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Current Status and **Impacts** of Past Investments Made by the Public and Private Sectors, 1966-97

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Rashid M. Hassan, Mulugetta Mekuria, and Wilfred Mwangi*

Economics Program
International Maize and Wheat Improvement Center
CIMMYT

* R.M. Hassan is a Professor, Natural Resources and Agricultural Economics, Department of Agricultural Economics, Extension, and Rural Development, University of Pretoria, South Africa, and Affiliate Scientist, CIMMYT Economics Program. Mulugetta Mekuria is a Senior Scientist, CIMMYT Economics Program, Harare, Zimbabwe. Wilfred Mwangi is a Principal Scientist, CIMMYT Economics Program, Addis Ababa, Ethiopia

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Abstract: This report documents the impacts of international maize breeding research in eastern and southern Africa. It draws on information from a comprehensive 1998/99 survey of public and private maize breeding and seed production organizations active in the region. In many countries of eastern and southern Africa, policy reforms introduced in the 1980s and 1990s encouraged private sector participation in the maize seed industry. The private sector now supplies most of the maize seed in the region, spends more on research, and generates a larger number of maize releases than the public sector. Hybrids dominate varietal releases and seed sales, a trend that may negatively affect subsistence-oriented farmers who lack resources to buy fresh seed every season. Although farmers' adoption of improved maize varies throughout the region, it has increased steadily. Survey data show that CIMMYT's maize breeding program has had significant impacts in eastern and southern Africa, especially in recent years. Of the maize varieties released in the region since 1990, 31% (55% if South Africa is excluded) were developed using CIMMYT breeding materials. In 1996, more than 1.6 million hectares in eastern and southern Africa were planted to varieties developed using CIMMYT germplasm. The varietal release data and adoption data indicate growing demand for CIMMYT breeding materials from both public and private breeding programs, as well as growing acceptance by farmers of varieties developed using those materials.

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Contents

Tables

Figures

Executive Summary

In 1997, the International Maize and Wheat Improvement Center (CIMMYT) launched a major study designed to document the impacts of international maize breeding research in developing countries. The study was intended to update and extend the findings of CIMMYT's first global research impacts study, which had been published three years earlier in a report entitled *Impacts of International Maize Breeding Research in the Developing World, 1966-90* (López-Pereira and Morris 1994). Given the enormity of the data collection task, the follow-up study was divided into three regional studies—one each for Latin America, Asia, and sub-Saharan Africa. The sub-Saharan Africa study focused specifically on eastern and southern Africa; a separate impacts study for western and central Africa was conducted by the International Institute for Tropical Agriculture (IITA), which holds the mandate for maize germplasm improvement work in that region. This report presents the results of the eastern and southern Africa study.

The results presented in this report are based on information collected during 1998 and 1999 through a comprehensive survey of public and private maize breeding organizations and seed production agencies in 12 countries of eastern and southern Africa. The survey collected information on many aspects of maize research, seed production, and seed distribution (e.g., maize breeding activities, products of breeding programs, maize seed production and sales operations, seed industry regulations and policies). The countries covered by the survey accounted for more than 95% of all maize produced in the region in 1998/99. The organizations contacted as part of the survey currently control about 97% of the total maize seed market in the 12 countries.

Major findings of the study are summarized below.

Policy reforms have led to increased private-sector participation in many national maize seed industries

In many countries of eastern and southern Africa, policy reforms introduced during the 1980s and 1990s have succeeded in liberalizing national maize seed industries by opening up maize seed markets to increased private sector participation. This represents a major change from earlier years, when maize seed industries in most countries throughout the two regions were dominated by public agencies. Major policy reforms have included the lifting of outright bans on private seed companies, removal of restrictions on importation of commercial maize seed, and elimination of direct seed price controls. In a number of countries, however, implicit restrictions in the form of strict seed certification requirements and lengthy varietal registration procedures continue to limit the participation of private firms, both local companies and multinationals. Moreover, governments in some countries still are trying to influence maize seed prices indirectly by subsidizing maize seed production, especially where public agencies continue to operate and control large shares in the seed market.

Rapid growth in private-sector investment in maize breeding research has been accompanied by changes in varietal release patterns

Throughout eastern and southern Africa, private-sector investment in maize breeding research has been growing rapidly. In eastern Africa, public-sector

scientists still significantly outnumber private-sector scientists; in southern Africa, the numbers are roughly equal. Numbers of scientists provide an imperfect measure of total research investment, however, since private seed companies tend to support each scientist with considerably more operating funds. Adjusting for the difference in operating funds, total research investment by the private sector probably exceeds total research investment by the public sector, at least in southern Africa and possibly in eastern Africa as well.

Private-sector maize breeders have on average released a larger number of varieties than public-sector maize breeders. This difference in varietal release rates can be attributed to differences in the quantity and quality of investment, as well as to the commercial orientation of private seed companies compared to public breeding programs, which focus more on non-commercial breeding objectives. The composition of varietal releases reflects steady growth in the role of the private sector; by 1996, all maize varieties released in eastern and southern Africa originated from private seed companies. The recent decline in public-sector varietal releases also reflects reductions in public funding for agricultural research that have occurred in many countries in the region.

Increased private-sector participation in the maize seed industry has been accompanied by greater concentration of the industry

During the 1990s, the private sector effectively took over the seed supply function throughout most of eastern and southern Africa. In 1996, the most recent year for which complete data are available, private seed companies controlled more than 97% of all commercial maize seed sales in the region. Efforts to privatize maize seed markets were thus largely successful. It is important to note, however, that in a number of major maize producing countries (e.g., Kenya, Zambia, Zimbabwe), the leading private seed company is simply a transformed version of a previously public or parastatal seed agency that had long monopolized the local seed market. In several instances, these privatized parastatals continue to control more than 80% of the national seed market.

With privatization, the maize seed industry is becoming more concentrated as a relatively small number of large multinationals acquire, merge with, or buy large shares in local seed companies. While consolidation could lead to scale economies, reduced competition is a concern to farmers, who worry that they may eventually face restricted choices and have to pay higher prices. The fact that seed prices in many countries have not risen significantly may reflect continued attempts by governments to keep maize seed prices affordable by subsidizing public seed production agencies.

Hybrids now dominate varietal releases and seed sales

With the emergence of a flourishing private seed industry, the share of hybrids in varietal releases and seed sales has risen steadily. Coupled with the fact that public breeding programs are also concentrating increasingly on hybrids, this has led to a situation in which varietal releases and seed sales are now completely dominated by hybrids. This could have negative impacts on small-scale subsistence-oriented farmers, many of whom may lack the resources needed to buy fresh seed every season. To date, little empirical evidence has emerged to indicate that small-scale farmers have been adversely affected by the shift to hybrids, but the matter will require careful attention, because supplying seed to smallholders may not be of interest to profit-motivated private firms.

Adoption of improved maize varieties increased during the 1990s

Commercial maize seed sales data support estimates made by researchers and seed industry insiders that adoption of improved varieties increased steadily during the 1990s in eastern and southern Africa. However, adoption patterns have differed between countries and regions. Total sales of improved maize seed have fluctuated around 20,000 tons per year in eastern Africa, whereas in southern Africa total seed sales grew steadily in the early 1990s, peaking in 1992 at just under 100,000 tons before declining. Within individual countries, the percentage area planted to improved maize seed varies from less than 10% to nearly 100% in several major maize producing countries. The variability between countries in adoption rates can be attributed to differences in economic, institutional, and policy factors that affect the availability and affordability of improved seed.

Use by researchers of CIMMYT germplasm continues to increase, as does adoption by farmers of CIMMYT-derived varieties

CIMMYT's maize breeding program has had significant impacts in eastern and southern Africa, especially in recent years. Of all maize varieties released by public and private breeding programs since 1966, about 24% (35% if South Africa is excluded) were developed using CIMMYT source materials. Use of CIMMYT germplasm showed a strong positive growth over time; of the varieties released since 1990, over 31% (55% if South Africa is excluded) were developed using CIMMYT source materials. In 1996, more than 1.6 million ha in eastern and southern Africa were planted to varieties that had been developed using CIMMYT germplasm, representing over 20% of the area planted to modern varieties. Excluding South Africa, where farmers grow mainly temperate materials not targeted by CIMMYT's breeding program, nearly 37% of the area planted to modern varieties in eastern and southern Africa was planted to varieties containing CIMMYT germplasm. Taken together, the varietal release data and the adoption data indicate growing demand for CIMMYT source materials on the part of public and private breeding programs, as well as growing acceptance by farmers of varieties developed using those materials. The observed growth in demand for and use of CIMMYT germplasm in eastern and southern Africa over recent years validates the decision by the CIMMYT Maize Program to establish regional maize breeding programs in eastern and southern Africa and to allocate increased resources to local adaptive breeding.

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Introduction

Motivation and Objectives of the Study

The International Maize and Wheat Improvement Center (CIMMYT) holds a global mandate to increase maize production and boost the productivity of maize-based cropping systems in developing countries. In pursuing this mandate, CIMMYT collaborates with many public, private, and non-governmental organizations (NGOs) involved in technology development and diffusion activities. A crucial component of CIMMYT's strategy is to develop and distribute improved maize germplasm through an international network of maize breeding and seed production organizations.

During the early 1990s, CIMMYT carried out a study designed to document the impacts of international maize breeding research in developing countries, the results of which were published in 1994 in a report entitled *Impacts of International Maize Breeding Research in the Developing World, 1966-90* (López-Pereira and Morris 1994). The objectives of the study were to document—for CIMMYT, its collaborators, and the donor community—the impacts of international maize breeding efforts in developing countries. The study generated a wealth of useful information about levels of investment in maize breeding research, the spread of modern varieties throughout the developing world, and farm-level impacts of varietal adoption.[1]

In subsequent years, CIMMYT's maize research impacts database served as an important source of information for organizations involved in maize research and development activities. Based on the continuing strong demand for this information, the decision was taken to update and expand the database periodically. Accordingly, a follow-up study was launched in 1997. An additional factor motivating the follow-up study was the need to include more and better data from the private sector, given that limited effort was made during the first study to comprehensively survey private seed companies.

Given the enormity of the data collection task, the follow-up study was divided into three regional studies—one each for Latin America, Asia, and sub-Saharan Africa. The sub-Saharan Africa study focused specifically on eastern and southern Africa;

[1] Throughout this report, the term *varieties* is used in a generic sense to refer to both open-pollinated varieties and hybrids. The term *OPVs* refers much more specifically to open-pollinated varieties that have been improved by a breeding program.

a separate study focusing on western and central Africa was conducted by the International Institute for Tropical Agriculture (IITA), which holds the mandate for maize improvement work in that region. This report presents the results of the eastern and southern Africa study.

The objectives of the eastern and southern Africa regional impacts study resembled those of the Latin American and Asian regional impacts studies:

- to estimate the level of public and private sector investment in maize breeding research;
- to document the germplasm outputs of public and private maize breeding programs;
- to document the use of CIMMYT source materials by public and private maize breeding programs; and
- to estimate the rate of farm level adoption of improved maize germplasm.

