utilization ranged from an astonishing 15% in Vietnam to an anemic 0.1% in the Philippines (Table 8). Within individual countries, utilization trends reflected the combined effects of two tendencies: changes in feed use (usually positive and large) and changes in food use (usually negative and small).

Trends in Trade

During 1961-98, Asia's maize exports grew at 3.9% per annum; imports grew much faster at 12% per annum. Trade peaked at a net export of 4.2 m t

Table 7. Maize utilization, selected Asian countries and region, 1996-98

	Utilization (m t)	Per capita consumption (kg)	Proportion for		
			Food	Feed	Other
China (all)	125.6	10.6	11	76	13
India	10.7	8.8	79	2	19
Indonesia	9.9	38.0	78	6	16
Nepal	1.3	42.1	70	18	12
Philippines	4.6	7.3	11	76	13
Thailand	4.4	0.5	<1	96	3.4
Vietnam	1.5	4.1	20	74	6
Asia	158.0	11.8	20	67	13

Source: Basic data from FAOSTAT database, Utilization Domain, April 2001.
Note: Some columns do not sum due to rounding.

during the 1970s but dramatically declined to a net import of 823,000 t during the 1990s. The shift from being a net exporter to a net importer was pushed largely by the increasing domestic demand from China, Indonesia and the Philippines. Although a major maize producer, China's growing population and rising per capita income contributed to increased demand for meat products and, consequently, to increased maize utilization.

India and Vietnam meanwhile moved from being net importers up to the 1980s to being net exporters in the 1990s. Supported by improved production technologies, the growth in maize production in these two countries exceeded that of utilization and allowed the change in trade status.

Thailand has always been a net exporter of maize grain. Its volume of net export however has been declining in recent years. Thailand's average annual maize export peaked at 2.3 m t during the 1980s but was barely 70,000 t during the 1990s. The exploding domestic demand for maize as livestock feed led to this trend.

The expanding opportunities for maize production in Asia present many challenges for the region's maize seed industries. To understand how maize R&D serves (or can better serve) the needs of commercial as well as subsistence maize farmers in Asia, important questions to consider include:

- How is the maize R&D system in Asia organized?
- What roles do the public and private sectors play in maize R&D system?
- How do public and private sectors serve the varying needs of maize farmers around Asia?
- What technological and policy issues related to maize R&D concern players in the seed industry?

Table 8. Annual growth (%) in maize utilization, selected Asian countries and region, 1961-98

Country / period	Total utilization	Food	Feed	Country / period	Total utilization	Food	Feed
China (all)				Philippines			
1961-70	7.7	2.3	21.7	1961-70	5.9	6.6	5.8
1971-80	7.4	5.2	9.8	1971-80	5.7	5.9	5.7
1981-90	3.4	1.1	3.9	1981-90	3.3	2.3	3.6
1991-98	4.9	-8.3	7.5	1991-98	0.1	-15.2	4.6
India				Thailand			
1961-70	4.9	5.0	4.0	1961-70	4.8	9.3	-3.1
1971-80	1.4	1.7	-0.8	1971-80	6.1	8.8	10.0
1981-90	2.6	2.6	2.5	1981-90	20.1	14.8	22.7
1991-98	3.3	3.5	2.6	1991-98	4.6	2.2	4.6
Indonesia				Vietnam			
1961-70	1.1	1.4	-0.7	1961-70	-0.1	-1.5	10.5
1971-80	4.6	4.0	11.6	1971-80	3.7	5.0	-4.2
1981-90	5.7	5.4	5.7	1981-90	6.3	4.2	16.7
1991-98	6.4	6.5	6.0	1991-98	15.3	-5.1	30.5
Nepal				Asia			
1961-70	-0.9	-0.7	-1.3	1961-70	5.6	1.6	18.4
1971-80	-2.1	-2.0	2.6	1971-80	6.2	3.9	9.4
1981-90	6.0	5.0	23.7	1981-90	3.8	2.0	4.4
1991-98	1.3	-2.2	45.1	1991-98	4.8	-2.6	7.5

Source: Basic data from FAOSTAT database, Utilization Domain, April 2001.

These questions are explored in Chapter 2 for the region as a whole and in greater detail for individual countries in Chapters 3-8.

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Annex 1

Maize Producers and Consumers in Asia

Table A1.1. Major maize producers in Asia

	West Asia			East Asia		South Asia			Southeast Asia		
Indicator	Turkey	Iran	Afghanistan	China	Korea (D.P.R.)	India	Nepal	Pakistan	Indonesia	Thailand	Philippines
Average maize area harvested, 1997-99 (000 ha)	573	148	200	24,996	576	6,223	800	879	3,547	1,263	2,594
Average maize yield, 1997-99 (t/ha)	3.9	6.3	1.2	4.9	2.3	1.7	1.7	1.4	2.6	3.6	1.6
Average maize production, 1997-99 (000 t)	2,260	932	243	121,363	1,338	10,964	1,343	1,251	9,358	4,483	4,266
Growth rate of maize area, 1988-99 (%/year)	1.3	28.1	-3.2	2.3	-1.8	0.6	0.9	0.3	1.5	-3.0	-4.3
Growth rate of maize yield, 1988-99 (%/year)	-0.6	8.0	-4.2	2.0	-12.0	1.5	0.8	0.3	2.7	4.0	3.4
Growth rate of maize production, 1988-99 (%/year)	0.7	36.1	-7.5	4.3	-13.8	2.2	1.6	0.6	4.2	0.9	-0.9
Maize area as % of total cereal area (average), 1997-99 (%)	4	2	7	27	42	6	25	7	24	11	41
Average net imports of maize, 1996-98 (000 t)	832	1,068	na	1,938	354	-26	3	5	453	179	393
Average % maize used for animal feed, 1995-97 (%)	39	92	20	76	<1	2	3	20	5	96	74
Average % maize used for direct human consumption, 1995-97 (%)	47	3	74	11	54	77	85	59	79	<1	14

Source: CIMMYT (2001).
Note: na = not available.

Table A1.2. Major maize consumers in Asia

Indicator	Jordan	Lebanon	Sri Lanka	Malaysia	Korea, Republic of
Average maize area harvested, 1995-97 (000 ha)	<1	2	33	24	18
Average maize yield, 1995-97 (t/ha)	11.4	2.0	1.0	1.8	4.1
Average maize production, 1995-97 (000 t)	4	4	34	44	74
Growth rate of maize area, 1991-97 (%/year)	+ +	+ +	2.0	3.8	-3.7
Growth rate of maize yield, 1991-97 (%/year)	+ +	+ +	-1.1	0.9	1.6
Growth rate of maize production, 1991-97 (%/year)	+ +	+ +	0.9	4.7	-2.1
Maize area as % of total cereal area (average), 1995-97 (%)	<1	5	4	4	2
Average net imports of maize, 1994-96 (000 t)	363	250	4	2,184	7,821
Average % maize used for animal feed, 1994-96 (%)	95	94	42	91	63
Average % maize used for direct human consumption, 1994-96 (%)	1	2	56	3	9

Source: CIMMYT (1999).

Note: ++ indicates that data are not available or incomplete.

Chapter 2

Impact of Public and Private Maize Breeding Research in Asia, 1966-1997/98

Roberta V. Gerpacio

This chapter provides an Asia-wide synthesis of the impact of public and private maize breeding research. The data presented in this chapter (and elsewhere in the book) were collected through an extensive survey of public and private research organizations and seed companies located in seven countries: China, India, Indonesia, Nepal, the Philippines, Thailand and Vietnam. These seven countries account for 93% of the maize area in Asia. All told, data were collected from a total of 179 public agencies, private companies and non-governmental organizations (NGOs). Collectively, these organizations sold approximately 167,000 t of maize seed in 1997, representing an estimated 73% of the formal maize seed market in the region (Table 1).

The chapter begins by briefly describing the organization of maize research in the study countries, paying particular attention to the roles played by public research institutes and private seed companies. Estimates are presented of the level of investment in maize breeding research, and the germplasm products of public and private maize breeding programs are described. After analyzing patterns in farm-level adoption of modern maize varieties, the chapter concludes with a discussion of the policy implications of the study findings.

Maize Research and Technology Development in Asia

Organization of Maize Research

The improved open-pollinated varieties (OPVs) and hybrids that eventually make their way into farmers' fields are products of an international maize breeding system that includes CIMMYT (a publicly supported international research center); hundreds of public breeding programs operating at the national, regional, state or district level; and thousands of private seed companies, both national

Table 1. Coverage of the 1998/99 Asia maize impact survey

	Number of public organizations surveyed	Number of private companies interviewed	Maize seed sales, 1997 (t)	Percentage of formal maize seed market
China (south)	59	1	87,600	na
India	30	22	36,000	97
Indonesia	3	6	9,550	95
Nepal	2	21	1,450	6
Philippines	14	7	8,140	67
Thailand	2	7	20,700	94
Vietnam	2	3	3,810	76
Asia	112	67	167,250	73

Source: CIMMYT Asia Maize Impact Survey 1998-99.
Note: na = not available.

and international. The history, organization and performance of this international maize research system are described elsewhere,[1] so this chapter focuses on maize R&D systems in Asia.

In 1997/98, the reference year for this study, approximately 1,000 public agencies, private companies and NGOs in Asia were conducting maize breeding research, producing and distributing maize seed, or both (Table 2). This number should be considered conservative, because even though an extensive effort was made to identify as many seed industry participants as possible, undoubtedly a few were overlooked.

Role of the Public Sector

In most countries around the world, developing as well as industrialized, agricultural research has deep roots in the public sector (Morris 1998). During the period when national research systems are initially formed, state-sponsored organizations almost always play a dominant role in organizing the development of improved technology and financing its transfer to farmers. Over time, however, the role of the public sector typically declines, and functions that were once performed by government or parastatal organizations are gradually taken over by private companies.

In Asia, this process is already well advanced. Today, the dominance of the public sector in agricultural R&D is largely a thing of the past. Of all countries in the region, only China and India retain sizeable public agricultural research and extension systems. Public breeding institutes and seed agencies (including universities and cooperatives) make up about 71% of all seed organizations in Asia, but when China and India are excluded the proportion falls sharply. Excluding China and India, only 75 out of 216 total maize seed organizations (35%) are public (Table 2). The decline in publicly funded agricultural research has been particularly pronounced in Southeast Asia, where public maize breeding research is today carried out only in two or three organizations per country.

Experience from around the world suggests that after the private sector emerges as a major player in maize breeding research, private companies tend quickly to assume control of commercial maize seed markets (Morris 1998). Instead of competing head-on with private seed companies in the lucrative market for commercial hybrids, many public seed organizations choose to redirect their attention to

Table 2. Estimated number of maize seed organizations, selected Asian countries and region, 1997/98

	Public agencies	Private companies		Universities/ cooperatives	NGOs	Total
		Domestic	Multinational			
China (south)	519	na	1	na	na	520
India	27	218	10	6	na	261
Indonesia	3	3	3	1	na	10
Nepal	11	0	0	0	30	41
Philippines	2	6	5	6	na	19
Thailand	2	2	5	73	na	82
Vietnam	57	1	6	0	na	64
Asia	621	230	30	86	30	997
Asia (excluding China, India)	75	12	19	80	30	216

Source: CIMMYT Asia Maize Impact Survey 1998-99.
Note: na = not available.

[1] See Morris, Clancy and López-Pereira (1992); López -Pereira and Filipello (1994); López -Pereira and Morris (1994); and Dowswell *et al.* (1996).

focus on the needs of farmers in marginal areas who do not represent potential customers for profit-oriented private companies. Although some public breeding programs continue to develop hybrids in direct competition with private companies (as for example in the Philippines and Thailand), many public breeding programs opt to move upstream in the germplasm development process, for example by concentrating on genetic resource conservation and pre-breeding activities designed to produce basic germplasm that can be used as source material by commercial breeding programs. Similarly, rather than producing hybrid seed in direct competition with private companies, many public seed agencies concentrate on the promotion of informal seed production and distribution systems (Dowswell *et al*., 1996).

In Asia, most public agencies that are still actively involved in maize R&D concentrate on developing and evaluating varieties. In a few countries, public agencies also produce maize seed and distribute that seed, along with extension services, especially in marginal areas where maize is an important crop. Public agencies also work in favorable areas, although they face more competition from the private sector in these areas. More commonly, however, public R&D agencies no longer participate directly in seed production and distribution, preferring to cede that role to the private sector. In Indonesia, for example, the Research Institute for Maize and Other Cereals (RIMOC) sells parent seed of improved maize varieties to public parastatals and private seed companies, which multiply the seed for distribution to farmers around the country through their marketing networks. Similar partnerships between public breeding institutes and private seed production companies have also emerged in Thailand, the Philippines and India. China is a significant exception. In most provinces of China, private companies are prohibited by law from producing maize seed, so the maize seed industry is composed almost entirely of state-owned enterprises (Pray *et al*. 1998).

Role of the Private Sector

Private-sector participation in maize R&D in Asia has grown steadily since the early 1990s, when a wave of policy reforms broke up what in many countries had effectively been state monopolies on the seed industry. In 1997/98, about 230 national maize seed companies and about 30 multinational companies were operating in Asia (Table 2). Within individual countries, however, the number of private seed companies varied enormously. The huge maize economy of India was being supported by a large number of private national and multinational seed companies, approximately 30 of which had their own in-house breeding program (Singh *et al.* 1995). At the other extreme, no private companies with in-house breeding programs were operating in Nepal, where seed distributors were marketing seed of maize varieties imported from India.

The research activities pursued by maize seed companies in Asia typically vary depending on the size of the company and the volume of seed that it sells. Generally speaking, the larger the company, the larger is its ability to establish its own breeding program. Many smaller seed companies, lacking any in-house research capacity, contract with public research programs and sometimes even large private companies to multiply and distribute seed of improved OPVs and hybrids developed by others. These smaller companies usually specialize in maize and operate only within a limited area. In addition to the many small seed companies that work exclusively with varieties developed by others, a significant number of companies—probably between 75 and 100—have grown to the extent that it makes sense to establish the capacity to develop their own proprietary cultivars using conventional breeding methods. A much smaller number of seed companies—probably less than 15—are large enough to have ventured into biotechnology research. Most of the multinationals operating in the region fall into the latter category.

Public- and Private-Sector Research Investments

Numbers of Maize Researchers

The CIMMYT survey identified 116 public organizations and 44 private companies operating in Asia in 1997/98 that featured some level of maize breeding capacity (Figure 1). Collectively, these organizations employed approximately 670 scientists in maize genetic improvement (Tables 3 and 4).[2] Approximately 505 scientists were working in public organizations, roughly three times the number working in private companies.

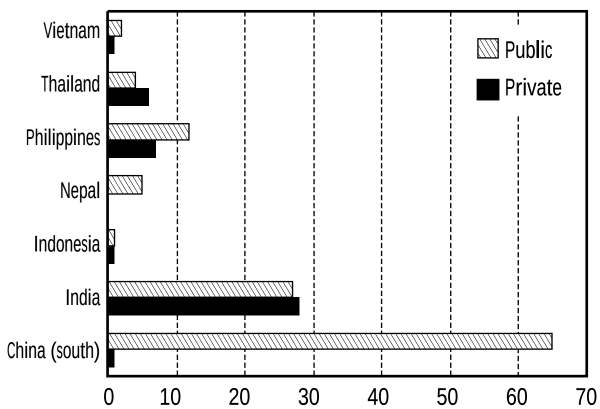

Figure 1. Number of seed agencies with maize breeding programs, Asia, 1997/98.
Source: CIMMYT Asia Maize Impact Survey 1998-99.

The relative intensity of public and private investment in maize breeding research can be determined by examining the number of scientists supported by each sector per 100,000 ha of maize area planted or per 100,000 t of maize produced. According to both measures, in most Asian countries public investment in maize research appears to be much higher than private investment (Tables 3 and 4). Private seed companies tend to target a much smaller maize area than public breeding programs, however, so the intensity of research investment may not be very different.

Level of Maize Research Expenditure

Skilled human capital is obviously a prerequisite for successful research, but even the most skilled maize breeder is unlikely to be effective without resources for screening new materials, making crosses and conducting varietal evaluation trials. How much financial support do Asian maize researchers receive? Table 5 shows the average annual investment in maize breeding research by the public

Table 3. Public-sector maize research indicators, selected Asian countries and region, 1990 and 1997/98

	Number of agencies engaged in maize breeding	Number of scientists engaged in maize breeding (FTE)	Scientists per 100,000 ha of total area planted to maize		Scientists per 100,000 t of maize produced	
			1997/98	1990	1997/98	1990
China (south)	65	270	6.6	3.0[a]	1.8	0.7[a]
India	27	56	0.9	2.8	0.5	1.9
Indonesia	1	13	0.4	1.2	0.1	0.6
Nepal	5	13	1.6	3.9	1.0	2.1
Philippines	12	50	1.9	1.1	1.1	0.9
Thailand	4	35	2.7	1.3	0.8	0.6
Vietnam	2	68	9.9	11.8	3.9	8.9
Asia	116	505	2.6	2.7	1.1	0.8
Asia (excluding China)	51	235	1.5	2.3	0.8	1.4

Source: CIMMYT Asia Maize Impact Survey 1998-99; CIMMYT (1992).
Note: FTE = full-time equivalent.
[a] Data for 1990 are for the whole of China.

[2] Throughout this book, references to scientist numbers denote full-time equivalents.

Table 4. Private-sector maize research indicators, selected Asian countries and region, 1990 and 1997/98

	Number of agencies engaged in maize breeding	Number of scientists engaged in maize breeding (FTE)	Scientists per 100,000 ha of total area planted to maize		Scientists per 100,000 t of maize produced	
			1997/98	1990	1997/98	1990
China (south)	1	na	na	0.0[a]	na	0.0[a]
India	28	74	1.1	0.8	0.7	0.6
Indonesia	1	11	0.3	0.2	0.1	0.1
Nepal	1	6	0.7	0.0	0.4	0.0
Philippines	7	34	1.3	3.1	0.7	2.4
Thailand	6	40	3.1	3.8	0.9	1.8
Vietnam	5	1	0.1	0.0	<1	0.0
Asia	49	166	0.8	0.6	0.4	0.2
Asia (excluding China)	48	166	0.8	0.5	0.4	0.9

Source: CIMMYT Asia Maize Impact Survey 1998-99; CIMMYT (1992).
Note: na = not available.
[a] Data for 1990 are for the whole of China.

Table 5. Estimated level of public- and private-sector investment (US$) in maize breeding research, selected Asian countries and region, 1997/98

	Average annual cost of supporting a senior maize breeder		
	Salary and benefits	Operating budget	Total annual research investment (US$ 000)
Public sector			
China	260	460	7,100
India	12,820	1,160	1,230
Indonesia	680	na	na
Nepal	1,820	1,130	1,250
Philippines	12,050	3,800	160
Thailand	6,000	na	1,200
Vietnam	800	240	90
Asia	12,900	2,950	1,580
Private sector			
China	0	0	0
India	30,000[a]	na	2,050
Indonesia	1,200[a]	na	50
Nepal	0	0	0
Philippines	10,800	31,250	180
Thailand	30,300[a]		480
Vietnam	*	*	*
Asia	20,500	10,420	400

Source: CIMMYT Maize Impact Survey 1998-99.
Note: na = not available; * = internal and confidential.
[a] Includes the estimated operating budget.

and private sectors in Asia in 1997/98. The data should be regarded as conservative; similar to their counterparts in Latin America (Morris and López-Pereira 1999), survey respondents in Asia (especially those working in public research organizations) had difficulty estimating the overhead expenses associated with supporting research personnel.

In 1997/98, the salary and benefits for a senior maize breeder working in the public sector ranged from US$ 260 per year in China to almost US$ 13,000 per year in India. Including annual operating budgets, the public sector spends from as little as US$ 720 per year in China to support a senior maize breeder to as much as US$ 16,000 per year in the Philippines. (Senior maize breeders in India were paid slightly higher salaries than those in the Philippines, but Filipino scientists received operating budgets that were nearly three times higher.) Averaging across the entire region, a senior maize breeder working with the public sector in Asia earns around US$ 13,000 per year in salary and benefits and receives US$ 3,000 in operating funds, for a total support level of about US$ 16,000 per year.

How do levels of support in the public sector compare to levels of support in the private sector? In 1997/98, expenditures by private seed companies on salary, benefits and operating budget for a senior maize breeder ranged from a low of US$ 1,200 per year in Indonesia to a high of US$ 42,000 per year in the Philippines. Averaging across the entire region, a senior maize breeder working with the private sector in Asia earns around US$ 20,000 per year in salary and benefits and receives US$ 10,000 in operating funds, for a total support level of about US$ 30,000 per year.

The estimated number of maize researchers in each country can be multiplied by the estimated annual support costs per researcher to generate a rough estimate of the total annual investment in maize breeding research in each country. Based on this admittedly crude estimation procedure, in 1997/98, public investment in maize breeding research ranged from a low of about US$ 90,000 in Vietnam to a high of about US$ 7.1 million in China (Table 5). These investment data can be adjusted for differences in the size of Asian countries. The research intensity measures indicate that in 1997/98 total public investment in maize research ranged from a low of US$ 13,000 per 100,000 ha of maize planted in Vietnam to a high of US$ 175,000 per 100,000 ha of maize planted in China (Figure 2). The government of Nepal spends relatively more on maize research per 100,000 ha of maize planted than other countries with larger areas planted to maize, such as Thailand and India. This relatively high intensity of Nepal's public investment in maize research presumably reflects a combination of structural factors (indivisibilities in research infrastructure), transactions costs (shortages of skilled personnel, inefficient research facilities) and possibly also compensatory investment by the public sector designed to make up for the absence of a strong private seed industry.

Research intensity measures can also be calculated and used to make inter-country comparisons of the levels of private investment. In 1997/98, the private

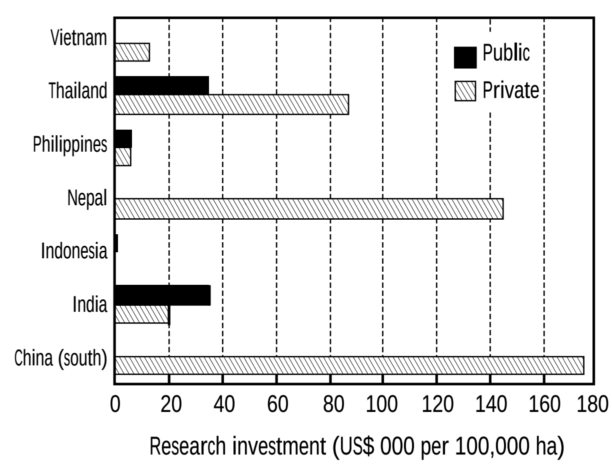

Figure 2. Average annual public and private research investment (US$ 000) per 100,000 ha of maize, selected countries in Asia, 1997/98.
Source: CIMMYT Asia Maize Impact Survey 1998-99.

sector in India and Thailand spent the most on maize research per 100,000 ha of maize planted (about US$ 35,000 in each country) (Figure 5). Inter-country differences in the intensity of research investment can be attributed to a number of factors. Other things equal, private seed companies will be encouraged to invest more heavily in countries with favorable business climates and attractive commercial seed markets. Large multinationals also tend to invest more heavily in countries that serve as the base for a regional breeding program; the expectation is that the investment will generate benefits that will later be captured by exploiting research spillovers to other countries. India and Thailand stand out as two countries that serve as hubs of regional breeding programs; hybrids bred in India and Thailand have been released and sold in Nepal, Vietnam, the Philippines and Indonesia.

Why has the private sector increased its investment in maize breeding research in Asia? One reason is that Asia represents an enormous potential market, not only for seed, but also for complementary inputs such as fertilizer, crop chemicals and machinery. Use of improved inputs remains modest in many Asian countries, particularly in subtropical and tropical environments, where most farmers still use traditional production practices. In 1997/98, 60% of the area planted to maize in the countries surveyed (excluding China) was planted to farm-saved seed and cultivated using few or no purchased inputs.

Disenchantment with the performance of public input-supply organizations has also provided an opening for increased participation by the private sector. With few exceptions, public seed production agencies in Asia have operated inefficiently. They frequently suffer from inadequate and unreliable funding, shortages of well-trained employees and a lack of efficient infrastructure and facilities. In addition, poor communication between government agencies frequently leads to poor coordination among various sectors of the industry (Vasal 1998). In an attempt to address these longstanding problems, governments in many Asian countries have introduced policy reforms designed to transfer responsibility for agricultural input supply to the private sector. Forced to compete without preferential subsidies, many government seed agencies have had difficulty maintaining an active presence in the market.

Many countries in Asia have introduced policy reforms designed to facilitate private-sector participation in the maize seed industry.[3] These reforms have encouraged the growth of private national seed companies and fostered a better business environment for multinationals, most of which have a strong maize R&D capacity, well-developed seed production facilities and modern distribution infrastructure that allows them to operate efficiently across national borders.

In India, for example, the 1966 Central Seed Act laid the legal foundation for a modern seed industry. In line with the national objective of attaining self-sufficiency in food production, the Act assigned responsibility for commodity research and seed production to public organizations (Morris *et al.* 1998; Pal *et al.* 1998). Maize breeding research and seed production remained firmly in the public domain until 1988, when the New Policy for Seed Development opened the doors to foreign participation. Today, public and private sectors both play an active role in India's maize seed industry. Public organizations continue to engage in breeding research, seed production and seed distribution, but their efforts are complemented by an increasingly active private seed industry that now dominates releases of new varieties and controls the lion's share of the commercial seed market.

[3] China's maize seed industry, a not-for-profit enterprise that remains entirely within the public sector, remains an exception to this trend (J. Huang, personal communication; Pray *et al.* 1998).

Public-Private Sector Linkages

International maize breeding is carried out by a complex system made up of a large number of diverse organizations—large and small, public and private, national and international. Many of the organizations that participate in the global maize breeding system are linked through the exchange of products, services or information.

How are these linkages playing out in the Asian context? Three types of collaborative activities serve to illustrate how public-private sector linkages are growing in Asia: international germplasm exchanges, public-private germplasm transfers and collaborative varietal testing networks.

International Germplasm Exchanges

Prior to 1960, no formal system existed to provide plant breeders with access to germplasm developed outside their home countries (Traxler and Pingali 1999). Movement of germplasm occurred informally as breeders exchanged promising materials with friends and professional colleagues. With the establishment of the Consultative Group on International Agricultural Research (CGIAR) in 1969, a mechanism appeared that provided the global breeding community with access to research products from public institutions. In Asia, the international maize germplasm distribution and exchange network is coordinated by CIMMYT. Any bona-fide maize breeder can write CIMMYT requesting samples of promising experimental materials. These materials, which are provided by CIMMYT free of charge, may be used by the breeder in his or her breeding program. Once used mainly as a mechanism for distributing materials to public breeding programs, the CIMMYT germplasm distribution network is increasingly being exploited by private seed companies as a source of promising experimental materials.

Public-Private Germplasm Transfers

The privatization of many national maize seed industries has been accompanied by an increase in the rate of germplasm transfers from public breeding programs to private seed companies. Under pressure to reduce expenditures, governments in many Asian countries have scaled back investment in seed production and distribution, activities that are readily assumed by private firms because they offer clear profit opportunities. As a result, managers of public breeding programs have had to seek out new mechanisms for moving their germplasm products into farmers' fields. In many countries, they are attempting to do this by making improved germplasm available to seed companies, often on a commercial basis. Thailand is a good example of the new types of germplasm transfer mechanisms being forged between public breeding organizations and private seed companies. Thailand's two main public maize breeding programs (based at Kasetsart University and in the Department of Agriculture) provide elite inbred lines to multinational and domestic private companies for use in forming commercial hybrids (see the Thailand country report, Chapter 7). Traditionally, the elite inbred lines were provided free of charge, but beginning in the mid-1990s, Kasetsart University started collecting royalties from private-sector recipients. An important feature of the arrangement is that the recipient is assured exclusive use of the germplasm.

Collaborative Varietal Testing Networks

The strengthening of linkages between the public and private sectors is also reflected in collaborative varietal evaluation trials, which provide a mechanism for public breeding programs and private seed companies to compare promising experimental materials and exchange information. The Tropical Asian Maize Network (TAMNET), whose membership includes public breeding programs and private seed companies from Asian countries, was established in 1993 with financial support from the Food and Agriculture Organization (FAO) of the United Nations. The purpose of TAMNET, which is managed by CIMMYT, is to facilitate and strengthen regional collaboration among and between member institutions, with the ultimate goal of increasing maize production and productivity (FAO 1999). One of TAMNET's main functions is to manage a multilocational varietal evaluation program; annual field trials are conducted throughout the region, and the resulting data on field performance across countries are synthesized and shared among TAMNET members.

Products of Maize Breeding Programs

The first CIMMYT maize impact survey published in 1994 yielded detailed descriptive data on the physical characteristics and genetic backgrounds of 842 maize varieties[4] released in developing countries between 1966 and 1990 (López-Pereira and Morris 1994). Of these, about 190 varieties were released by the public sector in South, East and Southeast Asia (135 in the seven countries included in the current study).

The current study updated the information collected in the earlier study and significantly expanded the varietal releases database. As in the earlier study, the coverage of public- and private-sector materials is not the same. Public breeding organizations were asked to provide information about all maize varieties developed since 1966, the year that CIMMYT was founded. In contrast, private seed companies were asked to provide information *only* about the maize varieties that they were currently selling; most of these materials consisted of hybrids released during the 1990s. In the case of the private sector, it was not possible to compile a complete list of all varieties developed since 1966; many private seed companies that operated during the 1960s, 1970s and 1980s no longer exist, and many of those that still exist would have difficulty retrieving information from 20-30 years ago. (A few private companies did provide information about varieties that were no longer being sold at the time of the survey, although the coverage of these older varieties was incomplete.)

The survey of public breeding organizations identified 360 maize varieties released by public breeding programs between 1966 and 1997/98 in the seven Asian countries that participated in the study (Table 6).[5] Nearly two-thirds of these public-sector varieties (232, or 64%) were being marketed at the time of the survey. The survey of private seed companies generated information about 302 maize varieties developed by private breeding programs. Over three-quarters (235, or 78%) were being marketed in Asia at the time of the survey.

Public-Sector Releases

Types of Materials

Of the 360 maize varieties released since 1966 by public maize breeding programs in Asia, 211 (59%) were OPVs and 149 (41%) were hybrids (Table 7). Public breeding programs in the Philippines released the largest number of OPVs (55), while those in China released the largest number of hybrids (69). In most Asian countries, there has

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[4] In this report, the term "varieties" is used in a generic sense to mean "improved OPVs and hybrids," whereas the terms "improved OPVs" and "OPVs" are used in a specific sense to mean "improved OPVs developed by a formal breeding program."

[5] Unless noted, the varietal counts refer only to field maize varieties. Specialty types, including baby corn, are not included.

Table 6. Characteristics of maize varieties released in Asia, by sector[a]

Indicator	Public sector[b]	Private sector[c]
Maize varieties in CIMMYT database (number)	360	302
Maize varieties being sold during late 1990s (number)[d]	232	235
Type of maize released (%)[a]		
Improved OPVs	59	Nil
Hybrids		
Single cross	21	21
Double cross	7	41
Three-way cross	6	35
Other	7	3
Maize characteristic (%)		
Ecological adaptation		
Lowland tropical	69	94
Subtropical/mid-altitude	30	6
Temperate	1	0
Grain color		
White	25	10
Yellow	75	90
Grain texture		
Flint	26	30
Semi-flint	40	37
Dent	12	10
Semi-dent	22	23
Maturity range		
Extra-early (<100 days)	29	30
Early (100-110 days)	34	46
Intermediate (110-120 days)	19	16
Late (120-135 days)	10	4
Extra-late (>135 days)	8	4
Age of varieties		
<10 years	47	84
11-20 years	35	14
21-30 years	13	2
>30 years	5	0

Source: CIMMYT Asia Maize Impact Survey 1998-99.

Note: Data for China, India, Indonesia, Nepal, Philippines, Thailand and Vietnam.

[a] Without double-counting varieties sold by different agencies within a country and/or released in more than one country in Asia.

[b] Released from 1966 to 1997/98.

[c] Snapshots of 1992 and late 1998/early 1999; not a complete listing of all private-sector varieties released since 1966.

[d] Many older OPVs are still being grown from farm-saved seed, even though seed is no longer sold.

been an inverse relationship between the number of OPVs released and the number of hybrids released. Only in Vietnam have public breeding programs given roughly equal emphasis to the development of OPVs and hybrids.

Since 1966, Asia's public breeding programs have released maize varieties at an increasing rate (Figure 3). Aggregating across the seven countries covered by the survey, during the late 1960s public breeding programs released maize varieties at an average rate of one per year. By the late 1990s, this had increased to five per year.

Not only the rate but also the composition of public releases has changed through time. Development of OPVs was emphasized until the 1990s, when attention shifted to hybrids (Figure 4). There are at least three reasons for this shift in research emphasis. First, most Asian countries were interested in promoting the adoption by farmers of higher-yielding cultivars that could help meet rapidly increasing demand for maize grain.[6] Second, managers of public breeding programs perceived an opportunity to provide hybrids to farmers at more affordable prices than those

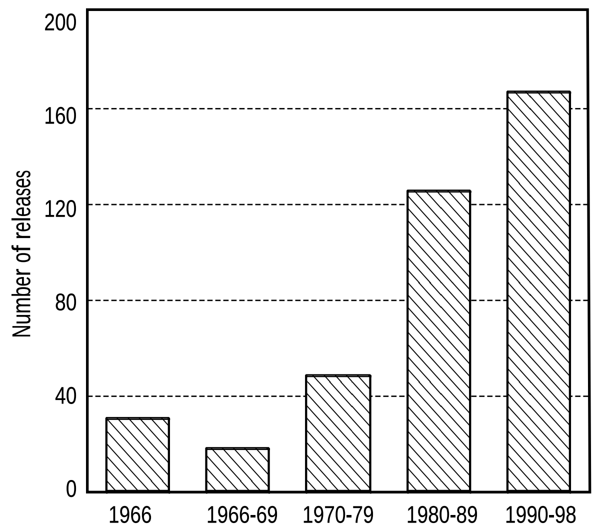

Figure 3. Number of maize releases by public breeding programs, Asia, 1966-97/98.
Source: CIMMYT Asia Maize Impact Survey 1998-99.

Table 7. Types and numbers of field maize varieties released by public breeding programs, selected Asian countries and region, 1966-1997/98

		Hybrids			
	Improved OPVs	Single cross	Three-way cross	Double cross	Other
China (south)[a]	14	50	7	2	10
India	80	8	5	10	8
Indonesia	21	1	3	2	0
Nepal	18	0	0	0	0
Philippines	55	1	3	4	0
Thailand	5	7	3	0	0
Vietnam	24	10	0	6	10
Asia[b]	211	77	21	24	27
Proportion	59	21	5	7	8

Source: CIMMYT Asia Maize Impact Survey 1998-99.
[a] Summary figures for each country do not double-count varieties marketed by different seed agencies within the same country.
[b] Regional summary figures do not double-count varieties marketed by different seed agencies within the same country and/or released in more than one country.

[6] The development of hybrids exploits hybrid vigor, or heterosis, which refers to the increase in size or rate of growth of offspring over parents, and can be observed in an increase in grain yield or reduction in the number of days to flowering. On average, hybrids yield 15% more grain than OPVs. Heterosis is also an important cause of hybrid superiority in yield and yield stability (Duvick 1999).

charged by private seed companies. Third, hybrids offered increased opportunities for public breeding programs to generate resources for themselves.

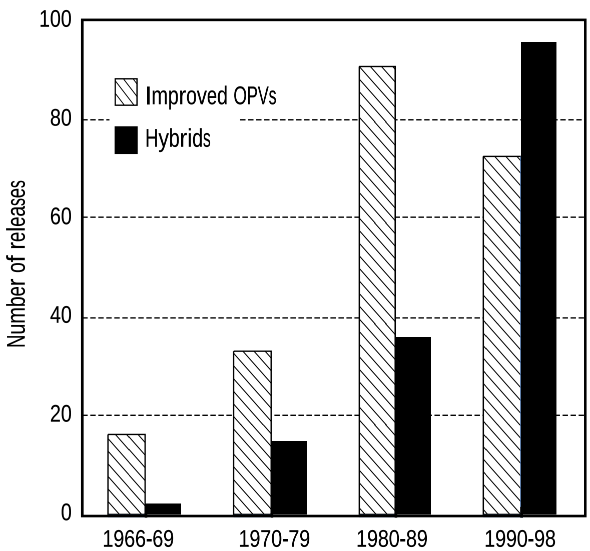

Figure 4. Number of public maize releases by type of material, Asia, 1966-97/98.
Source: CIMMYT Asia Maize Impact Survey 1998-99.

Ecological Adaptation

Over two-thirds (69%) of the maize varieties released by public breeding programs in Asia during 1966-97/98 have been adapted to lowland tropical environments (Table 8). As expected, only in China, India and Nepal have public breeding programs released varieties adapted to subtropical/mid-altitude environments.

Grain Characteristics

Three-fourths (75%) of the maize varieties released by public breeding programs in Asia during 1966-97/98 were yellow-grained and one-fourth were white-grained (Table 9). In countries such as the Philippines, where considerable quantities of maize are still consumed directly as food, especially by subsistence farmers, relatively more white-grained maize varieties were released. In countries such as Thailand, where maize is grown mainly for use in livestock feed industries, yellow-grained varieties predominated.

Table 8. Number of maize varieties released by public breeding programs, by ecological adaptation, selected Asian countries and region, 1966-1997/98

	Lowland tropical	Subtropical/mid-altitude	Temperate[a]
China (south)[a,b]	3	15	1
India	20	55	3
Indonesia	27	0	0
Nepal	9	9	0
Philippines	63	0	0
Thailand	15	0	0
Vietnam	50	0	0
Asia[c]	181	78	4
Proportion	69	30	1

Source: CIMMYT Asia Maize Impact Survey 1998-99.