Data Collection

The information and analysis presented in this report are based on data collected in 1998 and 1999 through a comprehensive survey of research organizations and seed production agencies located throughout eastern and southern Africa. A structured questionnaire was used to gather information about each organization's maize research activities, maize seed production activities, and/or maize seed distribution activities. Secondary sources also were tapped for additional information about seed regulations and seed policies.

The survey covered 12 countries (Table 1). Collectively, these countries include more than 90% of the total area planted to maize in eastern and southern Africa and account for more than 95% of all maize produced in the region. All major public organizations that engage in maize improvement research and/or seed production were contacted,

Table 1. Coverage of the 1998/99 CIMMYT maize research impacts survey, eastern and southern Africa

Country-region	Public agencies		Number of private seed companies	Total agencies surveyed	Share of formal seed sales (%) in 1996
	Number of research organizations	Number of seed companies			
Ethiopia	1	1	2	4	100
Kenya	1	0	3	4	96
Uganda	1	0	1	2	100
Eastern Africa	3	1	6	10	96
Angola	1	1	2	4	81
Lesotho	1	0	1	2	50
Malawi	1	0	1	2	83
Mozambique	1	0	1	2	100
South Africa	1	0	7	8	100
Swaziland	1	0	1	2	52
Tanzania	1	1	2	4	78
Zambia	1	0	2	3	100
Zimbabwe	1	0	5	6	100
Southern Africa	9	2	22	33	97
Southern Africa, excluding South Africa	8	2	15	25	93
Eastern and southern Africa	12	3	28	43	97
Eastern and southern Africa, excluding South Africa	11	3	21	35	94

Source: CIMMYT Maize Research Impacts Survey, 1998/99.

as were 31 private seed companies (including all of the industry leaders). Between them, these organizations controlled 97% of the total maize seed market in 1996. The survey could not be administered in a few countries due to civil strife, but given that these countries account for a negligible proportion of total regional maize area and production, the omissions are of minimal significance.

Data collection proceeded in stages. First, copies of the questionnaire were mailed to directors of national maize research programs and to senior researchers (mainly plant breeders) in public seed agencies and private seed companies. After the respondents had been given time to review the questionnaire and assemble information, they were personally interviewed, in most cases by one or more of the study authors, and in a few cases by experienced non-CIMMYT researchers. Following the interviews, data recorded in the questionnaires were extensively cross-checked for accuracy and consistency. During this process, staff of the CIMMYT Maize Program helped to resolve numerous questions related to the genetic backgrounds of commercial varieties. In a number of cases, the original respondents were contacted a second time to clear up inconsistencies.

The Maize Economy of Eastern and Southern Africa

Maize dominates the food economy of eastern and southern Africa, where it is by far the dominant staple crop grown by the vast majority of rural households.

Maize Production Environments

Maize in sub-Saharan Africa is produced in a wide range of production environments. Based on agro-climatic factors and grain maturity characteristics, the CIMMYT Maize Program has identified eight distinct maize production environments, known as *mega-environments*:

- Tropical lowlands
- Tropical mid-altitude zones
- Tropical highlands
- Subtropical lowlands
- Subtropical mid-altitude zones
- Subtropical highlands
- Subtropical winter zones
- Temperate / subtropical zones

These eight mega-environments can be grouped into four basic agro-ecological zones:

1. **Lowland tropical zones** (0-1,000 masl) located in Ethiopia, Kenya, Malawi, Mozambique, Tanzania, Somalia, South Africa, and Zambia cover about 18% of the maize area in eastern and southern Africa. Some areas feature a distinct rainy season, while in other areas rainfall is bimodally distributed. Maize is usually grown as a monocrop or intercropped with grain legumes, sesame, cassava, cowpea, pigeon peas, tomatoes, or rice.
2. **Wet subtropical zones** (900-1,500 masl, >1,000 mm annual rainfall) located in Angola, Burundi, Kenya, Malawi, Mozambique, Rwanda, Swaziland, Tanzania, Uganda, Zambia, and Zimbabwe constitute 49% of the area planted to maize in the region. Rainfall generally decreases as altitude increases. Some areas are characterized by bimodally distributed rainfall, which enables two maize crops to be grown each year. Soils range from deep fertile soils along river bottoms and in lake basins to well drained and easily worked upland soils.
3. **Dry subtropical zones** (900 –1,500 masl, < 1,000 mm annual rainfall) located in Ethiopia, Kenya, Tanzania, Uganda, and Zimbabwe constitute 16% of the area under maize in eastern and southern Africa. These zones are characterized by unreliable and inadequate rainfall, which discourages farmers from investing in inputs such as improved seed and chemical fertilizer.

4. **Highland zones** (>1,800 masl) located in Burundi, Ethiopia, Kenya, Lesotho, Rwanda, South Africa, Tanzania, and Uganda cover about 16% of the total area planted to maize in eastern and southern Africa. Highland zones are endowed with adequate to excessive rainfall, cool temperatures, and long growing seasons. The soils are highly fertile, well drained, and have high organic matter content.

Maize Production and Consumption Trends

Maize production statistics for sub-Saharan Africa show pronounced variability through time, reflecting the vulnerability of Africa's mostly rainfed maize production systems to extremely unpredictable weather patterns (Table 2). Disregarding short-term variability, over the longer term the area planted to maize has been expanding in eastern and southern Africa, growing at an annual average rate of 1.8% from 1961-70 before accelerating to 2.5% during the 1991-97 period. In contrast, no clear long-term pattern has been discernible in western and central Africa; during the past four decades, the area planted to maize in this region alternately expanded and contracted.

Maize yield growth has been similarly variable (Table 2). Throughout sub-Saharan Africa, annual growth in maize yields fluctuated around 1% during the 1960s and 1970s before accelerating noticeably during the 1980s and 1990s. In eastern and southern Africa, particularly large yield increases were realized during the mid- and late 1990s as maize production recovered from the devastating drought that affected southern Africa in 1991/92. During the latter part of the 1990s, El Niño-related weather phenomena again disrupted maize production in a number of countries, especially in southern Africa, but on the whole the effects were less devastating than expected.

Maize production trends reflect combined effects of area and yield variability (Table 2). In eastern and southern Africa, periods of unfavorable weather have often been followed by periods of favorable weather, which has served to reduce the variability in production growth over the longer term. For eastern and southern Africa as a whole, maize production growth averaged about 2.2% throughout most of the 1960s, 1970s, and 1980s before accelerating sharply during the 1990s. Production growth has been much more variable in western and central Africa and actually fell to negative levels during the 1970s as a result of the Sahelian drought.

Consumption of maize is high throughout most of the region, reflecting its role as the primary food staple (Table 3). Maize accounts for over 50% of total calories consumed in eastern Africa and 30% of total calories consumed in southern Africa. In southern Africa, per capita annual consumption of maize averages more than 100 kg in several countries, including Lesotho (149 kg), Malawi (181 kg), South Africa (195 kg), Swaziland (138 kg), Zambia (168 kg), and Zimbabwe (153 kg) (CIMMYT 1999). In eastern Africa, per capita annual consumption is somewhat lower, ranging from a low of 40 kg in Burundi to a high of 105 kg in Kenya.

Table 2. Trends in maize area planted, yield, and production, 1961-97 (% annual growth)

	1961-70			1971-80			1981-90			1991-97		
	Eastern and southern Africa	Western and central Africa	All developing countries	Eastern and southern Africa	Western and central Africa	All developing countries	Eastern and southern Africa	Western and central Africa	All developing countries	Eastern and southern Africa	Western and central Africa	All developing countries
Area	1.8	0.9	2.0	0.4	-0.8	0.8	1.6	10.2	1.5	2.5	-0.9	1.4
Yield	0.7	1.9	2.8	1.9	0.4	3.0	0.5	3.3	1.6	3.6	2.5	1.9
Production	2.4	2.8	4.8	2.3	-0.4	3.8	2.1	13.4	3.1	6.1	1.7	3.3

Source: FAOSTAT online database.

Table 3. Maize imports, consumption, and utilization, 1994-96

	Eastern and southern Africa	Western and central Africa	All developing countries	World
Net imports (000 t), 1994-96	-588	119	27,937	-
Per capita net imports (kg/yr), 1994-96	-2	<1	6	-
Per capita consumption (kg/yr), 1994-96	79	43	66	98
Growth in consumption per capita (%/yr), 1987-96	-0.7	1.7	2.6	0.9
Percentage used for human consumption, 1994-96	73	95	30	17
Percentage used for animal feed, 1994-96	18	NA	56	66

Note: NA = Not available.
Source CIMMYT (1999).

Maize Breeding Research and Seed Supply

In eastern and southern Africa, as in other developing regions, seed of modern maize varieties reaches farmers through the efforts of many different organizations, including public national research institutes, public and parastatal seed production agencies, private multinational and national seed companies, public international agricultural research centers, NGOs, and farmer cooperatives. Over the years as the institutional and policy environment has evolved, some division of labor has emerged, and many of these organizations have become quite specialized.

Policies Affecting National Maize Seed Industries

During the 1980s and 1990s, many countries in eastern and southern Africa made significant progress in liberalizing and restructuring their maize sectors. Policy and institutional reforms targeted both output markets (markets for maize grain) as well as input markets (markets for maize seed). Reform of maize grain markets started earlier, however, and therefore has gone on longer.

The distinction between output and input markets is important, because reforms needed to restructure grain markets often differ from those required to induce desired changes in seed markets. In attempting to reform output markets, policy makers are interested mainly in the welfare of consumers, given the importance of maize as the major food staple for the vast majority of the population. In the case of input markets, policy makers are interested mainly in the welfare of producers, since improved maize seed is a key component of maize production technology. The distinction is to some extent arbitrary, however, because output and input markets are linked, directly and indirectly. For instance, efforts to help consumers by imposing a ceiling on grain prices represent a disincentive to maize farmers; if price controls reduce the profitability of maize production, farmers may respond by reducing the area planted, which in turn will depress the demand for seed and reduce availability of maize grain to consumers. Similarly, improved seed is an important input in maize production, the price of which directly influences production costs and hence farmers' income. Thus the availability and price of maize seed influence farmers' production decisions, which in turn affect the total supply of grain maize and determine its price and availability to consumers.

Given the importance of seed as a key technology component, the maize seed industry often receives special attention from policy makers (Tripp 1998, Pray and Tripp 1998). In eastern and southern Africa, as in many regions of the world, targeted institutional and policy provisions are in place to ensure that national seed industries perform well. For example, varietal registration and seed certification are mandatory in most countries, ostensibly to control the genetic and physical purity of commercial seed sold to farmers. Moreover, policies related to restricting or increasing participation in the seed industry, foreign investment and trade in commercial seed, price controls and intellectual property rights for protection of germplasm ownership are the norm.

How have national maize seed industries in eastern and southern Africa been affected by recent changes in the prevailing policy environment? Private seed companies are currently operating in all of the surveyed countries. The presence of an active private seed industry reflects a fundamental shift in policy, as private-sector participation was legally proscribed in most countries until recently. However, implicit restrictions limiting the participation of private seed companies are still in place in most countries. Barriers to entry faced by private firms include lengthy varietal registration procedures and mandatory seed certification requirements (Table 4).

One important policy change affecting national maize seed industries in all of the surveyed countries has been the lifting of restrictions on the importation of commercial maize seed. This change promises to be particularly beneficial for small countries in which the limited size of the seed market makes establishment of local seed production capacity uneconomic. It may also benefit countries in which multinational firms have refrained from selling their best hybrids for fear of losing the valuable inbred lines to competitors. In several countries, however, commercial seed imports are still subject to import duties; if these duties are passed along in the form of higher prices, imported seed may be unaffordable for many farmers. While direct controls on maize seed prices have significantly diminished, governments in some countries continue to attempt to influence seed prices indirectly, for example by subsidizing the price of seed produced by public agencies.

The recent policy reforms are encouraging, but one area in which significant progress has yet to be made is in the area of intellectual property rights. As of 1998, no country in eastern and southern Africa was a signatory to the International Union for the Protection of New Varieties (UPOV) agreement, although several countries had enacted plant varietal protection laws or had extended patent protection statutes to plant varieties and/or plant genetic materials (Table 4). Yet even if intellectual property regimes relating to plant germplasm are still relatively undeveloped, some organizations are successfully using legal measures to appropriate benefits from investments in breeding research. For example, in Malawi, Mozambique, South Africa, and Tanzania, public research institutes collect royalties from private companies on the use of public varieties.

Table 4. Policies affecting national maize seed industries, eastern and southern Africa, 1998

Country/region	Seed price control	Public seed production	Seed imports allowed	Mandatory seed certification	Plant variety protection laws on maize	Plant patents for maize	Varietal registration required	Average time needed for completing registration	Royalties on public material
Eastern Africa:									
Ethiopia	-	Yes	Yes	Yes	Yes	Yes	Yes	3	No
Kenya	-	No	Yes	Yes	Yes	Yes	Yes	3	No
Uganda	-	No	Yes	Yes	No	No	Yes	-	No
Southern Africa:									
Angola	-	-	-	-	-	-	-	-	-
Lesotho	-	Yes	Yes	Yes	No	No	Yes	0.5	No
Malawi	No	No	Yes	No	No	No	No	3	No
Mozambique	-	No	Yes	Yes	No	No	No	3	Yes
South Africa	-	No	Yes	Yes	No	No	Yes	2	Yes
Swaziland	No	No	Yes	No	Yes	No	Yes	1	Yes
Tanzania	No	No	Yes	Yes	No	No	Yes	-	No
Zambia	-	Yes	Yes	Yes	Yes	Yes	Yes	1.5	No
Zimbabwe	-	No	Yes	Yes	No	No	Yes	4	Yes

Source: CIMMYT Maize Research Impacts Survey, 1998/99.

Structure of National Maize Seed Industries

Following widespread efforts to liberalize national seed industries, today there are only four public maize seed organizations operating in eastern and southern Africa, compared to 47 private seed companies (Table 5). Between 1992 and 1998, the number of public maize seed organizations decreased by nearly half, whereas the number of private maize seed companies more than doubled.

Changes in the relative numbers of public and private seed companies were reflected in a shift in the composition of seed sales. At the beginning of the 1990s, public and parastatal seed agencies accounted for most of the commercial maize seed sold in eastern and southern Africa, but by the latter half of the decade, private companies were supplying about 95% of the total amount sold (just over 90,000 tons were sold in 1996).

In the four countries that still have public seed organizations, only in Tanzania has the importance of the public seed industry declined in the face of growing competition from the private sector. In Angola, Ethiopia, and Uganda, public seed organizations continue to hold sizeable market shares, and private seed companies have made few inroads. The factors that have contributed to the continuing dominance of the public seed industry in these three countries are unique to each country. In Angola, the political atmosphere is not yet ripe for private seed companies to start doing business, mainly due to continuing civil strife. (The eight "private companies" listed for Angola in Table 5 are all NGOs, some of which distribute seed at no cost.) In Ethiopia, policy makers have been unusually reluctant to encourage the emergence of a private maize seed industry. In Uganda, commercial incentives needed to attract private-sector investment have been lacking, and the only maize seed company currently in operation is a public seed production project based at Kwanda Agricultural Research Centre.

The data presented in Table 5 clearly show that except for the four countries mentioned earlier, during the 1990s the private sector assumed control of national maize seed industries throughout most of eastern and southern Africa. It is important to note however, that in several countries (e.g., Malawi, Zimbabwe, Zambia), the leading private seed company is merely a transformed version of what was previously a public or parastatal agency. Since often these public or parastatal agencies had enjoyed monopoly status, their privatization has left the national maize seed market heavily dominated by a single firm. Although the entry of additional private companies is expected to improve industry competitiveness in the future, currently the transformed parastatals remain in control of more than 80% of the national maize seed market in several countries.

The ability of the transformed state and parastatal seed agencies to maintain their dominant position can be explained by a number of factors. At the time of their privatization, these companies inherited well-established networks of seed growers, conditioning and storage facilities, distribution depots, and wholesale and retail distribution networks. Furthermore, these companies enjoyed (and in many cases continue to enjoy) a privileged relationship with the public research systems that have been the source of most of the popular commercial hybrids grown in the region.[2]

The situation is hardly static, however, and indeed the structure of many national maize seed industries continues to change. Since the initial wave of privatization, additional concentration has taken

[2] For a more detailed review of the evolution of maize seed production and marketing in eastern and southern Africa, see Rusike and Smale (1998), Rusike (1998) Howard and Mungoma (1997), Smale and Heisey (1997), Hassan and Karanja (1997), Rusike and Eicher (1997) and Eicher and Kupfuma (1997).

place in several countries as a result of mergers and acquisitions among private companies. Although industrial concentration could be beneficial if it allows seed companies to capture scale economies and to pass the resulting cost savings along to farmers in the form of lower seed prices, industrial concentration could also be harmful if it leads to reduced competition in the seed industry. Reduced competition could allow companies to engage in monopolistic pricing practices, which might threaten the affordability of improved maize seed for the small-scale, subsistence-oriented farmer.

Organization of Maize Research

Many countries in eastern and southern Africa feature very strong public maize breeding programs. Historically, these public breeding programs have played a crucial role in transforming local maize production practices. For example in Kenya, South Africa, and Zimbabwe, public maize breeding efforts began more than 50 years ago, and public breeding programs in these countries continue to be the main source of improved germplasm (see van Rensburg 1994, Byerlee and Jewell 1997, Eicher and Kupfuma 1997, Hassan et al. 1998). Until quite

Table 5. Maize seed organizations and seed sales, eastern and southern Africa, 1996

	Public seed companies			Private seed companies						
					Number in 1996					
Country / region	Number in 1992[a]	Number in 1996	Percentage of seed sales in 1996	Total in 1992	National	Multi-national	Other[b]	Total	Percentage of seed sales in 1996	Total maize seed sales in 1996 (t)
Ethiopia	1	1	92	1	0	1	1	2	8	2,630
Kenya	0	0	0	1	2	2	1	5	100	17,220
Uganda	1	1	0	0	0	0	1	1	100	796
Eastern Africa	2	2	9	2	2	3	3	8	88	20,646
Angola	-	1	74	-	0	0	8	8	26	1,859
Lesotho	0	0	0	4	0	3	1	4	100	1,302
Malawi	0	0	0	2	1	1	1	3	100	3,140
Mozambique	2	0	0	0	1	0	0	1	100	1,780
South Africa	1	0	0	5	3	2	2	7	100	39,257
Swaziland	-	0	0	-	0	3	1	4	100	723
Tanzania	1	1	52	4	0	2	1	3	48	1,340
Zambia	1	0	0	1	2	1	1	4	100	2,600
Zimbabwe	0	0	0	4	2	2	1	5	100	19,000
Southern Africa	5	2	3	20	9	14	16	39	97	71,000
Southern Africa, excluding South Africa	4	2	6	5	6	12	14	32	94	31,743
Eastern and southern Africa	7	4	5	22	11	17	18	47	95	91,646
Eastern and southern Africa, excluding South Africa	6	4	9	17	8	15	16	40	91	52,389

Source: CIMMYT Maize Research Impacts Survey, 1998/99.

[a] CIMMYT (1994).

[b] Mainly NGOs (in Angola and South Africa) and national seed dealers importing seed from multinational companies based in other countries (in the remaining countries).

recently, in almost all of the countries covered by the CIMMYT survey, public breeding programs were the only source of improved maize germplasm adapted to local conditions.

Traditionally, public breeding programs in eastern and southern Africa did not engage directly in seed production. Improved varieties released by public breeding programs were usually handed over to public or parastatal seed agencies, which multiplied seed for sale to farmers. The public and parastatal seed agencies often enjoyed a de facto legal monopoly; regulations restricting the participation of private companies in the maize seed industry were common in almost all countries (López-Pereira and Morris 1994).

Except for Lesotho and Swaziland,[3] all of the countries covered by the CIMMYT survey currently feature public maize breeding programs that engage in varietal development activities (Table 6). Public and parastatal seed organizations no longer engage in varietal improvement research; the four public seed companies still in operation (in Angola, Ethiopia, Tanzania, and Uganda) have eliminated their research divisions and now serve exclusively as the seed multiplication arm of the national breeding program. Half of the private seed companies surveyed (14 out of 28) maintain in-house breeding programs and produce improved germplasm. The rest of the private companies that operate in the region either import seed from foreign affiliates or restrict themselves to multiplying seed of varieties developed by another branch of their company located elsewhere in the region.

Two international agricultural research centers that are members of the Consultative Group for International Agricultural Research (CGIAR) provide support to national maize research programs in Africa: CIMMYT and the International Institute for Tropical Agriculture (IITA). These two centers, whose mandate is to strengthen and support maize research capacity in developing countries, have developed strong linkages with national maize research programs.

Since IITA focuses mainly on western and central Africa, CIMMYT has by far the stronger presence in eastern and southern Africa. Through offices in Ethiopia, Kenya, and Zimbabwe, CIMMYT provides direct and indirect support to national maize programs throughout the two regions. CIMMYT does not provide finished varieties intended for release directly to farmers. Instead, CIMMYT

Table 6. Number of public and private maize breeding programs, eastern and southern Africa, 1998

	Public agencies			
Country / region	Research organizations	Seed companies	Private seed companies	Total agencies surveyed
Ethiopia	1	0	0	1
Kenya	1	0	2	3
Uganda	1	0	0	1
Eastern Africa	3	0	2	5
Angola	1	0	0	1
Lesotho	0	0	0	0
Malawi	1	0	0	1
Mozambique	1	0	1	2
South Africa	1	0	5	6
Swaziland	0	0	0	0
Tanzania	1	0	0	1
Zambia	1	0	1	2
Zimbabwe	1	0	5	6
Southern Africa	7	0	12	19
Southern Africa, excluding South Africa	6	0	7	13
Eastern and southern Africa	10	0	14	24
Eastern and southern Africa, excluding South Africa	9	0	9	18

Source: CIMMYT Maize Research Impacts Survey, 1998/99.