[a] Many maize varieties released in northern China are adapted to temperate conditions, but these varieties are not included in the CIMMYT database.

[b] Summary figures for each country do not double-count varieties marketed by different seed agencies within the same country.

[c] Regional summary figures do not double-count varieties marketed by different seed agencies within the same country and/or released in more than one country.

Table 9. Number of maize varieties released by public breeding programs, by grain characteristic, selected Asian countries and region, 1966-1997/98

	Grain color		Grain texture			
	White	Yellow	Flint	Semi-flint	Dent	Semi-dent
China (south)[a]	15	56	6	11	22	24
India	20	90	71	11	9	14
Indonesia	3	22	11	12	0	1
Nepal	7	11	14	0	1	3
Philippines	34	27	25	10	1	1
Thailand	0	15	5	10	0	0
Vietnam	3	31	1	23	4	9
Asia[b]	81	246	129	76	36	51
Proportion (%)	25	75	44	26	12	18

Source: CIMMYT Asia Maize Impact Survey 1998-99.

[a] Summary figures for each country do not double-count varieties marketed by different seed agencies within the same country.

[b] Regional summary figures do not double-count varieties marketed by different seed agencies within the same country and/or released in more than one country.

More than two-thirds (70%) of the maize varieties released by public breeding programs in Asia during 1966-97/98 were hard-grained flint or semi-flint materials; the rest (30%) were soft-grained dent or semi-dent materials (Table 9). The emphasis of most Asian public breeding programs on flint and semi-flint materials can be attributed to the greater suitability of these materials for use as livestock feed and their added advantage of storing well. Only in China have public breeding programs focused more on dent and semi-dent materials, a pattern that may reflect a preference among Chinese consumers for soft-grained food maize that is easier to process. The relatively high proportion of soft-grained materials among Chinese releases may also reflect the fact that Chinese breeders make extensive use of breeding materials from the US Corn Belt, most of which are dents or semi-dents.

Most of the maize varieties released by public breeding programs in Asia during 1966-97/98 were short-duration varieties. Nearly two-thirds (63%) of all public-sector releases were classified as "extra early" (maturing in less than 100 days) or "early" (maturing in 100-110 days) (Table 10). Short-duration varieties offer both technical and economic advantages: they can be accommodated more easily into intensive cropping patterns in which two or more crops are grown annually; they enable the maize crop to escape drought in areas where the rainfall period is too brief to support late-maturing varieties; and they shorten the length of the "hungry season" by providing a source of food well before other food sources become available. These advantages are offset by several potential disadvantages, however. Compared to full-season varieties, short-duration varieties tend to be lower yielding, more susceptible to diseases and more vulnerable to insect damage. The challenge for maize breeders therefore has been to develop short-duration varieties that combine high yield potential with acceptable levels of disease and insect resistance or tolerance.

Private-Sector Varieties

In interpreting the tables and figures presented in this section, it is important to recall that the data on private-sector varietal releases are not directly comparable with those presented earlier on public releases. Two points must be kept in mind.

Table 10. Number of maize varieties released by public breeding programs, by maturity class, selected Asian countries and region, 1966-1997/98

	Extra-early (<100 days)	Early (100-110 days)	Intermediate (110-120 days)	Late (120-135 days)	Extra-late (>135 days)
China (south)[a]	3	16	16	18	10
India	23	34	8	0	5
Indonesia	17	5	0	1	1
Nepal	4	4	4	2	4
Philippines	31	21	1	0	2
Thailand	1	2	12	0	0
Vietnam	3	11	11	7	0
Asia[b]	78	91	52	28	22
Proportion (%)	29	34	19	10	8

Source: CIMMYT Asia Maize Impact Survey 1998-99.

[a] Summary figures for each country do not double-count varieties marketed by different seed agencies within the same country.

[b] Regional summary figures do not double-count varieties marketed by different seed agencies within the same country and/or released in more than one country.

First, whereas the information collected from public breeding programs relates to all public varieties released between 1966 and 1997/98, the information collected from private seed companies relates only to varieties available on the market in 1992 (collected during the original CIMMYT impact survey) and in 1997/98 (collected during the recent follow-up survey). These mostly consisted of commercial hybrids released during the 1990s. In other words, coverage of private-sector varieties developed and sold during the 1960s, 1970s and 1980s is incomplete.

Second, although varieties developed by public breeding programs typically are released only in the country in which they were developed, commercial hybrids from the private sector often are introduced simultaneously in several countries (especially hybrids developed by multinational seed companies).[7] Also, multinational companies often contract with one or more private national seed companies within the same country to produce and distribute seed. Under these conditions, multiple counting is difficult to avoid, because many varieties appear a number of times in the database. To avoid distortions due to multiple counting, if a variety was sold by more than one seed company within the same country, it was listed only once in the varietal releases database (under the name of the company that developed and released the variety).

Country-level analyses based on the private-sector varietal releases database are presented in Tables 11-14. Regional analyses are presented in Figures 5-8.

Types of Materials

Table 11 shows the number of private maize varieties available on the market in Asia during 1997/98, disaggregated by type of material (OPVs vs. hybrids) and by type of seed company (private national vs. multinational).

[7] India and Nepal present a special case. All of the private-sector varieties and some public-sector varieties available in Nepal were developed by private seed companies and public maize R&D agencies in India. Nepali input traders market the seed across the borders.

During the late 1990s, most of the private-sector varieties being sold in Asia had been developed by multinational companies; only in India had the majority of private-sector varieties been developed by national companies. In interpreting these figures, it is important to keep in mind that no national seed companies were engaged in maize R&D in Indonesia, Nepal or Vietnam. In Indonesia and Vietnam, private-sector maize R&D was being carried out only by multinationals. In Nepal, no national seed companies were engaged in maize R&D; seed companies in Nepal were selling seed mainly of imported varieties developed by Indian companies. In China, virtually no private-sector maize R&D of any description was being carried out.

As expected, both national private companies and multinationals were concentrating heavily on hybrids. Only one private company had developed an OPV—P.T. BISI of Indonesia, a multinational (Table 11).

The number and types of hybrids being marketed by private seed companies varied between countries. Private companies in India had the largest number of different hybrids on the market (102), while private companies in Vietnam had the fewest (11). Three-way-cross and double-cross hybrids dominated private-sector offerings in India, Nepal and the Philippines, whereas single-cross hybrids dominated in Thailand and Vietnam.

Differences between countries in the numbers and especially the types of hybrids being sold can be explained by economic as well as political factors. In a number of countries, especially those in which maize production is still predominantly subsistence-oriented, demand for higher-priced hybrid seed types has simply been lacking. In other countries, demand for hybrid seed has been strengthening, but seed companies have had difficulty responding to this demand.

Table 11. Types and numbers of private-sector maize varieties available on the market, selected Asian countries, late 1990s

		Hybrids			
	Improved OPVs	Single cross	Three-way cross	Double cross	Other
Private national companies					
China (south)[a]	na	na	na	na	na
India	0	14	19	40	0
Indonesia	na	na	na	na	na
Nepal[b]	0	2	2	8	0
Philippines	0	1	14	3	0
Thailand	0	4	1	0	0
Vietnam	na	na	na	na	na
Multinational companies					
China (south)[a]	na	na	na	na	na
India	0	2	4	19	4
Indonesia	1	7	13	1	1
Nepal[b]	0	0	1	2	1
Philippines	0	1	14	6	0
Thailand	0	16	11	2	0
Vietnam	0	7	2	1	1

Source: CIMMYT Asia Maize Impact Survey 1998-99.

Note: na = not available, because type of company is not involved with maize R&D in the country.

[a] Summary figures for each country do not double-count varieties marketed by different seed agencies within the same country.

[b] Maize varieties from private national and multinational companies of India, exporting to Nepal.

Since hybrid seed tends to be expensive to produce, it must be sold at premium prices to recoup production costs. In a number of Asian countries, private companies have difficulty implementing prices at levels that ensure full cost recovery. Direct seed price controls are no longer common in Asia (except in China), but the ability of private companies to set remunerative prices is affected indirectly by policies that favor public seed agencies. In Vietnam, for example, representatives of several private companies interviewed for the CIMMYT survey observed that they are forced to compete with government seed agencies that not only receive subsidies but also benefit from favorable regulatory treatment. As an example of the latter, shortly before the survey was conducted, the Vietnamese government announced plans to require private seed companies to establish in-country seed production facilities. For most of the multinationals operating in Vietnam, in-country seed production would be inefficient owing to the small size of the Vietnamese hybrid seed market; most multinationals would prefer to import commercial seed into Vietnam from more efficient production facilities located in neighboring countries.

High production cost is only one of the factors that have discouraged some private seed companies from selling hybrids. To produce commercial seed of hybrids, the seed companies must provide contract growers with the parent inbred maize lines. In the absence of enforceable intellectual property rights, private companies are often reluctant to release their best hybrids, especially single-cross and three-way-cross hybrids, since it may be extremely difficult to protect the inbred lines used to produce these types of hybrids. Fear of losing their valuable inbred lines to unscrupulous competitors has discouraged several multinationals from marketing their best hybrids in several Asian countries.

Despite these economic and political constraints, private seed companies have in recent years been expanding their product lines, and many now sell seed of several different types of hybrids. Many seed companies recognize that they can increase sales by segmenting the market, and that selling into a commercial farming sector willing and able to pay for technically sophisticated single-cross and three way-cross hybrids does not prevent them from at the same time targeting other segments of the market for whom less sophisticated double-cross and top-cross hybrids may be more appropriate. For this reason, companies that sell single-cross and three-way-cross hybrids often also sell double-cross, top-cross and double-top-cross hybrids.

Ecological Adaptation

Most of the maize varieties developed by the private sector and sold in Asia during the late 1990s were adapted to lowland tropical environments (Table 12). This is hardly surprising, given that most of the area planted to maize in Asia (excluding China's temperate maize area) was located in such environments. The proportion of private-sector varieties showing lowland tropical adaptation was particularly high in Indonesia (100%), Vietnam (100%), the Philippines (98%) and Thailand (85%). Only in India and Nepal were a significant number of private-sector varieties adapted to other production environments (subtropical/mid-altitude environments).

Grain Characteristics

Most of the maize varieties developed by the private sector and sold in Asia during the late 1990s were yellow-and hard-grained (flint or semi-flint) materials (Table 13). This suggests that private companies have made a deliberate attempt to meet the large and increasing demand for livestock feed. The Asian feed industry generally prefers yellow maize because it imparts desirable color to eggs and poultry meat. Hard-

Table 12. Number of maize varieties from the private sector available on the market, by ecological adaptation, selected Asian countries, late 1990s

	Private national companies			Multinational companies		
	Lowland tropical	Subtropical / mid-altitude	Temperate	Lowland tropical	Subtropical / mid-altitude	Temperate
China (south)[a]	na	na	na	na	na	na
India	1	5	0	3	0	0
Indonesia	na	na	na	23	0	0
Nepal[b]	5	3	na	4	0	0
Philippines	17	1	0	24	0	0
Thailand	5	0	0	29	0	0
Vietnam	na	na	na	11	0	0

Source: CIMMYT Asia Maize Impact Survey 1998-99.
Note: na = not available, because type of company is not involved with maize R&D in the country.
[a] Summary figures for each country do not double-count varieties marketed by different seed agencies within the same country.
[b] Maize varieties from private national companies and multinational companies of India, exporting to Nepal.

Table 13. Number of maize varieties from the private sector available on the market, by grain characteristic, selected Asian countries, late 1990s

	Grain color		Grain texture			
	White	Yellow	Flint	Semi-flint	Dent	Semi-dent
Private national companies						
China (south)[a]	na	na	na	na	na	na
India	4	69	19	26	9	19
Indonesia	na	na	na	na	na	na
Nepal[b]	0	12	3	4	0	5
Philippines	1	17	4	5	0	0
Thailand	0	5	0	2	0	3
Vietnam	na	na	na	na	na	na
Multinational companies						
China (south)[a]	na	na	na	na	na	na
India	8	20	5	12	7	5
Indonesia	4	19	6	17	0	0
Nepal[b]	0	4	0	1	1	2
Philippines	1	28	12	4	0	1
Thailand	1	28	18	7	3	1
Vietnam	0	11	3	6	0	2

Source: CIMMYT Asia Maize Impact Survey 1998-99.
Note: na = not available because type of company is not involved with maize R&D in the country.
[a] Summary figures for each country do not double-count varieties marketed by different seed agencies within the same country.
[b] Maize varieties from private national and multinational companies of India, exporting to Nepal.

grained (flint or semi-flint) maize is preferred because it tends to be more resistant to fungi and insects, and because it is less likely to spoil during shipping and storage than soft-grained (dent or semi-dent) maize (Dowswell *et al.* 1996). The latter characteristic is particularly important in less-developed countries, where it often takes time to transport maize grain from production zones to processing points in larger cities. Only in India were private seed companies offering a wide range of maize grain textures.

With regard to the maturity class of maize varieties sold during the late 1990s by private companies, short-duration varieties (extra-early and early) predominated in India, Indonesia and the Philippines, whereas medium-duration varieties (intermediate) featured more prominently in Thailand and Vietnam (Table 14). As cropping intensity increases in the region's more favored production environments, the demand for high-yielding, short-duration varieties can be expected to increase.

Regional Patterns in Varieties Developed by the Private Sector

Regional patterns in maize varieties developed by the private sector can be discerned by summing the country-level data, but this method may give misleading results because the same hybrid was often released in several countries. To avoid problems with multiple counting, a single-entry database was constructed containing information about all private varieties being sold in Asia during the late 1990s. The database was constructed by eliminating redundant entries (i.e., multiple entries for varieties that were released in more than one country). To allow comparisons between varietal release patterns of private and public breeding programs, a single-entry database was also constructed containing information about all of the public varieties being sold during the late 1990s.

Table 14. Number of maize varieties from the private sector available on the market, by maturity class, selected Asian countries, late 1990s

	Extra-early (<100 days)	Early (100-110 days)	Intermediate (110-120 days)	Late (120-135 days)	Extra-late (>135 days)
Private national companies					
China (south)[a]	na	na	na	na	na
India	28	32	9	1	0
Indonesia	na	na	na	na	na
Nepal[b]	4	5	3	0	0
Philippines	6	10	0	0	2
Thailand	0	3	2	0	0
Vietnam	na	na	na	na	na
Multinational companies					
China (south)[a]	na	na	na	na	na
India	9	8	8	0	4
Indonesia	12	8	0	0	0
Nepal[b]	1	1	1	0	1
Philippines	6	14	0	0	3
Thailand	1	12	12	3	0
Vietnam	1	8	2	0	0

Source: CIMMYT Asia Maize Impact Survey 1998-99.

Note: na = not available because type of company is not involved with maize R&D in the country.

[a] Summary figures for each country do not double-count varieties marketed by different seed agencies within the same country.

[b] Maize varieties from private national and multinational companies of India, exporting to Nepal.

As in other regions of the developing world (Morris and López-Pereira 1999, Hassan *et al*. 2001), in Asia the private sector has concentrated on selling hybrids (Figure 5). Among all the maize varieties developed by the private sector and marketed in Asia during the late 1990s, double-cross hybrids predominated (41%), followed by three-way-cross hybrids (35%) and single-cross hybrids (21%). Double-cross and three-way cross hybrids were marketed both by national seed companies and multinationals; single-cross hybrids were marketed much more frequently by multinationals. The strong emphasis by private seed companies on hybrids contrasted sharply with the emphasis of public seed agencies in Asia, which during the same period were selling mainly OPV seed. The private sector's strong emphasis on hybrids was based on commercial considerations: farmers who plant hybrids are often commercial growers who not only require significant quantities of seed but who also tend to purchase fresh seed every year. In addition,

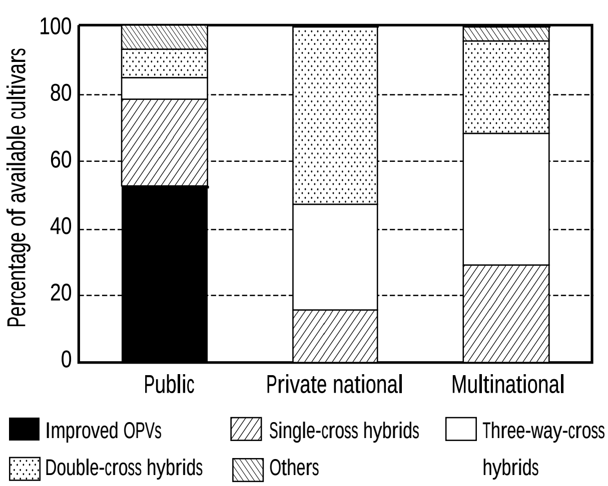

Figure 5. Maize varieties available in the late 1990s in Asia, by type of cultivar and seed agency (in %).
Source: CIMMYT Asia Maize Impact Survey 1998-99.

hybrid seed usually commands higher prices than seed of OPVs and thus provides increased profit opportunities for seed companies.

The vast majority of maize varieties being marketed in Asia by private seed companies during the late 1990s (94%) were adapted to lowland tropical environments. A relatively small number of varieties (6%) were adapted to subtropical/mid-altitude environments. With the notable exception of northern China (which was not included in the CIMMYT survey), none of the maize varieties being marketed in Asia by the private sector was adapted to temperate environments.

Regional patterns in grain color, grain texture and maturity class are summarized in Figure 6. In the private sector as in the public sector, most of the varieties sold in Asia during the late 1990s were yellow, hard-grained (flint or semi-flint) and short-duration (extra-early, early or intermediate). By implication, both public and private breeding programs mainly were targeting feed grain producers. In terms of absolute numbers, public breeding programs were selling many more white- and soft-grained varieties than were private companies, but expressed as a proportion of their overall product lines, the relative attention given to white vs. yellow varieties and to flint vs. dent varieties was comparable in both sectors. Given the apparent preponderance of feed-type varieties, the question arises whether public and private breeding programs have been giving undue attention to the needs of commercial farmers at the expense of the subsistence-oriented farmers who represent the majority of the region's poorest households.

How old were the maize varieties available in Asian markets during the late 1990s?[8] Generally speaking, the available private varieties were

[8] The list of varieties is based on commercial seed being sold during the late 1990s, which was not necessarily correlated with the actual area planted to modern maize varieties. In the case of OPVs, farmers can replant farm-saved seed, so many older OPVs were still being grown even though seed of those varieties was no longer available in the market. Also, seed of some of the varieties available in the market may not have been sold.

considerably younger than the available public varieties (Figure 7). Only about 2% of the available private varieties had been released during the 1970s or earlier. In contrast, approximately 13% of the available public varieties were at least 30 years old. A number of factors could explain this difference. For example, the continuing presence in the market of old public varieties could be due to the fact that small local seed companies which lack their own R&D capacity continue to produce seed of these varieties. Alternatively, it is possible that private seed companies have simply been more aggressive in introducing new varieties and more successful in convincing farmers to replace their varieties on a regular basis.

Despite the differences mentioned earlier, on the whole the public and private maize varieties being sold in Asia during the 1990s were fairly similar (see Figure 8, next page; see also the discussion in the previous section).

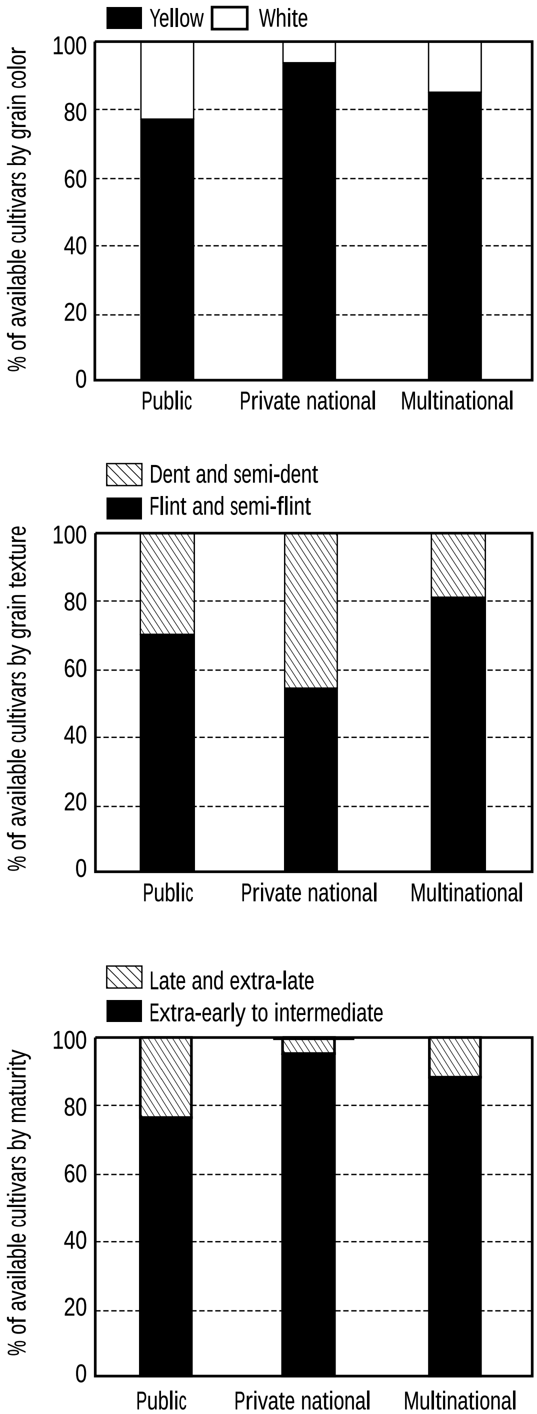

Figure 6. Characteristics of improved maize cultivars available in the market, by type of seed company, Asia, late 1990s.
Source: CIMMYT Asia Maize Impact Survey 1998-99.

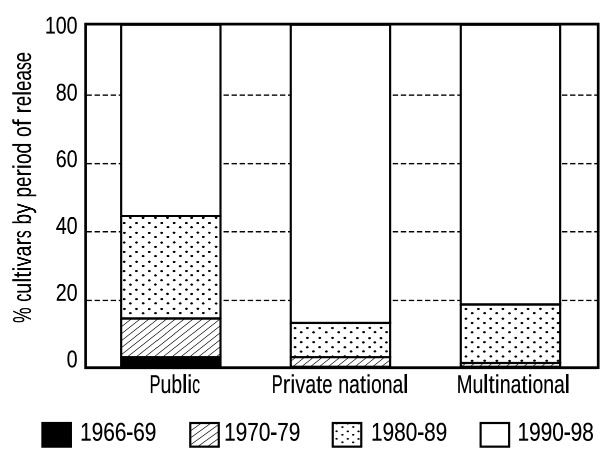

Figure 7. Percentage of materials available in the late 1990s in Asia, by type of seed company and age of material.
Source: CIMMYT Asia Maize Impact Survey 1998-99.

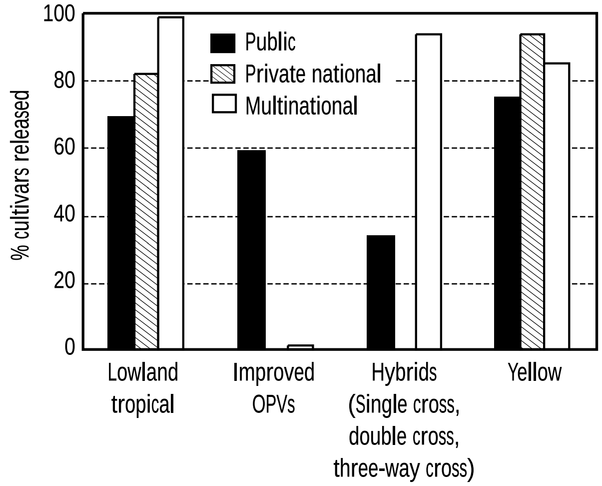

Figure 8. Selected characteristics of public varieties released during 1966-97/98 vs. private varieties available during the late 1990s, Asia.
Source: CIMMYT Asia Maize Impact Survey 1998-99.

Status and Performance of the Maize Seed Industry

Commercial Maize Seed Sales and Market Shares

By analyzing patterns in releases of maize varieties, it is possible to draw inferences about the activities of public and private maize breeding programs. But varietal releases in and of themselves do not reveal anything about impact at the farm level, because some varieties are grown much more widely than others. To estimate the farm-level impact of maize breeding programs, it is therefore necessary to examine evidence on adoption of varieties.

The most direct way to estimate adoption is through farm-level surveys. Farm-level adoption surveys are costly to implement, however, and they are rarely performed at the national level. Therefore it is usually necessary to estimate varietal adoption indirectly. One way to do this is by examining data on commercial maize seed sales. Unfortunately, commercial seed sales are difficult to estimate with precision. In most countries, data on commercial seed sales are not compiled by the government, and even where they are compiled, they are often inaccurate, because government seed agencies and private seed companies both may have incentives to misrepresent their sales figures.

Data on commercial maize seed sales in Asia were collected from public seed agencies and private seed companies as part of the CIMMYT survey. While it was not possible to collect information about all of the commercial maize seed sold in Asia during the reference year (1996/97), the coverage of the survey was extensive. Information was collected for well over two-thirds of total estimated 1996/97 commercial maize seed sales in Asia. Assuming that the seed which was not included in the survey was similar to the seed included by the survey, it is possible to draw conclusions that are valid for the entire commercial maize seed market.

The 179 public and private seed agencies in Asia interviewed for this study reported selling just over 167,000 t of improved maize seed in 1996/97 (Table 15), of which 5,000 t (3%) consisted of OPV seed and 162,000 t (97%) consisted of hybrid seed. China had by far the largest commercial maize seed market in the region; in 1996/97, Chinese seed organizations (all of which were public companies) sold 87,600 t of hybrid maize seed, equivalent to 52% of all commercial maize seed sold throughout Asia.[9] India and Thailand ranked second and third in commercial maize seed sales, followed by Indonesia, the Philippines and Vietnam. Nepal had the region's smallest commercial maize seed market; only 1,500 t of commercial maize seed was sold in Nepal, equivalent to slightly less than 1% of the Asian market.

Because all commercial maize seed sold in China is produced by public organizations, and because

[9] The numbers for China would of course be much larger if northern China were included.

Table 15. Sales of maize seed (t) from the public and private sector, by type of organization, selected Asian countries and region, 1997

	Public seed agencies	Private national companies	Multinational companies	Total	Percent of total	Percent of total, excluding China
China	87,600	0	0	87,600	52.4	–
India	4,500	12,250	19,250	36,000	21.5	45.2
Indonesia	900	300	8,350	9,550	5.7	12.0
Nepal[a]	150	1,300	0	1,450	0.9	1.8
Philippines	140	1,300	6,700	8,140	4.9	10.2
Thailand	200	3,500	17,000	20,700	12.4	26.0
Vietnam	2,660	0	1,150	3,810	2.3	4.8
Asia	96,150	18,650	52,450	167,250	100.0	–
Asia, excluding China	8,550	18,650	52,450	79,650	–	100.0
Asia (%)	57.5	11.2	31.4	100.0	–	–
Asia (%), excluding China	10.7	23.4	65.9	100.0	–	–

Source: CIMMYT Asia Maize Impact Survey 1998-99.

[a] Private national maize seed companies in Nepal trade improved seed from India. No multinational maize seed companies operate in the country.

China's maize seed market is so large, seed sales by public organizations exceed seed sales by private companies for the region as a whole. Including the data for China, 58% of all commercial maize seed sold in Asia during 1996/97 was produced by public organizations. When China is excluded from the analysis, however, the picture changes dramatically: excluding the data for China, private seed companies dominate the Asian maize seed industry, accounting for 89% of all commercial maize seed sales during 1996/97. Within the private sector, multinational companies are much more important that national companies; in 1996/97, multinationals accounted for 66% of all commercial maize seed sales, whereas nationals accounted for only 23%.

China's enormous public maize seed industry differs from the public maize seed industries in other Asian countries in having emphasized hybrids rather than OPVs. For this reason, even though most commercial maize seed in Asia is produced by public organizations, seed sales in Asia have been dominated by hybrids. Of all commercial maize seed sold in Asia during 1996/97, 56% was seed of public hybrids, 41% was seed of private hybrids and only 3% was seed of OPVs from public and private agencies[10] (Table 16). Excluding the data for China, the picture changes: fully 85% of all commercial maize seed sold during 1996/97 consisted of hybrid seed produced by private seed companies.

What explains the increasing domination of private hybrids, especially outside China? Three factors appear to be at work. First, many of the hybrids developed by private seed companies are simply better than the hybrids developed by public breeding programs. The superior performance of many private-sector hybrids reflects the longstanding concentration of private seed companies on hybrid breeding, as well as more focused targeting of production environments. Second, the quality of the hybrid

[10] This proportion is probably an underestimate because of poor documentation of sales and distribution by public seed agencies.

Table 16. Maize seed sales (t) by the public and private sector, by maize type, selected Asian countries and region, 1997

	Public sector			Private sector			Both sectors		
	Improved OPVs	Hybrids	Total	Improved OPVs	Hybrids	Total	Improved OPVs	Hybrids	Total
China	0	87,600	87,600	0	0	0	0	87,600	87,600
India	650	3,850	4,500	700	30,800	31,500	1,350	34,650	36,000
Indonesia	350	550	900	1,250	7,400	8,650	1,600	7,950	9,550
Nepal	150	0	150	900	400	1,300	1,050	400	1,450
Philippines	60	80	140	0	8,000	8,000	60	8,080	8,140
Thailand	170	30	200	400	20,100	20,500	570	20,130	20,700
Vietnam	360	2,300	2,660	0	1,150	1,150	360	3,450	3,810
Asia	1,740	94,410	96,150	3,250	67,850	71,100	4,990	162,260	167,250
Asia, excluding China	1,740	6,810	8,550	3,250	67,850	71,100	4,990	74,660	79,650
Asia (% total)	1.0	56.4	57.5	1.9	40.6	42.5	3.0	97.0	100.0
Asia (%, excluding China)	2.2	8.5	10.7	4.1	85.2	89.3	6.3	93.7	100.0

Source: CIMMYT Asia Maize Impact Survey 1998-99.

seed produced by private companies is often better than that of the hybrid seed produced by public seed agencies. Private companies tend to pay a lot of attention to seed quality assurance, since their economic survival depends on the reputation that they are able to establish among farmers. In contrast, public seed agencies usually have little incentive to look after seed quality. Third, private seed companies on the whole have been much more effective in marketing their hybrids through aggressive advertising and promotion campaigns. They have generally done an excellent job of building production and distribution networks that allow seed to be delivered efficiently to the end user, often on credit, and sometimes along with complementary inputs such as fertilizer and crop chemicals. In contrast, public seed agencies have tended to distribute their seed through centralized distribution facilities that frequently are difficult for farmers to reach.

If the rising popularity of private-sector hybrids can be explained largely by technical and economic factors, what explains the increasing dominance of Asian seed markets by multinational companies? Case study evidence suggests that many farmers in Asia make seed purchasing decisions based on the reputation of the seed company, rather than on detailed knowledge about the performance of specific hybrids (for example, see Singh and Morris, 1997). In other words, when it comes to selling maize seed, brand name recognition is important. Many multinational companies have been able to establish national reputations by investing aggressively in advertising and promotion. In contrast, most national companies are known only within certain regions of a country or at the local level. Public seed agencies, which usually have limited resources to promote and advertise their products, are known even less widely. Although public and private national seed agencies in some countries have been able to sell hybrid seed through government-supported maize production campaigns, this outlet can dry up abruptly when the subsidies end. In the Philippines, for example, maize farmers are provided subsidized hybrid seed through the Agrikulturang Makamasa (Agriculture for the Masses) Program; without the program, farmers generally will not buy hybrid seed because of financial constraints.

Evolution of Commercial Maize Seed Sales

How have commercial maize seed sales in Asia changed through time? Aggregating across the region as a whole, commercial maize seed sales rose from about 91,000 t in 1990 to just over 167,000 t in 1997 before decreasing to 144,000 t in 1998 (Figure 9). The decline recorded in 1998 was a direct result of the severe financial crisis in the region, which among other things dramatically increased the real cost of seed and other purchased inputs. Over the entire 1990-98 period, sales of OPV seed declined at an average rate of 4% per year, while sales of hybrids increased at an average rate of nearly 8% per year (Table 17).

These aggregate growth numbers conceal important differences between what was happening in the public and private sectors. Between 1990 and 1998, sales by public seed organizations grew at an average rate of 2% per year, while sales by private companies grew at the much higher average rate of 24% per year. The relatively sluggish growth in sales by public seed organizations was driven mainly by sales of OPV seed, whereas the explosive growth in sales by private companies was fueled entirely by increased sales of hybrid seed. The divergent rates of seed sales growth between the public and private sectors led to the increasing dominance of the private sector alluded to previously (Figure 10).

Prices and Price Ratios

Table 18 shows average maize seed prices prevailing in Asian countries in 1997/98. To eliminate possible exchange rate distortions, seed prices are expressed not only in terms of US

Table 17. Annual growth (%/yr) in commercial maize seed sales by the public and private sector, by maize type, Asia, 1990-98

	1990-93	1994-98	1990-98
Public sector			
Improved OPVs	-16.3	28.6	10.9
Hybrids	1.8	2.0	2.0
Total	1.7	2.4	2.2
Private sector			
Improved OPVs	-19.7	0.9	-9.0
Hybrids	58.9	13.4	32.4
Total	35.5	12.7	24.4
Both sectors			
Improved OPVs	-19.3	9.6	-4.0
Hybrids	8.2	5.7	7.9
Total	6.9	5.8	7.4

Source: CIMMYT Asia Maize Impact Survey 1998-99.
Note: Data for China, India, Indonesia, Nepal, Philippines, Thailand and Vietnam.

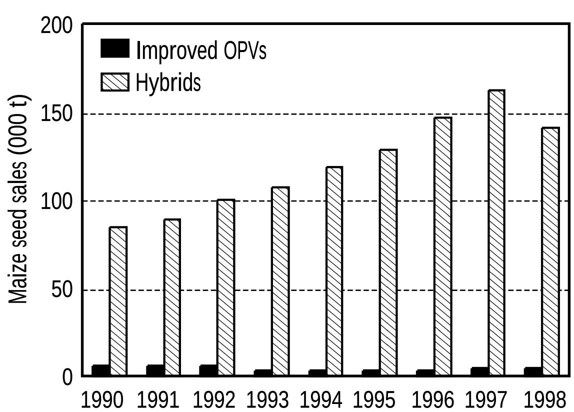

Figure 9. Evolution of maize seed sales by type of cultivar, Asia, 1990-98.
Source: CIMMYT Asia Maize Impact Survey 1998-99.

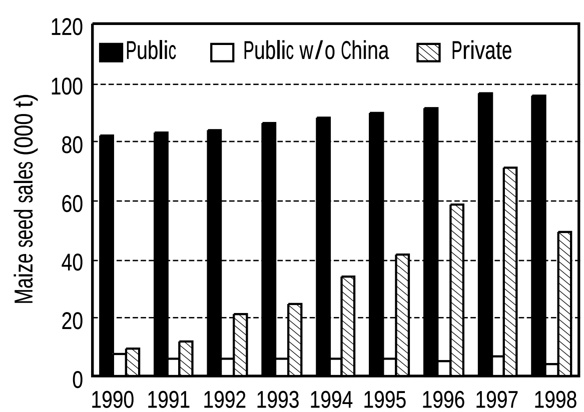

Figure 10. Evolution of maize seed sales by sector, Asia, 1990-98.
Source: CIMMYT Asia Maize Impact Survey 1998-99.

Table 18. Average maize seed prices and seed-to-grain price ratios, by type of material and seed company, Asia, 1997/98

	Public sector	Private sector: National companies	Private sector: Multinational companies	Private sector: All private companies	Both sectors
Maize seed price (US$/kg)					
Improved OPV	0.71	0.57	0.57	0.57	0.59
Single cross	na	1.61	2.48	2.07	2.07
Three-way cross	2.00	1.15	1.69	1.46	1.51
Double cross	1.17	1.33	1.23	1.29	1.27
Non-conventional	na	1.11	1.84	1.35	1.35
All hybrids	1.45	1.37	1.87	1.58	1.57
All types of seed	1.15	1.09	1.85	1.38	1.35
Seed-to-grain price ratio					
Improved OPV	7.51	4.53	5.94	4.64	5.05
Single cross	na	11.65	21.13	16.71	16.71
Three-way cross	24.00	8.89	13.81	11.70	12.77
Double cross	9.37	10.62	9.54	10.21	10.11
Non-conventional	na	6.26	13.68	8.73	8.73
All hybrids	14.25	10.76	15.75	12.85	12.99
All types of seed	10.81	8.63	15.48	11.26	11.21

Source: CIMMYT Asia Maize Impact Survey 1998-99.
Note: na = not available. Data for China, India, Indonesia, Nepal, Philippines, Thailand and Vietnam.

dollars per kilogram (US$/kg), but also as seed-to-grain price ratios (which show the number of kilograms of maize grain that must be sold to pay for one kilogram of seed).

As expected, seed of single-cross hybrids commanded the highest prices, averaging US$ 2.07/kg across the region as a whole, followed by seed of three-way-cross hybrids, which averaged US$ 1.51/kg. Seed of OPVs commanded the lowest prices, averaging US$ 0.59/kg across the region as a whole. These differences in retail selling prices correlate closely to differences in production costs. Seed of single-cross hybrids is the most expensive type of seed to produce (mainly because seed yields are low), followed by seed of three-way-cross hybrids. Seed of OPVs is relatively inexpensive to produce (not only because seed yields are high, but also because many costly and laborious operations required for hybrid seed production are unnecessary).