[3] Swaziland's small public breeding program tests varieties released elsewhere (mainly in South Africa) to determine their suitability for Swaziland farmers.

develops and distributes intermediate germplasm products that are designed to be used as inputs into public and private breeding programs.

During the 1960s and 1970s, much of the maize germplasm provided by CIMMYT to national breeding programs in eastern and southern Africa originated from CIMMYT's breeding program in Mexico. After it became evident that materials developed in Mexico required substantial additional selection in order to become adapted to African production environments, in 1985 CIMMYT established a major regional research station in Zimbabwe to strengthen its maize breeding efforts in eastern and southern Africa. The function of the regional breeding program in Zimbabwe is to develop stress-tolerant, high-yielding maize germplasm adapted to the mid-altitude environments of eastern and southern Africa. Germplasm products of the CIMMYT regional breeding program include sources of resistance to prevalent biotic and abiotic constraints, open pollinated varieties, and inbred lines for use in hybrid formation.

Currently more than 100 seed shipments are distributed each year from the CIMMYT Harare program to breeding programs located throughout eastern and southern Africa. These shipments include more than 200 yield trials (each consisting of a set of elite varieties) and several hundred experimental lines. In accordance with standard CIMMYT policy, germplasm developed by CIMMYT is available free of charge to researchers in public and private breeding programs, both within the region as well as elsewhere throughout the world.

Public and Private Investment in Maize Breeding

Managers of public and private maize breeding programs contacted for the CIMMYT impacts survey were asked to provide information about human and financial investments in maize breeding research. In eastern Africa, the number of maize scientists employed in the public sector far exceeds the number employed in the private sector (Tables 7 and 8). In southern Africa, by contrast, the number of scientists employed in the two sectors is very similar. These numbers suggest that maize breeding in eastern Africa remains largely concentrated within the public sector, unlike in southern Africa, where private breeding programs have made considerable advances.

With regards to the intensity of research investment (measured here as the number of research scientists employed per million hectares of maize area planted), significant differences are evident by sector and region. Public research organizations in eastern Africa employ more than twice as many maize scientists per million hectares of maize area planted as public research organizations in southern Africa. This pattern is reversed in the private sector: private breeding programs have concentrated their investments in southern Africa, while largely ignoring eastern Africa.

What can be said about the productivity of maize scientists employed in the public and private sectors? Based on the average number of varieties released, scientists employed in the private sector have been twice as productive as scientists employed in the public sector, both in eastern and southern Africa.[4] The figures can be expected to change, however, as the private seed industry matures. Since private seed

[4] The figures in Tables 7 and 8 may understate the relative productivity of scientists working in the private sector, because the productivity measure for private-sector scientists takes into account only varieties being sold in 1998. By contrast, the productivity measure for public-sector scientists takes into account all varieties released between 1966 and 1998, a much longer period.

Table 7. Human resources invested in maize research, public sector, eastern and southern Africa, 1998

Country / region	Human resources in research (FTE)[a]				Number of non-research support	Total human resources	Number of scientists per million ha maize	Number of cultivars released per senior scientist
	Number of senior scientists	Number of junior scientists	Other	Total				
Ethiopia	3.0	14.0	60.0	77.0	0.0	77.0	1.7	4.0
Kenya	30.0	10.0	910.0	950.0	51.0	1,001.0	21.7	0.7
Uganda	2.0	2.0	14.0	18.0	0.0	18.0	3.6	1.0
Eastern Africa	35.0	26.0	984.0	1,045.0	51.0	1,096.0	9.4	1.0
Angola	3.3	11.0	3.0	17.5	5.0	22.5	5.0	2.0
Lesotho	0.5	0.5	1.2	2.2	3.4	5.6	2.7	0.0
Malawi	7.0	4.0	27.0	38.0	13.0	51.0	5.4	3.4
Mozambique	2.0	2.0	37.0	41.0	0.0	41.0	1.8	3.0
South Africa	20.0	0.0	40.0	60.0	0.0	60.0	5.3	0.4
Swaziland	0.0	6.0	25.7	31.7	0.0	31.7	0.0	-
Tanzania	11.0	0.0	18.0	29.0	81.0	110.0	6.1	1.6
Zambia	3.5	1.0	50.0	54.5	0.0	54.5	5.4	6.3
Zimbabwe	0.2	2.0	24.0	26.2	9.2	35.4	0.2	60.0
Southern Africa	47.7	26.5	225.9	300.1	111.6	411.7	4.4	2.2
Southern Africa, excluding South Africa	27.7	26.5	185.9	240.1	111.6	351.7	3.9	3.5
Eastern and southern Africa	72.7	52.5	1,209.9	1,345.1	162.6	1,507.7	5.0	1.9
Eastern and southern Africa, excluding South Africa	62.7	52.5	1,169.9	1,285.1	162.6	1,447.7	5.8	2.1

Source: CIMMYT Maize Research Impacts Survey, 1998/99.
[a] FTE = Full-time equivalents.

Table 8. Human resources invested in maize research, private sector, eastern and southern Africa, 1998

Country / region	Human resources in research (FTE)[a]				Number of non-research support	Total human resources	Number of scientists per million ha maize	Number of cultivars released per senior scientist
	Number of senior scientists	Number of junior scientists	Other	Total				
Ethiopia	-	-	-	-	-	-	-	-
Kenya	3.0	2.0	51.0	56.0	176.0	232.0	2.2	1.7
Uganda	0.0	0.0	0.0	0.0	65.0	65.0	-	-
Eastern Africa	3.0	2.0	51.0	56.0	241.0	297.0	0.8	2.0
Angola	-	-	-	-	-	-	-	-
Lesotho	-	-	-	-	-	-	-	-
Malawi	0.0	0.0	0.0	0.0	1.0	1.0	0.0	-
Mozambique	1.0	0.0	9.0	10.0	482.0	492.0	0.9	6.0
South Africa	35.0	11.5	155.5	202.0	227.5	429.5	9.3	1.9
Swaziland	-	-	-	-	-	-	-	-
Tanzania	2.0	1.0	11.0	14.0	209.0	223.0	1.1	2.8
Zambia	1.0	0.5	20.0	21.5	66.0	87.5	1.5	2.0
Zimbabwe	5.5	6.0	137.5	149.0	685.5	834.5	4.1	6.2
Southern Africa	44.5	19.0	333.0	396.5	1,671.0	2,067.5	4.1	2.9
Southern Africa, excluding South Africa	9.5	7.5	177.5	194.5	1,443.5	1,638.0	1.3	6.6
Eastern and southern Africa	47.5	21.0	384.0	452.5	1,912.0	2364.5	3.3	2.9
Eastern and southern Africa, excluding South Africa	12.5	9.5	228.5	250.5	1684.5	1,935.0	1.2	5.5

Source: CIMMYT Maize Research Impacts Survey, 1998/99.
[a] FTE = Full-time equivalents.

companies are still relatively new in most countries of eastern and southern Africa, they have been releasing varieties at an unusually high rate in an effort to win a greater share of markets that have long been dominated by public agencies.

Investment indicators and productivity indices based on numbers of scientists can be misleading if they conceal significant differences in levels of financial support received by each scientist. Table 9 summarizes data on the cost of supporting senior maize scientists in the public and private sectors (salary and benefits, operating budgets). In both eastern and southern Africa, maize scientists employed in the private sector receive nearly twice as much financial support as maize scientists employed in the public sector. These data may explain the productivity difference between the public and private sectors; private-sector scientists produce twice as many varieties as public-sector scientists, but they do so with double the financial resources.

In interpreting the data relating to research investment and research productivity, it is important to remember that the average number of varieties released per scientist is not an ideal measure of research productivity, because all scientists may not have the same objectives. For example, scientists working in public breeding programs typically place greater emphasis on "upstream" research activities, such as population improvement, development of special trait materials, and other forms of "pre-breeding" work, whereas scientists working for private seed companies typically place greater emphasis on development of finished varieties. Furthermore, scientists working in the private sector are usually supported by well-established testing, production, and marketing systems, whose goal is to increase seed sales and maximize profits. By contrast, scientists working in the public sector normally face less pressure to increase sales and profits; instead, they are often encouraged to focus on activities that are expected to generate important social benefits.

Patterns of Maize Varietal Releases

The impacts of maize breeding research ultimately are felt when modern varieties are adopted and grown in farmers' fields. Farm-level technology adoption decisions are affected by many factors that cannot be controlled directly by breeders, however, so varietal adoption rates provide an imperfect measure of breeding productivity. Widespread adoption of modern varieties indicates that breeding efforts have been productive, but lack of adoption does not necessarily mean that breeding efforts have been unproductive. In many instances breeding programs have developed excellent varieties, only to see adoption stymied by

Table 9. Cost (US$ / year) of supporting a senior maize scientist, eastern and southern Africa, 1998

	Public sector		Private sector	
Country / region	Salary and benefits	Operating budget	Salary and benefits	Operating budget
Ethiopia	3,429	-	-	-
Kenya	6,667	8,333	-	-
Uganda	5,100	-	-	-
Eastern Africa	5,065	7,276	-	-
Angola	3,117	-	-	-
Lesotho	-	-	-	-
Malawi	1,750	3,205	-	-
Mozambique	7,200	-	19,667	28,111
South Africa	31,915	51,643	50,531	-
Swaziland	19,557	-	-	-
Tanzania	1,440	-	12,000	24,000
Zambia	2,400	2,248	750	5,875
Zimbabwe	10,667	13,201	11,667	-
Southern Africa	9,756	12,161	18,923	11,597
Southern Africa, excluding South Africa	6,590	6,520	11,021	14,497
Eastern and southern Africa	7,410	9,718	18,923	11,597
Eastern and southern Africa, excluding South Africa	5,827	6,898	11,021	14,497

Source: CIMMYT Maize Research Impacts Survey, 1998/99.

bottlenecks in the seed supply system, lack of economic incentives, lack of awareness on the part of farmers about new varieties, or other factors.

Numbers and types of varietal releases therefore provide useful intermediate indicators for judging the productivity of breeding programs. One objective of the 1998/99 survey was to update CIMMYT's varietal releases database for eastern and southern Africa. Compared to the original 1992 survey, the 1998/99 survey went to much greater lengths to collect data from the private sector. Based on the information provided by many private seed companies, the varietal releases database was updated and considerably expanded.