Do maize seed prices in Asia differ depending on whether the seed is produced by public agencies or private companies? Averaging across all types of materials for which complete data were available (single-cross hybrids, three-way-cross hybrids, double-cross hybrids, OPVs), seed sold by multinational companies was the most expensive (US$ 1.85/kg), followed by seed sold by public agencies (US$ 1.15/kg) and seed sold by private national companies (US$ 1.09/kg). Contrary to expectations, in many instances seed sold by public agencies commanded higher prices than seed sold by private companies, especially national companies.[11] Several possible explanations might account for this unexpected finding. For example, public agencies may be less efficient at producing

[11] In some countries, however, the prices of OPV seed from the public and private sectors were similar, mainly because private companies produce and market OPVs for the public agencies (see the Indonesia country report, chapter 4).

seed than private companies, and they may be passing along higher seed production costs in the form of higher prices. Alternatively, varieties marketed by public agencies may perform better, with the result that their seed can be sold at higher prices. It is also possible that the public-sector varieties simply are not priced competitively.

To exploit the full genetic potential of modern maize varieties, especially hybrids, farmers must use complementary inputs, especially fertilizer and pesticides, and they must perform improved management operations that often require additional labor. The profitability of using complementary inputs and of performing improved management practices depends among other things on their cost. Input-to-grain price ratios can be used to make inter-country comparisons of the relative costliness of key inputs, which in turn can serve as rough indicators of the profitability of adopting modern varieties. Nitrogen-to-grain price ratios and labor-to-grain price ratios prevailing in Asia during 1998/99 are shown in Table 19. Across all seven countries that participated in the CIMMYT survey, the nitrogen-to-grain price ratio averaged about 2.5, and the labor-to-grain price ratio averaged about 14. Input-to-grain price ratios were highest in Thailand and lowest in Nepal.

How do prices for maize seed and complementary inputs prevailing in Asia compare to prices prevailing in other developing regions? In Latin America, seed-to-grain price ratios ranged from 6 for OPVs to 16 for double-cross hybrids to 33 for single-cross hybrids (Morris and López-Pereira, 1999). Also in Latin America, nitrogen-to-grain price ratios ranged from 1.1 to 1.9 in most countries (CIMMYT 1999). This suggests that improved maize seed is less costly in Asia relative to Latin America, but nitrogen fertilizer is more costly in Asia relative to Latin America.

Composition of Maize Seed Prices

In an effort to gain insights about the production cost structure of commercial maize seed, survey respondents were asked to break down the retail selling price of maize seed into five major components: (1) R&D costs, (2) seed multiplication costs, (3) marketing and distribution costs, (4) overhead and (5) gross margins. Since the relative importance of these components can be

Table 19. Average input prices and input-to-grain price ratios for nitrogen fertilizer and labor, selected Asian countries and region, 1997/98

	Input price (US$)		Input-to-grain price ratio	
	Nitrogen fertilizer (per kg N)	Farm labor (per person-day)	Nitrogen fertilizer	Farm labor
China	na	na	na	na
India	0.24	1.07	2.27	9.35
Indonesia	0.19	1.05	1.99	13.08
Nepal	0.27	1.27	1.88	8.45
Philippines	0.34	3.93	2.16	24.36
Thailand	0.38	3.55	2.82	26.06
Vietnam	0.40	1.31	2.82	9.62
Asia	0.34	1.92	2.48	13.72

Source: CIMMYT Asia Maize Impact Survey 1998-99.
Note: na = not available.

expected to vary depending on the seed type, the respondents were asked to base their estimates on the production cost structure for double-cross hybrid seed. Double-cross hybrid seed serves as a convenient standard for this comparison because it is a common seed type sold in all seven of the survey countries.

The composition of retail maize seed prices is shown in Figure 11. Averaging across the entire sample, public seed agencies reported relatively high research and development costs compared to private seed companies and relatively low seed multiplication costs. Marketing and distribution costs and overhead made up comparable proportions of the retail price of seed for both types of organizations. Summing the first four categories and subtracting the total from the retail selling price, private companies earn higher gross margins (15% on average) than public seed agencies (8% on average).

When the data for private seed companies are disaggregated by type of company (national vs. multinational), differences are evident between the two categories. Research and investment costs make up a relatively greater proportion of the retail price of seed sold by multinationals (21% vs. 12%), while seed multiplication costs and marketing and distribution costs make up a relatively smaller proportion (43% vs. 53%). Expressed as a proportion of the retail selling price, gross margins are comparable for both types of private company (14-17%), but since seed sold by multinationals tends to command higher prices, in absolute terms gross margins are higher for multinationals.

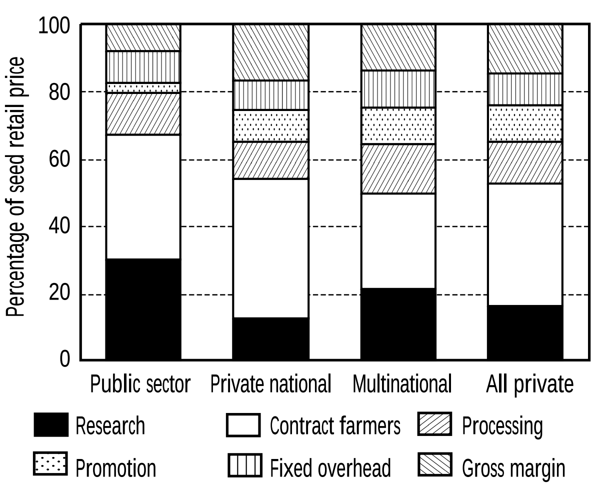

Figure 11. Composition of maize seed prices by type of seed organization, Asia, 1997 / 98.
Source: CIMMYT Asia Maize Impact Survey 1998-99.

Adoption of Modern Maize Varieties in Asia

The number of modern maize varieties developed and released by public and private breeding programs in Asia has increased steadily during the last 30 years. During the same period, commercial maize seed sales have risen sharply. Has the development, release and sale of increased numbers of modern maize varieties been reflected in greater adoption by Asian farmers?

Estimating the area planted to improved maize varieties is difficult for two reasons. First, maize in Asia is grown in a wide range of environments and as a component of many different cropping systems, many of which are poorly monitored by government crop reporting services. Second, because maize is an open-pollinating species, it is often very difficult to identify improved germplasm in the field. Many farmers (and even researchers) have difficulty distinguishing between so-called “local” or “traditional” varieties and improved maize varieties, especially when the latter have been grown from farm-saved seed that has been recycled many times. These considerations should be kept in mind when interpreting the adoption estimates presented in the following section.

Area Planted to Improved Germplasm

Crop varietal adoption surveys are rarely conducted at the national level, so in impact studies such as this it is often necessary to rely on subjective methods to estimate the area planted to improved varieties. For this study, the data on area planted to modern maize varieties in each Asian country were based on "expert opinion" estimates made by senior scientists working in national maize programs and by representatives of private seed companies. In each country, these knowledgeable informants were asked to estimate the percentage of the national maize area planted to local varieties, OPVs and hybrids. These estimated percentages were then applied to the total national maize area for 1997 to derive estimates of the number of hectares planted to each type of material.[12]

Table 20 presents estimates of the area planted in 1997 to local varieties, OPVs and hybrids in the seven Asian countries covered by the study. Of the 19.6 m ha planted to maize in 1997, 6.1 m ha (31%) were planted to local varieties, 4.8 m ha (24%) were planted to OPVs and 8.7 m ha (44%) were planted to hybrids. The combined 13.5 m ha planted to OPVs and hybrids represent a significant increase over the 8.2 m ha estimated to be planted to modern varieties in Asia during the early 1990s (López-Pereira and Morris 1994).

Adoption rates vary significantly between individual countries (Table 21). In Thailand and China, virtually the entire national maize area is planted to OPVs and hybrids. At the other extreme, in the Philippines only about 36% of the national maize area is planted to OPVs and hybrids.

As in other regions of the developing world, in Asia the area planted to hybrids is now more than twice as large as the area planted to OPVs (Table 21). At the individual country level, only in Nepal and Indonesia is the area planted to OPVs still larger than the area planted to hybrids. These findings, which are consistent with the commercial maize seed sales data presented earlier (Table 16), reflect the active role of the private sector in promoting hybrids in many Asian countries (except for China, where hybrids have been promoted by public seed companies).

Summary and Conclusions

This chapter has presented data on the activities of national maize seed industries in Asia. It has documented the human and financial resources invested over the last three decades in developing

Table 20. Area planted to maize, selected Asian countries and region, 1997

	Estimates of local experts / scientists (000 ha)	FAO statistics (000 ha)	Ratio of local experts' estimates FAO scientists
China (non-temperate)	4,113.7	4,113.7	1.00
India	6,180.0	6,511.0	0.95
Indonesia	4,900.0	3,456.4	1.42
Nepal	860.0	802.3	1.07
Philippines	2,757.0	2,701.0	1.02
Thailand	1,400.0	1,300.0	1.08
Vietnam	659.1	686.9	0.96
Asia	20,869.8	19,571.3	1.07

Source: CIMMYT Asia Maize Impact Survey 1998-99; FAO database, Production Domain, April 2001.

12 The estimates of total area planted to maize in each country in 1997 provided by survey respondents sometimes differed slightly from official FAO data. To resolve inconsistencies, the local experts' estimates were adjusted by multiplying the percentage area planted to each type of maize material by the official FAO data on the total area planted to maize in each country.

Table 21. Area planted to maize, by maize type, based on estimates of national public-sector researchers (adjusted using FAO area data), selected Asian countries and region, 1997

		Area planted to improved germplasm			
	Farm-saved seed	OPVs	Hybrids	Total modern varieties	Total maize area (adjusted FAO)
		(000 ha)			
China (non-temperate)	41.1	485.4	3,587.1	4,072.6	4,113.7
India	3,190.4	1,432.4	1,888.2	3,320.6	6,511.0
Indonesia	1,036.9	1,417.1	1,002.4	2,419.5	3,456.4
Nepal	288.8	364.2	149.2	513.5	802.3
Philippines	1,728.6	324.1	648.2	972.4	2,701.0
Thailand	3.9	180.7	1,115.4	1,296.1	1,300.0
Vietnam	305.7	101.0	280.3	381.2	686.9
Asia	6,595.4	4,305.0	8,670.8	12,975.8	19,571.3
		(percentage of maize area)			
China (non-temperate)	1.0	11.8	87.2	99.0	100.0
India	49.0	22.0	29.0	51.0	100.0
Indonesia	30.0	41.0	29.0	70.0	100.0
Nepal	36.0	45.4	18.6	64.0	100.0
Philippines	64.0	12.0	24.0	36.0	100.0
Thailand	0.3	13.9	85.8	99.7	100.0
Vietnam	44.5	14.7	40.8	55.5	100.0
Asia	33.2	21.8	44.9	66.7	100.0

Source: CIMMYT Asia Maize Impact Survey 1998-99.

improved maize and delivering improved seed to Asian farmers, described the products of public and private maize breeding programs and estimated the area planted to modern varieties.

Summary of Major Findings

What major conclusions emerge from this overview concerning the organization and performance of Asia's maize seed industries?

- *The area planted to OPVs and hybrids continues to expand.*

The total area planted to OPVs and hybrids in Asia continues to expand at a rapid rate. In 1997/98, approximately 13.5 m ha were planted to OPVs and hybrids in the seven countries covered by the CIMMYT survey, equivalent to 67% of these countries' total maize area. This represents a significant increase from earlier years. For example, the first CIMMYT maize impact study estimated that 8.2 m ha were planted to OPVs and hybrids in 1992. Meanwhile, the area planted to farm-saved seed declined from around 11 m ha in 1990 to only 6.6 m ha in 1997/98.

- *The area planted to hybrids now significantly exceeds the area planted to improved OPVs.*

In 1990, 5.8 m ha in Asia (71% of total maize area) were planted to OPVs, and 2.4 m ha (29% of total maize area) were planted to hybrids. By 1997/98, this trend was reversed: OPVs were being grown on 4.3 m ha (33% of the improved maize area), and hybrids were being grown on 8.7 m ha (67% of the improved maize area).

- *The locus of maize breeding research in Asia has shifted from the public sector to the private sector.*

With the significant exception of China, the primary locus of maize breeding research in Asia has shifted from the public sector to the private sector. In countries where both public research organizations and private seed companies conduct maize breeding research, the level of investment by the private sector significantly exceeds that of the public sector. Although the number of scientists working in public breeding programs is larger than the number working for private seed companies, researchers in the private sector generally are remunerated better. Because of the greater levels of support provided to private-sector scientists (salary, benefits, operating budgets), the total level of investment in the private sector exceeds that in the public sector.

- *Outside China, the private sector dominates the commercial maize seed market in Asia.*

In 1997/98, approximately 56% of the commercial maize seed sold in Asia was seed of public hybrids, 41% was seed of private hybrids and 3% was seed of OPVs (most of these OPVs had been developed by public breeding programs, although in many cases the seed was produced and sold by private companies). When the data for China are excluded, the market share controlled by private companies rises to 89% (85% hybrids and 4% OPVs). Across the region as a whole, multinational seed companies control a larger share of the market than national seed companies. In some countries, the market share of the multinationals is extremely high. For example in Indonesia, the Philippines and Thailand, multinationals hold more than 80% of the commercial maize seed market.

- *Adoption of modern maize varieties has been uneven from one Asian country to another.*

Adoption of modern maize varieties has increased for Asia as a whole, but the level of adoption varies from country to country. As in Latin America and Africa, in Asia the use of modern maize varieties is concentrated in countries (and regions within countries) in which maize is a commercial crop. Meanwhile, adoption has been much more limited in countries where maize is grown mainly as a subsistence crop intended for home consumption. Thailand and the Philippines represent two extreme cases. Virtually all of the area planted to maize in Thailand in 1997/98 was planted to OPVs and hybrids, whereas only about one-third of the area planted to maize in the Philippines was planted to OPVs and hybrids.

- *Maize R&D efforts by the public and private sectors are complementary, and links between the public and private sector appear to be expanding.*

In recent years, governments throughout Asia have had to confront two major challenges: first, increasing demand for improved maize production technologies, and second, a stagnant or declining resource base that has constrained the ability of public research organizations to develop and disseminate improved production technology. In response to these challenges, Asian policy makers have enacted measures to encourage the private sector to participate more actively in the maize seed industry.

Private seed companies have responded to policy reforms by increasing their investment in maize R&D. The emergence of a private seed industry in all countries of the region except China has been accompanied by increasing specialization in both public and private sectors. Hoping to avoid wasteful competition with private seed companies, public breeding programs in many countries have begun to concentrate on activities that are unlikely to be attractive to profit-oriented firms, for example, genetic resource conservation, pre-breeding, population improvement, development of special trait materials and development of OPVs. Private seed companies meanwhile have emphasized inbreeding, hybrid development, hybrid seed production and hybrid seed marketing and distribution. Despite this increasing specialization, however, public and private maize seed organizations continue to be linked through various types of collaborative activities. In Asia these include international germplasm exchanges, public-private germplasm transfers and collaborative varietal testing networks.

Looking to the Future

How will the relationship between public organizations and private seed companies evolve in the future? A group of experts convened by CIMMYT recently met in Tlaxcala, Mexico, to discuss the conditions necessary for productive and harmonious collaboration between public and private sectors with respect to R&D for maize and two other leading staple crops, wheat and rice (CIMMYT 1999). This group of experts, which included scientists from public and private sectors, development agency officials, NGO representatives, media specialists and farmers, agreed upon the following points:

- Public organizations can and should continue to play an active role in maize research and seed production; public-sector involvement will help to reduce R&D costs for private firms (for example by generating improved germplasm that can be used as inputs into commercial breeding programs and by training researchers).
- Where conditions permit the existence of competitive seed markets, the public sector should complement and support rather than compete with the private sector in providing improved seed and related technology to farmers.
- The public sector has a particularly important role to play in supporting local private seed companies, which can enhance competition in seed markets.
- Where technical, economic or institutional conditions discourage private companies from providing improved seed technology to farmers, public agencies may be called upon to assume responsibility for meeting farmers' needs.
- Even where international research organizations and private seed companies are active, strong national public research programs will often be needed to adapt privately and internationally developed research products to local conditions.

This chapter has presented recent evidence showing that elements of the productive and complementary relationship described at the Tlaxcala meeting are beginning to take shape in Asia. Examples of successful collaboration are especially evident in India and Thailand, where strong public breeding programs have encouraged and supported the development of extremely successful and competitive private seed industries.

The lack of effective plant varietal protection laws in Asia, however, makes the private sector (especially the large multinational seed companies) skeptical about sharing its materials with public research agencies. Without property protection regulations, the private sector feels that it is difficult to safeguard research outputs. While the private sector has established a strong presence with the introduction of many excellent hybrids in Asia, particularly in India, the Philippines and Thailand, the lack of essential intellectual property laws can discourage many private seed companies from introducing their best materials into the market. In such a scenario, the range of better production technologies available to farmers becomes restricted.

While acknowledging the potential benefits of increasing the private sector's participation in Asia's maize seed industries, at the same time it is important to remember that those benefits may not be available to all of the region's maize farmers, including millions of subsistence farmers.

How might the roles and responsibilities of the public sector be developed in the future to accommodate the needs of these farmers that until now have attracted limited attention from private seed companies? The anticipated expansion in demand for maize in Asia will lead to the intensification and commercialization of existing production systems, as well as expansion into less favorable maize production environments. These marginal environments will play an increasingly important role in feeding the region's rapidly growing populations. The public sector can work on identifying principal technological constraints to increasing maize productivity in these areas, designing crop and resource management technologies to alleviate the principal constraints and support sustainable practices in the fragile environments, and develop technology dissemination plans and more effective agricultural extension strategies.

The strong likelihood that the private sector will be reluctant to address the needs of farmers in marginal areas should encourage public-sector research organizations, including international research centers like CIMMYT, to continue their active role in maize R&D and seed production, particularly for improved OPVs. Within each country, the public sector should assume a more complementary and supportive role with regard to the private sector by developing policies that facilitate private-sector operations. These policies may include the simplification of product test rules or seed certification procedures and the formulation of intellectual property rights laws, which together will ensure that the best varieties will be available to maize farmers as quickly as possible.

Finally, it is important to recognize that improved maize seed is not the only key to increasing maize productivity and uplifting the conditions of resource-poor maize farmers in Asia. No amount of advanced public- or private-sector maize research will help the most disadvantaged farmers unless substantial parallel investments are made in infrastructure, agricultural extension, input production and distribution systems, grain harvest and post-harvest facilities and grain marketing. In the end, the role and impact of appropriate government policies—from those on input and grain prices to those on intellectual property rights—should certainly not be overlooked.

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Chapter 3

An Interface in Public and Private Maize Research in India

R.P. Singh

Maize ranks third in volume among the cereals grown in India. Its contribution to the country's total production of food grain in 1994-97 was about 5% (MOA 1997). Maize has traditionally been grown as a staple food for household consumption. However, the increasing commercial orientation of India's agricultural economy has resulted in a rising demand for maize, especially for feed and industrial use. In addition, policy reforms introduced in the late 1980s to encourage private sector participation in the seed industry stimulated investments in plant breeding research and seed production. Substantial investment in maize research, in particular, has generated a wide range of improved production technologies in response to market demand (Singh and Morris 1997). Private maize seed companies have been established in many important maize-producing states, offering farmers a wide range of improved open-pollinated varieties (OPVs) and hybrids. These companies have captured a significant and continuously expanding share of the national maize seed market. Some analysts note that private seed companies are making a useful contribution, but they also warn that their activities should complement, rather than compete with, the work of government agencies.

The lack of readily accessible information on the maize seed industry, however, makes it difficult for policy makers and research administrators to make decisions on appropriate development strategies. Basic data on research investment, research products and farm-level research impacts are scarce, either because they are difficult to measure or are kept confidential (Singh *et al.* 1995). This chapter summarizes information on investment in and products of public and private maize research and describes policy options for sustainable growth in maize production in India. Data on India's maize seed industry were collected mainly through interviews with 30 public organizations and 23 private (national and multinational) seed companies actively pursuing research and development (R&D) for maize breeding, seed production and sales.

Maize Production and Consumption Trends in India

Maize is grown in a wide range of production environments. The total area under maize in India expanded from 3 m ha in 1951 to 6 m ha in 1970, growing annually at an average rate of 2.9% (Singh *et al.* 1995). In the early 1970s, expansion in area under maize cultivation slowed dramatically, and for three decades the maize area remained virtually unchanged. A significant shift occurred in the 1990s when irrigated winter (*rabi*) maize cultivation expanded rapidly, particularly in the states of Bihar, Andhra Pradesh and Karnataka, where conditions are favorable for maize production (Singh and Morris 1997). Overall, irrigated area increased from 16% in 1970 to 23% of total area under maize in 1997 (Singh 1998). At the same time, maize cultivation moved into marginal areas with relatively low production potential, as farmers reserved more productive areas for more profitable crops like wheat, paddy and sugarcane.

The spread of improved germplasm and crop management practices resulted in a continuous growth in average maize yields from the 1950s onwards (Singh and Morris 1997). Rising yields, coupled with a steady expansion in area, led to growth in maize production of 5.9% and 5.2% per annum in the 1950s and 1960s, respectively (Table 1). After slowing down in the 1970s as the area under cultivation stabilized, growth in maize production, fueled by continuing improvements in yield, averaged about 2.6% per annum in the 1980s and 3.2% per annum in the 1990s. Total maize production exceeded 10 million tons in 1997-98.

Virtually all of India's maize is used domestically for food (70%), feed (15%) and industrial uses (15%) (Singh and Pal 1992). Direct human consumption of maize has declined over time, while feed and industrial uses have increased. Rising household incomes have shifted consumption from maize to other cereals like rice and wheat. They have also led to an increased consumption of meat, particularly of poultry, which has increased the demand for maize as feed. Increased industrial demand for maize comes primarily from the starch industry. Although exports of maize remain negligible, they are expected to increase with improvements in productivity.

The Maize Seed Industry

The 1966 Central Seed Act laid the legal foundation for India's seed industry. This legislation was designed to govern the production, certification and distribution of all seed in India, prescribe seed certification standards, and assign the responsibility for enforcing the standards to state governments. In line with the national objective of attaining food self-sufficiency, the Act assigned responsibility of commodity research and seed production to public organizations. Maize research and seed production activities thus remained firmly in the public domain (Pal *et al.* 1998).

Table 1. Annual growth (%) in maize area, yield and production, India, 1950-98

Period	Area	Yield	Production
1950–60	2.85	2.92	5.92
1960–70	3.52	1.67	5.25
1970–80	0.04	1.36	1.15
1980–90	0.07	2.53	2.59
1990–98	1.07	2.08	3.17

Source: MOA (various years).

The emergence of a vibrant commercial farming sector during the late 1970s and early 1980s (attributable in part to the green revolution in wheat and rice) created incentives for private-sector participation in the seed industry. The result was increased involvement of private companies in research, seed multiplication and distribution activities. As the Indian market was still relatively closed, most of these seed companies were Indian owned. Many did not establish their own research programs but specialized in multiplying seed of public OPVs and hybrids.

The implementation of the New Policy for Seed Development in 1988 opened the doors to foreign participation in the seed industry (Morris *et al*. 1998). Today both the public and private sectors play an active role in the maize seed industry. Public organizations continue to engage in research, development, seed production and seed distribution. Their efforts are now strongly complemented, however, by an increasingly active private seed industry.

Investments in Maize Research

Public Sector Investments

India's national maize research program has several components. In 1957, the Directorate of Maize Research (DMR, formerly the All-India Coordinated Maize Improvement Project) was established by the Indian Council of Agricultural

Research (ICAR) to promote and coordinate basic and applied research on maize in India. The DMR maintains more than two dozen research centers in different parts of the country, covering a wide range of agro-climatic conditions. In addition, it interacts through ICAR with other national and international research organizations. A network of state agricultural universities (SAUs) that, in addition to their teaching functions, are responsible for addressing specific research problems supports the DMR. Government departments, research organizations, and non-agricultural universities also undertake research directly or indirectly related to maize (Pal *et al.* 1998).

Since detailed expenditure data are not available for several research cost categories, the level of public investment in maize research cannot be determined precisely. Even so, the level of investment can be estimated indirectly by using measurable indicators such as numbers of scientists (Pal *et al*. 1998). In 1997, 102 full-time equivalent (FTE) scientists were employed in 30 DMR and SAU research centers with an annual budget of Rs 42.3 million (US$ 1.1 million) for maize research (Table 2). This is equivalent to 17 FTE scientists for every million hectares of maize planted in India, quite low by global standards (CIMMYT 1994). The level of training of these scientists is impressive. Of the 102 FTE maize scientists, 33 were senior scientists with Ph.D. or M.Sc. degrees, and 69 were intermediate- and junior-level scientists.

Scientists involved in germplasm improvement (including plant breeders and those providing direct support to plant breeding efforts) dominate the public research system. Seventy-eight percent of all maize researchers are involved in germplasm improvement, 17% are engaged in crop agronomy and only 2% in social science research (including economics and statistics) and extension. All public breeding programs screen and evaluate materials and perform basic population maintenance and improvement work, but only the larger and better equipped breeding programs generate and test cross inbred lines.

Private Sector Investments

As noted earlier, policy reforms introduced in the late 1980s removed many obstacles to private (foreign) participation in maize research in India. Currently, 18 national companies and 5 multinational companies engage in maize breeding. They are usually connected to seed production operations. Private breeding programs

Table 2. Maize research personnel and expenditure in the public and private sectors, India, 1997

		Private sector		
Indicator	**Public sector**	**National companies**	**Multinational companies**	**All companies**
Number of respondents	30	18	5	23
Maize research personnel	342	295	40	336
Senior-level scientists	33	42	8.5	50.5
Intermediate-level scientists	69	29	7.5	36.5
Technical staff	240	225	24	249
Scientists per million ha under maize	16.5	–	–	14.1
Annual budget (Rs million)	42.3	27.1	37.5	64.6
Annual budget (US$ million)	1.1	0.71	0.98	1.7

Source: IARI-CIMMYT Survey, 1998-99.
Note: Rs 38.5 = US$1.

are thus the first step to a vertically integrated industry combining research, seed production and seed distribution functions.

In 1997, 23 private companies reported employing 336 FTE workers (Table 2), most of whom were involved in seed production and distribution. These workers included 87 FTE junior or senior maize scientists, with an annual research budget of about Rs 64.6 million (US$ 1.7 million). This represents a significant change from earlier years, when virtually all maize research was carried out by the publicly funded programs of ICAR and the SAUs. In contrast to the public sector, maize research in the private sector is totally confined to developing and marketing proprietary, branded hybrids. No private company works on developing commercial OPVs or on crop agronomy.

Products of Public and Private Research Programs

The germplasm products of public breeding programs and private seed companies show the differences in their research priorities. Of the 256 improved maize materials developed by public and private breeding programs for commercial cultivation in India between 1961 and 1997, about 31% were improved OPVs and 65% comprised various types of hybrids (Table 3). Seventy-seven percent of all hybrids released came from the private sector and the rest from public breeding programs. All improved OPVs developed since 1961 have originated from the public sector and 50% of all public improved OPVs were released in the 1980s. The public sector had more releases than the private sector until 1989. Among all public-sector materials released between 1960 and 1999, 79% were released in the 1990s. Among all private-sector materials released over the same period, 33% were released during the 1990s (Figure 1).

Public agencies concentrate their research efforts on developing improved OPVs. Private companies meanwhile emphasize double-cross and three-way cross hybrids; the production of single-cross hybrids is unattractive owing to the difficulty of protecting parental lines (parent materials can easily go astray once provided to contract seed growers). In 1990-99, the private sector released only 11 single-cross hybrids compared to a total of 83 double- and three-way crosses (Figure 2).

About 75% of the improved OPVs and hybrids developed by the public programs and private companies since 1961 have had yellow grain, serving the preference for yellow grain in some regions. Public breeding programs have produced mainly flinty materials. Private companies put greater emphasis on semi-flints and semi-dents and a moderate emphasis on dent maize, reflecting their greater reliance on exotic germplasm based mainly on North American materials (Singh *et al.* 1995).

Most of the improved OPVs and hybrids developed in India are suitable for favorable production conditions. Although public breeding programs have produced a somewhat broader range of materials than private companies, neither sector has placed any emphasis on developing materials for marginal production environments with highly unfavorable agro-climatic conditions (e.g., drought or waterlogging, extreme heat or cold, severely nutrient-deficient or imbalanced soils) (Pal *et al.* 1998).

Of the 256 materials released since 1961, about 33 improved OPVs and 88 hybrids were still available in the Indian maize seed market in 1997. These consisted of 33 improved OPVs and 12 hybrids released by the public sector and 76 hybrids released by private companies. Most of the hybrid seed sold by public agencies and private companies is seed of double-cross hybrids. No improved OPV seed sold as of 1997 was developed by the private sector.

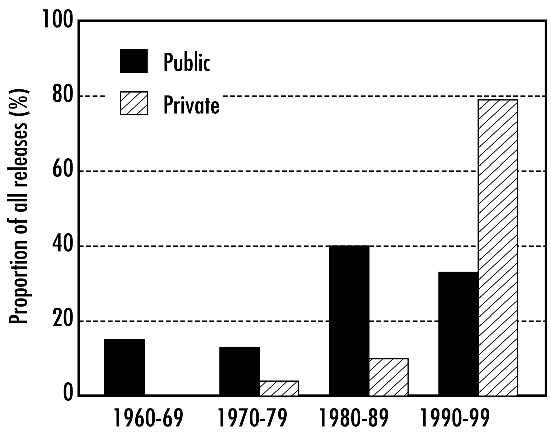

Figure 1. Proportion of maize releases by sector, India, 1960-99.

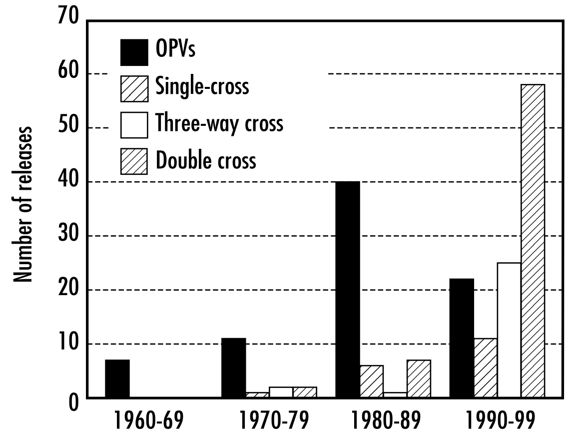

Figure 2. Number of public improved OPVs and private-sector hybrids, India, 1960-99.

Table 3. Maize cultivars developed in India, 1961-97

Cultivar types and characteristics	Public agencies	Private companies		All seed companies
		National	Multinational	
Cultivar type (number)				
Improved OPV	80	0	0	80
Hybrid	40	91	36	167
All improved material	120	97	39	256
Cultivar type (%)				
Improved OPV	67	0	0	31
Hybrid	32	94	92	65
Top cross	1	0	0	<1
Double top cross	7	0	10	5
Three-way cross	4	22	18	14
Double cross	13	56	59	36
Single cross	7	16	5	10
Unspecified hybrid	0	6	3	9
Grain color				
Yellow	81	82	69	74
White	18	7	26	13
Other	0	10	3	13
Grain texture				
Flint	65	24	23	48
Semi-flint	10	33	38	17
Dent	8	12	21	20
Semi-dent	13	31	18	15
Maturity				
Extra early	19	34	23	25
Early	30	40	33	39
Intermediate	7	16	21	13
Late	4	3	15	23

Source: Data from IARI-CIMMYT Survey 1998-99.
Note: Some proportions will not total 100% because of incomplete varietal descriptions.

Seed Production and Sales

Organization of Seed Production in the Public and Private Sector

The central government and various state governments are involved in maize seed production and distribution. The National Seeds Corporation (NSC) administered by the central government produces and distributes significant quantities of maize seed, as do some state seed corporations (SSCs) (Pal *et al.* 1998). In addition, a number of state agricultural departments, research institutes and SAUs supply small quantities of maize seed directly to farmers, often to promote new releases. Many of these public seed agencies work with contract growers for seed production.

Maize seed production in the private sector is concentrated in the states of Andhra Pradesh, Karnataka and Maharasthra. All private seed companies are engaged in production and distribution of maize seed. They do not produce seed commercially using their own land and labor but rather employ contract growers to produce the seed. The contract growers are provided with seed and, in some cases, other material inputs and services on credit (Pal *et al.* 1998). A few family-run seed enterprises are operated by commercial grain farmers. With modest levels of processing, these farmers try to sell their maize produce as seed rather than as ordinary grain in the hope of capturing an attractive price premium. The private companies interviewed in 1998-99 estimated the share of such seed at 10-15% of the total volume of maize seed marketed annually.

Seed Sales by the Public and Private Sector

Sales of maize seed are difficult to estimate with precision. Data on seed sales of private companies are difficult to collect. Both public seed agencies and private seed companies have cause to misrepresent their sales figures (Pal *et al.* 1998). Nevertheless, partial data compiled from public and private sources reveal some interesting trends. First, maize seed sales of all public agencies and private seed companies grew seven-fold, from only around 4,500 t in 1981-85 to around 33,000 t in 1995-97 (Table 4). Across all maize materials, the market share of public agencies declined over the last 15 years from 90% in 1981-85 to barely 15% in 1995-97, while that of private seed companies rose from 10% to 85% (Table 4). The private sector now dominates the market for improved maize seed. It must be noted that public seed agencies handle many unprofitable crops and are required to operate in marginal production environments where demand for seed is low and distribution costs are high. In contrast, in areas where public seed agencies and private companies both operate, private companies appear to provide better service in producing seed and delivering it to farmers.

Second, the volume of hybrid seed sold by private companies has grown much more rapidly than that of public OPV seed sales, raising serious questions about whether or not OPV seed will continue to be available in the future. Similarly, the volume of proprietary hybrid seed sold by private companies has grown more rapidly than that of public hybrids, confirming that private companies are more effective than public agencies at delivering their materials to the farmers (particularly in more favorable production environments) (Pal *et al.* 1998).

Adoption of Improved Germplasm

Official production statistics indicate that about 56% and 60% of the total area under maize was planted to improved materials in 1995 and 1997, respectively (FAI 1998). In 1995, Singh and Morris (1997) surveyed 864 maize growers located in the six most important maize-growing states and reported that approximately 51% of the maize area in these locations was planted to improved materials (Table 5). Approximately 22% of the area was planted to improved OPVs and 29% to hybrids (Pal *et al.* 1998).

Table 4. Maize seed sales (t) by public agencies and private companies in India, 1981-97

	1981–85	1986–90	1991–94	1995-97
Public seed agencies				
Improved OPVs	278	817	479	388
Hybrids	3,659	2,598	3,622	4,382
Private seed companies				
Improved OPVs	0	332	434	653
Hybrids	427	2,063	14,494	27,130
All public and private sales				
Improved OPVs	278	1,150	914	1,040
Hybrids	4,087	4,661	18,116	31,512
All materials	4,365	5,811	19,030	32,553
Market share of private sector (%)				
Improved OPVs	0	29	48	63
Hybrids	10	44	80	86
All materials	10	41	78	85

Source: Data from IARI-CIMMYT Surveys 1992 and 1998-99.

The use of improved germplasm, however, varies considerably by state. The adoption of improved maize varieties is very high (at 81-98%) in the commercial maize-growing areas of Karnataka, Andhra Pradesh and Bihar (Table 5) (Singh and Morris 1997). Hybrid maize adoption is also very high (at 55-86%) in these states, where agro-climatic conditions are generally favorable for the production of two maize crops annually and where private seed companies are particularly active. In contrast, the use of local materials continues to dominate in the semi-subsistence maize areas of Uttar Pradesh, Rajasthan and Madhya Pradesh, where production conditions are generally less favorable and where private seed companies have been less active. In these areas, the use of improved germplasm is much less extensive and hybrid maize adoption levels have not yet reached 10% (Singh 1998). In cases where farmers have adopted improved materials, improved OPVs are more popular than hybrids. This pattern is attributable to the fact that farmers in the latter three states prefer short duration materials with good eating quality, and few improved materials meet these criteria.

Farmers who grow OPVs generally do not replace their seed frequently. In areas where hybrid use is extensive, most maize farmers replace their seed at the beginning of each cropping cycle, but approximately 10% of the area planted to hybrids is planted with recycled F2 seed (Singh 1998). Although the market for hybrid maize seed in India is growing rapidly, knowledge of specific maize hybrids remains very limited. Most farmers select hybrid seed based on the reputations of the seed companies, rather than on detailed information on the performance of the seed in the field.

Table 5. Percentage of maize area under improved germplasm in selected states, India, 1995

	Improved varieties				
State	**Improved OPVs**	**Hybrids**	**All improved**	**Local varieties**	**All varieties**
Andhra Pradesh	15	79	94	6	100
Bihar	26	55	81	19	100
Karnataka	12	86	98	2	100
Madhya Pradesh	23	15	38	62	100
Rajasthan	18	8	26	74	100
Uttar Pradesh	31	8	39	71	100
Total[a]	22	29	51	49	100

Source: Singh and Morris (1997).
Note: These six states accounted for 70% of total area under maize in 1995.

Conclusion and Policy Options

Public and Private Participation in the Seed Industry

India's earlier policy of entrusting the public sector with maize research, seed multiplication and distribution generally had positive results, particularly during the early stage when farmers were still learning about the benefits of improved production technologies (Pal *et al.* 1998). The national maize program was quite successful in developing improved OPVs and hybrids, and the public seed agencies proved to be reasonably effective in delivering seed to millions of small-scale maize growers.

Policy reforms introduced during the late 1980s opened up the maize seed industry to private sector participation, including foreign multinational companies. Over time, the private sector became increasingly active not only in maize research to develop improved germplasm but also in producing and distributing seed (Singh *et al.* 1995). This development benefited many farmers as adoption of improved OPVs and hybrids increased.