Varietal release data are analyzed in this section of the report. In comparing the results of the 1998/99 survey with the results of the earlier 1992 survey, minor differences can be observed in varietal release data. Most of these differences arose because a number of research organizations that were formerly public or parastatal had been privatized since the original impacts report was published; varieties released by these organizations were reclassified as private-sector releases. In addition, two adjustments were made to avoid multiple counting of individual varieties. In cases where two or more organizations were found to be selling the same variety in a given country, the variety was listed only once in the varietal releases database. Similarly, in cases where the same variety was being sold in two or more countries, it was listed only once.

Last but not least, it is important to keep in mind that the temporal coverage of the public- and private-sector varietal releases databases is not the same. The public-sector varietal releases database includes information about all public varieties released from 1966 through 1998. Since the data form a complete time series, they provide insights into changes through time in the numbers and types of varieties developed by public breeding programs. In contrast, the more limited private-sector varietal releases database includes information only about private-sector varieties that were being sold in the late 1990s; it does not include information about private-sector varieties that may have been sold in the past but that had been discontinued by the late 1990s. The private-sector varietal releases database thus provides a detailed snapshot of the varieties available in the market in the late 1990s, but it does not provide a complete picture of changes that have occurred through time in the numbers and types of varieties developed by private seed companies.

Maize Varietal Releases

Summary information about the maize varieties released by public breeding programs in eastern and southern Africa between 1966 and 1998 appears in Table 10. Of 133 total releases, one-quarter (35) were varieties developed in eastern Africa, and three-quarters (98) were varieties developed in southern Africa. While the absolute number of releases was much greater in southern Africa, since the area planted to maize is also much greater in southern Africa, the number of releases per million hectares of maize was similar across the two regions.

Regional differences are evident in the types of materials developed by public breeding programs. In eastern Africa, public-sector releases have been evenly divided between OPVs and hybrids, while in southern Africa hybrids have dominated. Summing across both regions, hybrids have constituted a 30% greater share in the overall number of releases. Interestingly, the composition of public-sector varietal releases has not changed appreciably in recent years. The share of hybrids increased during the 1960s and 1970s before stabilizing in the 1980s at about 55% (Figure 1).

Regional differences also are evident in the types of hybrids that have been released. Almost all the hybrids released in eastern Africa have been double-cross hybrids, top-cross hybrids, or varietal hybrids. In contrast, breeding programs in southern Africa seem to have emphasized "large hybrid vigor," as more than 70% of the hybrids released in southern Africa have been single-cross hybrids or three-way-

cross hybrids. Single-cross and three-way-cross hybrids are generally very uniform and tend to perform especially well under high levels of management, making them suitable for large-scale commercial farmers. These advantages come at a price, however: single-cross hybrids and three-way-cross hybrids are time-consuming and difficult to develop, and because they are characterized by low seed yields, seed is more expensive to produce (Pandey, 1998). Double-cross hybrids, top-cross hybrids, and varietal hybrids are less uniform and generally do not yield as well, but their seed is less costly to produce, and their performance is not as severely affected by seed recycling. For these reasons, they are more suitable for small-scale, subsistence-oriented farmers, who are not always able to provide high levels of management, and who are more likely to recycle seed.

These differences in the types of hybrids being released suggest that public breeding programs in each region have targeted different groups of farmers. Public breeding programs in eastern Africa evidently have focused on providing for the needs of the small-scale, subsistence-oriented farmer, whereas in southern Africa the main target has been commercial producers. This difference could be linked to the timing of political independence in the

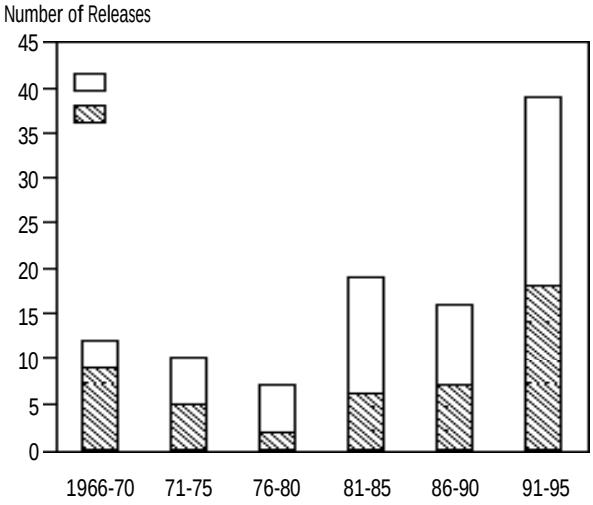

Figure 1. Public maize varietal releases, by type of cultivar, eastern and southern Africa, 1966-95
Source: CIMMYT Maize Research Impacts Survey, 1998/99.

Table 10. Number of maize varieties released by public breeding programs, eastern and southern Africa, 1966-98

Country / region	OPVs	Hybrids					Total MVs	MVs per million ha of maize
		Single cross	Three-way cross	Double cross	Other	Total		
Ethiopia	8	1	1	0	2	4	12	6.2
Kenya	8	0	0	0	13	13	21	15.8
Uganda	2	0	0	0	0	0	2	3.6
Eastern Africa	18	1	1	0	15	17	35	9.4
Angola	7	0	0	0	0	0	7	10.0
Lesotho	0	0	0	0	0	0	0	0.0
Malawi	12	2	7	0	3	12	24	18.5
Mozambique	5	0	0	0	1	1	6	5.4
South Africa	0	0	0	0	0	0	0	0.0
Swaziland	0	0	0	0	0	0	0	0.0
Tanzania	12	2	3	1	0	6	18	10.0
Zambia	7	10	9	4	1	24	31	47.7
Zimbabwe	0	9	3	0	0	12	12	0.9
Southern Africa	43	23	22	5	5	55	98	9.6
Southern Africa, excluding South Africa	43	23	22	5	5	55	98	13.7
Eastern and southern Africa	61	24	23	5	20	72	133	9.8
Eastern and southern Africa, excluding South Africa	61	24	23	5	20	72	133	12.3

Source: CIMMYT Maize Research Impacts Survey, 1998/99.

two regions: many countries in eastern Africa achieved independence earlier and therefore were quicker to shift the focus of breeding away from large-scale commercial production systems (which had been favored under colonial rule) to smallholder farming systems (which had traditionally been neglected).

Summary information about the maize varieties being sold during the late 1990s by private seed companies in eastern and southern Africa appears in Table 11. Compared to public breeding programs, private seed companies have placed much greater emphasis on hybrids. Out of 137 total private-sector releases, only six were OPVs; the remaining 131 (or 95%) were hybrids. Private-sector varietal releases have originated mainly from southern Africa, reflecting the much greater amount of private-sector activity in that region. Only six varieties have been released by private seed companies in eastern Africa; the remaining 131 have been released by seed companies operating in southern Africa (mainly in Malawi, South Africa, and Zimbabwe).

Similar to public-sector varietal releases, the composition of private-sector varietal releases has not changed appreciably in recent years. Summarizing across the two regions, the share of hybrids increased during the 1960s and 1970s before stabilizing in the 1980s at about 95% (Figure 2).

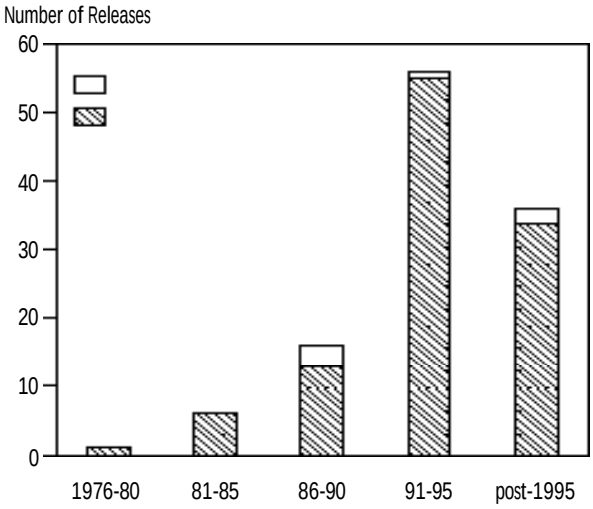

Figure 2. Private maize varietal releases, by type of cultivar, eastern and southern Africa, 1976-98
Source: CIMMYT Maize Research Impacts Survey, 1998/99.

Table 11. Number of maize varieties (available in 1998) released by private seed companies, eastern and southern Africa

Country / region	OPVs	Hybrids					Total MVs	MVs per million ha of maize
		Single cross	Three-way cross	Double cross	Other	Total		
Ethiopia	0	0	1	0	0	1	1	0.6
Kenya	0	0	1	1	3	5	5	3.6
Uganda	0	0	0	0	0	0	0	0.0
Eastern Africa	0	0	2	1	3	6	6	1.6
Angola	0	0	0	0	0	0	0	0.0
Lesotho	0	0	0	0	0	0	0	0.0
Malawi	0	0	17	0	0	17	17	13.1
Mozambique	3	0	1	1	1	3	6	5.4
South Africa	0	14	21	26	7	68	68	20.8
Swaziland	0	0	0	0	0	0	0	0.0
Tanzania	0	1	3	1	0	5	5	2.8
Zambia	0	0	0	2	0	2	2	3.1
Zimbabwe	3	2	27	0	1	30	33	24.9
Southern Africa	6	17	69	30	9	125	131	12.0
Southern Africa, excluding South Africa	6	3	48	4	2	57	63	8.8
Eastern and southern Africa	6	17	71	31	12	131	137	9.4
Eastern and southern Africa, excluding South Africa	6	3	50	5	5	63	69	6.4

Source: CIMMYT Maize Research Impacts Survey, 1998/99.

In terms of the types of hybrids that have been released by private seed companies, regional differences are evident. In eastern Africa, the number of "high vigor" hybrids (single crosses, three-way crosses) has been half as large as the number of "low vigor" hybrids (double crosses, top crosses, varietal hybrids). By contrast, in southern Africa "high vigor" hybrids have clearly dominated.

Taking into account both public-sector and private-sector releases, and adjusting for differences in the area planted to maize in each region, relatively more varieties have been developed for southern Africa (21.6 varieties per million ha maize area) than for eastern Africa (11.0 varieties per million ha maize area). This could be due to the greater diversity of maize production environments found in southern Africa, to the higher level of competition prevailing in the private seed industry in southern Africa, or both.

In attempting to discern trends through time in patterns of varietal releases, it is important to remember that the temporal coverage of the public-sector varietal releases database is much more complete than that of the private-sector varietal releases database. Despite the lack of information about private-sector releases in earlier years, however, there has clearly been significant growth through time in the proportion of releases coming from the private sector. Of all new varieties released since 1995, close to 100% have come from private seed companies (Figure 3a). Not surprisingly, given the commercial orientation of private seed companies, nearly 95% of these releases consisted of hybrids (Figure 3b).