The private sector has, however, largely ignored marginal areas where maize production potentials are low, because sales of improved seed to resource-poor farmers are not profitable. Public institutions are responsible for developing improved production technologies, supported with appropriate policies, for the small-scale subsistence farmers in these areas. Public seed agencies in India have not been as effective as private companies in producing high quality maize seed and distributing it to farmers in a timely and cost-effective fashion. The difference in performance is largely attributed to economic factors: profit-driven private companies must pay attention to the bottom line, whereas public agencies continue to receive government directives to maintain relatively low seed prices, which undermines their incentive to operate efficiently.

The policy directives aim to promote innovative new strategies for private seed companies and public seed agencies to share the responsibility of serving the needs of a wide range of end users, especially small-scale maize farmers located in marginal environments. Although the emergence of a flourishing private maize seed industry has relieved some of the pressure on public breeding programs, government administrators must continue to ensure that research resources are allocated to support national policy objectives (Singh 1998).

Regulations and Intellectual Property Rights

There are numerous government regulations to prevent both public seed agencies and private seed companies from indulging in unscrupulous practices that could harm vulnerable groups of producers and consumers. The government safeguards are justified, but some regulations may be unnecessary (Pal *et al.* 1998). The government could simplify the seed quality certification framework and allow private seed companies to operate within broad policy directives. To serve maize producers and consumers more effectively and efficiently, the best strategy is to ensure that seed markets are transparent and competitive.

The absence of legislation protecting intellectual property rights of plant breeders has influenced the strategies pursued by many private seed companies, particularly transnational companies and larger Indian companies that have their own research capacity. Many seed companies have been reluctant to establish full-fledged breeding programs in India because they are uncertain of earning adequate financial returns from their investment in research (Pal *et al.* 1998). Similarly, many companies have been unwilling to introduce single-cross hybrids into the Indian market because they feel they cannot protect the valuable parental lines. As a result, Indian scientists have been denied access to cutting-edge research technologies and Indian farmers have been denied access to some of the best available germplasm. Regulatory measures should promote strong research linkages between public and private research programs, ensuring a free flow of genetic materials.

Economic liberalization can provide new opportunities for exploiting competitive advantage leading to export-led growth in agriculture. On the scientific front, advancement in maize biotechnology can provide new avenues for attaining higher and more stable productivity levels and in reducing research lags. To benefit from these new, complex and capital-intensive developments, the public and private sectors in the maize industry must work together in generating funds and undertaking research to attain the desired levels of research intensity to improve national maize research and production.

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Chapter 4

Impact of Breeding Research on Maize Production and Distribution in Indonesia

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Agricultural development in Indonesia primarily focuses on increasing the production of food crops, especially rice, maize and soybean, to fulfill domestic demand. The use of high yielding varieties has been recognized as a major factor in attaining this national objective.

Since the early 1970s, Indonesia has been facing difficulties in producing sufficient cereals in general, and maize in particular, to meet its domestic needs. Maize is widely grown for human consumption and for animal feed. At least 2.8 m ha were planted to maize in the 1980s and 3.4 m ha in the 1990s, compared to only about 1.5-2.0 m ha between the 1940s and 1960s (Timmer 1987). Badan Pusat Statistik (BPS), the national statistics bureau, reported that 3.8 m ha were planted to maize in 1998 (BPS 1998). Until the 1990s, maize production remained almost entirely a smallholder enterprise, providing income and staple food for farm households. During the 1970s and 1980s, production techniques were rudimentary, and farmers had been bypassed by the spread of improved plant varieties and cultural practices. Maize farmers used mostly local varieties and simple tools. Labor intensity and capital inputs were low.

Although growing adoption of improved technology led to substantial progress in maize production, the increased production still failed to meet domestic demand, which continued to grow. Demand for maize as feed alone was recently estimated to be growing at 12% per annum (Subandi 1998). Net imports rose from 292,000 t in 1991 to 894,000 t in 1995 and 570,000 t in 1996 (Subandi *et al.* 1998). This trend highlights the need to overcome remaining obstacles to increased domestic maize production (BIMAS 1997).

Some of the obstacles to greater maize productivity included problems related to inputs. For example, agricultural inputs were either unavailable or difficult to obtain because of the inefficient distribution system. Large numbers of farmers were unable to adopt seed of improved maize varieties because it was either unavailable or cost too much. These technological and socioeconomic barriers to increased productivity were reduced to some extent in the 1980s. The large investment in rice production in the 1970s had a positive spillover effect in improving maize production in Indonesia. Farmers became more receptive to using new high yielding varieties (HYVs) of maize, fertilizers, pesticides and other agronomic practices for increasing farm yields. Presently most maize production areas have timely access to vital production inputs, particularly fertilizers and pesticides.

Maize breeders sought to contribute to increased maize production by developing high-yielding open-pollinated varieties (OPVs) and hybrids, but adoption of these materials has varied. Metro, an improved OPV, was released in 1956 but did not increase maize yields significantly because of its susceptibility to downy mildew. The use of hybrids began in 1984 following the release and commercialization of the variety C1 in 1983, but this variety was not used widely because seed was not available. Even so, by the 1990s, some maize farmers had shifted from local varieties to hybrids. Later, some farmers shifted back to local maize because hybrid maize technology could not succeed without better access to seed; hybrid maize was not profitable for small-scale, resource-poor farmers; and seed of open-pollinated maize varieties, like rice seed, was more easily produced and distributed from farmer to farmer.

This paper reviews the impact and potential of R&D on improved maize, especially hybrid maize, on maize seed production and distribution in Indonesia. Data were obtained from a survey of the maize seed industry sponsored by CIMMYT, conducted in early 1999, as well as from published and unpublished government information.

Indonesian Maize Production and Consumption

Production Systems

Maize is produced on *tegalan* (rainfed drylands) and *sawah* (floodable wetlands) in Indonesia. Production systems vary by land type, cropping system and management system. Surveys carried out by the Stanford University-BULOG Project found that low productivity systems prevail over about 69% of the total maize area (Mink *et al.* 1987, cited in Subandi 1998). Farmers in these systems usually plant early, use white or yellow local/ traditional varieties, apply a low quantity of fertilizer and use the maize mainly for home consumption. Low productivity systems are generally located in the less developed and relatively remote areas.

A specialized tidal swamp maize production system is found mainly in newly opened land outside Java. On this type of land, maize is grown using the *surjan* system (raised and sunken beds). Rice is commonly grown in standing water in the sunken beds, and maize and/or other *palawija* (perennial) crops are grown on the raised beds. Farmers in these production areas grow maize as one component of the farming system and, depending on market demand, maize may be harvested for grain or as a green crop. No data exist on the extent of the area devoted to this production system, although around 11 million hectares of swamp area are estimated to have good potential for agricultural production (Subandi 1998).

Production Location and Trends

Maize (*jagung*) is Indonesia's second most important food crop after rice. Grown either as a monocrop or as an intercrop with other food crops, about 73% of all maize in Indonesia is planted in rainfed upland and lowland areas with erratic rainfall, and 27% is planted in irrigated upland and lowland areas (Dahlan and Mejaya 1998). Other estimates indicate that 80% of maize is grown in dry upland areas, about 10% in irrigated lowlands and the remaining 10% in rainfed lowlands (Subandi *et al.* 1998). Maize is planted early in the wet season in the uplands and late in the wet season in the lowlands. Two crops of maize are grown in the uplands. The first crop is planted in November/ December and harvested in February/March, and it is immediately followed by a shorter duration second crop that is harvested in June. In some lowland areas, especially those close to cities, short-duration maize is planted before the rice crop is harvested and is harvested as fresh corn (Sinring and Talanca 1998).

The main maize-growing provinces in Indonesia are East Java, Central Java and South Sulawesi. East Java accounts for about 34% of all area under maize. In 1994-98, yields in East Java were 6-8% higher than the national average. Before the 1980s, Central Java produced mostly white maize that was used as a supplementary staple to rice. More recently, some farmers have shifted to growing yellow varieties in line with the government's maize production intensification programs aimed at serving the grain requirements of the livestock and poultry industries. South Sulawesi ranks third and has long been a leading producer of food maize in the outer islands.

The average area under maize was around 2.9 m ha in the 1960s, 3.6 m ha in the 1970s and 1980s and reached about 4.7 m ha in the 1990s. Average annual maize yields increased slowly from 1.0 t/ha in the 1960s to 1.7 t/ha in the 1980s and 2.3 t/ha in the 1990s (Table 1). Maize production first exceeded 10 m t in 1992, and the highest production level, 14 m t, was recorded in 1998.

In terms of average annual growth rates, all production parameters declined during the 1960s but posted remarkable recoveries during the 1970s. In the 1980s, area and yield grew at rates similar to those in the earlier decade. The 1990s saw a slowdown in the growth of production parameters, with area and yield increasing at 2.6% and 1.8% per year, respectively, resulting in a 5.0% annual increase in maize production, which is considered high (Table 1).

Table 1. Maize area, yield and production, Indonesia, 1960-98

	Area harvested (ha)	Yield (t/ha)	Production (t)
Annual averages			
1960–69	2,897,059	0.96	2,802,255
1970–79	3,592,169	1.13	4,061,319
1980–89	3,647,699	1.72	6,262,371
1990–98	4,744,308	2.29	10,843,785
Average annual growth rate (%)			
1960–69	-5.6	-1.5	-7.9
1970–79	4.1	4.1	9.0
1980–89	4.0	3.9	10.1
1990–98	2.6	1.8	5.0

Source: Basic data from DGFCH (1998); Timmer (1987); BPS (1998).

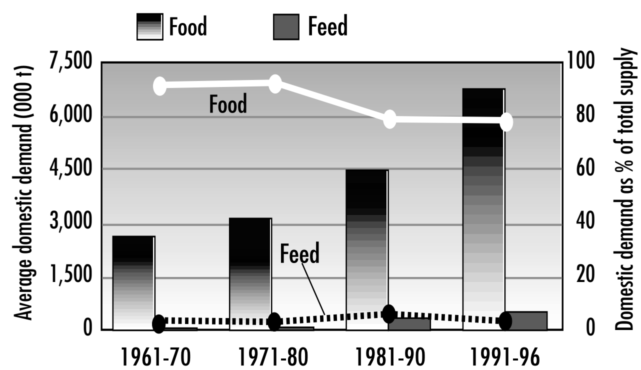

Figure 1. Average domestic food and feed demand for maize in Indonesia, 1961-96.
Source: Basic data from FAOSTAT (March 1999).

Utilization and Imports

A versatile crop, maize is either consumed directly as a secondary staple food or used as raw material for the food and animal feed industries. Figure 1 and Table 2 show that the volume of maize grain used in these industries has increased over time. Unfortunately, no reliable data on direct human consumption could be obtained. FAOSTAT (1999) indicates that maize used as food constituted the bulk of domestic demand, averaging about 2.4 m t annually in the 1960s and 6.3 m t in the 1990s. Feed use of maize was almost 57,000 t annually in the 1960s, 318,600 t in the 1980s and 480,000 t in the 1990s (Figure 1). The proportion of maize utilized as food decreased from 91% in the 1960s and 1970s to about 78% in the 1990s. The proportion used as animal feed increased from 2% in the 1970s to almost 6% in the 1990s.

Table 2. Maize utilization and imports, Indonesia, 1960s to 1990s

Period	Average annual domestic demand (000 t)			Average volume
	Food industry	Feed industry	Total utilization	of imports (000 t)
1961-70	2,453.0	56.6	2,685.6	3.0
1971-80	2,924.2	78.4	3,210.6	28.6
1981-90	4,187.4	318.6	5,316.3	68.7
1991-96	6,311.4	480.3	8,079.7	628.9
	As proportion of total supply			
1961-70	91.3	2.1	nc	nc
1971-80	91.2	2.3	nc	nc
1981-90	78.8	5.9	nc	nc
1991-96	78.0	5.9	nc	nc

Source: Basic data from FAOSTAT (March 1999).
Note: nc = not computed.

Maize Seed Research and Production

Currently three public agencies, four private national and three private multinational seed companies, work on maize R&D, seed production and/or seed distribution in Indonesia. All were interviewed for this study (Table 3).

Only one public agency, the national Research Institute for Maize and Other Cereals (RIMOC), and one private multinational company, P.T. Benihinti Suburintani (BISI), affiliated with Charoen Pokphand Seeds Company of Thailand, pursue maize breeding research on improved OPVs as well as hybrids (Table 4). The government has established two national companies, P.T. Sang Hyang Seri and P.T. Pertani, for mass seed production and distribution. These companies, together with the National Seed Board (NSB) and 15 regional Seed Certification and Control Services (SCCS), are primarily responsible for ensuring an adequate supply of quality seed, supporting the growing seed industry and assisting in the distribution of quality seed to maize farmers. The NSB mainly is responsible for approving the release of new maize varieties based on recommendations from RIMOC.

Table 3. Type and number of maize seed organizations in Indonesia, 1998

Type of organization	Number
Public seed agency with breeding program	
National focus	1
Province, state, district	0
Public seed company with no local breeding program that produces and sells seed locally (can also import seed)	2
Private national seed company	
With local breeding and seed production program	0
With no local breeding or seed production program (only imports seed for sale)	0
With no local breeding program, but produces and sells seed locally (can also import seed)	4
Multinational seed company	
With local breeding and seed production program	1
With no local breeding or seed production program (only imports seed for sale)	1
With no local breeding program, but produces and sells seed locally (can also import seed)	1
University, cooperative with breeding program	0
Non-profit organization that produces and sells seed	0
Individual seed producer (farmer)	0

Source: CIMMYT Maize Impact Survey 1999.

Table 4. Number of maize seed organizations by sector and activity, Indonesia, 1998

Activity	Public sector	Private sector
Population improvement, development of OPVs	1	1
Inbreeding, development of hybrids	1	1
Biotechnology research (e.g., transgenics, marker-assisted selection)	0	1
Agronomy research (e.g., fertilizer trials, pesticide trials)	1	2
Seed production (OPVs)	2	4
Seed production (hybrids)	2	4
Seed sale (OPVs)	3	4
Seed sale (hybrids)	3	5

Source: CIMMYT Maize Impact Survey 1999.

Role of the Public Sector

Located in Maros, South Sulawesi, RIMOC (or BALITJAS - Balai Penelitian Tanaman Jagung dan Serealia Lain*)* is a technical working unit of the Central Research Institute for Food Crops (CRIFC). In general, CRIFC is charged with conducting research on the country's primary staple food crops, including rice, maize, legumes and root crops, for which respective specialized research institutes have been established. Its range of research includes plant breeding, agronomic studies, pest and disease management and biotechnology. The scope of work is influenced by the diverse crop-growing conditions found in Indonesia (AARD 1997).

Public agencies involved in maize R&D mainly are responsible for developing and producing high-yielding maize cultivars and for mass seed production and distribution. RIMOC is mandated to undertake varietal and agronomic research on improved maize OPVs and hybrids. Aside from actively testing new cultivars prior to release, RIMOC is responsible for producing the parent stocks of improved maize cultivars for sale to public seed production entities as well as private seed companies. Resource constraints limit the quantity of parent stocks that RIMOC can produce. On average, RIMOC needs about Rp 8-10 million/ha (about US$ 1,150-1,400/kg) to produce 100-200 kg/ha of male and 400-500 kg/ha of female parents on its 20 ha research farm. Government funding is usually inadequate and often delayed, hindering the timely production of much-needed parent stocks.

As noted, the two big public corporations P.T. Sang Hyang Seri and P.T. Pertani mass-produce improved OPV and hybrid maize seed for distribution to maize farmers around the country through their respective marketing networks. Both entities also handle seed of rice, soybeans and other vegetables. Maize seed is produced either on company land or through numerous farmer-cooperators, using parent stocks obtained from RIMOC. Both companies also have hybrid maize seed production and/or seed distribution contracts with multinational companies such as P.T. BISI, P.T. Pioneer and Cargill. P.T. Sang Hyang Seri, for example, has had two five-year seed production and distribution contracts with Cargill. From its inception until 1998, P.T. Pertani acted only as a local distributor of maize seed produced by P.T. BISI and P.T. Pioneer. Contract arrangements specify that P.T. Sang Hyang Seri and P.T. Pertani receive a mutually agreed percentage of the market price. While seed production and distribution are currently their main tasks, both public entities foresee going into maize R&D in the future.

Role of the Private Sector

Only one private multinational company, P.T. BISI, among the seven private companies operating in Indonesia, maintains its own maize R&D program, including some biotechnology research. Most private companies concentrate on maize seed production and distribution. Unlike the multinationals, which produce and distribute their own proprietary materials, local private seed companies handle improved OPVs and hybrids produced by RIMOC. These small, usually family-owned, corporations work exclusively on maize and operate only within a province or region, unlike the multinationals, which operate in several regions or countrywide and also sell seed of crops other than maize (rice, soybeans and vegetables).

Both the private national and multinational companies produce maize seed through farmer-cooperators that are provided the parent materials, fertilizers and pesticides. Assistance for mechanizing selected farm operations is also provided if needed. The companies buy seed produced by the farmer-cooperators at a premium over the market grain price. The premium can be up to 40% higher, depending on how well the seed satisfies pre-set quality standards.

The newest participant in Indonesia's maize seed market is the multinational Monsanto, which arrived in July 1998. Monsanto currently imports F1 seed from the Philippines, India and Thailand and plans to establish its own maize seed R&D and production facilities in Indonesia, which Monsanto officials reported to have the lowest seed production costs in Asia.

Public and Private Sector Research Investment

Table 5 shows the average level of annual investments devoted by the public and private sectors to maize research in Indonesia. While the public sector has three and the private sector has four maize research programs, only one in each sector is engaged in breeding and development activities. The rest are involved only in agronomic research.

The public sector has 23 researchers working on maize (in full-time equivalents, FTEs), which is equivalent to having 6 maize scientists per million hectares of maize area and 2 scientists per million tons of maize produced (Table 5). These numbers are lower than those registered in 1990, when the public sector had a total of 37 FTE maize researchers or 12 scientists per million hectares of maize area (CIMMYT 1992). The private sector currently has 46 FTE scientists engaged in maize research, equivalent to 12 maize scientists per million hectares of maize area and almost 5 scientists per million tons of maize produced—twice the human resources of the public sector for maize R&D. In 1990, the private sector had only 7 FTE maize scientists or 2 full-time maize researchers per million hectares of land planted to maize (CIMMYT 1992). These numbers indicate that, while government investment in human resources for maize research declined over the last decade, private-sector investment increased significantly.

Table 5. Public- and private-sector investment in maize research, Indonesia, 1998

Research indicator	Public sector	Private sector
Total number of maize research programs	3	4
Number of programs with maize breeding activities	1	1
Total number of maize researchers (FTEs)	23	46
Number of maize scientists		
Per m ha of maize area	6	12
Per m t of maize produced	2.3	4.6
Percentage of researchers engaged in maize breeding and/or crop management research	21	nd
Number of cultivars developed (1960 to 1997/98)		
Improved OPVs	22	1
Hybrids	13	31
Total	35	32

Source: CIMMYT Maize Impact Survey 1999.
Note: nd = not determined.

Public-Private Sector Linkages

The roles of the public and private sectors in the maize seed industry are linked through several activities: knowledge and information dissemination; cooperative trials for yield potential, pest and disease resistance and overall seed quality;

releases of new hybrids; and human resource development via training programs, workshops and collaborative research (Suherman 1997).

In the future, both the public and private agencies involved in maize R&D will benefit from strong and active collaboration in developing a more efficient system of varietal registration, certification and release; establishing and enforcing intellectual property rights and plant variety protection laws; transferring and disseminating biotechnology techniques; and promoting public awareness of biotechnology issues, including biosafety and environmental impacts (as per Undang-Undang Budidaya Tanaman or Government Decree No. 12/1996).

Products of Maize Breeding Programs

Cultivars Released

From 1960 to the time of this study, 67 improved OPVs and hybrids were released and commercialized in Indonesia (Annex 1). Public research agencies released 22 improved OPVs and 13 hybrids while the private sector released one improved OPV and 31 hybrids. The public sector released its first improved OPV, Gajah Warangan, before 1945 and its first hybrid, IPB-4 (a single-cross variety), in 1985. The private sector released its first maize hybrid (C1, developed by Cargill) in 1983. In general, maize cultivars released and commercialized in Indonesia are flint to semi-flint, yellow, mature in less than 100 days and are adapted to the tropical lowlands (Table 6).

Table 6 also reveals each sector's maize research priorities. Public agencies emphasize R&D for improved OPVs, whereas private companies give priority to hybrid maize research. In terms of product characteristics, both sectors work towards developing improved cultivars with higher yields, better pest and disease resistance and better abiotic stress tolerance.

Seed Production

Most of the quality maize seed is produced in East Java and supplied to other islands, particularly Sumatra, Java, Kalimantan, Sulawesi, Nusa Tenggara and Irian Jaya. Some maize seed is also produced in Central Java, Lampung in Sumatra and Sulawesi, but production in these areas is not sufficient for local requirements (Suherman 1997). To alleviate the problem of inadequate maize seed supply, the government uses provincial

Table 6. Characteristics of maize cultivars released by the public and private sectors, Indonesia, 1960-98

Characteristic	Public sector	Private sector	Both sectors
Number of releases			
1960-69	5	0	5
1970-79	1	0	1
1980-89	10	5	15
1990-98/99	19	27	46
Type of material (%)			
Improved OPV	63	3	34
Hybrid			
Single cross	3	25	13
Double cross	0	3	1
Three-way cross	26	63	43
Top cross	0	6	3
Grain color			
White	9	13	10
Yellow	77	87	82
Other	14	0	8
Grain texture			
Flint	31	19	25
Semi-flint	54	81	67
Dent	11	0	7
Semi-dent	3	0	1
Maturity class			
<100 days	66	53	60
100-110 days	17	34	25
110-120 days	0	0	0
120-135 days	3	0	1
>135 days	3	0	1

Source: CIMMYT Maize Impact Survey 1999.
Note: All (100%) cultivars adapted to the lowland tropics. Some proportions will not total to 100% because of incomplete varietal descriptions.

institutions, such as the Agricultural Extension Service, to multiply foundation seed, stock seed and parent stock seed. Among the country's 27 provinces, 14 are equipped with seed multiplication facilities.

Maize seed is also produced by government seed farms and national seed companies (P.T. Sang Hyang Seri and P.T. Pertani). High quality breeder and foundation seed are produced at RIMOC and at the Directorate General for Food Crops (DGFC). For hybrids, four levels of seed are produced: (1) breeder seed, which comes directly from research programs and is used to produce (2) foundation seed; (3) stock seed, produced *en masse* from foundation seed; and (4) extension (or commercial) seed produced from stock seed. Breeder seed has the highest quality and is the most expensive to produce. Extension seed is the relatively lower-quality, cheaper seed.

Although RIMOC is mandated to develop, release, produce and sell breeder seed, it can do so only in small amounts primarily because of human, physical and financial resource limitations. RIMOC has an effective area of only 20 ha devoted to producing parent seed stock. The area yields about 400-800 kg/ha of improved OPV breeder seed. RIMOC produces about 100-200 kg/ha of male parents and 400-500 kg/ha of female parents for hybrids, at an average cost of Rp 8-10 million/ha (US$ 1,150-1,400/ha). When government funds are lacking or delayed, the area under parent stock production is reduced. Such constraints limit the quantity and sometimes quality of maize seed available for distribution to public and private seed agencies. In addition, maize seed yields of government facilities in Indonesia have often been very low, especially when compared to the US standard for single-cross hybrids of a minimum of 1 t/ha of parent stock (D. Beck, personal communication).

Foundation seed is multiplied by the provincial seed centers BBI (Balai Benih Induk, or central seed farm); stock seed by the regional seed producers BBU (Balai Benih Pembantu, main seed farm); and extension seed by the seed multipliers and farmer cooperatives KUDs (Koperasi Unit Desa). The BBIs and BBUs are located in various cities across the 27 provinces of Indonesia. The BBIs receive breeder seed; BBUs receive foundation seed from BBIs; and seed multipliers receive the stock seed from BBUs. All seed needs to pass multilocational testing and be certified and registered prior to commercialization. The SCCS conducts these multilocational tests in ten locations for two seasons with RIMOC and implements the seed certification and registration process.

Seed Prices, Sales and Adoption

Seed Prices

Table 7 shows the range of maize seed prices in Indonesia and the seed-to-grain price ratios. As expected, seed of single-cross hybrids is the most expensive, ranging from a low of Rp 10,000/kg (US$ 1.43/kg) to a high of Rp 23,000/kg (US$ 3.29/kg). Single-cross hybrids are more expensive to produce because of lower seed yields, but farmers are willing to pay more for seed of single crosses because of their higher grain yields. Seed of improved OPVs is the cheapest, at Rp 3,000-7,000/kg (US$ 0.43-1.00/kg). The price of improved OPV seed from the public and private sectors is similar, primarily because the private companies handling improved OPVs produce and market them for the public agencies. Three-way hybrids marketed by the public sector are slightly more expensive than those sold by the private sector, indicating that either the public agencies are less efficient than the private ones or that public three-way crosses perform better in the field and can be sold at higher prices. In terms of seed-to-grain price ratios, single-cross hybrids from the private sector cost 10-23 times more than maize grain, and three-way crosses cost 6-12 times more. Seed of improved OPVs costs only 3-7 times the price of maize grain.

Table 7. Maize seed prices and seed-to-grain price ratios by maize type, Indonesia, 1997/98 (grain price = Rp 1,000/kg)

	Private sector		Public sector	
	Low	High	Low	High
Seed price (Rp/kg)				
Single-cross hybrid	10,000	23,000	–	–
Three-way-cross hybrid	6,000	12,500	7,000	15,000
Improved OPV	3,500	7,000	3,000	7,000
Seed price (US$/kg)				
Single-cross hybrid	1.43	3.29	–	–
Three-way-cross hybrid	0.86	1.79	1.00	2.14
Improved OPV	0.50	1.00	0.43	1.00
Seed-to-grain price ratio				
Single-cross hybrid	10.0	23.0	–	–
Three-way-cross hybrid	6.0	12.5	7.0	15.0
Improved OPV	3.5	7.0	3.0	7.0

Source: CIMMYT Maize Impact Survey 1999.

The volume of sales of all seed types have been increasing since 1990, which indicates that farmers demand improved seed even at higher prices because higher yield and better field performance more than compensate for the higher seed cost.

Seed Sales

Reliable and consistent data on seed production and sales by sector have been difficult to collect for this study, especially since official published sources report conflicting figures. Maize seed companies were surveyed directly, and the seed sales figures declared by public and private agencies during these interviews are used in this study. It should be noted that respondents might have provided sales figures lower or higher than the actual sale figure for tax or other reasons.

In principle, all seed sold in Indonesia should be certified. However, data on the volume of certified seed does not match the estimated area planted to maize, making it difficult to draw conclusions based on seed certification data. Seed companies using certification data may often project seed demand poorly and over- or under-produce seed. It is also possible that not all seed that is produced is certified and that not all certified seed is sold. Table 8 shows the reported volume of seed certified by the government and the estimated seed sales of the public and private sectors by type of material from 1990 to 1998. Sales of all maize seed increased from about 1,700 t in 1993 to more than 12,500 t in 1998. As per available records, the volume of certified improved OPV and hybrid seed was around 3,800 t in 1993, peaked at 24,000 t in 1996 and declined to 4,500 t in 1998. Between 1993 and 1997, the volume of certified seed recorded has been higher than the volume of seed sold, confirming that not all certified seed is sold. In 1998, the volume of maize seed sold was higher than the volume certified for that year, because excess stocks of seed certified in 1997 were carried over for sale in 1998. Table 8 also shows a steady increase in the amount of hybrid maize seed sold during 1990-98, except for a significant decrease during the Asian economic crisis year of 1997. In contrast, sales of seed of improved OPVs were erratic, though a small increase was posted even during 1997. These trends indicate that in the crisis year of 1997 maize farmers may have shifted from growing the more expensive hybrid maize to growing the cheaper improved OPVs.

Adoption of Improved Germplasm

In 1998-99, public seed agencies and private companies reported total sales of about 12,500 t of improved maize seed, composed of almost 10,000 t of hybrids and 2,500 t of improved OPVs (Table 8). Assuming an average planting rate of 20 kg/ha for hybrids and 25 kg/ha for improved OPVs, and a seed recycling factor of 1.1 for hybrids and 3 for improved OPVs (Morris *et al*. 1999), the amount of seed sold translates to almost 550,000 ha planted to hybrids and 300,000 ha planted to improved OPVs. The total area planted to high yielding improved maize varieties totals about 850,000 ha, or about

Table 8. Seed sold and certified by type of material, Indonesia, 1990-98

Year	Estimated seed sales (t)			Reported volume of certified seed (t)		
	Hybrids	Improved OPVs[a]	Total	Hybrids	Improved OPVs	Total
1990	980	237	1,217	na	na	na
1991	1,097	255	1,352	na	na	na
1992	1,586	277	1,864	na	na	na
1993	1,607	129	1,736	2,731	1,055	3,786
1994	3,636	1,405	5,041	4,410	2,104	6,514
1995	5,084	1,202	6,286	5,672	1,842	7,514
1996	9,442	1,559	11,001	16,792	6,919	23,711
1997	7,941	1,625	9,566	14,479	6,843	21,322
1998	9,972	2,532	12,504	3,440	1,071	4,511

Source: CIMMYT Maize Impact Survey 1999.
Note: na = not available.
a Seed sales data for 1990-93 incomplete.

22% of Indonesian maize area in 1998. The remaining 78% is planted to local/traditional varieties or uncertified seed (Table 9). It is difficult to estimate precisely the area under each type of cultivar, primarily because maize farmers in Indonesia treat hybrids like OPVs and recycle the F2 or F3 seed.

The seed industry data indicate that in 1990 barely 2% of all area under maize in Indonesia was planted to improved OPVs and hybrids and 98% was planted to local/traditional maize varieties. The proportion of area planted to improved cultivars has since gradually increased. The interview respondents estimated that around 8% and 13% of the area was planted to improved OPVs and hybrids in 1997. As these estimates may either over- or under-report area, this study also referred to data from *CIMMYT World Maize Facts and Trends* (Table 9), which reported that in 1985 only 1% of all area under maize in Indonesia was planted to hybrids and 25% to improved OPVs. In 1990, area had increased to 10% and 50%, respectively. By 1997, a mere 6% of Indonesia's maize area was planted to local/traditional varieties and 94% was planted to improved cultivars (of which 23% were hybrids and 71% improved OPVs).

Table 9. Percentage of area under maize by type of cultivar, Indonesia, 1990-98

Year	Hybrids	Improved OPVs	Local/traditional varieties
Estimated from Table 8			
1990	1.7	0.9	97.4
1991	2.1	1.0	96.9
1992	2.4	0.9	96.7
1993	3.0	0.5	96.5
1994	6.4	5.4	88.2
1995	7.7	3.9	88.4
1996	13.9	5.0	81.1
1997	13.0	5.8	81.2
1998	14.3	7.9	77.8
Estimated from CIMMYT *World Maize Facts and Trends* (various issues)			
1985	1	25	74
1988	3	27	70
1992	10	50	40
1997	23	71	6

Local experts believe, however, that the cumulative quantity of improved OPV seed distributed in Indonesia covers a much higher portion of the total area under maize than is indicated by seed sales and other data reported in this study. Today it is difficult to find a true local/traditional maize variety in the field, except in remote villages, because improved OPVs have become very popular. Local experts also expect that hybrids will contribute increasingly to maize production.

Government Programs and Policies

In the last five years, the growing demand for maize grain from Indonesia's livestock and poultry industries has required about 1 m t of maize grain imports annually. For this reason, the government has formulated production programs and support policies to strengthen the domestic maize industry.

Production Programs

In late 1998, a new production intensification program called GEMA PALAGUNG 2001 was launched to attain self-sufficiency in rice, maize and soybean production by the year 2001. The program also aimed to plant 4 m ha with certified improved seed of high-yielding maize varieties. The government targeted a seed replacement rate of 100% over at least 8% of cultivated area to ensure better quality and quantity of grain production. Public and private seed companies were given incentives to produce breeder seed all year round through collaborative seed production, by making hybrid maize technology more accessible to farmers, and by making HYV seed available to farmers at the right time, quantity and price.

Support Policies

The Indonesian government has taken a keen interest in supporting the development of improved cultivars, particularly of hybrid maize, in line with its maize production improvement program. It supports public research institutes as well as private seed companies in maize R&D and has encouraged the formation of farmer groups to produce seed for public and private companies.

The government has also established public institutions to ensure adequate seed supply. These include the National Seed Board, two national seed centers (P.T. Sang Hyang Seri and P.T. Pertani), the 15 SCCS offices and other support units. Several food and horticultural crop research institutes have been established, with a mandate for developing improved varieties with higher yields and better disease and pest resistance. In February 1994, the Directorate of Seed Development was established under the Department of Agriculture to help strengthen SCCS work (Suherman 1997).

In 1995, the government formulated a policy to make the best quality seed of improved maize varieties available to farmers to raise maize production for national self-sufficiency and possible export. The policy's main objectives are to: expand research on breeding, development and maintenance of improved maize OPVs and hybrids; multiply quality maize seed and distribute it to farmers in sufficient quantities; develop public and private sector seed enterprises; support seed technology development by providing training and technical support to private seed producers and farmers for producing, processing, storing, and utilizing high quality seed; and control and regulate the quality and quantity of seed distributed within the industry (Suherman 1997).

Constraints

Historically, the production of maize grain in Indonesia has been insufficient to meet demand for human food and animal feed for several reasons.

One major constraint is the distance between maize production areas and major seed production sites. East Java is the major maize seed producing province, but the main grain producing areas are located quite far from East and Central Java, in Lampung and North Sumatera in Sumatra and in Nusa Tenggara Timur and South Sulawesi. Seed prices are always much higher outside East Java because of distribution and transport costs.

Appropriate post-harvest facilities and practices also remain to be established and promoted in the major maize producing areas. Post-harvest facilities for shelling, drying and storage are needed at the farm level. Better institutional support and physical infrastructure are required to improve maize grain marketing.

Many proprietary hybrids have been released within a short time, causing confusion among farmers about the best choice of hybrid for their specific location. In government seed farms, parent stock production is usually low because of lack of money and human resources. Although government policies do support maize research, the resources provided to implement these policies and increase the research capacity of government institutes and seed farms are inadequate (Suherman 1997).

Lastly, R&D activities are limited, especially in the public sector, by resource constraints. RIMOC is primarily mandated to produce inbred lines and new varieties that resist downy mildew and stemborers and tolerate drought and stalk lodging, but it conducts little research in this area because of lack of funds and qualified human resources (Suherman 1997). The private sector has recently offered significant financial and technical support for public maize R&D, including payment of incentives and royalties to maize breeders and researchers, on the condition that the private companies receive exclusive rights to the products of that research. This arrangement conflicts with the mandate of public agencies to serve all beneficiaries, however. The absence of laws on intellectual property rights, plant variety protection and breeders' rights complicates the matter even further. It will be interesting to see how the conflict is resolved as the various participants in the seed industry seek to achieve their various objectives.

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Annex 1

Improved Open-Pollinated and Hybrid Maize Cultivars Released in Indonesia

Maize type and cultivar name	Year of release	Days to maturity	Dry grain yield (t/ha)	Resistance to downy mildew	Resistance to rust
Improved OPVs					
1. Metro	1956	110	3.2	S	–
2. Malin	1951-60	100	3.0	S	–
3. Kania Putih	1951-60	150	3.3	–	–
4. Baster Kuning	1951-60	130	3.3	S	–
5. Harapan	1964	105	3.3	S	–
6. Permadi	1966	96	3.3	S	–
7. Pandu	1966	130	3.7	–	–
8. Bima	1966	140	3.7	–	–
9. Bogor Composite-2	1969	105	3.6	S	–
10. Harapan Baru	1978	105	3.6	R	MR
11. Arjuna	1980	90	4.3	R	MR
12. Bromo	1980	90	3.8	R	MR
13. Parikesit	1981	105	3.8	R	MR
14. Abimanyu	1983	80	3.3	R	–
15. Nakula	1983	85	3.6	R	MR
16. Sadewa	1983	86	3.7	MR	–
17. Kalingga	1985	96	5.4	R	–
18. Wiyasa	1985	96	5.3	R	–
19. Rama	1989	100	5.0	R	R
20. Bayu	1991	87	4.0	R	–
21. Antasena	1992	98	5.0	MR	–
22. Bisma	1995	96	5.7	R	R
23. Wisanggeni	1995	90	5.3	R	–
24. Surya	1997	98	6.0	R	–
25. Lagaligo	1997	90	5.3	R	R
26. Arjuna Bisi	1998	85			
Hybrids (public and private)					
27. C1	1983	100	5.8	MR	–
28. Pioneer-1	1985	100	5.0	MR	–
29. CPI-1	1985	100	6.2	MR	–
30. IPB-4	1985	100	5.6	R	–
31. Pioneer-2	1986	100	5.9	MR	–
32. C2	1989	93	6.3	R	–
33. C3	1992	95	6.4	–	R
34. Semar-1	1992	100	5.3	R	R
35. Semar-2	1992	90	5.0	R	R
36. CPI 2	1992	97	6.2	R	R
37. Pioneer-3	1992	98	6.4	S	S
38. Pioneer-4	1993	100	6.9	–	S
39. Pioneer-5	1993	99	6.8	S	S
40. Bisi-1	1995	92	7.0	R	R
41. Bisi-2	1995	103	8.9	R	R
42. Semar-3	1996	94	6.3	R	–
43. P6	1996	96	9.0	R	R
44. P7	1996	100	8.7	R	–
45. P8	1996	100	8.8	R	R
46. P9	1996	100	9.0	R	R
47. Bisi-3	1996	94	6.6	R	R
48. Bisi-4	1996	98	6.9	R	R
49. C4	1997	103	7.5	R	R
50. C5	1997	100	8.1	MR	R
51. C6	1997	104	7.9	MR	MR
52. C7	1997	100	8.0	MR	MR
53. Bisi-5	1998	97	8.3	R	R
54. Bisi-6	1998	100	7.7	R	R
55. Bisi-7	1998	97	8.3	R	R
56. Bisi-8	1998	97	8.0	R	R
57. P10	1999	105	7.7	MR	R
58. P11	1999	110	8.1	–	MR
59. P12	1999	106	8.1	–	R
60. P13	1999	103	8.0	MR	–
61. P14	1999	101	7.6	MR	–
62. Semar-4	1999	90	5.9	R	R
63. Semar-5	1999	98	6.8	R	R
64. Semar-6	1999	98	6.9	R	R
65. Semar-7	1999	98	6.8	R	R
66. Semar-8	1999	94	6.9	MR	R
67. Semar-9	1999	95	6.6	MR	R

Note: R = resistant; MR = moderately resistant; S = susceptible.

Chapter 5

Impact of Public- and Private-Sector Maize Research in Nepal

K.R. Paudyal and S.K. Poudel

Agriculture is the largest sector of the Nepalese economy, contributing over 40% of the gross domestic product (GDP), employing more than 80% of the labor force and accounting for the bulk of export earnings. Despite a growth rate of about 4.4% in the second half of the 1980s, real growth in the agricultural sector has remained lower than population growth in the first half of the 1990s. Cereal crops (paddy, maize, wheat, millet and barley) contribute the larger share to the output of the agricultural sector.

Broadly speaking, Nepal is divided into three ecological zones or belts running east to west. In the south, along the border with India, is the Terai (flat plains, less than 1,000 masl). In the middle are steep hills (1,000–3,000 masl) set alongside rivers, small and large. In the north and along the border with Tibet and China are high mountains (≥3,000 masl). The Terai is the most important area for agriculture, followed by the hills and mountains. Maize is the third most important crop in the Terai, after paddy and wheat. In the hills and mountains, maize is the most important crop, both in terms of area planted and production (Annex 1). Thus, maize is the main crop in the more marginal environments. In 1997/98, maize was grown on about 800,000 ha (25%) of the total area planted to cereals. Production was around 1.37 m t, contributing 21% of the total production of cereals in the country. The hill and mountain zones accounted for 40% and 30%, respectively, of these production figures.

Maize cultivation has always been a way of life for most of the hill farmers. It is the traditional crop cultivated as food, feed and fodder, generally by resource-poor farmers using marginal, semi-marginal and sometimes irrigated prime land. Maize is grown mostly under rainfed conditions during the summer season (April-August), either as a single crop or with millet as a relay crop. In the Terai, inner valleys and low-lying river basin areas of the hills where irrigation is available, maize is also grown during the winter (October-February) and spring (March-June).

Systematic maize research in the country started in 1965. Since then several improved maize varieties have been released, promoted and adopted by maize farmers. As Nepal has not yet developed a hybrid maize variety, a significant number of hybrids have been imported from India, but local/traditional varieties still dominate maize production.

This study aims to assess the impact of public and private sector maize research on long-term maize production in Nepal. Specifically, it attempts to collect, collate and document all available information on maize research and development activities in Nepal; analyze the adoption of maize technology by Nepalese farmers; and estimate the impact of improved maize technologies in the fields. This study uses secondary information from several sources, combined with primary information from a survey of public and selected private companies dealing with maize seed in

Nepal and a survey of some maize seed suppliers in India. Before proceeding to the data analysis and discussion, we provide some background on agricultural research and development in Nepal, especially with respect to maize.

Agricultural Research and Development in Nepal

Agricultural research dates back to the establishment of the Department of Agriculture (DOA) in 1924. Since then, several institutional changes were made to focus the agricultural research system on farmers' problems.

Initially agricultural research was conducted at several agriculture stations on a multi-commodity basis to test and modify technologies borrowed from other countries. In 1966, the Ministry of Agriculture (MOA) was reorganized, and the agricultural research paradigm shifted to a discipline-based approach that was later found to be fragmented and uncoordinated. A new and better-coordinated agricultural research initiative began in 1972/73, following the re-organization of the DOA. The research paradigm once again shifted to multidisciplinary research concepts, with coordinated research programs in major crop commodities such as rice, maize, wheat, potato, citrus, pulses, oilseeds, sugarcane and hill crops. Although it was instrumental in developing relevant technologies, this approach failed to address the important needs of farmers. In 1991 the government passed the Nepal Agricultural Research Council (NARC) Act, establishing NARC as an autonomous apex corporate body for agricultural research attached to the MOA.

Charged with formulating, coordinating and implementing agricultural research programs in Nepal, NARC has three organizational levels: central, regional and subregional. Central management functions are performed by the Office of the Executive Director (OED). Regional administration is entrusted to four regional centers, which in turn share the command over all other agricultural research stations and commodity programs. Across regions, the number of subordinate stations (or substations) differs depending upon the regional setup. The on-farm research of these stations is conducted at outreach research sites. The number of such sites varies according to the needs of the area.

In 1972, to strengthen and broaden maize research and boost national production, the National Maize Research Program (NMRP) was established as a full-fledged commodity program under NARC. Located in Rampur, Chitwan, a major maize growing area in the central Terai, NMRP spearheads maize research in close collaboration with other divisions, stations and research farms under NARC and DOA. Maize breeding, production and agronomy research acquired a new momentum. International collaboration with CIMMYT and other agencies soon followed to improve and broaden the germplasm base through local collection and introduction of new varieties. The main objective of NMRP's maize breeding research has been to develop high yielding, stress tolerant, widely stable cultivars and technology packages suitable to the different agro-ecological zones. Two major agro-ecological zones and six production domains have been defined precisely for maize research (Annex 2). Accordingly, work plans have been developed for each of the NMRP's collaborating research facilities, both within NARC and DOA.

Organization of the Maize Seed Industry

Nepal's seed industry formally began in 1966/67, when the Agriculture Supply Corporation (presently Agriculture Inputs Corporation, AIC) collected and sold 140 t of paddy and 162 t of wheat seed. Since then, AIC has been the only public-sector entity responsible for producing and marketing improved/certified seed. In the private sector, several traders handle less bulky, high value seed in comparatively accessible areas, but their contribution to maize seed supply and distribution is limited.

Role of the Public Sector

Among the major responsibilities of NMRP is to maintain the purity of commercially released open-pollinated maize varieties and to produce targeted breeder and foundation seed. Coordinated by NMRP, the latter activity is also carried out in the different Agricultural Research Stations (ARSs) under the supervision of experienced maize scientists.

Breeder seed produced in the research stations is used for research only and not distributed to the private sector. Foundation seed produced by NMRP and the ARSs is sold to AIC, the Department of Agriculture Development (DOAD)/District Agriculture Development Offices (DADOs), NGOs, private trading seed companies and development projects. These entities in turn produce certified seed through progressive contract farmers in different parts of the country.

The certified/improved maize seed produced by AIC contract farmers is bought back at a price about 15% higher than the local market price of grain maize plus a quality premium of up to 15%. Private seed companies, NGOs and development projects buy back maize seed from contract farmers at prices agreed upon at the time of planting. The DADOs usually do not have a budget allocation to procure improved maize seed produced under their seed multiplication program. Instead they assist the farmers to find a market for the seed and promote these with other farmers.

Role of the Private Sector

Maize hybrids are currently being tested at the research stations, but none has been released by the public sector. Farmers are aware of the performance of maize hybrids in India and are willing to adopt the promising cultivars. Realizing this, private seed companies are importing maize hybrids from India and selling them in Nepal.

There are no official records of the number of maize seed traders in Nepal. The Seed Entrepreneurs' Association of Nepal (SEAN), an organization of private seed traders, has 108 members across the country. It is estimated that its membership would be as high as 150 if all seed traders joined the association. About two-thirds of them (100 traders) handle maize seed. Unlike in other Asian countries, in Nepal no private seed company has established a maize research and development program. These companies only import and distribute hybrid maize seed. Some produce seed of improved OPVs through contract farmers. No official data are maintained on the quantity of seed imported, produced and sold by these entrepreneurs. This study found that, in 1997, private traders handled between 10 kg and 24 t of imported hybrid maize seed and between 100 kg and 20 t of improved OPV seed each.

Seed Production and Distribution

Supply Systems

The public-sector wholesaler, AIC, is responsible for supplying fertilizers and seed of cereals, vegetables and cash crops throughout Nepal. These include wheat, paddy, maize, jute, lentils and vegetables. Available data show that AIC produces and sells between 3,000 and 4,000 t of seed of different crops annually. In the past three years, maize seed composed only about 3% of all seed sold by AIC. Rai and Gyawali (1997) estimated that the maize seed traded by AIC was less than 1% of the total national improved maize seed requirement. This study estimates that about 13,750 t of fresh commercial improved maize seed was required in 1997 (Table 1). Probably AIC handled less than 137 t in that year.

The bigger seed companies can also produce improved maize seed through contract growers, with production operations and buy-back prices agreed upon before planting. The companies provide technical services during cultivation through DADO or their own technicians. They buy, process, package and store the harvested seed. The seed is later sold either through dealers or directly to the farmers. Smaller seed companies, in turn, buy from AIC or other private seed companies, as dictated by availability and prices.

All improved open-pollinated maize seed marketed in Nepal is produced in the country. Although some farmers near the Indian border might be importing improved OPV seed, the quantity is estimated to be insignificant. However, all hybrid maize seed used in Nepal comes from India. Seed traders contact the hybrid maize seed producers in India and order the quantity well ahead of the planting season. In most cases, advance payment is required. The specified amount of seed is delivered to the border, where the traders receive and clear the shipment through the Nepalese Plant Quarantine and Customs Office. So far, the government has not restricted maize seed imports from India. However, Indian regulations do not allow export of either seed or grain without proper licensing, so that the smaller traders who import small quantities of seed from the nearby Indian markets have some problems. Nevertheless, once the seed arrives at the Nepalese customs office, it is treated like any other agricultural product and no customs duty is levied.

An advance income tax of 4% of the seed value is charged at the entry point. This amount is considered a deposit and returned to the trader once he clears all his income tax dues. Nepal's plant quarantine regulations do not restrict seed imports, provided these are accompanied by phyto-sanitary certificates issued by the counterpart agency of the country of origin (Gautam 1994). Import permits are not required. An application fee of NRs 10 (US$ 0.17) per consignment, regardless of the total volume imported, is paid to the plant quarantine office at the entry point in Nepal.

The larger seed companies market imported hybrid maize seed through appointed dealers or their own branches throughout Nepal. The smaller seed traders simply sell from their own shops. As most traders import upon farmers' demand, the traders do not risk being unable to sell expensive imported seed.

Type and Quantity of Seed Traded

In 1997, total maize area in the country was estimated to be 860,000 ha, including winter and spring maize (about 60,000 ha) grown in irrigated lowlands. About 64% (550,000 ha) was planted to improved maize (Agricultural Statistics Division 1998). Commercial seed covers slightly less than 30% of this area while recycled seed produced by the farmers themselves covers the rest. Local landraces or traditional varieties are cultivated on the remaining 310,000 ha of maize area (Table 1).

Table 2 presents the involvement of the public and private sectors in the maize seed market in Nepal in 1997. Of the 3,850 t of commercial maize seed

Table 1. Maize area and seed requirement, Nepal, 1997

	Area (000 ha)	Seed (t)
Total maize	860 [a]	21,500
64% improved varieties, of which	550	13,750
29% commercial seed	157	3,850
71% recycled seed	393	9,900
36% traditional varieties	310	7,750

Source: CIMMYT Maize Impact Survey 1998/99.

[a] Includes an estimated 60,000 ha under winter/spring maize in the Terai/inner Terai, in addition to about 800,000 ha reported by the Central Bureau of Statistics.

Table 2. Quantity (t) of maize seed sold by type of material and organization, Nepal, 1997

	Hybrids	Improved OPVs	Total
NMRP and AIC	–	124	124
NARC research stations[a]	–	86	86
Non-profit organizations (INGOs, NGOs)	–	180	180
Farmer groups collectively producing and selling seed[b]	–	210	210
Individual farmers under DADO seed multiplication program[c]	–	2,535	2,535
Direct import by individual farmers	100	–	100
National private traders	215	400	615
Total	315	3,535	3,850

Source: CIMMYT Maize Impact Survey 1998/99.

[a] The 12 research stations under NARC are located at Surkhet, Nepalgunj, Lumle, Khairenitar, Parwanipur, Kavre, Pakhribas, Hardinath, Nawalpur, Kapurkot, Pokhara and Rampur.

[b] Seed production and marketing are done through the farmer group under the Secondary Crops Development Project.

[c] Includes seed produced by progressive farmers in the Tarai and in mid-hill districts, for which foundation seed is produced and distributed by DADO and its outreach research stations.

sold in Nepal in 1997, around 210 t was distributed by public-sector agencies. Private seed dealers sold about 615 t of maize seed, of which 215 t (35%) was hybrids imported from India and 400 t was improved OPV seed produced locally. Farmer-cooperators of the Secondary Crops Development Project produced and sold another 210 t of improved OPV maize seed. In addition, national and international NGOs and other projects produced about 180 t of OPV maize seed through progressive farmers under their technical supervision. Progressive individual farmer-cooperators in the DADO seed multiplication program (where DADO provides the foundation seed and technical know-how, but farmers are free to sell the seed to any buyer) produced a total of 2,535 t of public OPVs, accounting for about 66% of total maize seed sales.

Seed Quality Control

Seed entrepreneurs, maize farmers, and planning and policy-making authorities are aware of the importance of seed quality and of an efficient seed quality control system in developing a viable seed production and distribution program. In 1988, the Nepal Seed Act was enacted to provide for voluntary seed certification but compulsory labeling of marketed seed (Raut 1997). It also created the National Seed Board (NSB), mainly to formulate national seed policies and set standards for seed quality control. The Seed Development and Quality Control Services Section, under the DOA Division of Crop Science, in turn certifies different crop seeds according to minimum quality standards determined by NSB. The AIC has an in-house seed quality control system. Seed procured from contract farmers is tested by the Internal Quality Control Section, graded and the premium calculated. Processed seed is labeled, stored in good warehouses and sold to grain producing farmers through *sajhas* (cooperatives) and private dealers throughout Nepal.

The Seed Act has not yet been fully implemented owing to the lack of set rules and regulations (Pandey *et al*. 1997). At present, only cereal seed produced by government farms and research stations is certified. Seed produced by other agencies does not require certification and traders can market it without correct labelling. There is no legal provision to make the trader accountable for any misinformation.

Products of the Research and Development System

Improved Open-Pollinated Varieties

As noted, systematic maize improvement work in Nepal began in 1965, when the Division of Agricultural Botany initiated the Coordinated Maize Program. Between 1965 and 1972, four improved OPVs of maize were released: Rampur Yellow for lower elevation areas; Khumal Yellow for the mid-hills; Kakani Yellow for the high hills; and Hetunda Composite for the foothills and inner Terai. Between 1972 and 1985, the NMRP released Janaki and Arun-2 for cultivation in the Terai, inner Terai and the foothills, and Makalu-2 for the hills.

In the early 1980s, germplasm improvement was formally initiated to develop varieties suitable for the different ecological regions of Nepal. All available local and exotic elite genetic materials in the country were classified into seven groups based on maturity, grain color, adaptability and other desirable characteristics (Misra *et al*. 1980). Using materials from these populations, breeders improved the yield potential, earliness and plant height of Rampur Yellow, Khumal Yellow, Kakani Yellow, Rampur Composite and Hetunda Composite. Breeding work on these populations produced six varieties, i.e., Ganesh-2, Manakamana-1, Rampur-1, Rampur-2 and Arun-1, which were released for commercialization in the late 1980s and early 1990s. Annex 3 lists improved varieties released in Nepal and their basic characteristics.

Hybrids

Hybrid maize research began in 1978 with efforts to develop conventional hybrids by inbreeding plants from well-adapted improved populations. In the first half of the 1980s, promising hybrids of the Pioneer series were imported from Thailand and India and were evaluated. Their performance, however, was not consistent and was inferior to that of Rampur Composite during the rainy seasons (Rajbhandary 1982). In the 1980s, pure lines of maize were introduced from the International Institute of Tropical Agriculture to fulfill the demand for hybrid maize in suitable areas. A few single-cross varieties were made out of those superior lines and evaluated. The results were not significantly superior to Rampur Composite and the Indian hybrid Deccan-103 already being grown in eastern Nepal (Lal *et al.* 1987). Crossbreeding between pure lines, development of non-conventional hybrids and simultaneous improvement and evaluation efforts continue at the NMRP station in Rampur. As in other developing countries, facilities and resources are not adequate to vigorously pursue full-fledged inbreeding/test crossing in Nepal.

Adoption and Impact of Improved Maize

Adoption

Since 1955/56, when exotic materials were first introduced, 15 maize varieties have been developed and released for cultivation in the different agro-ecological zones of Nepal. Variety-specific adoption in farmers' fields is not known precisely, but available aggregate data indicate that, in 1993/94, about 30% of all maize area in Nepal was planted to "fresh" improved varieties (i.e., varieties that farmers have recycled for no more than one to three years) and the rest to local/traditional varieties (Table 3). The proportion of maize area under fresh improved varieties increased to about 40% in 1997/98. Although hybrid maize seed has been imported from India in the last few years, this seed is not officially recorded as it is sold to local farmers without prior testing and certification from Nepalese government agencies.

Among the three ecological zones, the Terai has more irrigated land under improved maize than the hills and mountains. In 1993/94, 84% of the Terai maize area was planted to improved varieties compared to 46% of the maize area in the hills and about 39% in the mountains. By 1997/98 these proportions had increased significantly (Table 3). Adoption of improved maize varieties is more widespread in the Terai because of better access, irrigation and climate, all of which make it more profitable to invest in improved seed. However, maize farmers in the hills and mountains are also gradually shifting to improved maize because of its higher yield potential. Farmers are introduced to seed of improved OPVs either by other farmers or by AIC and private seed distributors.

IMPACT

Annex 3 shows the yield potential of improved maize released in Nepal. The yield potential of cultivars released for the Terai, inner Terai and foothills ranged from 2.2 t/ha (Arun-2) to 6.5 t/ha (Janaki). Janaki is the only variety released for winter cultivation in this zone. Winter cultivation is more favorable and produces a higher yield for maize because of lower pest and disease incidence. In the hills, yield potential ranged from 3.9 t/ha (Ganesh-2) to 4.9 t/ha (Khumal Yellow). Varieties used in the high hills can yield 3-5 t/ha. These yield potentials far exceed the mean yield obtained from local varieties planted during the monsoon (1.75 t/ha) and winter (1.96 t/ha) (NMRP 1997).

In 1993/94 and 1997/98, improved maize varieties had consistently higher yields of 400-600 kg/ha more than the local/traditional varieties in all ecological regions (Table 4). Over the same periods, yields of improved maize either increased slightly or remained constant, while yields of local varieties declined. This indicates that the maximum potential yield levels of currently available improved maize varieties were probably achieved, either because there was not much

Table 3. Area planted to improved and local maize varieties, Nepal, 1993/94 and 1997/98

	1993/94		1997/98	
Location	Area (ha)	Proportion (%)	Area (ha)	Proportion (%)
Mountains				
Local	36,438	61.4	30,944	48.6
Improved	22,952	38.6	32,762	51.4
Total	59,390	100.0	63,706	100.0
Hills				
Local	283,608	53.9	241,999	43.2
Improved	242,640	46.1	317,610	56.8
Total	526,248	100.0	559,609	100.0
Terai				
Local	27,828	16.5	14,719	8.4
Improved	140,663	83.5	161,026	91.6
Total	168,461	100.0	175,745	100.0
Nepal				
Local	347,874	46.1	287,662	36.0
Improved	406,225	53.9	511,398	64.0
Total	754,099	100.0	799,060	100.0

Source: Agricultural Statistics Division (1995, 1997).

Table 4. Yield performance of improved and local maize varieties, Nepal, 1993/94 and 1997/98

	Yield (t/ha)	
Location	1993/94	1997/98
Mountains	1.53	1.57
Local	1.36	1.33
Improved	1.79	1.80
Hills	1.60	1.66
Local	1.42	1.36
Improved	1.82	1.89
Terai	1.90	1.92
Local	1.60	1.38
Improved	1.96	1.97
Nepal	1.67	1.71
Local	1.43	1.36
Improved	1.87	1.91

Source: Agricultural Statistics Division (1995, 1997).

varietal turnover (so there was no gain in yield potential) or there was not much increase in the use of purchased inputs. Further increases were possible only through an integrated nutrient and pest management approach, both of which are currently at their lowest level. Declining yields of local maize varieties have been observed throughout Nepal since the early 1970s and are attributed mainly to declining soil fertility and varietal degeneration.

In general, the impact of improved maize technology (which is almost synonymous with the use of improved cultivars) has been an increase in production. The full impact of the new technology, however, has yet to be realized in the absence of achieving the complete adoption and realizing the full yield potential of these varieties. Varietal technology has always been the dominant component of improved maize technology, but its impact will be more significant once improved seed is adopted in tandem with recommended agronomic practices.

Key Issues

Regulations and Policies

Following the creation of NARC in 1991, the Ninth Five-Year Development Plan clearly spelled out agricultural research policies consistent with priority inputs and outputs set forth in the Agricultural Perspective Plan (APP). (The APP is the basic planning document for the long-term development of Nepal's agriculture sector.) Important elements of the policy are provisions to attract the participation of private and non-governmental sectors in agricultural research; the promotion of client-based competitive research by contracting out research; and the incorporation of environmental and gender dimensions in agricultural research. As clearly pointed out by APP, several policy issues in Nepal's agricultural research system need to be addressed properly.

The first issue is the balance between adaptive and basic research. It has often been argued that Nepal can easily borrow agricultural technologies from India. This is possible if the agricultural research system in the border states of India is strong and Nepal has a strong adaptive research system of its own. Indian technology, however, may not be applicable to all of Nepal's ecological zones, so that the extent of transfer needs to be evaluated critically. It is thus imperative for Nepal to develop a clear vision and mandate for adaptive and basic research.

The second issue is that of returns to investments in agriculture research. Sharma (1983) and Morris *et al*. (1991) have shown that returns to investment in rice, maize and wheat research in Nepal, ranging from 33% to over 80%, have been high and comparable to those in neighboring countries. Although individual farmers in favorable pockets may have benefited substantially, most farmers have yet to enjoy the products of agricultural research. This situation calls for investment to expand research recommendation domains through complementary investments in infrastructure and other production inputs.

The third issue is the appropriate level of expenditure on agriculture research. Should ex ante analysis suggest that returns to research investments are likely to be high, spending more on agricultural research is justifiable, as additional investment is likely to have high returns. Determining the appropriate level of research expenditure is difficult in the absence of long-term disaggregated data. Although the World Bank and Food and Agriculture Organization (FAO) of the United Nations have recommended spending between 1-2% of agricultural gross domestic product on agricultural research, NARC has to develop alternative research spending scenarios that will support the realization of APP growth targets.

Intellectual Property Rights

Nepal is considered a small seed market in Asia and private investments on maize research and development may not be attractive. To attract private and non-governmental organizations to Nepal's agricultural research sector, a set of policy measures targeting individual researchers and research organizations and focusing mainly on providing incentives and a better research environment were adopted. These measures include the provision of adequate research facilities; recognition of outstanding research achievements (with monetary awards); naming new technologies after the researcher; providing patent rights to original research outputs; and providing scholarships and research grants to outstanding researchers. Appropriate legislative measures that will provide researchers and research organizations exclusive ownership rights, or property rights, to their innovations and findings, as well as guarantee the transferability and enforceability of such rights, are also required. A key issue is protecting the intellectual property of importers of technology, since the private sector brings in updated technology from India. Although it has been discussed frequently, the issue of intellectual property rights in agricultural research has yet to receive legal recognition in Nepal.

Equity Issues

Given the government policy of regionally balanced development and poverty alleviation, equity considerations in agricultural research in general, and maize research and development in particular, are gaining importance. National resources need to be allocated to regional maize research needs, based on each region's contribution to national maize production and on the size of the population dependent on maize.

Environment, Health and Safety Issues

New and modern agricultural production technologies that involve chemical fertilizers and pesticides, both in research trials and in the fields, have significant environmental implications. To internalize environmental protection concerns in all development activities, a National Environmental Impact Assessment (EIA) guideline was prepared in 1993 by the National Planning Commission in collaboration with IUCN (The World Conservation Union). Guidelines covering forestry (1995), industry (1995), roads (1996) and power and irrigation (1999) have been prepared and are in different stages of implementation. Similarly, the Environmental Protection Act (1996) and Environmental Conservation Rule (1997) were enacted, adopting the rules of conducting EIAs for all types of development plans/activities. However, the EIA guidelines drafted by the Ministry of Agriculture in 1996 for the agricultural sector have yet to be finalized and approved. The Pesticide Act (1991), designed for the judicious use of harmful pesticides and for adopting precautionary measures to safeguard the health and safety of the general public, is yet to be effectively implemented. For now, maize is unlikely to attract the application of a lot of pesticides, particularly in the hills and mid-hills. If labor becomes scarce, the use of pesticides (especially herbicides) could become an issue.

The legislative framework required to protect the environment and general public from the harmful effects of pesticides has been prepared. The pertinent issue is how effectively these legislative measures will be implemented, particularly when the agricultural intensification programs recommended by APP are underway. Given the limited implementation capacity of the stakeholders, the extent to which the legislation will be internalized into the agricultural research system is a question with no definite answer.

Summary, Conclusions and Recommendations

Maize is one of the most important cereals in Nepal, but despite the high yield potential of improved maize cultivars, their adoption and yield performance in farmers' fields appear to be far from satisfactory. Improved cultivars occupied about 40% of the maize area, but farmers' yields of improved maize still remain lower than potential yields. One reason for this yield gap is that farmers do not regularly replace seed; another is that farmers apply minimum or no modern inputs, especially chemical fertilizers, because of the difficulty of accessing and transporting inputs to the farm.

The National Maize Development Project (NMDP) is the only government institution responsible for supporting the country's maize seed industry, including the maintenance and production of breeder and foundation seed. However, it has yet to officially release a hybrid maize variety in Nepal. Because farmers have shown their willingness to adopt hybrid maize, the private sector fulfills this need by importing hybrids from India. Recently, the Nepalese government adopted a liberalization policy under which the private sector can supply agricultural inputs on an equal footing with AIC, a government agency. This new policy has attracted traders to the seed trade. Today, about 60% of all agro-veterinary traders in Nepal also trade maize seed.

Unfortunately, no systematic effort has been made to obtain reliable estimates of the total effective demand for improved maize seed in Nepal, which hampers the growth and development of the local maize seed industry. In addition, the public sector's dominance of Nepal's seed industry has discouraged stronger private sector participation. Private seed companies see the seed business as risky because of unwarranted and sudden government policy shifts.

The area planted to maize (around 860,000 ha) requires around 16,000 t of certified seed, 80 t of foundation seed and 400 kg of breeder seed. Fulfilling this seed demand requires a well-coordinated and decentralized seed production system. Such a system has yet to evolve in Nepal. The government's capacity to produce breeder and foundation seed is constrained by limited resources and facilities. The production of quality certified seed by either public agencies or private companies is also constrained by limited information on effective demand as well as by inconsistencies in government policies affecting the seed industry.

Given the above situation, several important recommendations are in order. First, NARC should initiate a detailed study of maize agro-ecological zones and production domains to understand conditions in the field and incorporate socioeconomic and systems perspectives into the national maize research program. Second, government facilities for seed research and production should be improved for NARC and NMDP to implement their mandates effectively. Third, quality seed of improved maize varieties needs to be made more accessible and available to farmers through a decentralization of the seed supply system. Fourth, public-sector dominance in the seed industry should be completely removed, to allow the more efficient and effective private sector to become more active in producing better quality commercial seed. The government's role should be confined to the production and distribution of breeder and foundation seed and to regulate the quality of improved maize cultivars imported into Nepal.

It is clear that the demand for hybrid maize seed is growing fast in the country, though the exact size of the potential market is not known. The quantity of hybrid maize seed imported annually from India is unknown, as the trade is mainly informal. Although a systematic effort to coordinate imports is imperative, establishing the feasibility of a hybrid maize seed program in the country by estimating potential demand is most urgent.

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Annex 1

Maize Area (ha), Production (t) and Yield (t/ha) by Ecological Zone, Nepal, 1974/75 to 1997/98

	Mountain			Hills			Terai			Nepal		
Year	Area	Production	Yield	Area	Production	Yield	Area	Production	Yield	Area	Production	Yield
1974/75	57,178	105,503	1.85	504,612	945,598	1.87	153,310	243,501	1.59	715,100	1,294,602	1.81
1975/76	57,085	103,483	1.81	503,670	898,932	1.78	152,364	193,280	1.27	713,119	1,195,695	1.68
1976/77	57,081	103,830	1.82	503,032	935,695	1.86	155,283	245,314	1.58	715,396	1,284,839	1.80
1977/78	57,304	92,127	1.61	505,747	841,090	1.66	154,299	246,772	1.60	717,350	1,179,989	1.64
1978/79	57,643	95,871	1.66	509,390	828,788	1.63	154,228	240,908	1.56	721,261	1,165,567	1.62
1979/80	56,886	78,345	1.38	505,413	648,355	1.28	153,769	208,807	1.36	716,068	935,507	1.31
1980/81	57,337	89,767	1.57	511,026	808,527	1.58	156,964	259,014	1.65	725,327	1,157,308	1.60
1981/82	57,702	91,197	1.58	511,767	788,109	1.54	156,586	253,772	1.62	726,055	1,133,078	1.56
1982/83	58,015	82,847	1.43	515,988	699,718	1.36	156,966	247,097	1.57	730,969	1,029,662	1.41
1983/84	58,346	86,132	1.48	517,757	706,251	1.36	155,677	278,388	1.79	731,780	1,070,771	1.46
1984/85	57,816	91,533	1.58	519,506	683,314	1.32	156,290	249,339	1.59	733,612	1,024,186	1.39
1985/86	57,866	85,012	1.47	521,437	709,475	1.36	156,077	244,718	1.57	735,380	1,039,205	1.41
1986/87	58,261	87,092	1.50	523,496	688,590	1.32	157,385	245,065	1.56	739,142	1,020,747	1.38
1987/88	59,310	80,409	1.36	531,471	683,636	1.29	159,078	239,368	1.50	749,859	1,003,413	1.34
1988/89	58,205	80,873	1.39	536,107	769,362	1.44	160,779	272,125	1.69	755,091	1,122,360	1.49
1989/90	58,828	82,711	1.41	529,900	823,034	1.55	162,502	295,703	1.82	751,230	1,201,448	1.60
1990/91	58,415	88,095	1.51	535,730	843,854	1.58	161,937	296,478	1.83	756,082	1,228,427	1.62
1991/92	57,700	86,679	1.50	535,800	825,983	1.54	160,590	292,023	1.82	754,090	1,204,685	1.60
1992/93	59,950	90,370	1.51	546,880	874,740	1.60	168,400	308,670	1.83	775,230	1,273,780	1.64
1993/94	51,920	84,930	1.64	526,810	812,140	1.54	172,420	312,800	1.81	751,150	1,209,870	1.61
1994/95	58,870	90,130	1.53	536,600	853,420	1.59	175,870	331,250	1.88	771,340	1,274,800	1.65
1995/96	61,270	93,020	1.52	556,960	905,190	1.62	173,470	332,850	1.92	791,700	1,331,060	1.68
1996/97	62,210	96,080	1.54	556,040	886,370	1.59	174,750	329,760	1.89	793,000	1,312,210	1.66
1997/98	63,706	100,116	1.57	559,609	929,163	1.66	175,745	338,061	1.92	799,060	1,367,340	1.71
Growth rate (%)	0.24	-0.29	-0.53	0.45	0.21	-0.23	0.62	1.86	1.22	0.47	0.53	0.05

Source: Agricultural Statistics Division, *Statistical Information on Nepalese Agriculture* (various issues).

Annex 2

Production Domains and Trends in Maize Production

Major Production Domains

For research and development, Nepal is divided into two major agro-ecological zones: (1) the Mid- and High Hills Zone and (2) the Terai, Inner Terai and Foothill Valleys Zone. These zones and their subzones show different responses to cultivars and other maize production technology and are briefly described below.

Production Domains in the Mid-and High Hills Zone

In this zone, altitude ranges between 900-2,500 m above sea level (masl), climate varies from warm to cool temperate depending upon altitude, and various micro-climatic regions prevail depending upon aspect. Soil temperature regimes also vary from thermic in the low-lying areas to mesic in high areas.

The first subzone of this agro-ecology is the *Dry Eco-Zone* of the mid- and far-western hills, spanning areas west of Dhaulagiri/Karnali and Rapti River System watersheds. It is characterized by late, low-intensity and short-duration monsoon rains. The major production domain in this sub-zone is summer monocropped maize on *bari* land, with maize-wheat-fallow, maize-barley-fallow, maize-potato or maize-fallow cropping systems. Crops are mainly rainfed, grown without chemical fertilizers but with farmyard manure (FYM).

The second subzone, the *Wet Eco-Zone* of the western, central and eastern hills, spans areas east of Dhaulagiri/Gandaki and Koshi River System watersheds and is characterized by early, higher intensity and longer duration monsoon rains. The two production domains in this subzone are summer relay maize on *bari* land and spring monocropped maize on *khet* land. In the first production domain, cropping systems include maize-millet-fallow, maize-potato or maize/millet-mustard or maize/millet-wheat or maize-buckwheat or maize+soybean-mustard. These crops are mainly rainfed, grown without chemical fertilizers but with FYM. In the second production domain, the maize-paddy-fallow system is followed either with or without fertilizer and with FYM.

Production Domains in the Terai, Inner Terai and Foothill Valley Zone

In this zone, altitudes range between 100-1,000 masl, climate is mostly subtropical with narrow variations on N-S and E-W microclimates, and soil temperature varies from hyperthermic in the low-lying areas to thermic in high elevations. Within this zone are three major maize production domains: summer monocropped maize on *bari* land, spring monocropped maize on *khet* land, and winter monocropped maize on *bari/khet* land.

The first production domain in this zone is characterized by highly accessible areas but lacks irrigation facilities. Maize is grown as a rainfed crop either with or without fertilizer but with some FYM. Major cropping systems include maize-mustard-fallow, maize-upland paddy-fallow, maize-millet-fallow and maize+upland paddy-blackgram. In the second domain, characterized by drought stress and rainfed conditions, the main cropping systems are maize-paddy-fallow, maize-paddy+legume and maize-paddy-buckwheat. The third domain, characterized by highly accessible and irrigated conditions, has maize-paddy-fallow, maize-maize-fallow and maize-paddy+pea as the main cropping systems.

Trends in Maize Area and Production

Trends in maize area, production and yield by ecological zone are presented in Annex Table 2.1. Maize area increased from about 715,000 ha in 1974 to about 734,000 ha in 1984/85, and 799,000 ha in 1997/98. This shows that maize area in Nepal grew by 0.47% per year, partly as a result of bringing more forest land under maize cultivation and to expansion of winter and spring maize in the Terai, inner Terai and river basins in the hills and the mountains. Despite a moderate rate of growth in maize area, production between 1974/75 and 1997/98 increased by only about 0.53% because of very low growth (0.05%) in productivity.

Annex Table 2.1. Annual growth (%) in maize area, production and yield by ecological zone, Nepal, 1974/75 to 1997/98

Ecological zone and period	Area	Production	Yield
Mountains			
1974/75-1997/98	0.24	-0.29	-0.53
1975/76-1979/80	0.03	-6.16	-6.15
1980/81-1984/85	0.28	-0.18	-0.53
1985/86-1989/90	0.32	-1.28	-1.58
1990/91-1994/95	-0.90	0.25	1.16
1995/96-1997/98	1.97	3.74	1.63
Hills			
1974/75-1997/98	0.45	0.21	-0.23
1975/76-1979/80	0.19	-7.46	-7.61
1980/81-1984/85	0.45	-4.36	-4.72
1985/86-1989/90	0.56	4.16	3.55
1990/91-1994/95	-0.14	0.06	0.13
1995/96-1997/98	0.24	1.32	1.23
Terai			
1974/75-1997/98	0.62	1.86	1.22
1975/76-1979/80	0.12	1.37	1.25
1980/81-1984/85	-0.14	0.16	0.26
1985/86-1989/90	1.03	4.95	3.83
1990/91-1994/95	2.39	2.95	0.49
1995/96-1997/98	0.65	0.78	0.00
Nepal			
1974/75-1997/98	0.47	0.53	0.05
1975/76-1979/80	0.16	-5.71	-5.85
1980/81-1984/85	0.31	-2.96	-3.42
1985/86-1989/90	0.64	3.93	3.35
1990/91-1994/95	0.36	0.79	0.43
1995/96-1997/98	0.46	1.35	0.89

Source: Agricultural Statistics Division, *Statistical Information on Nepalese Agriculture* (various issues).

Annex 3

Improved Maize Varieties Released in Nepal

Zone and variety	Year released	Source	Parentage	Grain color	Days to maturity	Average yield potential (t/ha)
Terai, Inner Terai and Foothills Zone						
1 Rampur Yellow	1966	IACP	Composite J1	Yellow	105	4.70
2 Hetunda Composite	1972	–	Local landraces	Yellow	115	4.30
3 Rampur Composite	1975	IACP	Thai Composite-1*Suwan-1	Orange	108	4.40
4 Sarlahi Seto	1978	IACP	Phil. DMR 2	White	115	4.10
5 Janaki	1978	CIMMYT	Rampur 7434*Blanco Subtropical	White	155	6.50
6 Arun-2	1982	CIMMYT	Uncac 242*Phil DMR Subtropical	Yellow	85	2.20
7 Rampur-2	1989	CIMMYT	Local*Exotic	Yellow	108	4.00
8 Arun-1	1995	CIMMYT	Local*Exotic	White	100	4.00
9 Rampur-1	1995	CIMMYT	Local*Exotic	White	115	3.80
Hills Zone						
1 Khumal Yellow	1966	IACP	AntiguaG2D*Guatemala	Yellow	125	4.90
2 Manakamana-1	1986	CIMMYT	Local*Exotic	White	125	4.00
3 Makalu-2	1989	CIMMYT	Amarillo del Bajio	White	145	4.00
4 Ganesh-2	1989	CIMMYT	Local*Exotic	Yellow	165	3.50
High Hills Zone						
1 Kakani Yellow	1966	IACP	AntiguaG2D*Guatemala	Orange	195	3.00
2 Ganesh-1	1997	CIMMYT	Pool 9A	White	175	5.00

Source: Adhikari *et al.* (eds.) 1998.