Ecological Adaptation

The ecological adaptation of maize varieties released by public breeding programs and private seed companies in eastern and southern Africa reflects the characteristics of local production environments (Tables 12 and 13). About two-thirds (66%) of all released varieties have been adapted to subtropical environments, which is roughly congruent with the share of subtropical environments in the region. Another 13% of all released varieties have been adapted to lowland tropical environments, and an additional 10% have been adapted to mid-altitude environments. Just under 6% of all released varieties have been adapted to highland environments; these highland varieties

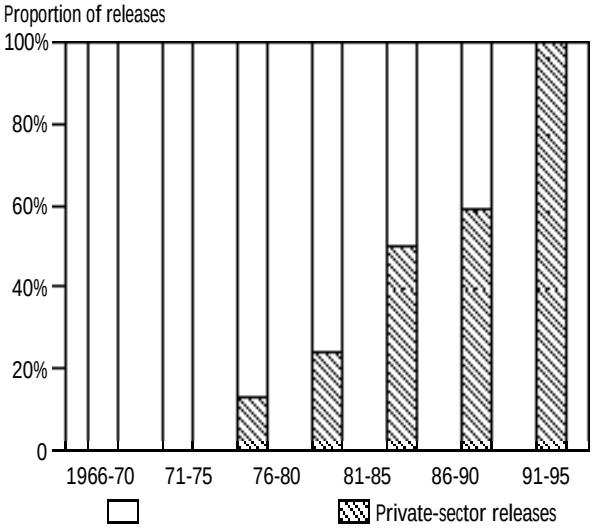

Figure 3a. Trends in maize varietal releases, by sector, eastern and southern Africa, 1966-98
Source: CIMMYT Maize Research Impacts Survey, 1998/99.

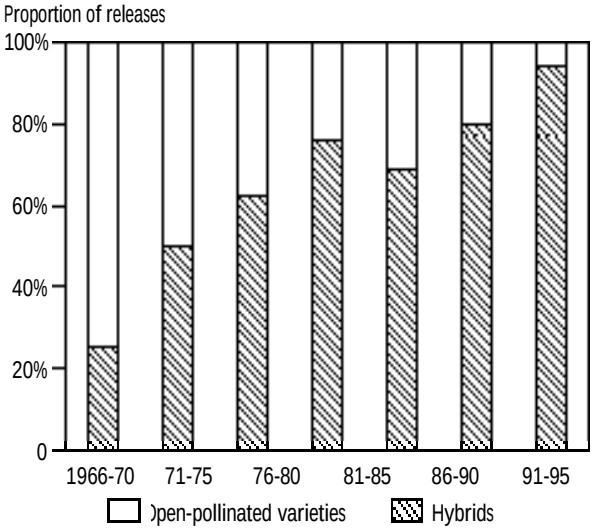

Figure 3b. Trends in maize varietal releases, by type of cultivar, eastern and southern Africa, 1966-98
Source: CIMMYT Maize Research Impacts Survey, 1998/99.

have been released only in Kenya and Tanzania, the two countries in which most highland maize production is concentrated. Finally, about 5% of all varieties released in eastern and southern Africa have been adapted to temperate production environments; varieties with temperate adaptation have been released mainly in South Africa and to a limited extent in Kenya.

Table 12. Ecological adaptation of maize varieties released by public breeding programs, eastern and southern Africa, 1966-98 (number of varieties)

Country / region	Lowland tropics	Subtropics	Mid-altitude areas	Highlands	Temperate areas
Ethiopia	1	6	5	0	0
Kenya	1	10	2	5	3
Uganda	0	2	0	0	0
Eastern Africa	2	18	7	5	3
Angola	2	3	0	0	0
Lesotho	0	0	0	0	0
Malawi	11	1	6	0	0
Mozambique	1	4	0	0	0
South Africa	-	-	-	-	-
Swaziland	0	0	0	0	0
Tanzania	0	0	7	4	0
Zambia	2	20	0	0	0
Zimbabwe	6	6	0	0	0
Southern Africa	22	34	13	4	0
Southern Africa, excluding South Africa	22	34	13	4	0
Eastern and southern Africa	24	52	20	9	3
Eastern and southern Africa, excluding South Africa	24	52	20	9	3

Source: CIMMYT Maize Research Impacts Survey, 1998/99.

Table 13. Ecological adaptation of maize varieties (available in 1998) released by private seed companies, eastern and southern Africa (number of varieties)

Country / region	Lowland tropics	Subtropics	Mid-altitude areas	Highlands	Temperate areas
Ethiopia	0	1	0	0	0
Kenya	0	0	0	3	2
Uganda	0	0	0	0	0
Eastern Africa	0	1	0	3	2
Angola	0	0	0	0	0
Lesotho	0	0	0	0	0
Malawi	1	2	0	0	0
Mozambique	3	3	0	0	0
South Africa	1	54	0	0	7
Swaziland	0	0	0	0	0
Tanzania	0	0	1	1	0
Zambia	0	2	0	0	0
Zimbabwe	0	33	1	0	0
Southern Africa	5	94	2	1	7
Southern Africa, excluding South Africa	4	40	2	1	0
Eastern and southern Africa	5	95	2	4	9
Eastern and southern Africa, excluding South Africa	4	41	2	4	2

Source: CIMMYT Maize Research Impacts Survey, 1998/99.

Grain Characteristics

The predominant grain color of maize varieties released in eastern and southern Africa has differed by region and by type of breeding program. Among varieties released by public breeding programs, 100% of those released in eastern Africa and 88% of those released in southern Africa have been white-grained (Table 14). Since white maize is the dominant food staple in both regions, this indicates the strong influence of consumer preferences on public breeding strategies. Among the varieties released by private seed companies, 100% of those released in eastern Africa but only 56% of those released in southern Africa have been white-grained (Table 15). Yellow-grained varieties have been released in South Africa and Zimbabwe, where they are in demand for use as animal feed (mainly in Angola, South Africa, Zambia, and Zimbabwe).

Variability by region and by type of breeding program has also been evident in the predominant grain texture of maize varietal releases. In both eastern and southern Africa, public-sector releases have included roughly equal numbers of hard (flint) and soft (dent) grain types (Table 14). However, the predominant grain type has differed between countries. Soft-grained varieties have been relatively uncommon in Malawi (11%) and Tanzania (21%), whereas they have dominated in most other countries (including Zimbabwe, where 100% of all public-sector releases have been soft-grained). These differences reflect differences in consumer preferences. In Malawi, for example, most consumers strongly prefer flinty grain types, which has influenced the national breeding program to concentrate on hard-grained materials (Ellis 1959, Heisey and Smale 1995, Rusike and

Table 14. Grain characteristics of maize varieties released by public breeding programs, eastern and southern Africa, 1966-98 (number of varieties)

	Grain color		Grain texture			
Country / region	White	Yellow	Dent	Semi-dent	Semi-flint	Flint
Ethiopia	12	0	6	2	4	0
Kenya	21	0	2	8	9	2
Uganda	2	0	1	0	1	0
Eastern Africa	35	0	9	10	14	2
Angola	5	2	1	0	0	6
Lesotho	0	0	0	0	0	0
Malawi	18	0	2	0	5	11
Mozambique	5	0	0	1	1	3
South Africa	3	4	0	7	0	0
Swaziland	0	0	0	0	0	0
Tanzania	18	0	3	1	5	9
Zambia	28	3	20	6	2	3
Zimbabwe	9	3	12	0	0	0
Southern Africa	86	12	38	15	13	32
Southern Africa, excluding South Africa	83	8	38	8	13	32
Eastern and southern Africa	121	12	47	25	27	34
Eastern and southern Africa, excluding South Africa	118	8	47	18	27	34

Source: CIMMYT Maize Research Impacts Survey, 1998/99.

Table 15. Grain characteristics of maize varieties (available in 1998) released by private seed companies, eastern and southern Africa (number of varieties)

	Grain color		Grain texture			
Country / region	White	Yellow	Dent	Semi-dent	Semi-flint	Flint
Ethiopia	1	0	1	0	0	0
Kenya	5	0	1	4	0	0
Uganda	0	0	0	0	0	0
Eastern Africa	6	0	2	4	0	0
Angola	0	0	0	0	0	0
Lesotho	0	0	0	0	0	0
Malawi	3	0	1	1	1	0
Mozambique	6	0	3	2	0	1
South Africa	24	44	41	19	7	1
Swaziland	-	-	-	-	-	-
Tanzania	2	0	0	0	0	2
Zambia	2	0	0	2	0	0
Zimbabwe	27	7	6	22	5	1
Southern Africa	64	51	51	46	13	5
Southern Africa, excluding South Africa	40	7	10	27	6	4
Eastern and southern Africa	70	51	53	50	13	5
Eastern and southern Africa, excluding South Africa	46	7	12	31	6	4

Source: CIMMYT Maize Research Impacts Survey, 1998/99.

Smale 1998). In Tanzania, farmers similarly prefer flinty grain types, which not only lend themselves more easily to traditional processing methods (hand pounding) but also store better. With regard to grain texture, private seed companies also have demonstrated sensitivity to consumer preferences, although in this case the consumers being targeted are often different. Soft-textured grain types have dominated among private-sector varietal releases, accounting for 100% of all releases in eastern Africa and 84% of all releases in southern Africa (Table 15). Soft-grained dent maize has superior industrial processing qualities that millers prefer and hence is preferred by many commercial farmers.

Maturity Classes

Most of the maize varieties released by public breeding programs since 1966 have been intermediate or late maturing (Table 16). In eastern Africa, 20% of all public-sector releases have been intermediate maturing, and 66% have been late maturing. In southern Africa, 26% of all public-sector releases have been intermediate maturing, and 64% have been late maturing. In contrast, a larger proportion of the varieties released by private seed companies have been early maturing. Of all private-sector releases, 43% of those released in eastern Africa and 18% of those released in southern Africa have been early maturing (Table 17). Breeders in the private sector evidently have placed more emphasis on developing short-duration materials that are less vulnerable to drought occurring late in the growing season.

Since many maize-growing environments in eastern and southern Africa are susceptible to drought, especially in areas populated mainly by small-scale, subsistence-oriented farmers, the relatively small proportion of short-duration varieties among all releases suggests that the supply of germplasm suited to these environments is quite limited. In an effort to expand the range of technology choices available to farmers, CIMMYT recently initiated a major breeding project in southern Africa, the Southern Africa Drought and Low Fertility Project. The objective of the project, which is being carried out in collaboration with public NARSs and private seed companies, is to develop materials showing increased drought tolerance and enhanced nitrogen use efficiency. Early results appear extremely promising, and improved germplasm developed through the project is rapidly making its way into breeding programs throughout the region.

Table 16. Maturity classes of maize varieties released by public breeding programs, eastern and southern Africa, 1966-98 (number of varieties)

Country / region	Extra early	Early	Intermediate	Late	Extra late
Ethiopia	1	0	0	6	5
Kenya	2	2	6	1	10
Uganda	0	0	1	1	0
Eastern Africa	3	2	7	8	15
Angola	2	0	1	2	0
Lesotho	0	0	0	0	0
Malawi	1	0	14	1	2
Mozambique	0	0	1	2	2
South Africa	0	0	0	0	0
Swaziland	0	0	0	0	0
Tanzania	0	2	1	7	1
Zambia	0	2	2	3	15
Zimbabwe	0	0	0	9	3
Southern Africa	3	4	19	24	23
Southern Africa, excluding South Africa	3	4	19	24	23
Eastern and southern Africa	6	6	26	32	38
Eastern and southern Africa, excluding South Africa	6	6	26	32	38

Source: CIMMYT Maize Research Impacts Survey, 1998/99.

Impacts of CIMMYT's Maize Breeding Program

The CIMMYT Maize Program, working out of its headquarters in Mexico and out of regional offices located in Central and South America, sub-Saharan Africa, and Asia, produces improved germplasm that is distributed to public and private breeding programs around the world for use in developing finished varieties. Since CIMMYT does not release finished varieties, the impacts of CIMMYT's maize breeding efforts are best estimated by investigating the extent to which CIMMYT germplasm has been used by public and private breeding programs. This is not an easy task. Tracking the use of CIMMYT germplasm is difficult for several reasons. To begin with, modern maize breeding is an extremely complex undertaking. The development of OPVs and hybrids normally involves repeated cycles of crossing involving a wide range of source materials; consequently, it is often very difficult to trace the complete genetic history of individual varieties. Documenting the origins of individual varieties is greatly complicated by the fact that the pedigrees (genetic background and crossing history) of most commercial hybrids are confidential, since most private breeding programs and even some public ones are reluctant to disclose pedigree information for fear of providing information that might be useful to potential competitors.

Table 17. Maturity classes of maize varieties (available in 1998) released by private seed companies, eastern and southern Africa (number of varieties)

Country / region	Extra early	Early	Intermediate	Late	Extra late
Ethiopia	0	0	1	0	0
Kenya	2	0	3	0	0
Uganda	0	0	0	0	0
Eastern Africa	3	0	4	0	0
Angola	0	0	0	0	0
Lesotho	0	0	0	0	0
Malawi	0	1	1	1	0
Mozambique	0	2	1	3	0
South Africa	2	8	19	18	15
Swaziland	0	0	0	0	0
Tanzania	0	0	1	0	0
Zambia	0	0	0	2	0
Zimbabwe	0	4	7	12	11
Southern Africa	2	15	29	36	26
Southern Africa, excluding South Africa	0	7	10	18	11
Eastern and southern Africa	5	15	33	36	26
Eastern and southern Africa, excluding South Africa	3	7	14	18	11

Source: CIMMYT Maize Research Impacts Survey, 1998/99.

Despite these difficulties, for this study an attempt was made to compile information on the use of CIMMYT-derived germplasm by public and private maize breeding programs in eastern and southern Africa. Although it was not possible to obtain complete pedigree information for most varieties, especially commercial hybrids developed by private seed companies, the survey respondents were asked the following three questions about each cultivar that had been developed by their breeding program:

1. Does the cultivar contain CIMMYT germplasm?
2. If it does contain CIMMYT germplasm, which CIMMYT population(s), pool(s), and / or inbred line(s) were used in developing the cultivar?
3. How were the CIMMYT population(s), pool(s), and / or inbred line(s) used? [5]

In the analysis that follows, data for southern Africa are often reported in two ways: (a) including South Africa, and (b) excluding South Africa. South Africa is sometimes excluded from the analysis because commercial maize hybrids cultivated in South Africa contain mainly temperate germplasm, most of which comes from the US and Europe. CIMMYT maize breeders do not work with temperate germplasm, so most of South Africa's maize-growing area falls outside the area targeted

[5] For information about the survey instrument, see Morris and López-Pereira (1998).

by the CIMMYT Maize Program. In assessing the impacts of CIMMYT's breeding efforts, it is therefore often appropriate to exclude South Africa.

Use of CIMMYT Germplasm

Of all maize varieties released by public and private breeding programs since 1966 and whose parentage is known, 24% were developed using CIMMYT source materials (35% if South Africa is excluded).

Use of CIMMYT germplasm has varied by region and by type of breeding program (Table 18). Among public breeding programs, use of CIMMYT germplasm has been more extensive in southern Africa (35% of all public-sector releases for which the CIMMYT germplasm content is known contain CIMMYT germplasm) than in eastern Africa (22% of all releases for which the CIMMYT germplasm content is known contain CIMMYT germplasm). Among private breeding programs, the pattern is reversed; use of CIMMYT germplasm has been more extensive in eastern Africa (67% of all private-sector releases for which the CIMMYT germplasm content is known contain CIMMYT germplasm) than in southern Africa (15% of all releases for which the CIMMYT germplasm content is known contain CIMMYT germplasm; 44% if South Africa is excluded). In interpreting these percentage figures, it is important to remember that the total number of private-sector releases is approximately 10 times higher than the number of public-sector releases.

Aggregating across both regions (eastern and southern Africa) and both types of breeding programs (public and private), CIMMYT germplasm shows up much more frequently in OPVs than in hybrids (Table 18).

How has the use of CIMMYT germplasm changed through time? Trends in the use of CIMMYT germplasm are shown in Table 19 and Figure 4. In both regions, use of CIMMYT germplasm has increased steadily among public and

Table 18. Use of CIMMYT germplasm by public and private breeding programs, eastern and southern Africa, 1966-98

	Percentage of all public releases developed using CIMMYT germplasm[a]			Percentage of all private releases developed using CIMMYT germplasm[a]			
Country / region	**OPVs**	**Hybrids**	**Total**	**OPVs**	**Hybrids**	**Total**	**Grand total**
Ethiopia	25.0	50.0	36.4	0.0	0.0	0.0	33.3
Kenya	25.0	0.0	10.5	0.0	40.0	100.0	19.0
Uganda	50.0	0.0	50.0	0.0	0.0	0.0	50.0
Eastern Africa	27.8	11.8	21.9	0.0	33.3	66.7	25.7
Angola	-	-	-	-	-	-	-
Lesotho	-	-	-	-	-	-	-
Malawi	77.8	33.3	55.6	0.0	0.0	0.0	55.6
Mozambique	100.0	0.0	100.0	33.3	0.0	33.3	75.0
South Africa	0.0	0.0	0.0	0.0	2.9	2.9	2.9
Swaziland	-	-	-	-	-	-	-
Tanzania	60.0	0.0	54.5	50.0	0.0	50.0	53.8
Zambia	40.0	5.9	13.6	0.0	0.0	0.0	12.5
Zimbabwe	-	-	-	33.3	30.0	50.0	31.3
Southern Africa	58.8	9.3	35.3	37.5	10.4	14.7	23.3
Southern Africa, excluding South Africa	58.8	9.3	35.3	37.5	23.7	44.4	37.9
Eastern and southern Africa	48.1	10.0	31.0	37.5	11.6	16.3	23.7
Eastern and southern Africa, excluding South Africa	48.1	10.0	31.0	37.5	25.0	46.7	34.6

Source: CIMMYT Maize Research Impacts Survey, 1998/99.

[a] Percentage of releases whose CIMMYT germplasm content is known.

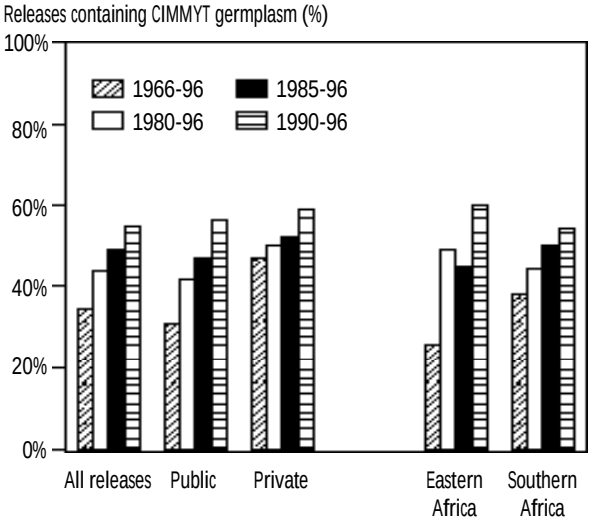

Figure 4. Use of CIMMYT maize germplasm, eastern and southern Africa, 1966-96
Source: CIMMYT Maize Research Impacts Survey, 1998/99.

private breeding programs. During the 1990s, 50% of all public-sector releases in eastern Africa contained CIMMYT germplasm, as did 53% of all public-sector releases in southern Africa (excluding South Africa). During the same period, 100% of all private-sector releases in eastern Africa contained CIMMYT germplasm, as did 55% of all private-sector releases in southern Africa (excluding South Africa). Aggregating the data for both regions and for both types of breeding program, 31% of all varieties released during the 1990s contained CIMMYT germplasm (55% if South Africa is excluded), indicating strong and increasing demand for CIMMYT germplasm. The observed growth in the use of CIMMYT germplasm during recent years strongly validates the decision of the CIMMYT Maize Program to establish a breeding station within the region to concentrate on local adaptive breeding.

Table 19. Trends in use of CIMMYT germplasm by public and private breeding programs, eastern and southern Africa, 1966-98

	Percentage of all public releases developed using CIMMYT germplasm[a]				Percentage of all private releases developed using CIMMYT germplasm[a]				Percentage of all releases developed using CIMMYT germplasm[a]			
Country / region	**1966-96**	**1980-96**	**1985-96**	**1990-96**	**1966-96**	**1980-96**	**1985-96**	**1990-96**	**1966-96**	**1980-96**	**1985-96**	**1990-96**
Ethiopia	36.4	50.0	50.0	50.0	-	-	-	-	33.3	50.0	50.0	50.0
Kenya	10.5	20.0	22.2	33.3	100.0	100.0	100.0	100.0	19.0	33.3	36.4	60.0
Uganda	50.0	100.0	100.0	100.0	0.0	-	-	-	50.0	100	100	100
Eastern Africa	21.9	36.8	38.9	50.0	66.7	100.0	100.0	100.0	25.7	42.9	45.0	60.0
Angola	-	-	-	-	-	-	-	-	-	-	-	-
Lesotho	-	-	-	-	-	-	-	-	-	-	-	-
Malawi	55.6	62.5	71.4	69.2	0.0	0.0	0.0	0.0	55.6	62.5	71.4	69.2
Mozambique	100.0	100.0	100.0	100.0	33.3	33.3	33.3	50.0	75.0	75.0	71.4	80.0
South Africa	-	-	-	-	2.9	2.9	2.9	3.7	2.9	2.9	2.9	3.7
Swaziland	-	-	-	-	-	-	-	-	-	-	-	-
Tanzania	54.5	71.4	50.0	66.7	50.0	50.0	50.0	0.0	53.8	66.7	50.0	66.7
Zambia	13.6	15.8	20.0	22.2	0.0	0.0	0.0	0.0	12.5	14.3	16.7	18.2
Zimbabwe	-	0.0	0.0	0.0	50.0	52.6	55.6	62.5	31.3	40.0	47.6	55.6
Southern Africa	35.3	43.4	51.4	53.3	14.7	14.9	15.1	17.6	23.3	25.2	25.0	27.9
Southern Africa, excluding South Africa	35.3	43.4	51.4	53.3	44.4	46.2	48.0	55.0	37.9	44.3	50.0	54.0
Eastern and southern Africa	31.0	41.7	47.2	52.6	16.3	16.7	16.8	19.7	23.7	27.4	27.7	30.7
Eastern and southern Africa, excluding South Africa	31.0	41.7	47.2	52.6	46.7	50.0	51.9	59.1	34.6	44.0	48.8	55.0

Source: CIMMYT Maize Research Impacts Survey, 1998/99.
[a] Percentage of releases whose CIMMYT germplasm content is known.