Chapter 6

The Impact of Public and Private Sector Maize Research in the Philippines

A.C. Costales

Maize provided a seemingly minor contribution of 5.6% of gross value added (GVA) of the agricultural, forestry and fishery (AF&F) sector in the Philippines in 1997. The contribution of the maize sector becomes significant, however, when seen in relation to the livestock and poultry industries. These industries have been the fastest growing sectors in agriculture in the past decade, contributing 22.4% of GVA in the AF&F sector. The feed requirements of poultry and livestock are close to 60% of domestic maize output (BAS 1998). In standard hog and poultry feed formulations, maize constitutes 50-60% of the ingredients on the basis of weight and 40-50% on the basis of cost (Costales 1990). In addition, maize production occupies one-fifth (2.7 m ha) of the country's agricultural area, provides a major source of livelihood to about 30% of Filipino farmers (Costales *et al.* 1999) and supplies part of the staple food of about 20% of the population (Tagle 1997).

The question to be asked is: Should so many land resources continue to be devoted to a sector that contributes relatively little to GVA? The maize sector deserves special attention because its current performance indicates substantial potential for improving productivity and efficiency through technological transformation of maize production systems, especially in areas where yields are still very low (usually barely 1.0 t/ha). Improved maize technology could significantly increase total maize output with the same land area under maize. A substantial increase in the productivity of large tracts of maize land would also relieve pressure to cultivate maize in extremely marginal lands where other economic activities could be more profitable.

This paper reports the major findings of the CIMMYT-sponsored survey of public and private sector maize seed companies to document the impact of their R&D on maize production in the Philippines.

Maize Demand and Supply

Maize demand mainly comes from two sources: white maize milled into corn grits for direct human consumption and yellow maize used in producing livestock feed.

White Maize

Currently, there are only soft estimates of the aggregate demand for white maize used as food. Food consumption surveys conducted every five years by the Philippine Food and Nutrition Research Institute (FNRI) estimate that the per capita consumption of food maize was 9 kg in 1987 and 13 kg in 1993 (FNRI 1995). Projected at the 1995 population, the 13 kg per capita would translate to around 892,000 t of white maize or about 18% of total maize demand. The Bureau of Agricultural Statistics (BAS) estimated the 1995 per capita food consumption of white maize at about 10.6 kg, aggregating to 735,000 t or about 15% of total maize demand (BAS 1998).

Over the last decade, white maize production has exceeded its consumption as food, which ranged between 39% and 48% of the 1995-97 average output. Since white maize is an inferior good in the Philippines, with an estimated income elasticity of –0.15 (Rosegrant *et al.* 1999), future increases in per capita income will reduce demand, with only population growth increasing it. A relatively small portion of white maize is industrially processed, mainly into starch and starch products (Costales 1994). The rest is fed to livestock in a trade policy environment where users of white maize for livestock feed cannot readily import yellow maize as demand increases. (White maize can readily substitute for yellow maize, particularly in hog feed mixes, where grain color is not very important.)

Yellow Maize

Even with consistent surpluses in food maize, there is a chronic shortage of maize in the aggregate. Maize is a major feed input into the hog and broiler chicken industries, and maize imports, mainly of yellow maize for livestock feed, increased rapidly from 174,000 t in 1992 to 1.1 m t in 1997 (Figure 1), and the share of imports in total maize supply increased from 3.5% to 21%.

There are no robust estimates of demand for maize used for livestock feed. Using the livestock inventory approach, Costales (1996) estimated the 1995 feed maize demand at 3.4 m t. For the same year, a deficit of about 982,000 t was estimated, but actual imports of yellow maize were around 851,000 t (Table 1) or 87% of the deficit. The gap is commonly covered by imports of low-quality wheat.[1]

[1] To take advantage of lower tariffs on wheat as food compared to that on maize, feed wheat is imported with the generic name "wheat" (Mangabat 1998).

Future Prospects

Rapid growth of the livestock and poultry sectors and declining maize area and output will lead to higher domestic deficits over the next two decades, especially in the absence of significant measures to increase yield. Compared to 4% per year during 1984-90, maize yields grew at 3.2% per year during 1990-97, with an average yield of only 1.59 t/ha in the last year. Maize area decreased by 4.7% per year during 1990-97, so that aggregate maize output declined by 1.6% per year.

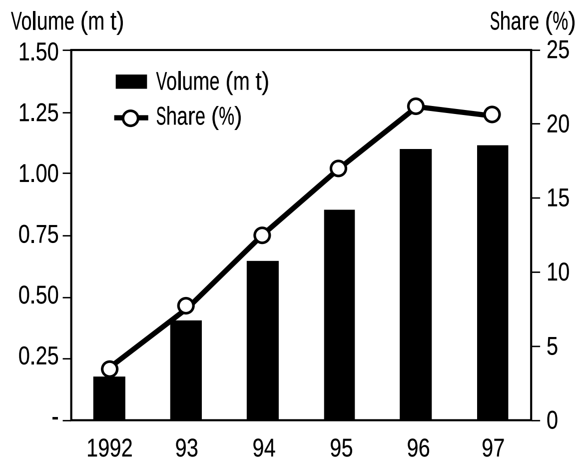

Figure 1. Volume and share of maize imports in total maize supply, Philippines, 1992-97.

Table 1. Estimate of maize deficit with supply and use parameters, Philippines, 1995

Supply/use parameters	Volume (000 t)
Domestic output	**4,129**
Direct food (10.7 kg/cap)	734
Other industrial uses (7.7% of output)	318
Seed (20 kg/ha)	54
Subtotal (non-livestock feed uses)	1,106
Wastage allowance (15% of output)	619
Residual of output	**2,403**
Estimate of livestock feed requirement (Costales 1996)	3,385
Estimate of surplus (deficit)	(982)
Actual maize imports	**851**
Presumed supply shortfall	(131)

The low mean yield indicates the magnitude of the potential to increase maize production, as potential yield from improved cultivars has been shown to be as high as 7-8 t/ha on experiment stations in the Philippines (NSIC 1999).

Maize Area and Seed Market

In 1990, the area planted to hybrid maize was estimated to be only about 9% (347,000 ha) of the total area under maize in the Philippines; improved OPVs occupied another 5% (195,000 ha) (Costales 1993). In 1997, the market for commercial hybrid maize seed consisted of 10,958 t of private sector materials (86% of which was from the multinational firms) and 954 t of public sector hybrids (see Table 2). The total of 11,912 t of hybrid seed sold was equivalent to 595,600 ha or 22% of the total area planted to maize in 1997. Private seed industry sources estimated that 19% of the total maize area in 1997 was under hybrid maize and 4% was under improved OPVs, which suggests that the farmers planted hybrid maize at a higher seeding rate or that not all hybrid seed produced in 1997 was sold.

The size of the Philippine maize seed market was about 14,420 t in 1997 (Table 2). Private-sector hybrid seed accounted for 76% of the market, public-sector improved OPVs accounted for 17% and public-sector hybrids the remaining 7%. This volume of maize seed is equivalent to 26% of the total maize area in 1997 without recycling, or about 36% with recycling. It should be noted that this does not include sales transactions of improved OPVs or traditional varieties that have not been properly recorded.

Public agencies distribute and sell improved OPVs, although these transactions are not well documented. While IPB, the University of Southern Mindanao Agricultural Research Center (USMARC) and BPI-IES reported sales of 34 t, 312.5 t and 6 t of improved OPV seed, respectively, the DA-BAR RIARCs simply reported the area planted to improved OPVs and not actual seed sales. As such, the estimate of 2,154 t of improved OPV seed "sold" through the RIARCs (computed based on the reported planted maize area) would have to be taken with some caution.

In 1989, the maize production subsidy programs of the government included the promotion of certified seed of improved OPVs. Its coverage was estimated at 195,000 ha (Costales 1993), which gives an improved OPV seed market of about 3,900 t. During 1992-98, under the government's Gintong Ani (Golden Harvest) maize program, hybrid maize was vigorously promoted, concomitantly de-emphasizing the use of improved OPVs. This may partly explain the public sector's poor documentation of sales of improved OPV maize seed.

Table 2. Estimated commercial maize seed market, Philippines, 1997

	Reported seed sales (t)	Percent of seed market	Percent maize area covered: Without recycling	Percent maize area covered: With recycling
Improved OPVs	2,506	17	4	12
Hybrid maize				
Private hybrid	10,958	76	20	22
Public hybrid	954	7	2	2
Total improved maize	14,418	100	26	36

Source: CIMMYT Maize Impact Survey 1999.
Note: Seed recycling factors used: 1.1 for hybrids and 3 for improved OPVs (Morris *et al.* 1999).

Organization of Maize Research

Public and Private R&D

In 1997, 6 public institutions and 11 private seed companies were involved in maize R&D in the Philippines (Annex 1). The public agencies include the Department of Agriculture–Bureau of Plant Industry (DA-BPI) experiment stations, which develop maize varieties and undertake seed testing, as well as the Bureau of Agricultural Research (BAR) and its 15 Regional Integrated Agricultural Research Centers (RIARCs), which conduct maize R&D and extension activities in regions where maize is an important crop. Among the public organizations, only the Institute of Plant Breeding (IPB), a research institute of the University of the Philippines Los Baños, conducts maize R&D with a national focus. The other universities and government agencies operate at a regional level (Table 3).

The majority of the private maize seed companies (four multinationals and six nationals) have local breeding programs. Two of the multinationals do not have local maize breeding programs but have commercial tie-ups with local companies: Novartis (Thailand) with Cornworld and DeKalb with Ayala.

Table 3. Maize seed organizations in the Philippines, 1997

Type	Number	Number with breeding programs	Name	Estimated maize seed sales in 1997 (t)			
				Public OPVs	Public hybrids	Private hybrids	Total
Public or parastatal seed company (national)	1	1	IPB	34	720	–	754
Public or parastatal seed company (province, region)	1	1	DA-BPI (IES, LB-Economic Garden, LG-NRDC)	6	6.5	–	12.5
Universities, cooperatives, etc., with breeding program	3	3	USMARC, CMU, ViSCA	312.5	0	–	312.5
Private national seed company with breeding program (also produce and sell seed)	7	7	Ayala Genetics Research, Inc.; Cornworld Breeding Systems; Dow AgroSciences B.V.; Far East Hybrid Research, Inc.; Asian Hybrid Philippines, Inc.; PlanTek, Inc.; Tropical Hybrid Seed Genetics, Inc.	–	–	1,537	1,537
Multinational seed company with local breeding program	3	3	Bioseed Research, Phils.; Pioneer Hi-Bred; Cargill Phils.	–	–	9,421	9,421
Private national seed company with no breeding program (only produce and sell or import seed)	–	–	–	–	–	–	–
Multinational seed company with no local breeding or seed production program (only import seed for sale)	1	–	Novartis (Thailand), Ltd.	–	–	(Not available)	–
Multinational seed company with no local breeding program but produce and sell seed locally	–	–	–	–	–	–	–
Universities, government agencies, cooperatives with no breeding program	1	–	DA-BAR (RIARCs)	2,153.9	227.1	–	2,381.0
Individual seed producer (farmer), produce and sell seed	–	–	–	–	–	–	–
Total	–	–	–	2,506.4	953.6	10,958	14,418.0
Percentage share in 1997 seed market	–	–	–	17.4	6.5	76.0	100.0

Source: CIMMYT Maize Impact Survey 1999.

Initially, IPB was concerned with the development of superior OPVs, also called composites. In the 1980s, IPB began a modest program for breeding hybrids. Some of the released cultivars are sold and used in areas covered by the government's integrated maize production program. The other five public institutions were established in the 1980s, their main focus being to generate and promote improved OPVs. Private seed companies have always focused on hybrid maize R&D and commercialization.

Human Resources and Level of Investment

Only six of the ten private seed companies provided information on the deployment of personnel and investment in maize R&D. In the public sector, most respondents reported that investment expenditure on R&D also included activities commonly classified as "extension." The figures should therefore be interpreted with qualifications.

Staff Deployment

The private companies responding to the survey (excluding the multinationals) reported a total of 264 personnel working on maize. Forty-four percent of the personnel were involved in R&D, about 31% in marketing and administration and 25% in seed production (Table 4). On average, each company employed about 44 staff members for its maize program, most of them being skilled technicians and support personnel (54%). The public sector had fewer maize program personnel, totaling 139. Most of these were deployed in R&D (61%). On average, each public institution has 17 personnel, most of them skilled technicians and support staff (Table 4).

The private sector employs more human resources for maize activities than the public sector. Also, the private sector's (excluding multinationals') proportion of personnel working on marketing and administration is higher than the public sector's, which has most of its maize personnel working on R&D. This reflects the business side of maize R&D for the private sector and the research thrust of the public agencies.

Investments in R&D

In 1997, the investment in maize R&D by private seed companies ranged from PhP 1.5 to 6.0 million (US$ 39,500 to 157,900) per year (Table 5). The five private seed companies that responded spent PhP

Table 4. Distribution of personnel in the private and public sectors, Philippines, 1997

Function / level	Private sector		Public sector	
	Number	Percent	Number	Percent
Respondents	6	_	8	_
Personnel				
R&D	116	44	85	62
Seed production	65	25	27	19
Marketing and administration	83	31	27	19
Total	264	100	139	100
Hierarchy of position (average per firm)				
Senior level	5	10	3	18
Intermediate level	8	17	3	18
Technical and other support	24	54	8	46
Laborers	8	19	3	18
Total	44	100	17	100

Source: CIMMYT Maize Impact Survey 1999.

14.8 million (US$ 390,000) on maize R&D, an average of PhP 3 million per firm (US$ 78,000). This figure underestimates the total investment in private maize R&D because data from the large multinationals were not available.

In the public sector, seven respondents had a maize R&D expenditure ranging from PhP 12,400 to 4.6 million (US$ 326 to 121,100) per year (Table 5). A total of PhP 8.63 million (US$ 230,000) was spent on maize R&D in 1997, averaging PhP 1.23 million (US$ 32,440) per public institution. The IPB, which has a national maize R&D focus, was allotted more than half of the public aggregate expenditures. If IPB is excluded from the calculations, the average expenditure on maize R&D by a public agency declines to about PhP 672,000 (US$ 18,000), which is less than one-quarter of R&D investments made by a relatively small private seed firm. The public expenditure also includes non-R&D activities like extension.

Table 5. Average annual investment in maize R&D by sector, Philippines, 1997-98

	Private sector (n=5)		Public sector (n=7)	
	PhP	US$	PhP	US$
Low level	1,500,000	39,500	12,400	326
High level	6,000,000	157,900	4,600,000	121,053
Total across companies	14,750,000	388,158	8,629,216	227,085
Average per firm	2,950,000	77,632	1,232,745	32,440
Average w/o IPB	–	–	671,536	17,672

Source: CIMMYT Maize Impact Survey 1999.

Products of Maize R&D

Varietal Releases, 1966-99

Information on the products of the maize R&D system was obtained from the National Seed Industry Council (NSIC, formerly the Philippine Seed Board). Between 1966 and 1999, a total of 180 maize cultivars, including 168 field maize cultivars, were approved for release. Of the field maize cultivars, 105 were hybrids developed by the private sector and 55 were improved OPVs developed by public R&D institutions (Table 6). The public sector also released 8 hybrids for commercial use, all of which were developed by IPB.

Among the public regional institutions, USMARC, the center for improved OPV development, accounted for 16 (30%) of all improved OPVs released as of 1999. The Ilagan Experiment Station in northern Luzon released 11 improved OPVs (20% of the total). The IPB released 18 improved OPVs, 4 of which were still available in the market in 1999.

Consistent with the relative magnitude of resources invested in maize R&D, the outputs showed the increasing dominance of the private sector in the Philippine maize seed industry, as it released 62% of all maize cultivars (Table 6). Table 6 also reflects the emphasis of the private sector on the higher value hybrids that provide higher returns both to the private sector and the maize farmers.

Table 6. Field maize cultivars released by private and public seed institutions, Philippines, 1966-99

	Private sector		Public sector		Both sectors	
Type of cultivar	Number	Percent	Number	Percent	Number	Percent
Hybrids	105	100	8	13	113	67
Improved OPVs	0	0	55	87	55	33
Total	105	100	63	100	168	100
Sector share		62		38		100

Sources: CIMMYT Maize Impact Survey 1999; NSIC 1999.

Seed Characteristics and Prices

Table 7 summarizes the characteristics of the 31 public and private maize cultivars available in the market in 1997. Most of the cultivars were hybrids (65%, mostly three-way crosses), yellow (71%), flint (32%), maturing in less than 100 days (45% being extra-early), and all were adapted to lowland tropical conditions. Five single-cross hybrids were available, four from private companies and one from IPB, but no data on the actual volume of seed sales were made available to this study.

Table 7. Characteristics of public and private sector cultivars of field maize available in the Philippine market, 1997

Characteristic	Number of cultivars	Proportion
Type of maize	31	100
Improved OPV	11	35
Hybrid	20	65
Single-cross hybrid	0	0
Double-cross hybrid	1	3
Three-way-cross hybrid	13	42
Top-cross hybrid	0	0
Grain color		
White	9	29
Yellow	22	71
Grain texture		
Flint	10	32
Semi-flint	5	16
Dent	0	0
Semi-dent	1	3
Ecological adaptation		
Lowland tropical	31	100
Subtropical/mid-altitude	0	0
Highland	0	0
Maturity class		
Extra-early (<100 days)	14	45
Early (100-110 days)	8	26
Intermediate (110-120 days)	0	0
Late (120-135 days)	0	0
Extra-late (>135 days)	5	16

Source: CIMMYT Maize Impact Survey 1999.
Note: Sums may not total to 100% because some cultivar descriptions were missing.

Single-cross hybrids were the most expensive, selling for PhP 72-105/kg (US$ 1.90–2.76/kg) for private sector material. The IPB sold its single-cross hybrid for PhP 65/kg (US$ 1.71/kg) (Table 8). Seed of three-way-cross hybrids ranged from PhP 56 to PhP 94/kg (US$ 1.47-2.47/kg) and seed of improved OPVs was PhP 25-33.33 (US$ 0.66-0.88)/kg. Excluding the public-sector single-cross, the average market price for seed of single-cross hybrids was three times higher than the price of improved OPV seed and 19% higher than the price of seed of three-way crosses. Seed of three-way crosses was priced 2.5 times higher than seed of improved OPVs (Table 8).

At a farm-gate maize grain price of PhP 5/kg in 1997, the seed-to-grain price ratios for single crosses were 14.4-21.0 for private-sector seed, and 13.0 for the public seed (Table 8). For three-way crosses, the ratio ranged at 11.2-18.8 and for improved OPVs seed it was 5.0-6.7. Farm-gate grain prices are artificially inflated by very high tariffs (100% in 1995, gradually declining to 50% by 2004) on maize imports in excess of the minimum access volumes (MAV) of the Philippine commitments to the World Trade Organization (WTO). Even within the MAV, tariffs are relatively high (35%).

Table 8. Seed prices and seed-to-grain price ratios, Philippines, 1997 (grain price = PhP 5.00/kg)

	Seed price (PhP/kg)				Seed-to-grain price ratio			
	Private sector		Public sector		Private sector		Public sector	
Type of seed	Low	High	Low	High	Low	High	Low	High
Single-cross hybrid	72.00	105.00	65.00	—	14.4	21.0	13.0	—
Three-way-cross hybrid	56.00	94.00	—	—	11.2	18.8	—	—
Improved OPV	33.00	—	25.00	33.33	6.6	—	5.0	6.7

Source: CIMMYT Maize Impact Survey 1999.

Adoption and Impacts

Private seed industry sources estimated the hybrid maize area in 1990 to be about 347,000 ha, a mere 9% of the total area planted to maize. For the same period, BAS estimated the area under improved OPVs at 195,000 ha, or about 5% of the total maize area. This study found that, while the total area planted to maize declined, the area under hybrids had increased to around 595,600 ha, or 22% of maize area, by 1997. With seed recycling, this is about 24% of all area planted to maize. Recent unofficial industry estimates, however, estimate the area under commercial maize hybrids at only about 18.9% of maize area in 1997 (Table 9).

Relying on reported sales of public maize R&D institutions and area under the coverage of relevant RIARCs, this study estimates the area under improved OPVs to have been about 108,000 ha, or 4% of total maize area in 1997 (12% with seed recycling). Both the absolute and relative figures are lower than the 1990 levels reported by BAS. The extremely small value obtained for area planted to improved OPVs may simply be the result of poor documentation of the disposal of improved OPV seed by public institutions.

Based on the recent industry and CIMMYT survey estimates, hybrid maize area increased by 91% between 1990/91 and 1997, but this was still only a fourth of the total maize area in 1997. Most hybrids in the market had yellow grain, indicating that farmers had adopted mostly yellow hybrids. Total area under yellow-grained maize was 1.03 m ha in 1997, and the area under hybrids was 64% of this area. Very few white-grained hybrids were present in the market. Seed industry sources estimated that seed of white-grained hybrids constituted only about 3-6% of total seed sales in 1997, covering at most 24,000 ha or only about 1.4% of the 1.7 m ha planted to white maize.

The difference in hybrid seed technology adoption has also resulted in different mean yields for yellow maize and white maize production systems, or food and feed production systems, or subsistence and commercial maize production systems. During 1995-97, yellow maize areas yielded an average of 2.3 t/ha and white maize areas yielded only 1.1 t/ha. Furthermore, while yellow maize yields steadily improved from 1987 to 1997, those of white maize barely changed (Figure 2).

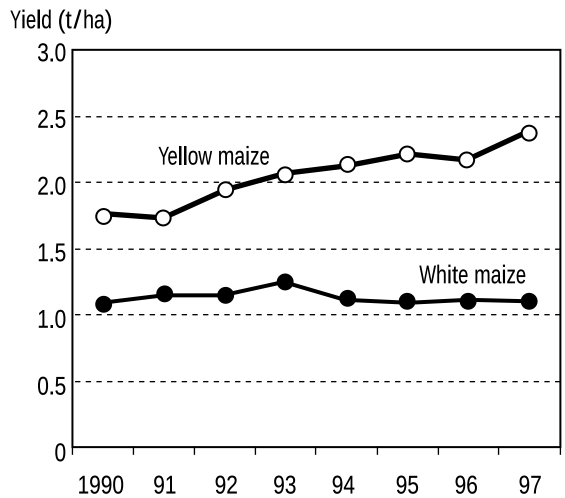

Figure 2. Actual mean yield of yellow and white maize in the Philippines, 1987-97.

Table 9. Estimated adoption of improved maize seed (without recycling), Philippines, 1990/91 and 1997

	1990/91				1997			
	Area (000 ha)		Proportion (%)		Area (000 ha)		Proportion (%)	
Source of information	Hybrids	OPVs	Hybrids	OPVs	Hybrids	OPVs	Hybrids	OPVs
BAS 1999	—	196	—	5.2	681	566	25.0	20.8
CIMMYT Maize Impact Survey 1999	—	—	—	—	596	135	21.9	4.9
Recent seed industry sources, 1999	347	—	9.1	—	515	—	18.9	—
Total maize harvested	3,745	—	—	—	2,725	—	—	—

Key Issues

Plant Variety Protection

The Philippines has not yet instituted any plant variety protection (PVP) law, although as a signatory to the WTO, the country was committed to having one in place by the end of 1999. As of July 2000, the Lower House of Congress (House Bill No. 10654; 2000) and the Senate had already passed the final reading of their respective versions of the PVP bill. Both versions are close to the provisions of the International Convention for the Protection of New Varieties of Plants (UPOV Convention) of 1991. The maize seed company respondents agree that some form of PVP should be enforced. They differ on the degree of strictness on what should constitute an infringement of intellectual property rights, particularly on the use of material already in the market or in farmers' fields. The more established companies with strong crop R&D programs prefer a more stringent PVP law patterned after the 1991 UPOV Convention. Smaller seed companies that are still establishing their own niche in the seed market prefer a less stringent form that will allow them access to a relatively wide range of genetic material. Local breeders currently operate with a "gentleman's agreement" based on professional and personal ethical norms. While no blatant violations of this sort of arrangement have been documented, isolated instances of what local breeders term "flashlight breeding" have occurred, but so far they are not considered serious. Several respondents emphasized the need for a credible and enforceable PVP law because the resulting incentive to invest will be more vital to the seed industry than the financial incentives (e.g., tax deductions or holidays) currently offered under the Seed Industry Development Act (SIDA) of 1992.

Government Programs, Policies and Regulations

Hybrid Seed Promotion

During 1992-98, the Gintong Ani hybrid maize seed promotion program distributed seed to farmers at 50% of cost together with a specialized credit scheme. The national government allocated seed quotas for public and private seed companies. These companies also offered further bulk purchase discounts. Small and new seed companies noted that this scheme allowed them to introduce their materials into the market as a starting point for brand name recognition. Some companies doubted that the program significantly spurred the adoption of hybrid maize technology, as it mainly covered areas where hybrids were already in use or where farmers were about to switch from OPVs to hybrids even without special intervention.

The Gintong Ani program has continued as the Makamasa (Pro-Masses) maize program. Under the current scheme, the allocation of quotas to seed companies is delegated to local government officials. The seed companies see this scheme as distorting the market because local officials choosing seed of favored companies have replaced farmers choosing the seed themselves.

Hybrid Seed Imports

Historically, imports of hybrid maize seed into the Philippines have been regulated, subject to only a 3% tariff when allowed. The statutory 10% value-added tax (VAT) has also been waived for seed imports. These actions reflect the tendency towards greater liberalization of the seed industry, but unless the policy commitment becomes a firm one, opponents to the liberalization of maize seed imports may appeal to Section 15 of SIDA 1992, which expressly prohibits "the importation in commercial quantities of species of seeds that are being produced locally…only exempted of which are seeds that are not produced in sufficient quantities" (R.A. 7308, SIDA 1992).

It is valid to restrict imports of seed that does not meet the commonly accepted sanitary and phyto-sanitary standards. Apart from that, seed quality, suitability and performance in local conditions should be the field within which competition takes place. The country should not deprive itself of better quality seed, regardless of where it is produced.

The National Food Authority

The National Food Authority (NFA) is mainly responsible for stabilizing grain prices (by setting price support levels) and procuring and importing grain to maintain buffer stocks. As a result of NFA's regulatory functions, domestic maize prices may not reflect the movement of international prices, preventing efficient adjustments in the domestic market. The NFA also participates in the grain market, but it fulfills its stabilization function at the cost of large and chronic financial losses (Clarete 1999). It has been suggested that NFA focus its intervention (price support and buffer stocking) on white maize, relegating the trade in yellow maize to market forces. On equity grounds, the idea of supporting white maize farming households sounds appealing. However, the welfare consequences of possible economic distortions (e.g., a shift from yellow to white maize production) may exacerbate existing inefficiencies, especially in the absence of significant technological improvements in white maize production. Such a move may reduce NFA's financial losses and save it from possible WTO sanctions, but it may also support the inefficiency of white maize production systems.

Regardless of the policy changes the NFA undertakes, the interests of efficiency and equity would be served by splitting the regulatory and commercial trading functions of NFA into two separate bodies. Each one should concentrate on the pursuit of its respective objectives: (1) keeping domestic prices "attuned" to world price movements and (2) maintaining a buffer stock of maize as a secondary staple.

Equity Issues

Government intervention is based on the goal of protecting the interests of maize farmers, who are usually the poorest households in the agriculture sector. In practice, however, the hybrid seed promotion and subsidy program essentially favors yellow maize producers, the more progressive farmers in the maize sector. The high tariff on maize also favors yellow maize, as practically no white maize is imported. The current NFA price support at PhP 6.00/kg (US$ 0.16/kg) also benefits mainly yellow maize, since white maize is consistently priced higher than yellow maize.

For white maize, production technology has stagnated, mean yields are significantly lower and cropped area coverage is larger than for yellow maize. Given that farmers who grow white maize are generally poorer than those who grow yellow maize, a technological intervention to increase the productivity and lower the production cost of white maize will have positive welfare effects on farm households. All things equal, lower costs and higher yields will translate into higher net benefits, whether output is sold in the market or consumed at home. Increased white maize production may however simply reduce imports, with the maize price remaining unchanged at the import parity level, or increased production may result in lower market prices of white maize, dampening the welfare gains to producers if all the output is marketed. For farmers who are also consumers of white maize as a food staple, welfare losses from lower prices in production are simply recaptured as gains in consumption, if output is constant. But all welfare effects from output expansion are net efficiency gains in production and consumption. For pure consumers, the increase in output and lowering of price will be an unambiguous welfare gain. At the aggregate level, the net welfare gain from increased efficiency in white maize production would be positive.

Environmental Issues

One of the main environmental concerns in maize production systems in the Philippines pertains to land degradation in hilly uplands and marginal environments. Monzalud (1999) investigated the productivity and environmental effects of maize production in selected marginal environments in the Philippines and found that the more marginal the environment, the faster the rate of soil degradation and the lower the yields of maize and net income. Shively and Corcolon (1999) proposed soil conservation technologies in production systems in selected upland environments in the Philippines. Soil conservation technologies were shown to have positive net returns in the long run but required significant land investments that would result in negative net incomes for farmers in the short run. Thus, special intervention would be necessary to encourage investments in land conservation and to bridge short run losses. The alternative is to remove distortions caused by economic incentives to agricultural products, e.g., protection to maize, which may lead to a natural exit from unsustainable production systems.

The full extent of maize production in marginal environments in the Philippines is not yet known. What is known is that total area planted to white maize declined from 2.7 m ha in 1990 to 1.7 m ha in 1997, while yellow maize area has remained fairly stable. It was not clear where the reduction in white maize area occurred (i.e., whether it was in marginal lands) and what cropping systems have replaced it.

Health Issues

Health issues in maize production systems relate to the level of aflatoxin (caused by a pathogen that has toxic side effects when contaminated grain is consumed) in grain maize. Aflatoxin results from inadequate post-harvest facilities and rural road infrastructure. Grain traders attributed inadequate private investment in large grain drying and storage facilities to NFA's heavy involvement in grain trading and to the high capital costs.

More recently, health concerns have been raised in regard to *Bt* (*Bacillus thuringiensis*) maize. *Bt* maize contains a naturally occurring toxin that is fatal to certain insect pests. Several international and national NGOs are vigorously campaigning for the government to prohibit field testing and commercialization of *Bt* maize in the Philippines. Public discussion has taken place in academic and local community settings, and opinions on the subject differ. A community in Laguna Province did not favor approving *Bt* maize (UPLB Perspective 1999), for example, but farmers in General Santos City, South Cotabato were more receptive to field testing of *Bt* maize, because the corn borer problem has been quite severe in this area (The Philippine Star 1999). After several rounds of consultation and discussion, the National Biosafety Commission recently approved field testing of *Bt* maize. Utilization and consumption of *Bt* maize output will certainly generate further public debate.

Summary and Conclusions

Historically, the average yield of maize in the Philippines has been low (1.6 t/ha), and improvements in yield have been quite slow. The yellow maize sector has been performing better than the white maize sector, partly because modern seed technology, particularly hybrid maize technology, has focused almost solely on the development of yellow hybrids. In addition, although public agencies have commercialized several high-yielding improved OPVs of white maize, the infrastructure required to produce and distribute them efficiently has been grossly neglected. India has established systems to channel publicly developed seed to farmers, and in the Philippines such channels need to be established in areas where white maize is produced to experience significant gains in productivity.

At around 2.4 t/ha, the average yield of yellow maize in the Philippines is still low compared to yields in other Asian countries. This yield level may perhaps result from slow adoption of more modern technology, especially during the first half of the 1990s when the hybrid maize seed industry was small. In the later half of 1990s, the more liberal government policy allowed new companies to enter the seed industry, promoting more dynamic private sector participation. Industry players perceive that there are still seed market niches to explore, especially with maize farmers who are shifting from another crop (usually rice) to maize and, in the process, exploring the potential of hybrid seed technology. The industry estimates that the hybrid seed market is potentially about 80% of the 1 million hectares devoted to yellow maize production, implying an additional 250,000-300,000 ha over the area already planted to hybrids.

However, seed industry representatives also perceive several challenges facing the industry. Foremost is the need for a PVP law. The more established seed companies see the implementation of PVP as the government's role in accelerating the generation and transfer of modern maize technology from the private sector to the farmers. While the established companies would prefer a simple yet strict PVP law, new entrants feel that a strict law might restrict their opportunities to develop hybrids for commercial use.

Another concern is related to the government's role in promoting hybrid seed among farmers. Seed allocation programs in key maize producing areas have allegedly led to unfair allocations among seed companies. Uncertainties about allocations and unscrupulous deals have made some firms cautious about joining government crop production programs. In the beginning, small companies appreciated the program, which assured a ready market for their products. More recently they have indicated that local politics has become decisive in seed allocation and that it would be better if there were no program at all and farmers were simply allowed to choose the best hybrids based on field performance and seed price. For the seed and maize industries to advance in the Philippines, these concerns need to be addressed, keeping in mind that farming households and communities should be the final beneficiaries of modern technology.

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Annex 1

MAIZE SEED COMPANIES OPERATING IN THE PHILIPPINES, 1999

Private companies

1. Ayala Genetics Research Inc.
2. Asian Hybrid Philippines Inc.
3. Bioseed Research Philippines
4. Cargill Philippines Inc.
5. Cornworld Breeding Systems Corporation
6. Dow AgroSciences B.V. Philippines
7. Far East Hybrid Research Inc.
8. Novartis (Thailand) Ltd.
9. Pioneer Hi-Bred Agricultural Technologies Inc.
10. PlanTek Incorporated
11. Tropical Hybrid Seed Genetics Inc.

Public organizations

1. Institute of Plant Breeding, University of Philippines, Los Baños
2. University of Southern Mindanao Agricultural Research Center (USMARC), North Cotabato
3. Central Mindanao University (CMU), Musuan, Bukidnon
4. Visayas State College of Agriculture (VISCA), Baybay, Leyte
5. Department of Agriculture, Bureau of Plant Industry (DA-BPI) Experimental Stations: Ilagan Experimental Station (IES), Isabela; Los Baños Economic Garden, Los Baños, Laguna; La Granja-National Research and Development Center (LG-NRDC), La Granja, Negros Occidental]
6. Department of Agriculture-Bureau of Agricultural Research (DA-BAR) with its Regional Integrated Agricultural Research Centers (RIARCs)

Chapter 7

Impact of Maize Breeding Research in Thailand: Public- and Private-Sector Collaboration

Benchaphun Ekasingh, Phrek Gypmantasiri and Kuson Thong-Ngam

Maize is a crop recently introduced in Thailand and is largely produced commercially (there is very little subsistence production). Over the last 30 years, the growth of maize production in the country has been the result of intensive R&D. In close collaboration with CIMMYT, public-sector research in Thailand developed several locally adapted and disease resistant OPVs of maize, which dominated the market and area under maize until 1990. The nearly 2 m ha planted to maize (out of about 4 m ha planted to major field crops) and an annual production of 4 m ha attested to the success of these OPVs. In the 1990s, total output of maize grain has continued to increase steadily, while the average area planted to maize has fallen somewhat and stabilized at around 1.4 m ha.

Beginning around 1990, there was a fundamental shift in the maize seed industry of Thailand, marked by substantial changes in production technology and market outlets. Several private multinational and national companies started to produce maize hybrids that began to dominate in farmers' fields. Active promotion of hybrids by the public and private sectors helped farmers rapidly learn to use the new hybrids and were one indication of productive collaboration between the two sectors. The private sector developed hybrids based on the locally adapted, disease resistant OPVs and inbred lines developed by the public sector. Active competition among private companies gave farmers a wide selection of hybrids.

Thailand is no longer a major exporter of maize. Domestic use of maize has increased over the years as a 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 Japan have resulted in a rapid growth in demand for animal feed, including maize. In 1966, most maize output was exported. In 1996, almost all of Thailand's maize production was used domestically, mainly as animal feed. In some years, imports of maize were necessary.

Organization of Maize Research in Thailand

Public-Sector Research

National

The two national public organizations undertaking substantial maize research in Thailand are Kasetsart University and the Department of Agriculture (DOA). Kasetsart University has a 368 ha experiment station in Nakhorn Ratchasima called the National Corn and Sorghum Research Center (NCSRC, commonly called Suwan Farm), which has conducted maize research, particularly breeding, since 1966. Maize research at Suwan Farm is conducted jointly by the staff of the university and NCSRC. The DOA is officially responsible for government research and policies for the development of maize cultivars. Maize breeding by the DOA is relatively recent compared to that by Kasetsart University.

International

The two public research organizations in Thailand have good collaboration with CIMMYT. For 30 years, CIMMYT had an Asian regional office in the DOA, housed within Kasetsart University in Bangkok. Scientists from these institutions conduct collaborative field trials, regular seminars and training programs. The collaboration between CIMMYT and Kasetsart University scientists dates to the 1970s, when scientists began working on Suwan OPVs.

Private-Sector Research

Multinational Companies

Until 1998, only five multinational seed companies operated in Thailand: Pioneer Hi-Bred, Pacific Seeds (Advanta/ICI/Zeneca), Novartis, Cargill Seeds and the Charoen Seeds Group (CP Group). CP Group is a Thai company involved in all lines of agribusiness, including seed. Charoen Seeds collaborates with US-based DeKalb Seeds, which provides access to DeKalb's germplasm and technology. In 1991, Charoen Seeds successfully commercialized the single-cross hybrid CP-DK888, which has accounted for around 50% of the hybrid maize seed market for the last nine years. Farmers have become very knowledgeable about hybrids and have shown a preference for certain hybrids.

Most germplasm used for breeding by these multinational companies comes from their mother companies. Within each company, research results, activities and outputs are shared among the regional branches. Three of these companies established offices in Thailand during the late 1970s or early 1980s. With their Thai staff, they are able to operate with adequate research backup and efficient management. After 15-20 years of operation in Thailand, these companies have acquired experience and skill in working with farmers, whose strong participation has also helped the private breeding programs to succeed. Competition among the private companies has provided the industry with a healthy working environment and many positive results.

National (Thai) Companies

Of the seven private companies involved in maize research in Thailand, three are domestic companies. The biggest one is the multinational CP Group. The other two companies (Uniseeds and Royal Seeds) are much smaller.

The smaller domestic companies are more dependent on public sector germplasm and research, both from CIMMYT and Kasetsart University's Suwan Farm. These companies have limitations on their research capacity (personnel and budget) relative to multinational companies. However, with the coordination and support of the public sector, they can make an important contribution. They foster competition in the industry and also provide alternative modes of research and business operation to those offered by multinational companies. For example, the smaller companies are more interested in pursuing further research on and marketing of improved OPVs and public sector hybrids.

In 1999, the structure of the Thai seed industry changed again as the US-based agrochemical company, Monsanto, acquired both Cargill Seeds (international section) and DeKalb Seeds. Since CP and DeKalb, together with Cargill Seeds, control around 70% of Thailand's seed market, the merger will substantially reduce market competition.

Impact of Maize Research

Varietal Releases

During the last 30 years, Kasetsart University's Suwan Farm has released at least 4 OPVs, 10 field maize hybrids, and 3 baby corn and 4 sweet corn varieties, apart from 46 inbred lines (Tables 1 and 2). Suwan Farm released 2 hybrids in the 1980s and 6-7 more in the 1990s. Inbred lines from Suwan Farm are especially valuable for breeding, both in the public and private sectors. Meanwhile, the DOA's Nakorn Sawan Field Crops Center developed and released the OPV called NS-1 in 1989 and has some hybrids in the pipeline for release.

Table 1. Maize OPVs and hybrids developed by the public sector from 1975 to 1997 and hybrids marketed by the private sector in Thailand, 1997-98

	Field maize					
Sector and seed agency	**OPV**	**Single-cross hybrid**	**Double-cross hybrid**	**Three-way-cross hybrid**	**Baby corn**	**Sweet corn**
Public sector						
Suwan Farm	Suwan-1	Suwan-2301		Suwan-2602	Suwan-2	TSC1-DMR
	Suwan-2	Suwan-3501		Suwan-3101	TSC1-DMR	HSX-27127
	Suwan-3	Suwan-3502		Suwan-3602	Kasetsart-1	HSX-11476
	Suwan-5	Suwan-3503				Insee-1
		Suwan-3504				
		Suwan-3601				
		Suwan-3851				
DOA	NS-1					
Private sector						
Charoen Seeds		CP-DK888	CP-DK818	CP-DK822		
		CP-DK999				
Cargill Seeds		C-922			C-501	
		BIG-919				
		BIG-929				
		BIG-717 (MSC)				
		BIG-727 (MSC)				
Pacific Seeds		Pacific-328	Pacific-11		Pacific-421	Hibrix-5
		Pacific-700			Pacific-116[a]	Hibrix-10
		Pacific-626			Pacific-129 [a]	
		Pacific-848				
Novartis Seeds		Red Iron-45		Hercules-31	G-5414	
		Venus-49		Convoy-93		
				G-5384		
Pioneer Seeds		3011		3248		
		3012		3006		
		3013		30A10		
				3014		
Uniseeds		Uniseeds-89		Uniseeds-38	Uniseeds-B50	Uniseeds-SW-1
		Uniseeds-90				
Royal Seeds		Royal I				
		Royal III				

Source: CIMMYT Maize Impact Survey 1998/99.
Note: MSC = modified single-cross hybrid.
a Released in 1998.

Table 2. Characteristics of field maize cultivars released by the public and private sector in Thailand from 1966 to 1997/98

	Public sector (cultivars released from 1966-97/98)		Private sector (cultivars sold in 1997/98)	
Characteristic	Number	Percent	Number	Percent
Maize cultivars released, 1966-97	15	100	58	100
Improved OPVs	5	33	0	0
Hybrids				
Single cross	7	47	30	52
Double cross	0	0	7	12
Three-way cross	3	20	20	34
Other	0	0	1	2
Adaptation				
Lowland tropical	15	100	58	100
Grain color				
White	0	0	1	2
Yellow	15	100	54	93
Other	0	0	3	5
Grain texture				
Flint	5	33	26	45
Semi-flint	10	67	24	41
Semi-dent	0	0	8	14
Maturity class				
Extra early (<100 days)	0	0	1	2
Early (100-110 days)	2	13	28	48
Intermediate (110-120 days)	13	87	24	41
Late (120-135 days)	0	0	4	7
Releases by period				
1970-79	2	13	0	0
1980-89	4	27	8	14
1990-97/98	9	60	50	86

Source: CIMMYT Maize Impact Survey 1998/99.
Note: Sums may not add up to 100% because of incomplete description for some cultivars.

The first successful improved OPV developed by the public sector, Suwan-1, was developed from 36 maize landraces from many areas of the world. Downy mildew resistance was incorporated through the introduction of two Philippine varieties. From 1975 to 1990, Suwan-1 was very well received by Thai farmers and was also used in other Southeast Asian countries. Suwan-1 is still widely used in breeding because of its broad genetic base.

As noted, the 1990s were the decade of the private sector. Private companies released about 3-5 hybrids per year. In 1997, there was a record release of 8 new hybrid varieties by the private sector, 6 of which were single crosses. During 1988-97, at least 36 hybrids developed for different ecological zones were released and sold in Thailand by the private sector. The share of individual companies in the seed market ranged from 2-3% for a small company to 50% for a large company. Farmers' association with specific private companies influences their preferences for different hybrids. A few of the more advanced farmers have also become contract growers of hybrid maize seed for the bigger private companies.

In 1997-98, approximately 60% of all hybrid maize seed sold in Thailand was seed of single-cross hybrids. The private sector was selling 19 single-cross hybrids, 1 double cross and 11 three-way crosses. Out of the 20 cultivars produced by Suwan Farm, 12 were single-cross hybrids and 3 were three-way-cross hybrids.

Seed Production

With widespread adoption of improved cultivars in Thailand, the production of improved seed has become a major activity for both public and private organizations. In the public sector, public-sector staff and hired workers produce seed; in contrast, private companies work mostly with contract farmers, who are closely supervised by company personnel, to produce seed. Some small local companies buy the right to produce Suwan parent lines, acquire parent seed, hire technical assistants, and produce F1 hybrid seed for sale under their own brand names. These companies do not conduct any research and do not produce new hybrids; they just produce and sell Suwan hybrid seed. They are essentially producers and marketing agents for Suwan improved OPVs and hybrid seed. Suwan Farm encourages these small companies to operate in this way and sells its inbred lines for the production of the hybrids. With an estimated 15,000 t of hybrid seed produced and sold in 1997 (Suwantaradon 1997), around 6,000 farm households and 12,000 ha[1] of land (0.8% of all maize area) appear to be devoted to hybrid maize seed production. At least 90% of maize farmers planted some form of hybrid seed, although some farmers reportedly used F2 seed in 1998-99.

Seed Prices

In 1997, small local private companies sold improved maize OPV seed for about baht 20/kg (US$ 0.77/kg). The average cost of hybrid seed ranged from about baht 45/kg (US$ 1.73/kg) for double-cross hybrids to about baht 80/kg (US$ 3.08/kg) for single-cross hybrids (Table 3). At that time, ordinary maize grain prices averaged about baht 4/kg (US$ 0.15/kg).[2] Seed-to-grain price ratios averaged from about 5.0 for improved OPVs to 20.0 for single-cross hybrids. A comparison of seed-to-grain price ratios in 17 countries by Krull *et al*. (1998) showed that OPV seed-to-grain price ratios ranged from 3.0 to 7.6 while those for private sector hybrids ranged from 6.4 to 26.7. Krull *et al*. pointed out that in mature markets, extensive use of improved seed is frequently associated with high seed prices. Experience has shown that farmers quickly appreciate that using improved maize seed does not cost more; it pays more. In a particular country, whether hybrid seed pays for the higher prices or not depends on the level of incremental yield the seed can provide. In Thailand, for example, an increase of only 0.4 t/ha yield (at baht 4/kg) will pay for the cost of single-cross hybrid seed used on 1 ha (at baht 80/kg and a seed rate of 18 kg/ha), provided that all other input costs are the same.

Adoption and Diffusion

In the 1970s and 1980s, maize farmers extensively adopted improved OPVs. During the 1990s, farmers began to switch to hybrid maize. Adoption of hybrid maize increased from 20% of total maize area in 1990 to 49% in 1993 and to 60% in 1995

Table 3. Seed prices and seed-to-grain price ratios, Thailand, 1997 (grain price = baht 4.00/kg=US$ 0.15/kg)

Seed type	Seed price		Seed-to-grain price ratio
	Baht	US$	
Single-cross hybrid	80	3.08	20.0
Three-way-cross hybrid	60	2.30	15.0
Double-cross hybrid	45	1.73	11.3
Improved OPV	20	0.77	5.0

Source: CIMMYT Maize Impact Survey 1998/99.

1 Assuming a yield level of 1.25 t/ha and farm size of 2 ha per household.
2 These prices were calculated at the rate of US$ 1 = baht 26 in June 1997, but the baht had devalued to US$ 1 = baht 45 by December 1997.

(Suwantaradon 1997). In 1997, it was estimated that 81% of the total maize area was planted to private-sector hybrids, 4.7% to public-sector hybrids, 13.9% to improved OPVs and only 0.3% to traditional varieties (Office of Agricultural Economics 1997).

A 1994 study of 200 maize farmers in Nakorn Sawan found that, despite an 85% increase in cost of materials and 13% increase in labor costs, farmers who adopted hybrids had a 32% increase in yield, 36% increase in net return, 29% increase in profit per kilogram and a 69% increase in profit per hectare (Jumroonpong 1996). It also reported that the higher yield is farmers' most important reason for using hybrids. The farmers who continue to use OPVs do so because of their lower price and better pest resistance compared to hybrid seed.

Despite the widespread adoption of hybrid varieties, there has not been a significant increase in the national average maize yield. Given the potential of the new hybrids, many experts feel that the national average yield should be at least 5.0 t/ha. Currently, the national average is only 3.4 t/ha, with some areas reporting significantly lower than average yields because of drought and inadequate use of chemical fertilizers. Some studies have suggested that, in shifting to hybrids, yields increase at a much slower rate than costs (Office of Agricultural Economics 1998).

Profitability

In experimental trials, hybrid maize has a substantial yield advantage over improved OPVs. The value of the incremental yield of hybrid maize offsets the incremental cost of higher seed prices and fertilizer costs. Aekatanasawan (1997) and Aekatanasawan *et al.* (1997) reported that in the Cooperative Hybrid Yield Trials during 1994-96, superior single-cross hybrids had an average yield of 9.5-9.9 t/ha, compared to 5.9-7.0 t/ha for Suwan-1 OPV and the national average of 2.9-3.3 t/ha.

Estimating yields in farmers' fields, Wuttiwan *et al.* (1993) found that maize yields in export, special promotion and all other zones[3] were 3.87 t/ha, 2.85 t/ha and 2.5 t/ha, respectively. A study by Kao-la and Wattanutcharitya (1993) conducted during the 1992/93 crop year in Sa Kaew Province found that the average yield for single-cross hybrids was 4.85 t/ha with a profit of baht 8,063/ha (US$ 322/ha). Other hybrids yielded an average of 4.4 t/ha for an average profit of baht 7,330/ha (US$ 293/ha). Meanwhile, the OPV Suwan-3 yielded, on average, about 3.58 t/ha and a profit of baht 5,654/ha (US$ 226/ha). The choice of seed (and its cost) explains these differences in profits because the cost of other production inputs did not vary much (Kao-la and Wattanutcharitya 1993). Similarly, Masjaroon *et al*. (1994) found that, in three provinces in northern Thailand, the average yield of improved OPVs was 3.2 t/ha with a profit of baht 255/ha (US$ 10.20/ha), while the yield of hybrid maize was 4.2 t/ha with a profit of baht 2,556/ha (US$ 102.20/ha). Hybrid yields were found to be higher while variable costs or grain prices were not significantly different for hybrids and improved OPVs.

Few studies confirm the overall impact of hybrid maize cultivation in Thailand, particularly in relation to farm profitability and income. Many studies show farm-level benefits of hybrid maize, but most are outdated. Over the last five years, the types of seed, as well as the prices of hybrids used by farmers, have changed substantially. Although there is a sense that hybrid maize has increased the incomes of maize farmers, there is not enough information on the extent of such impact on problems of marginal areas with suboptimal agronomic and environmental conditions, and on the gap between potential and actual yields.

[3] An export zone is an area where maize is produced for export and usually has good infrastructure. A special promotion zone is an area with special government projects. All other zones are areas that are not dedicated to these special export and promotion functions.

Public-Private Sector Linkages

Thailand's success in the widespread adoption of new maize technology, i.e., improved OPVs and hybrids, can be attributed to effective collaboration between the public and private sectors. The public sector laid the foundation with improved OPVs and quality inbred lines, to be followed by the private sector's intensive research on hybrids and successful seed production and marketing. The public sector has also provided strong promotion and extension as well as a supportive policy environment.

Germplasm Exchange

The first important linkage between the private and public sector (including international public organizations) involved flows of improved germplasm. The private sector can obtain breeding material from the public sector, especially from CIMMYT, whose maize germplasm bank houses some 13,000 accessions of seed collected from around the world. Private companies can also directly access CIMMYT germplasm, which they evaluate regularly. CIMMYT has been very open and helpful in distributing germplasm free of charge. CIMMYT material is also accessible to national public agencies like Kasetsart University and DOA, whose strong breeding programs, in turn, provide research support to multinational and domestic private companies.

The impact of CIMMYT germplasm is more pronounced among national research organizations and small domestic companies than among large multinational companies, national companies and their partnerships. 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 CIMMYT material for breeding (around 16% of germplasm used) and obtain the bulk of their breeding materials elsewhere. Approximately 56% of the germplasm used in breeding consists of in-country selections made by the company, 10% comes from their foreign branches and 18% comes from other public sources, within and outside Thailand.

Interviews conducted with seven private companies revealed that Suwan-1 is still used extensively for breeding. It was reported that CIMMYT material was not well adapted to local conditions. On the other hand, private companies extensively use inbred lines, OPVs and hybrids from Suwan Farm for further breeding.

Inbred Line Development

In the past, the private sector benefited from public sector research to develop inbred lines. Suwan Farm, for example, has successfully developed 46 inbred lines that public organizations as well as private companies use extensively to develop hybrids. Suwan Farm sells its inbred lines at reasonable prices, occasionally with instructions on how to develop hybrids from them. These inbred lines have provided support to small- and medium-scale seed producers. Large private companies buy the lines to develop them further or to limit the access of, and eventually weed out, competition. These inbred lines thus benefit both small and large private seed businesses.

Varietal Testing and Evaluation

Suwan Farm, DOA and the private sector work together for regular varietal testing and evaluation. The Department of Agricultural Extension (DOAE) has also established a seed quality testing program. The varietal testing and evaluation program provides a mechanism for comparing and contrasting material produced by the private sector and material produced by the public sector. Private companies use the results as reference points for working with farmers and with government agencies. At the international level, CIMMYT and FAO established the Tropical Asian Maize Network to provide a venue for varietal testing and evaluation across South and Southeast Asia. Trials conducted through this network show that the yield potential of many new hybrids is around 8-9 t/ha (Chantachume *et al.* 1998; Vasal 1998; Aekatanasawan 1997).

Human Capital Development

Another important public-private linkage is evident in the area of human capital development. The human capital in Thailand's public- and private-sector maize research consists of highly qualified, efficient and motivated people committed to their work. Universities provide degrees and short-term training for private-sector personnel. CIMMYT also trains both public- and private-sector researchers, all of whom have their initial training in the public universities. These researchers also relate with each other on a personal basis in many ways, either as friends, alumni, friends of friends, junior-senior, ex-students and teachers, and so on. Frequent personal contacts between public- and private-sector researchers make maize research more interesting yet competitive and clearly have contributed to the success of maize research in Thailand.

Information Exchange

There are several important venues for information exchange between the public and private maize sectors in Thailand. Regular workshops and conferences on maize research focus on plant breeding, agronomic work, biotechnology, or maize farming systems, among other topics. At an annual conference on national corn and sorghum research, delegates from public and private organizations actively participate. CIMMYT and other international organizations, such as the Bangkok-based Asia-Pacific Seed Association, conduct regular regional and international conferences attended by national maize scientists and researchers.

Another important public-private sector linkage occurs through national and international publication. Although the channels of information are relatively closed in the private sector, public organizations regularly produce research papers, journal articles, books and other publications. Knowledge is abundant in the private sector, but issues of confidentiality, patents and trade secrets make much of it inaccessible to the public. As more knowledge is accumulated in the private sector, there is a danger that public knowledge will become more limited and learning will be inhibited. It is the role of the public sector to diffuse and disseminate knowledge to counteract the private sector's need to protect its information.

Policy

The Thai government has been very supportive of private sector R&D. It has provided policies that support and expand the work of private companies, facilitating the rapid expansion, both in terms of adoption and cultivar development, of hybrid maize. Maize farmers also benefit from expenditures by the public and private sectors on research, extension and infrastructure development. The Ministry of Agriculture and Agricultural Cooperatives, for example, actively promotes maize production in view of increased demand in both domestic and foreign markets. Apart from providing seed subsidies, the government has pledged that it will continuously promote public and private collaboration in maize production. Plant breeders' rights are also high on the government's agenda, although the particular way in which these rights will be implemented will concentrate not only on plant breeders' rights *per se* but also cover plant varietal protection through community and farmers' rights.

In the five years from 1994 to 1998, a DOAE program subsidized the cost of hybrid seed for 128,000 ha or around 10% of the total maize area at that time. Under this program, farmers paid only 10% of the cost of hybrid seed (only baht 8/kg of the actual cost of baht 70-80/kg). After one year, farmers participating in the program had to purchase their own seed at the market price, and the DOAE moved the promotion program to another location. By rotating the areas it covered, this program was able to introduce some hybrid seed to farmers across at least 640,000 ha (45% of national maize area). In 1999, DOAE subsidized 50% of the seed cost on 240,000 ha. The subsidized seed program is jointly administered with private seed companies, which see it as an opportunity to introduce their seed to maize farmers. Thailand's Bank of Agriculture and Agricultural Cooperatives also promotes hybrid seed adoption by granting farmers agricultural loans that partly include credit in the form of seed and fertilizer.

Looking Ahead

Emerging Technologies

It is expected that advances in maize production technology, particularly in biotechnology, will be substantial in the near future. These advances will affect the public as well as private sectors of the maize seed industry. Issues relating to the biosafety, health hazards, costs and competitiveness of the industry will need to be addressed. For example, genetically modified seed promoted by the private sector represents a technology in which the public sector is unlikely to invest many resources, especially in developing countries. Human capital development and the role of private and public organizations (including international research centers such as CIMMYT) will have to be re-evaluated seriously. Impact studies for these emerging technologies will be required.

The Legal Environment

Emerging technologies will require a shift in paradigm with respect to plant breeders' rights and variety protection. In the past, when new varieties were not protected by law, private companies used breeders' "trade secrets" to protect their varieties while relying on contract law to enforce business deals. Because trade secrets are sometimes revealed and/or "stolen," private companies see the need to protect their varieties through legal means. Over the next few years, new forms of plant variety protection, together with the technical means to enforce these rights (e.g., DNA fingerprinting) will be required.

Changes in the Organization of Research and the Role of the Public Sector

As patents and/or plant variety protection laws increasingly protect private research, public-sector researchers and even farmers will be less willing to share information, research results and germplasm. Remuneration will be demanded in many cases. In the context of private funding for future public research, research results can be sold for profit, and some products of public sector research will need to be patented. Beginning in 2000, more universities in Thailand will be financed by the government through block grants, which will force them substantially to revise their research programs. Public research institutions will need to be more income-oriented and cost-effective than in the past. It is possible that public research will be financed increasingly by the private sector, patented, privately owned and eventually more expensive to farmers. If this trend becomes unacceptable, innovations will be necessary in public policy, management and the legal framework, both at the national and international level.

Conclusions

The current success of the maize seed industry in Thailand can be traced back to the 1970s and 1980s, when public breeding of improved OPVs laid a firm foundation for private breeding of hybrids in the 1990s. The expected gains in average productivity per unit area have not been realized in farmers' fields, however. Although some gain in farm income has been observed, additional data are needed for a full assessment of the aggregate impact of hybrids and thus of maize research in Thailand. Given the substantial gap between yield on experiment stations and farms, more research is needed to determine production constraints at the farm level, especially for resource-poor farmers in marginal environments.

Over the next decade, maize research will follow a different approach and provide a new set of impacts, owing to rapid changes in technology as well as in the legal and political environments in which R&D occur. As research becomes increasingly privatized, it will become necessary to rethink the roles of the public and private sectors to identify gaps in knowledge. Public sector research organizations, both national and international, will have to fill in these knowledge gaps.

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Chapter 8

The Maize Industry in Vietnam

Roberta V. Gerpacio and Nguyen Tri Khiem

Vietnam has a population of 78 m people (1998), 80% of whom live in rural areas and about 67% of whom are employed in the agricultural sector. Its soil and climatic conditions favor the development of a diverse agriculture. In December 1986, Vietnam started to replace its centrally administered socialist economic system with the free market economic system, known as *doi moi*, that led to a number of economic and policy reforms. Economic structural adjustments began with the de-collectivization of agricultural production, allowing private initiative and ownership of the means of production. Producers became free to decide the kinds and quantity of crops to grow, based on anticipated market demand and input costs. The household became the basic unit of agricultural production, with concomitant rights to use the land and sell its surplus production.

One notable result of doi moi has been a dramatic increase in Vietnam's agricultural output. Rice production rose from 17 m t in the mid-1980s to over 25 m t in the mid-1990s. In 1989, from being a net importer, Vietnam became the third largest exporter of rice, after Thailand and the US. In 1997, with 3.6 m t of rice exports, Vietnam was the second largest exporter. Doi moi also boosted the diversification of agricultural production. Vietnam slowly shifted from mono-crop, self-sufficient agriculture to more commercialized and profitable enterprises, serving both domestic and export markets. Now free to sell their produce and purchase their necessities from others, farmers began to venture into growing other crops and practicing animal husbandry and home fisheries.

Food shortages are now considered a thing of the past, but self-sufficiency in food production remains a priority for the Government of Vietnam. The country currently produces around 31 m t of food and aims to produce 32 and 40 m t by 2000 and 2010, respectively (Uy 1998). Although the biggest contributor to food production is rice, since the 1980s maize has become increasingly important in Vietnam's food security and agricultural production objectives. Maize area and production have gradually increased over the last two decades, in contrast to declining trends for other staples, like sweet potato, cassava and potato (Table 1). The rapid development of Vietnam's rice sector has spilled over to the maize industry, as major progress has been made in maize research and agricultural extension. Higher maize yields and total output were achieved with the development of improved OPVs and hybrid maize for marginal environments, improvements in agronomic techniques, establishment and maintenance of demonstration farms, farmer training and expansion of irrigation facilities (Uy 1998).

Table 1. Sown area and gross output of food crops, Vietnam, 1980-98

Year	Sown area (% of total)			Gross output (% of total)		
	Paddy	Maize	Other staples	Paddy	Maize	Other staples
1980	79.4	5.5	15.0	80.8	3.0	16.2
1985	83.5	5.8	10.7	87.2	3.2	9.6
1990	84.8	6.1	9.2	89.5	3.1	7.4
1995	84.9	7.0	8.1	90.5	4.3	5.2
1997	85.5	7.9	6.6	90.5	5.4	4.2
1998	86.2	7.6	6.2	92.1	4.7	3.2

Source: GSO 1995, 1997.

Production Systems

In Vietnam, maize is produced in six major agro-ecological regions or zones: the northern mountainous and midland region; Red River Delta; central coast region; central highland region; southeastern region; and the Mekong River Delta. Each of these regions can be further classified into subsistence (food) or commercial (feed) maize production areas. The northern mountainous and central coast regions support mostly subsistence maize production. The Red River Delta, parts of the northern midlands (e.g., Son La, Hoa Binh and Vinh Phu) and the northern central coast region (such as Thanh Hoa Province) are more commercially oriented, catering to the grain demand of the feed industry. The remaining parts of the central coast region are more subsistence oriented. The central highlands, southeastern region and the Mekong River Delta are mostly under commercial maize production (Annex 1).

In the upland mountainous region (300-1,000 masl), long-duration maize is grown as a subsistence crop from early May to September (Figure 1). Approximately 200,000 ha of maize are cultivated under the upland system, 50% of it in elevations higher than 600 masl.

Local white glutinous maize varieties are most commonly grown as a staple food of ethnic groups in this region. Improved OPVs and some hybrids have also recently been introduced. In 1998, maize yields in the mountainous subsistence system averaged 1.8 t/ha and production was around 307,000 t (Table 2).

In the central highlands, north midlands and southeastern region, two rainfed maize crops are grown every year. The first crop is seeded in late April/early May and harvested in July, whereas the second crop is sown in late July/early August and harvested in October/early November (Figure 1). To maintain soil fertility, farmers either intermittently replace the second maize crop by, or intercrop it with, a legume, usually soybean or

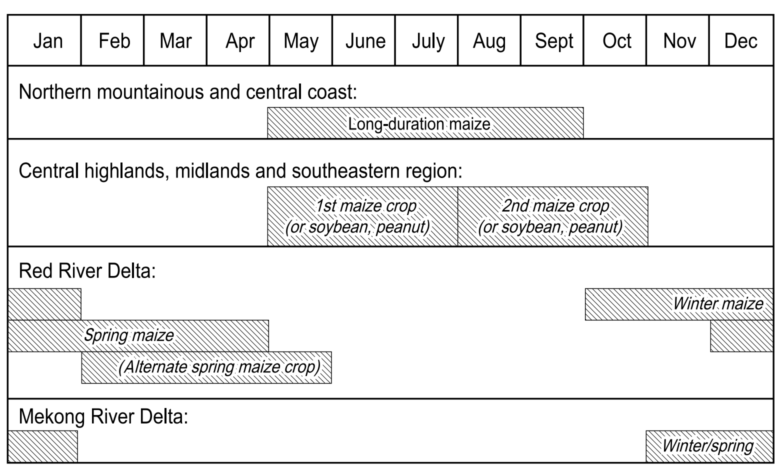

Figure 1. Crop calendar for maize in selected agro-ecological zones, Vietnam.
Note: Text in italics indicates commercial maize production systems.

Table 2. Maize area, yield, and production, Vietnam, 1990 and 1998

Production system	Area (000 ha)		Yield (t/ha)		Production (000 t)	
	1990	1998	1990	1998	1990	1998
Subsistence systems						
Northern mountainous	139.0	169.7	1.2	1.8	172.1	307.0
Central coast	32.4	46.2	1.0	2.0	33.7	91.8
Subtotal	171.4	215.9	1.2	1.9	205.8	398.9
Commercial systems						
Central highlands and midlands	90.7	176.7	1.8	2.6	165.9	453.9
Red River Delta	110.0	150.2	1.8	2.7	202.0	408.1
Southeastern region	48.5	89.8	1.5	3.1	71.7	278.9
Mekong River Delta	11.2	17.1	2.3	3.3	25.6	56.0
Subtotal	260.4	433.8	1.8	2.8	465.2	1,196.9
Total	431.8	649.7	1.6	2.5	671.0	1,595.7

Source: GSO 1996, 1997; *Agricultural, Forestry and Fishery Statistics 1985-1995*.

groundnut. Soybean is grown either from July/August to October/November (the most popular practice) or during the summer months of May to July. Although commercial crops such as coffee, tea, or sugarcane are heavy competitors for agricultural land, maize (mostly hybrid maize) is planted to about 230,000 ha in this region.

In the lowland areas (usually along riverbanks), one maize and one upland or vegetable crop are grown. In the Red River Delta, two maize crops are grown per year: winter maize[1] sown between two rice crops, and spring maize sown as the main crop along with a second cash crop. Common cropping patterns include spring rice-main rice-winter maize (the most widely practiced system); spring maize-main rice-vegetable or upland crop; spring maize-main rice; groundnut-main rice; and groundnut-main rice-winter maize. About 140,000-150,000 ha are planted to winter maize and another 80,000 ha to spring maize (usually intercropped with groundnut). Winter maize is grown from late September to January and spring maize is usually grown from December to April/May (some farmers also grow it from February to May/June). In the Mekong River Delta, the principal maize crop (mainly hybrids) is winter/spring maize grown from November to January (in An Giang Province). Irrigated maize is grown on about 30,000 ha, but a small area is also planted to local glutinous maize varieties on alluvium soil along riverbanks during summer or winter/spring seasons.

The central highlands, midlands, southeastern and lowland regions (all specialized maize areas) are the most important areas for commercial maize production in Vietnam. Cultivated maize area in these regions totaled around 430,000 ha in 1998 (Table 2). Upland farmers, whose hilly lands are less suitable for rice production, traditionally grew most of the maize in Vietnam as a single rainfed crop. Because none or minimal chemical fertilizer is applied, maize yields are low at about 1-1.5 t/ha (Ha 1993). In the lowland areas, irrigated maize production using higher-yielding maize varieties and chemical fertilizers and pesticides has been introduced in response to increasing market demand for maize as animal feed and industrial raw material.

[1] The planting of winter maize always uses the transplanting technique, in which maize seedlings are grown in beds, then balled using banana leaves or sheaths and transplanted to the paddy fields. This permits the use of only 14-15 kg of seed per hectare. Depending on soil type and varietal characteristics, transplanting maize results in stand densities of about 53,300-67,000 plants/ha. Transplanting is also used to overcome unfavorable conditions during planting time, such as low soil temperature and cold winds (Do Hai Dien 1997).

The Maize Economy of Vietnam

Utilization and Trade

Vietnam is predominantly a rice-consuming country, although maize constitutes a major portion of people's diets (especially in the rural areas and mountainous regions) and is used as a substitute staple when rice shortages occur. Maize is also the primary source of feed for Vietnam's poultry and livestock industries. FAO indicates that maize consumption as food increased four-fold from 266,000 t in 1961 to about 920,000 t in 1996 (FAOSTAT 1999). Maize utilization for animal feed also grew more than ten-fold from 20,000 t in 1961 to 250,000 t in 1996. Local experts believe that the quantity of maize used as feed in 1996 was actually much higher, since feed demand from the livestock sector alone was estimated at around 500,000 t. The Ministry of Agriculture and Rural Development (MARD) estimated the 1997 demand for feed maize at around 560,000 t. This increase is attributed mainly to the expansion of Vietnam's livestock and poultry industries as a result of growing household demand for livestock products.

Time-series data show that the proportion of total maize supply (domestic production and imports) used as human food has been decreasing gradually over the last three decades, while the proportion used as animal feed has been increasing. In the 1960s, 83% of the total maize supply was used as human food, while barely 11% was used as animal feed. In the 1990s, 66% of the total maize supply was consumed as food, while feed use increased to about 27% (Figure 2). The proportion of the maize supply used as seed appears to have remained at around 1.8-2%. Domestic consumption of maize as food, feed, seed and raw material (including wastage) has accounted for 92% of total domestic production in the 1990s.

From 1961 to 1997, Vietnam imported an average of 43,000 t of maize grain and exported around 38,000 t of maize products a year, mostly to neighboring Asian countries (FAOSTAT 1999). Net imports (in maize grain equivalent) for the same period averaged 4,620 t (Figure 3). In the 1990s, imports of maize grain and exports of maize and maize products grew at a rate of 20% annually. Over the last three decades, the increase in maize exports was more dramatic than the decrease in maize imports. Maize grain imports declined by more than 50%, dropping from 56,000 t in the 1960s to 20,000 t in the 1990s, whereas exports of

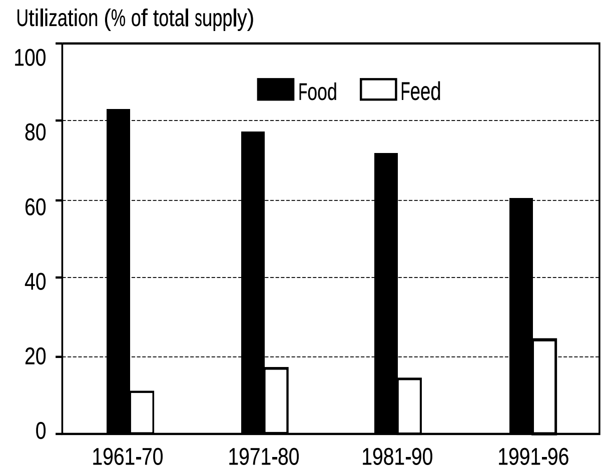

Figure 2. Average maize utilization as proportion of total supply, Vietnam, 1960s-1990s.

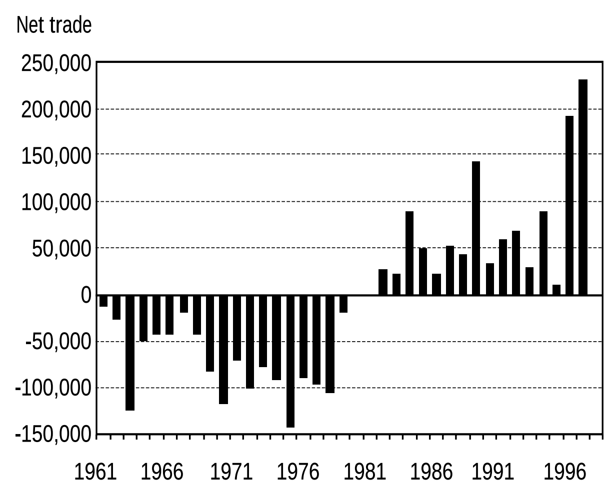

Figure 3. Net trade (export less import) of maize grain (t) in Vietnam, 1961-97.

maize and maize products rose from a mere 473 t in the 1960s to more than 118,000 t in the 1990s. In 1997 exports exceeded imports by about 230,000 t. The growing domestic market and the promising export potential, in tandem with strong government support, provided farmers with a strong incentive to increase maize production.

Production

In 1961, Vietnam planted 260,000 ha to maize, yielding an average of 1.1 t/ha for a total production of 292,200 t. In 1980, area under maize had increased to almost 390,000 ha and production to 429,000 t, but average yields remained at 1.1 t/ha. In 1990, Vietnam planted 432,000 ha to maize and, at an average yield of 1.5 t/ha, produced 671,000 t of maize grain. Maize production declined by almost 2% per annum in the 1960s but increased by 6.5% annually in the 1970s (Table 3). This increase occurred because of expanded area under maize, as yields continued to decline by almost 1% per year. In the 1980s, yield increased at 4% per year while area planted to maize grew at about 3% per year. From 1990 to 1997, production grew twice as rapidly as during the 1980s. This growth usually is attributed to the development and vigorous promotion of hybrid maize, supported by improvements in the production infrastructure.

Table 3. Annual growth in maize production, Vietnam (%/yr)

Period	Area	Yield	Production	Seed
1961–70	-1.55	-0.23	-1.78	-1.77
1971–80	7.20	-0.72	6.47	6.76
1981–90	2.86	4.08	6.94	2.73
1991–97	6.36	9.38	15.74	5.97
1961–97	2.68	1.94	4.62	2.82

Source: FAOSTAT April 1999.

The Maize Seed Market

As recently as ten years ago, maize farmers planted mostly improved OPVs and some local/traditional varieties. Use of hybrid maize was negligible. Hybrid maize R&D, actively pursued by the public sector, contributed to the rapid expansion of area planted to hybrid maize (Table 4). From almost nothing in 1990, by 1994 hybrid maize area had expanded to about 135,000 ha or

Table 4. Area planted to hybrids, Vietnam, 1990-97

	Northern provinces		Southern provinces		All Vietnam		Estimated seed
	000 ha	% total	000 ha	% total	000 ha	% total	requirement (t)[a]
1990	na	na	na	na	nil	nil	na
1991	na	na	na	na	0.5	0.1	25
1992	na	na	na	na	12.8	3	640
1993	40.0	11	20.0	14	60.0	12	3,000
1994	70.5	19	64.5	38	135.0	25	6,750
1995	84.9	22	78.1	43	163.0	29	8,150
1996	119.1	31	110.9	59	230.0	37	11,500
1997	159.0	34	141.0	61	300.0	43	15,000
1998	na	na	na	na	340.0	50	17,000
1999	na	na	na	na	650.0	65	32,500
2000	na	na	na	na	700.0	70	35,000

Source: Department of Agricultural and Forestry Extension 1999.
Note: na= not available.
[a] Estimated based on an average seeding rate of 20 kg/ha.

25% of total maize area, and by 1997, hybrid maize occupied 300,000 ha or 43% of the 690,000 ha of total maize area. Of this, 61% was in the southern provinces, particularly in Dong Nai (GSO 1997). During 1992-97, the area planted to hybrids grew at 57% per year.

The government planned to expand the area devoted to maize to 1 m ha by 2000 and to plant 65-70% of this area to hybrids (Department of Agricultural and Forestry Extension, 1999, personal communication). The additional 310,000 ha of land for expanding maize production would be mainly in the Red River Delta, north midland and eastern region and the central highlands. The expansion of maize area in the Mekong Delta would depend on the price of maize relative to the price of paddy.

Assuming an average seeding rate of 20 kg/ha, Vietnam is estimated to have required around 25 t of hybrid maize seed in 1991 (Table 4). This requirement had risen to 3,000 t in 1993 and to 15,000 t in 1997 (which included about 1,700 t of imported maize seed). During 1992-97, hybrid maize seed sales totaled only about 12% of the entire quantity required each year. In 1997/98, the hybrid seed market was estimated to be around 5,000-6,000 t, or only about 36% of the total requirement, which indicates that a large proportion of the hybrid maize area may have been planted with recycled hybrid seed. Should the government devote an additional 310,000 ha to hybrid maize by 2000, about 32,500-35,000 t of F1 hybrid seed will be required, or about seven times the current marketed volume of seed—a very large potential business for both national and multinational seed companies dealing in hybrid maize. Expanded operations by seed companies or the entry of new companies will depend not only on the total seed production capacity of these companies, but also on how open or competitive the maize seed market is in Vietnam.

Summary information on the maize industry in Vietnam is given in Table 5.

Table 5. Summary information on the maize industry of Vietnam

Total area planted to maize, 1997/98 (000 ha)	690
Traditional varieties and improved OPVs	390
Hybrids	300
Total maize production, 1997/98 (000 t)	1,641
Average maize yields, 1997/98 (t/ha)	2.39
Traditional varieties and improved OPVs	1.70
Hybrids	3.50
Estimated potential area for maize production (000 ha)	310
Year hybrids were introduced	1990
Estimated hybrid maize seed market, 1997/98 (t)	5,000
Average maize seed price per kg, 1997/98	VND 13,000 (US$ 0.96)
Improved OPVs	VND 3,000 (US$ 0.22)
Hybrids	VND 20,000 (US$ 1.48)
Average annual maize seed imports, 1990s (t)	1,700
Average maize grain price per kg, 1997/98	VND 1,900 (US$ 0.14)
Average annual grain maize imports, 1990s (t)	17,756
Proportion of total demand used as human food (1997/98)	68%
Proportion of total demand used as animal feed (1997/98)	26%
Average exchange rate (Vietnam dong per US$)	VND 13,500

Source: CIMMYT Maize Impact Survey 1998/99.

Organization of Research and Seed Production

Table 6 summarizes the types of maize seed organizations operating in Vietnam. Of these, four public and three private companies were interviewed for this study. Only the public seed companies deal with development, research, seed production and sales of OPVs. The private sector concentrates on hybrid maize (Table 7). Only one private seed company maintains its own hybrid maize breeding research and seed production facilities in Vietnam (Tables 6 and 7). The other private companies, all multinationals, import their seed from the mother company, after the cultivars pass seasons of agronomic and adaptation trials in Vietnam (Annex 2). None of the seed companies in Vietnam is involved in maize biotechnology research, although the National Maize Research Institute (NMRI), a public research agency, is currently exploring possible collaboration with Carnegie Mellon University in the US and a Swiss research organization in research, human resource development and upgrading facilities and equipment.

Table 6. Number of maize seed organizations in Vietnam, 1998

Type of organization	Number
Public seed company with breeding program	
National	3
Provincial, state, district	54
Private national seed company with breeding program (engaged in maize breeding, production and sales)	1
Multinational seed company	
With local breeding and seed production program	1
With no local breeding or seed production program (only imports seed for sale)	3
With no local breeding program, but produces and sells seed locally (can also import seed)	2
University, cooperative with breeding program	0
Non-profit organization that produces and sells seed	0
Individual seed producer (farmer)	0
Total number of maize seed organizations	64

Source: CIMMYT Maize Impact Survey 1998/99.

Table 7. Maize-related activities of seed organizations, by sector

Activity	Public sector	Private sector
Population improvement, development of OPVs	3	–
Inbreeding, development of hybrids	4	1
Biotechnology research (e.g., transgenics, marker-assisted selection)	–	–
Agronomy research (e.g., fertilizer trials, pesticide trials)	4	3
Seed production (OPVs)	3	–
Seed production (hybrids)	4	1
Seed sales (OPVs)	3	–
Seed sales (hybrids)	4	3

Source: CIMMYT Maize Impact Survey 1998/99.

Role of the Public Sector

Two public research agencies carry out most of the maize research in Vietnam: the NMRI, located near Hanoi and founded in 1988 under the Ministry of Agriculture and Rural Development, and the Institute for Agricultural Sciences (IAS), located in Ho Chi Minh City. The NMRI is responsible for the "formulation of maize research and production strategies for Vietnam; development of new maize germplasm and varieties, especially hybrids; evaluation of various agro-ecological systems for maize cultivation; development and evaluation of different maize post-harvest and processing technologies; as well as the lead in improving Vietnam's human resources on maize research and development through increased national and international collaboration" (NMRI 1998). The IAS, which also has a small program on legumes, maintains five research stations, a 10 ha research farm, and a 150 ha farm devoted to maize research and seed production. It maintains its own seed processing, storage and packing facilities and also collaborates with other government agencies for some farm mechanization and post-harvest processing requirements.

Work on hybrid maize in Vietnam began in 1961 when Vietnamese scientists collaborated with Romanian experts on hybrid maize breeding and production trials. Several hybrids and inbred lines from Hungary's Martonvasar Institute were introduced in Vietnam in 1971-73 but did not test successfully, primarily because of the great difference in the growing conditions between Vietnam and Europe (Uy 1998).

In 1973, NMRI (then known as the Song Boi Maize Research Center) initiated Vietnam's Maize Breeding Program by collecting local germplasm and importing tropical materials from countries with similar agro-ecological conditions. More than 150 local populations and thousands of lines, populations and varieties developed by CIMMYT and breeding programs in countries such as Russia and China have been evaluated for use in the Breeding Program (Uy 1998). Up to 1990, the Program emphasized research on developing improved OPVs with high yield, good grain quality, tolerance to adverse environmental conditions (such as drought, saline or acid soil), and resistance or tolerance to major pests and diseases (such as powdery mildew, leaf blight, *Rhizoctonia*, stalk rot and stem borer). In 1990, in response to a government initiative promoting hybrid maize adoption, the Maize Breeding Program shifted its emphasis to developing hybrid maize varieties suitable for Vietnamese production environments.

The counterpart of NMRI for maize breeding research in southern Vietnam is the IAS. Using inbred lines acquired from CIMMYT, IAS initiated hybrid maize research in 1992 and began testing single-cross hybrids in 1994. While it currently works only with single-cross maize hybrids, IAS also intends to develop double-cross and three-way-cross hybrids in the future.

In Hanoi, the National Seed Company No. 1 (NSC No. 1) produces and trades crop seed and planting materials and maintains the government's security stock seed. It produces and supplies about 5,000 t of seed of hybrid maize, hybrid rice, beans and other vegetables from its ten seed production farms and stations. About 500 ha of land on four farms and stations are devoted to producing hybrid maize seed. The NSC No. 1 also participates actively in improving Vietnam's seed production and technology and in creating high-quality products to meet demand.

In Ho Chi Minh City, the Southern Seed Company (SSC, sometimes referred to as National Seed Company No. 2) evaluates introduced and locally bred crop varieties prior to local adoption and investigates improvements in seed technology. The SSC produces OPV and hybrid seed of rice, maize, legumes and vegetables, usually under contract with local and foreign seed companies, for sale in the domestic and overseas markets. It has seven subsidiary provincial farms whose seed production area totals about 500 ha, apart from the area contracted with farmer groups or cooperatives. In 1998, SSC produced and distributed about 1,300 t of hybrid maize seed. Apart from crop seed, SSC also manufactures and supplies grain processing equipment and machinery.

Role of the Private Sector

About half a dozen national and multinational seed companies sell hybrid maize seed in Vietnam. The major ones are Bioseed Genetics International (Vietnam), CP Seeds (allied with DeKalb), and Cargill Vietnam (soon to begin operating under the Monsanto name). Minor companies include Pioneer and Uniseeds. A local private seed company, Luong Nong Company, has recently entered the market. Of these companies, only Bioseed Genetics Vietnam has a breeding and seed production program in Vietnam. As noted, the other companies import their own seed from Thailand or the Philippines or contract with public agencies or farmer groups to produce seed locally. For example, NSC No. 1 and SSC produce hybrid maize seed on a contract basis for Pacific Seeds Ltd. (a subsidiary of ITC-Zeneca). Under the terms of the contract, Pacific Seeds sells parent seed to the government companies and receives royalties on commercial sales. These arrangements are expected to result in developments in hybrid maize research in the mother companies, benefiting the maize seed industry in Vietnam.

Public and Private Sector Research Investments

Advancements in Vietnam's maize industry can be attributed to the combined public and private sector resources devoted to maize breeding and production research. All the seed companies that participated in the survey have maize breeding programs, agronomy research programs, or both. The public sector employs 91.5 maize researchers (in full-time equivalents), whereas the private sector employs 64 (Table 8). Sixty percent of the public sector and 17% of the private sector maize researchers are engaged in either breeding or crop management research. Thus, there were about 133 public sector scientists per million hectares of land planted to maize, or 56 public sector scientists per million tons of maize produced. These numbers represent an increase over 1990, when the public sector had 60 full-time maize researchers or about 118 researchers per million hectares of maize area (CIMMYT 1992). In 1990, the private sector was not yet active in maize research; now it has 93 scientists per million hectares of maize area and 39 scientists per million tons of maize production. The difference between sectors can be explained by the wider research network of the public sector compared to the new and smaller (single) breeding program in the private sector.

Over the last three decades, the public sector has produced 21 maize hybrids, 16 of which were developed between 1990 and 1997. Over the same period, the private (multinational) maize seed companies developed and released five new maize hybrids (Table 8). The public sector is much more efficient than the private sector, as it has more than two decades of research experience in dealing with OPVs while the private sector was allowed to enter the industry only in 1990/91. On average, the government provides the public sector around VND 1 billion per year (US$ 74,000) to conduct maize research.[2] Additional funds are obtained from income-generating activities such as the sale of hybrid maize seed. Information on the level of maize research investment in the private sector is confidential.

[2] It should be noted that this amount is allotted to cover operating research costs only; it does not include researchers' salaries and benefits or fixed and administrative overhead costs.

Table 8. Public and private sector investments in maize research, Vietnam, 1997/98

Research indicator	Public sector	Private sector
Number of maize research programs	4	3
Number of programs with maize breeding activities	3	1
Number of maize researchers (FTEs)	91.5	64
Number of maize scientists		
Per m ha of maize area	133	93
Per m t of maize produced	56	39
Percentage of researchers engaged in maize breeding and/or crop management research	60	17
Number of cultivars developed (1966 to 1997/98)		
Improved OPVs	13	0
Hybrids	21	5
Total	34	5
Average annual research investment	VND 1 billion	a
Average annual research investment (1998 US$)	US$ 74,100	a

Source: CIMMYT Maize Impact Survey 1998/99.
[a] Internal and confidential.

Seed Production Arrangements

For seed production, NMRI and IAS use several public seed companies located in the maize growing regions. The NMRI and IAS also maintain their own production farms, which are mostly used for growing parent seed as well as for producing limited quantities of commercial maize seed, in close collaboration with provincial research stations and agricultural extension offices. They also use the facilities of district seed companies for contacting farmers who might grow seed. The NMRI and IAS supply parent seed to these contract seed growers, provide technical support and implement other safeguards to ensure that the hybrid seed produced is of satisfactory quality. The NSC No.1, the SSC, and several provincial and district seed companies mainly produce seed of public hybrids.

As noted, both public and the private companies contract farmer groups or cooperatives to produce seed. Bioseed Genetics Vietnam, for example, contracts with 12-15 cooperatives around Hanoi and three to four farmer cooperatives in the south to produce their hybrid seed. Every year, NMRI contracts about 2,000 ha of maize area with farmers to produce seed in the north. The contracting agency sets an output standard and buys back the seed produced at a premium over the current market price of maize grain. Such seed production contracts have several advantages for farmers, including regular access to technical expertise during the production period; a lower investment in maize seed production as the most expensive input, seed, is provided by the seed companies; an assured market for the produce; and a higher income.

Products of Maize Breeding Programs

As part of the CIMMYT survey on the impacts of maize research in developing countries, detailed descriptive data on cultivar characteristics were collected for all public and private materials available in the market in Vietnam. In 1990 seven maize cultivars were sold, all of them from the public sector: four improved OPVs and three conventional hybrids. Many cultivars are no longer sold because newer materials, mostly hybrids, have been developed and released for commercialization.

General Characteristics

From 1973 to 1997/98, 62 improved OPVs and hybrids were developed and released for commercialization in Vietnam. The public and the private sectors developed 48 and 14 materials, respectively, over this period (Annex 3). Of these, 30 of the public sector materials and 9 of the private sector materials were released between 1990 and 1998. At the beginning of that period, public sector releases consisted mostly of improved OPVs; later, they consisted mostly of hybrids, as the government sought to increase maize production by promoting hybrids.

Currently, 44 improved OPVs and hybrids are available in Vietnam, of which 33 were developed by the public sector. These consist of 13 improved OPVs and 9 single-cross, 2 double-top-cross and 3 top-cross hybrids (Table 9).

Table 9. Characteristics of maize cultivars released, by sector, Vietnam, 1966 to 1997/98

Characteristic	Public sector (cultivars released in 1966-1997/98)	Private sector (cultivars sold in 1997/98)
Total number of cultivars released	48	14
Number of maize cultivars remaining on the market	33	11
Improved OPVs	13	0
Hybrids		
Single cross	9	7
Double cross	0	1
Double top-cross	2	1
Three-way cross	0	2
Top-cross	5	0
Ecological adaptation		
Lowland tropical	48	14
Grain color		
White	3	0
Yellow	29	14
Grain texture		
Flint	2	3
Semi-flint	23	7
Dent	4	0
Semi-dent	8	3
Days to maturity		
Extra-early (<100 days)	3	1
Early (100-110 days)	11	9
Intermediate (110-120 days)	11	2
Late (120-135 days)	7	0
Extra-late (>135 days)	0	0
Number of releases by period		
1970-79	3	0
1980-89	14	5
1990-99	30	9

Source: CIMMYT Maize Impact Survey 1998/99.

The first OPV developed by NMRI, HS36, was released in 1973. It is no longer available in the market, and was never considered a commercial success. The most commercially successful public hybrid so far has been NMRI's LVN10, for which an estimated 1,800 t of seed was sold in 1997. LVN10 is popular with Vietnamese farmers because its field performance and yield potential are comparable to those of the more expensive private sector hybrids. This public-sector hybrid is sold at attractive prices ranging from VND 14,000 to VND16,000/kg (US$ 1.04 to US$ 1.19/kg). The most recently released public-sector hybrid is MX1, the first hybrid developed by SSC. MX1, whose seed costs VND 18,000/kg (US$ 1.33/kg), is a single-cross hybrid, has a potential yield of 7-8 t/ha (similar to that of LVN10) and matures 7-10 days faster than LVN10.

The 11 hybrids marketed by the private sector consist of 7 single-cross, 1 double-cross, 1 double-top-cross and 2 three-way-cross hybrids (Table 9). Five of these cultivars were developed in Vietnam and the rest were imported, mostly from the various company headquarters in Thailand. The first private sector hybrid, CP-DK888, released in 1991, is popular with farmers because of its high yield and strong tolerance to a wide range of production stresses. Priced at VND 38,500/kg (US$ 3.08/kg), CP-DK888 faces strong competition from the less expensive but equally good LVN10.

All maize cultivars marketed in Vietnam are adapted to the lowland tropical production environments. Most are yellow, semi-flint and of early to intermediate maturity (100-120 days to harvest), fitting the requirements of the livestock and poultry industries. The public sector also provides very early and late maturing hybrids for the central highlands and mountainous regions.

Use of CIMMYT Germplasm

From 1973 to 1990, NMRI released 17 improved OPVs with an average grain yield potential of 3-6 t/ha. Some of these cultivars were developed using CIMMYT germplasm, including Populations 17, 18, 26, 28, 31, 36, 49, 63, Tuxpeño, Suwan-1 and Suwan-2 (Uy 1998). From 1990 to 1999, NMRI released 24 hybrids using materials maintained in its own maize gene pool. Early, intermediate, and late-maturing hybrids with yield potentials of 4-6, 5-6 and 5-7 t/ha, respectively, were first released in 1991-93. More conventional hybrids (mostly single crosses and double crosses) have been released since then.

Three private-sector hybrids available in Vietnam contain CIMMYT's Population 28 in their pedigrees. Twenty-five of the 48 public-sector OPVs and hybrids were developed using some CIMMYT germplasm (Pools 17 and 18, Experimental Varieties 54 and 524 and Populations 21, 26, 28, 31, 36, 49 and 63).

Private- and public-sector breeding programs use CIMMYT maize germplasm in different ways. From the limited information on pedigrees gathered during the survey, it appears that the public sector mostly uses CIMMYT populations, pools or experimental varieties as basic germplasm for their breeding and direct varietal releases. The private sector meanwhile acquires breeding lines (inbred lines or hybrids as parents and new genetic stocks) from CIMMYT for their pedigree or germplasm improvement program. Both sets of materials are subjected to substantial improvement prior to incorporation into the maize research and breeding programs.

Many of the survey respondents stated that the CIMMYT materials were not "specific enough" to be used directly in breeding programs. Some respondents noted that it is inefficient for commercial breeders to improve the CIMMYT materials themselves. CIMMYT maize breeders responded to this by stating that CIMMYT's mandate is to develop germplasm suitable for a larger number of agro-ecological zones and environmental conditions. Turning this germplasm into more location- or environment-specific cultivars should be the responsibility of national agencies involved in maize breeding research and development.

Seed Marketing and Distribution

As noted, sales of hybrid maize seed in Vietnam have grown rapidly since the early 1990s, when the first commercial hybrids appeared in the market. The total market for hybrid seed is currently estimated at around 5,000 t, of which approximately half is produced by public companies and half is produced (or imported) by private companies. In addition, a number of small provincial seed companies produce and sell seed of non-conventional hybrids and improved OPVs. The commercial maize seed market in Vietnam is estimated to have grown from about 25 t in 1992 to 5,350 t in 1997 (Table 10), decreasing to about 3,400 t in 1998 because unpredictable weather and after-effects of the Asian crisis provided disincentives for maize production.

Local branches of the Department of Agricultural Extension in the provinces and districts are responsible for promoting new maize cultivars, particularly hybrids, together with the recommended technology package. The extension services disseminate this information through radio and television programs as well as demonstration trials in farmers' fields. The public agencies market maize seed through the government marketing and distribution networks in each province or district. The central government transfers funds for maize seed acquisition to the public seed companies, who buy the seed either from public or private sources. The

Table 10. Description of the national maize seed market, Vietnam, 1997/98

Market indicator	Public sector	Private sector
Number of maize cultivars currently available in the market	34	8
Average seed price paid by farmers (US$/kg)		
Improved OPVs	0.22	na
Hybrids		
Single cross	1.15	2.59
Double cross, three-way cross	1.07	1.59
Average seed-to-grain price ratios		
Improved OPVs	na	na
Hybrids		
Single cross	19.81	7.75
Double cross, three-way cross	10.24	7.25
Estimated total market share (%)	51.1	48.9
Estimated hybrid market share (%)	47.2	52.8
Total sales of commercial maize seed (t)	2,821	2,704
Composition of maize seed sales (t)		
Improved OPVs	420	0
Hybrids	2,421	2,704
Commercial maize seed sales (t)		
1990	na	0
1991	na	0
1992	na	25
1993	na	225
1994	na	550
1995	na	690
1996	na	1,150
1997	2,700	2,650
1998	1,300	2,138

Source: CIMMYT Maize Impact Survey 1998/99.
Note: na=not available.

public seed companies then coordinate with district seed companies and district agricultural extension offices to distribute the seed to maize farmers, usually on credit. Farmers pay for the seed after harvest or as soon as they have the money. It is estimated that about 80% of the seed requirement is met through this state-managed distribution system and that about 15% of seed is exchanged among farmers (Mai Thi Sam 1997).

The private seed companies distribute their products through their own sales networks located in the provinces. The seed is sold primarily to private wholesalers or retailers, although some is sold to local government agencies. The seed distribution network may differ greatly between the northern and southern regions. The SSC, believed to be the largest hybrid maize seed supplier in the country, distributes 80% of its seed through private dealers in the south and mostly through district government agencies in the north. The district government agencies are usually responsible for implementing the central government's subsidized maize seed distribution program, which is aimed at promoting the use of hybrid maize and other new production technologies. Sales to local distributors usually involve a part-cash, part-credit payment agreement.

Seed Prices and Market Shares

Table 10 shows the difference between the price of maize seed from the public and private sectors. Seed of public-sector, single-cross hybrids costs an average of VND 15,500/kg (US$ 1.15/kg) and is about 56% cheaper than single crosses from the private sector, which have an average price of VND 35,000/kg (US$ 2.80/kg). Double-cross and three-way-cross hybrids are similarly priced within each sector, but the price varies between the two sectors. Double- and three-way-crosses from the public sector are cheaper by about 34%, with an average retail price of VND 14,500/kg (US$ 1.07/kg); those from the private sector cost around VND 21,500/kg (US$ 1.72/kg). The price differences are more obvious in terms of seed-to-grain price ratios. While the cost of hybrid seed from the private sector is 10-20 times higher than the maize grain price, that of public hybrids is 7 times the grain price.

Attractive prices and a well-established sales network have helped the public agencies secure about 51% of the total improved OPV and hybrid maize seed market. The market leader is NMRI, with 26% of the market, followed closely by Bioseed Genetics Vietnam and CP Seeds. These three companies control almost 70% of the commercial maize seed market in Vietnam. On average, the public and private sectors provide about 3,000 and 2,500 t, respectively, of maize seed annually.

The private sector controls almost 53% of the hybrid maize seed market, as against 47% by the public agencies. In the future, the extent of public- and private-sector activity in Vietnam's maize seed industry will depend on the sustainability and profitability of the market, given the overall policy environment provided by the government.

Key Issues

Improving Maize Productivity

Vietnam has recorded impressive gains in its maize economy since the 1970s, particularly with regard to maize hybrid technology. These gains were achieved primarily because of the government's vigorous effort to promote hybrids through sustained investment in hybrid maize research, subsidies for seed production and distribution, improvements in agricultural production and marketing infrastructure, and aggressive extension campaigns that educated farmers about the advantages of adopting hybrids. At present, the government provides public research institutions and farmers a production subsidy of about VND 8-10 million (US$ 590-740) per ton of hybrid maize grain produced, in addition to a subsidy of VND 2,000-5,000 (US$ 0.15-0.37) per kilogram of seed to farmers, especially to encourage production in marginal environments. The subsidy provides farmers producing hybrid seed with financial support to cover the cost of parent stock, material inputs such as fertilizers and pesticides and irrigation fees. With such financial and technical assistance from the government, both small- and large-scale farmers have adopted hybrid maize production.

According to Bui Thi Dan *et al*. (1998), maize production in Vietnam can be further promoted in several ways. Maize cultivation can be concentrated in more favorable areas where there is good irrigation and drainage (especially for the winter maize crop), and more maize seed, especially hybrid seed, can be produced at a lower cost in the provinces. Farmers can be further encouraged (through extension and other means) to adopt new production techniques, including hybrid maize, and to use better practices to minimize post-harvest losses. In addition, various maize and maize-based consumer products can be developed and promoted.

Intellectual Property Rights

Despite the impressive gains achieved in the use of hybrid maize, the maize seed industry in Vietnam may be entering a difficult period. As in any other developing country in Asia, the lack of effective plant variety protection laws makes it difficult for private companies to safeguard their materials. While the private sector has established a strong presence in Vietnam with the introduction of many excellent hybrids, the lack of an effective intellectual property law discourages many private companies from introducing their very best products. Several leading multinational seed companies that are active elsewhere in the region have decided not to enter the Vietnam maize seed market until the intellectual property rights issue is resolved.

Equity in the Seed Industry

Current government policies also raise questions about fairness. There is a perception among private companies that they have to compete with government agencies that not only receive subsidies but also benefit from favorable regulatory treatment. It is expected that the government will soon require commercial maize seed importers to establish their own seed research and production facilities in Vietnam. They will be given two or three years to establish local production facilities, during which time they will be allowed to import a limited amount of maize seed for sale in the domestic market. Private companies may not want to establish local breeding and production facilities because it will be difficult to secure parent lines and production costs will be higher in this low-volume seed market. In view of this situation, private companies operating in Vietnam are reassessing their long-term priorities and overall marketing strategies.

What lessons can be learned from Vietnam's maize seed industry? The Vietnamese experience is interesting because the national maize program has released, produced and sold commercial hybrids in direct competition with the private sector. In the short run, this competition has benefited maize farmers as seed of superior hybrids has become widely available, often at extremely low prices. Over the longer term, however, private companies may not be willing or able to continue to compete against a public sector that benefits from government support in the form of financial subsidies and favorable regulatory treatment. If the private companies scale back their activities because it is simply too difficult to do business in Vietnam, the maize seed industry will revert to being a government monopoly. In that case, the range of technology available to farmers may become severely restricted.

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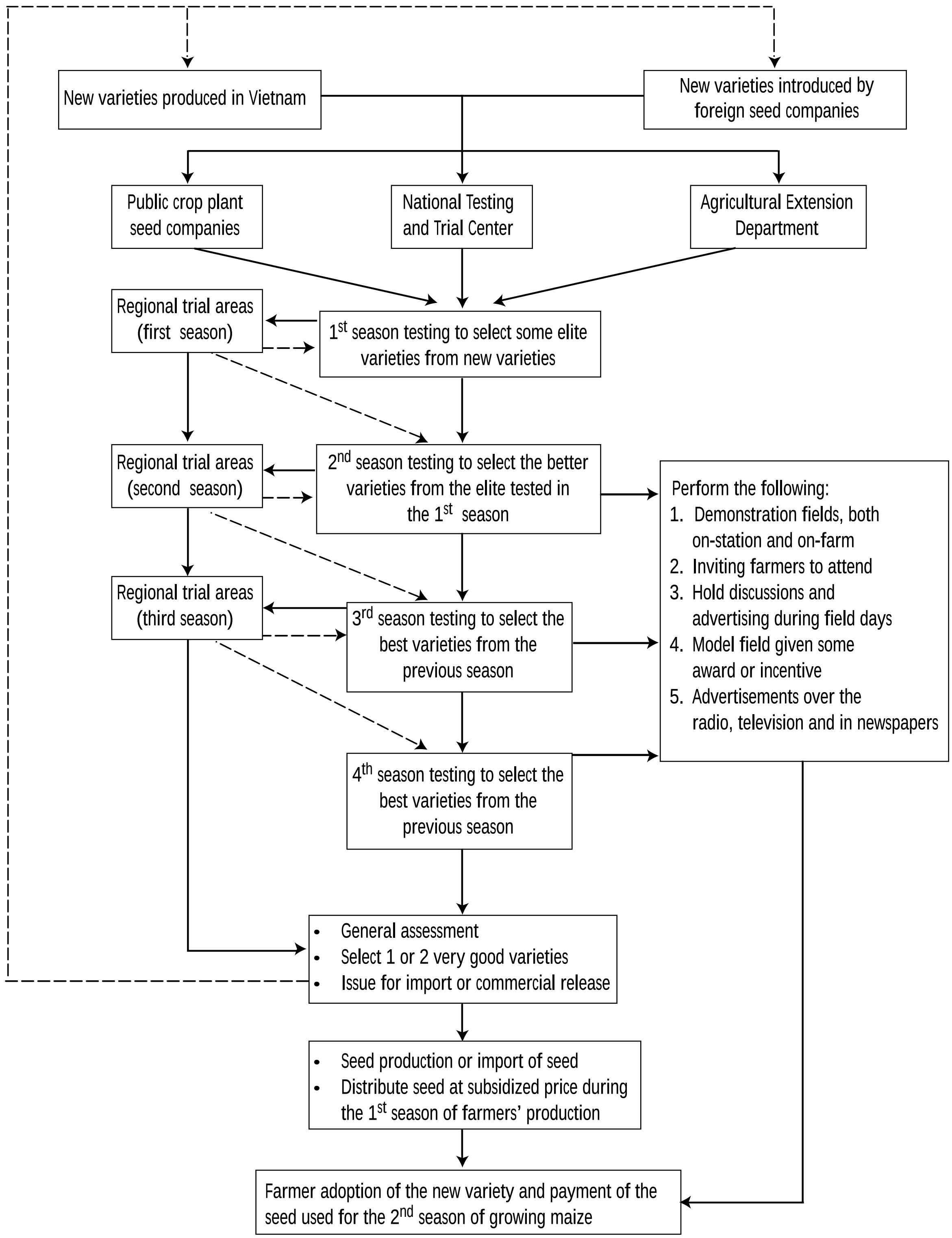
Annex 1

CLASSIFICATION OF SELECTED PROVINCES INTO MAIZE PRODUCTION ZONES/SYSTEMS, VIETNAM

Subsistence systems		Commercial systems			
Mountainous region	**Central coast**	**Highlands and midlands**	**Red River Delta**	**Southeastern region**	**Mekong River Delta**
Ha Giang	Ha Tinh	Son La	Ha Noi	HCM City	Long An
Tuyen Quang	Quang Binh	Hoa Binh	Hai Phong	Binh Phuoc	Dong Thap
Cao Bang	Quang Tri	Phu Tho	Ha Tay	Binh Duong	An Giang
Lang Son	Thua Thien	Vinh Phu	Hai Duong	Tay Ninh	Tien Giang
Lai Chau	Qnam Dnang	Bac Giang	Hung Yen	Dong Nai	Ben Tre
Lao Cai	Quang Ngai	Bac Ninh	Thai Binh	Baria Vtau	Vinh Long
Yen Bai	Binh Dinh	Gia Lai	Ha Nam		Tra Vinh
Thai Nguyen	Phu Yen	Kon Tum	Nam Dinh		Can Tho
Bac Can	Khanh Hoa	Dac Lac	Ninh Binh		Soc Trang
Quang Ninh	Ninh Thuan	Lam Dong	Thanh Hoa		Kien Giang
	Binh Thuan		Nghe An		Minh Hai

Annex 2

Scheme of Testing and Recommendation of New Varieties in Vietnam



Source: Do Hai Dien (1997).

Annex 3

Maize cultivars released in Vietnam, 1966-97/98

Cultivar name	Year of release	Type of material	Owner	Grain color	Grain texture	Important industrial trait	Days to maturity	Ecological niche	Contains CIMMYT materials	CIMMYT material used	Use of CIMMYT material	Commercial success?
HS36	1973	OPV	PUB	–	SD	–	–	TL	Yes	POP36	11	No
TH2A	1976	OPV	PUB	Y	SF	–	110-120	TL	No	–	–	No
TH2B	1977	OPV	PUB	Y	SF	–	110-120	TL	No	–	–	No
VM1	1980	OPV	PUB	WH	D	–	120-135	TL	Yes	POP 21, V.524	11	Yes
HLS	1985	OPV	PUB	Y	SF	–	90	TL	No	–		No
MSB31	1985	OPV	PUB	Y	F	–	–	TL	Yes	POP31	11	Yes
DL11	1986	OPV	PUB	Y	SF	–	–	TL	–	–	–	Yes
MSB26	1986	OPV	PUB	Y	SF	–	–	TL	Yes	POP26	11	Yes
MSB49	1986	OPV	PUB	WH	D	–	100-110	TL	Yes	POP49	12	Yes
TSB1	1986	OPV	PUB	Y	SD	–	115-130	TL	No	–	–	No
TSB2	1987	OPV	PUB	Y	SF	–	100-115	TL	No	–	–	No
G-45	1988	SC	PRIV	Y	SF	–	100-110	TL	–	–	–	Yes
G-49	1988	SC	PRIV	Y	SF	–	100-110	TL	–	–	–	Yes
HL 31	1988	OPV	PRIV	Y		–	–	TL	–	–	–	No
PI-3011	1988	SC	PRIV	Y	SF	–	100-110	TL	No	–	–	Yes
PI-3012	1988	SC	PRIV	Y	SF	–	100-110	TL	No	–	–	Yes
HL24	1988	OPV	PUB	Y	SF	–	–	TL	–	–	–	Yes
Pool 17B	1988	OPV	PUB	Y	–	–	–	TL	Yes	POOL17	–	–
Pool 18	1988	OPV	PUB	Y	–	–	–	TL	Yes	POOL18	–	–
Q1	1988	OPV	PUB	Y	–	–	–	TL	Yes	POP63	–	–
Q2	1988	OPV	PUB	Y	SD	–	100-115	TL	Yes	POP28	11	No
HL36	1989	OPV	PUB	Y	SD	–	90	TL	Yes	POP36	–	No
NEPTH	1989	OPV	PUB	WH	–	–	<100	TL	No	–	–	No
LD 1	1990	TC	PUB	Y	SF	–	–	TL	–	–	–	Yes
LD 2	1990	TC	PUB	Y	SF	–	–	TL	–	–	–	Yes
LD 3	1990	TC	PUB	Y	SF	–	–	TL	–	–	–	Yes
Pop 28	1990	OPV	PUB	Y	SD	–	–	TL	Yes	POP28	11	Yes
Pop 28 x TSB1	1990	OPV	PUB	Y	SD	–	–	TL	–	–	–	Yes
Pop 28 x TSB2	1990	–	PUB	Y	SF	–	–	TL	Yes	POP28, Suwan2	–	Yes
Q 63 (QPM)	1990	OPV	PUB	WH	–	QPM	–	TL	Yes	POP63	11	Yes
CP-DK888	1991	SC	PRIV	Y	SD	–	100-120	TL	No	–	–	Yes
LS3	1991	–	PUB	–	–	–	110-120	TL	Yes	POP49	11	–
LS4	1991	–	PUB	–	–	–	100-110	TL	Yes	POP28	21	–
LS5	1991	–	PUB	–	–	–	100-110	TL	–	–	–	–
LS6	1991	–	PUB	–	SD	–	110-120	TL	Yes	POP28	21	–
LS7	1991	–	PUB	–	–	–	120-135	TL	Yes	POP28	11	–
LS8	1991	–	PUB	–	SF	–	120-135	TL	–	–	–	–
LVN1	1991	SC	PUB	–	SF	–	100-110	TL	–	–	–	–
LVN11	1991	TC	PUB	–	SF	–	110-120	TL	–	–	–	–
LVN16	1991	SC	PUB	–	–	–	120-135	TL	–	–	–	–
LVN19	1991	SC	PUB	–	–	–	120-135	TL	–	–	–	–
LVN32	1991	TC	PUB	–	–	–	100-110	TL	–	–	–	–
9670	1992	DC	PRIV	Y	SD	–	100-110	TL	No	–	–	–
CP-DK999	1992	SC	PRIV	Y	F	–	100-110	TL	No	–	–	No
LVN6	1993	SC	PUB	Y	SD	HS	110-120	TL	Yes	POP31	21	No
CV1	1994	OPV	PUB	–	SF	–	–	TL	Yes	POP28	11	–
LVN10	1994	SC	PUB	Y	SF	HS	120-135	TL	No	–	–	Yes
LVN12	1994	DTC	PUB	Y	SF	–	110-120	TL	Yes	POP28	21	Yes
VN1	1994	OPV	PUB	Y	SF	HS	110-120	TL	Yes	POP21, V.54	11	No
9681	1996	DTC	PRIV	Y	SF	–	100-105	TL	No	–	–	–
9696	1996	TWC	PRIV	Y	F	–	110-115	TL	Yes	POP28	21	New
919V	1996	mod SC	PRIV	Y	SF	–	105-110	TL	No	–	–	–
LVN20	1996	SC	PUB	Y	D	HS	100-110	TL	Yes	POP49,26	11	Yes
LVN5	1996	DTC	PUB	Y	SF	HS	100-110	TL	Yes	POP28	21	Yes
MSB2649 (VIAMIT)	1996	OPV	PUB	Y	D	HS	100-110	TL	Yes	POP49	11	No
VN2 (waxy)	1996	OPV	PUB	WH	GLUT	–	<100	TL	No	–	–	Yes
9698	1997	SC	PRIV	Y	F	–	90-93	TL	Yes	POP28	21	New
9636	1998	TWC	PRIV	Y	SF	–	100-105	TL	Yes	POP28	21	New
LVN17	1998	SC	PUB	Y	SF	HS	110-120	TL	No	–	–	Yes
LVN18	1998	DTC	PUB	–	SD	–	110-120	TL	–	–	–	–
LVN26	1998	SC	PUB	–	SF	–	100-110	TL	Yes	POP26	21	–
LVN4	1998	SC	PUB	Y	SF	HS	110-120	TL	No	–	–	Yes
MX1	1999	SC	PUB	Y	F	–	90	TL	No	–	–	–
TSB3 (sweet corn)		OPV	PUB	–	–	–	–	TL	–	–	–	–

Note: Type of material: OPV = open-pollinated variety; CH = conventional hybrid; SC= single-cross hybrid; mod SC = modified single-cross hybrid; DC = double-cross hybrid; TWC = three-way-cross hybrid; DTC = double-top-cross hybrid; TC = top-cross hybrid. Owner: PRIV = private material; PUB = public material. Grain color: Y = yellow; WH = white. Grain texture: F = flint; SF = semi-flint; D = dent; SD = semi-dent; GLUT = glutinous. Ecological niche: TL = tropical lowland. Use of CIMMYT material: 11= population, pool or experimental variety used as basic germplasm (substantial improvement done after receipt from CIMMYT); 21= inbred line or hybrid used in pedigree program (substantial improvement done after receipt from CIMMYT). Important industrial trait: QPM = quality protein maize; HS = high starch.