How has use of CIMMYT germplasm varied across ecological zones? In both regions, public and private breeding programs have used CIMMYT germplasm most frequently in developing varieties targeted for tropical lowland and mid-altitude tropical environments (Table 20). Use of CIMMYT germplasm in developing highland materials has been more variable; none of the highland varieties released in eastern Africa contained CIMMYT material, compared to 40% of the highland varieties released in southern Africa. One interesting finding is that public and private breeding programs have made use of CIMMYT germplasm in developing varieties targeted for temperate production environments; 40% of the temperate varieties developed by Kenyan breeding programs and 14.3% of the temperate varieties developed by South African breeding programs have contained CIMMYT germplasm.

Simply knowing whether or not a variety was developed using CIMMYT germplasm provides a useful measure of the impact of CIMMYT's maize breeding program. Even more useful would be quantitative information about the importance of CIMMYT germplasm in the genetic makeup of each cultivar (i.e., the percentage share of CIMMYT germplasm). In the absence of complete pedigree information, unfortunately it was not possible to calculate such a measure.

Popular CIMMYT Materials

Survey respondents were generally reluctant to provide details about the use of particular CIMMYT population(s), pool(s), and/or inbred line(s), so this information was obtained for relatively few varieties. Within the limited sample for which data were available, Population 21 (Tuxpeño) was the most

Table 20. Percentage of public and total maize varietal releases containing CIMMYT germplasm, by ecological zone, eastern and southern Africa[a]

	Public releases				Total releases			
Country/region	Lowland tropics	Subtropics, mid-altitude	Highland tropics	Temperate areas	Lowland tropics	Subtropics, mid-altitude	Highland tropics	Temperate areas
Ethiopia	0.0	36.4	-	-	0.0	33.3	-	-
Kenya	100	8.3	0.0	0.0	100.0	8.3	0.0	40.0
Uganda	-	50.0	-	-	-	50.0	-	-
Eastern Africa	50.0	24.0	0.0	0.0	50.0	23.1	0.0	40.0
Angola	-	-	-	-	-	-	-	-
Lesotho	-	-	-	-	-	-	-	-
Malawi	54.6	57.1	-	-	50.0	66.7	-	-
Mozambique	100.0	100.0	-	-	25.0	71.4	-	-
South Africa	-	-	-	-	100.0	1.9	-	14.3
Swaziland	-	-	-	-	-	-	-	-
Tanzania	-	57.1	50.0	-	-	62.5	40.0	-
Zambia	50.0	5.0	-	-	100.0	4.6	-	-
Zimbabwe	0.0	0.0	-	-	0.0	20.0	-	-
Southern Africa	40.9	27.7	50.0	-	22.7	18.2	40.0	14.3
Southern Africa, excluding South Africa	40.9	27.7	50.0	-	34.6	28.1	40.0	-
Eastern and southern Africa	41.7	26.4	22.2	0.0	37.9	18.9	40.0	33.3
Eastern and southern Africa, excluding South Africa	41.7	26.4	22.2	0.0	35.7	27.0	40.0	40.0

Source: CIMMYT Maize Research Impacts Survey, 1998/99.
[a] Percentage of releases whose CIMMYT germplasm content is known.

popular CIMMYT source material, followed by Population 22 (Mezcla Tropical Blanco) and Population 32 (ETO Blanco). All three of these populations are adapted to lowland topical environments.

Manner of Use of CIMMYT Germplasm

Public and private breeding programs in eastern and southern Africa have tended to use CIMMYT germplasm in different ways (Table 21). Public breeding programs have made extensive use of CIMMYT populations, pools and experimental varieties; most of the time, the CIMMYT source materials have been used directly, with little or no additional selection. In contrast, private seed companies have used mainly CIMMYT inbred lines; in most cases, the CIMMYT lines were subjected to further selection before being used.

Aggregating across public and private breeding programs, among all varieties that were developed using CIMMYT germplasm, in 43% of cases CIMMYT source materials were incorporated with little or no additional improvement at the hands of local breeders. Conversely, in 57% of cases CIMMYT source materials were further improved before being used. This suggests that although many national breeding programs have developed the capacity to do their own improvement work, a considerable number of breeding programs—especially public breeding programs—continue to make direct use of CIMMYT germplasm.

Table 21. Manner of use of CIMMYT source materials by public and private breeding programs, eastern and southern Africa, 1966-98 (% of varietal releases)[a]

Level of improvement	Public releases	Private releases	All releases
No additional improvement of material	25.8	0.0	17.0
No improvement of hybrids/inbred lines	0.0	0.0	0.0
Some improvement of material	32.3	12.5	25.5
Some improvement of hybrids/inbred lines	0.0	0.0	0.0
Substantial improvement of material	41.9	25.0	36.2
Substantial improvement of hybrids/inbred lines	0.0	62.5	21.3

Source: CIMMYT Maize Research Impacts Survey, 1998/99.

[a] Percentage of varietal releases whose manner of use CIMMYT source materials is known.

Farm Level Impacts of Maize Breeding Research

Previous sections of this report have presented information about the numbers and types of maize varieties that have been produced by public and private breeding programs in eastern and southern Africa, as well as information about the CIMMYT germplasm content of these varieties. Information about varietal releases provides an important measure of the productivity of breeding programs, but it does not provide a complete measure of the impacts of breeding programs on maize production. Improved varieties are able to increase maize production and to improve farmers' incomes and welfare only when they are planted in farmers' fields. In assessing the impacts of public and private maize breeding efforts, it is therefore important to estimate the extent to which modern varieties have been adopted by farmers and to estimate the resulting productivity gains.

The most reliable way to measure the adoption of modern varieties is through farm-level surveys. Unfortunately, relatively few of the countries covered by this report have carried out comprehensive national surveys in recent years to document farmers' use of improved maize varieties. Only in Kenya (Hassan et al. 1998), Tanzania (Moshi et al. 1997), and Malawi (Smale and Heisey 1997) have national surveys been carried out.

In the absence of survey data, it is necessary to rely on alternative sources of information to estimate varietal adoption rates. For this report, two methods were used to estimate farmers' use of improved

maize germplasm. Through the questionnaire, individuals with knowledge of the maize sector (e.g., scientists working in public research organizations, representatives of private seed companies) were asked to estimate (a) the total area planted to maize in 1996, and (b) the proportions within that total area planted to local varieties, improved OPVs, and hybrids. In addition, data were collected on commercial seed sales by public seed agencies and private companies in 1996. Based on the seed sales data, and using knowledge of average planting rates in each country, it was possible to estimate the area theoretically planted to commercial seed. These area estimates were then compared with direct area estimates to provide a consistency check.

Direct NARS Estimates of Area Under Improved Maize

Table 22 shows the estimates made by the survey respondents of the total area planted to maize in each country in 1996, along with the 1996 maize area reported by the Food and Agriculture Organization of the United Nations (FAO). With the exception of Angola[6] and Lesotho, where the FAO figures were about 22% lower than the survey respondents' estimates, in all countries the estimates made by the survey respondents closely matched the FAO data (difference of less than 10%). Aggregating to the regional level, the divergence between two estimates was negligible (1.2% difference in eastern Africa and 2.4% difference in southern Africa).

Table 23 shows the estimates of the percentage area in each country planted to improved OPVs and hybrids. According to the national program respondents, in 1996, more than one-half of the maize area in eastern and southern Africa was planted to modern varieties. Adoption rates varied, between individual countries, however. Adoption of modern varieties was highest in South Africa (98%), Zimbabwe (95%), Swaziland (75%), Lesotho (75%), and Kenya (72%). Adoption was lowest in Ethiopia (6%), Mozambique (8%), Tanzania (10%), and Malawi (11%). The pronounced inter-country variability in adoption rates presumably reflects differences between countries in terms of institutional and policy factors, including seed delivery infrastructure, economic incentives to adopt modern varieties, and the strength of the local extension service. These factors may be more important than agroclimatic suitability for the successful diffusion of modern varieties.

Table 22. Area planted to maize in eastern and southern Africa, 1996 (comparison of survey respondents' direct estimates with FAO data)

Country-region	FAO estimate (000 / ha)	Estimate of scientists in national research programs (000 / ha)	Difference between two estimates (%)
Ethiopia	1,881	1,776	-5.6
Kenya	1,300	1,383	6.4
Uganda	584	560	-4.1
Eastern Africa	3,765	3,719	-1.2
Angola	570	700	22.8
Lesotho	151	184	21.8
Malawi	1,243	1,300	4.6
Mozambique	1,008	1,113	10.4
South Africa	3,761	3,761	0.0
Swaziland	61	65	0.7
Tanzania	1,646	1,800	9.4
Zambia	676	649	-4.0
Zimbabwe	1,535	1,330	-13.4
Southern Africa	10,651	10,902	2.4
Southern Africa, excluding South Africa	6,890	7,141	3.6
Eastern and southern Africa	14,416	14,621	1.4
Eastern and southern Africa, excluding South Africa	10,655	10,860	1.9

Source: CIMMYT Maize Research Impacts Survey, 1998/99.

[6] When shown the difference between their estimate and the FAO figure, the Angolan respondents confirmed their estimate and challenged the accuracy of the FAO figure.

The varietal adoption estimates reveal interesting patterns in the types of modern varieties being grown in eastern and southern Africa. Generally speaking, use of hybrids was much more extensive than use of improved OPVs. According to the national program respondents, in 1996, hybrids occupied approximately 46% of the maize area planted, compared to only 7% occupied by OPVs. The greater use of hybrids reflects the increasing dominance of the private seed industry.

Estimates of Area Under Improved Maize Based on Seed Sales

Seed sales data for 1996 collected from public and private companies were used to derive an alternative set of estimates of the area planted to commercial maize seed in eastern and southern Africa. This was done by dividing total commercial seed sales in each country by the average planting rate for that country. In eastern and southern Africa, recommended planting rates for maize generally range from 20-25 kg/ha, although they are lower in some countries, including South Africa (10kg/ha), Lesotho (10 kg/ha), Uganda (16 kg/ha), and Swaziland (16 kg/ha). Many of the survey respondents indicated that farmers often plant at rates lower than the recommended rate, however, so the recommended planting rates were adjusted downward. Accordingly, an average planting rate of 17.5 kg/ha was used for all countries except South Africa and Lesotho, where an average rate of 12.5 kg/ha was used. These planting rates implicitly accommodate a certain amount of wastage, since the seed sales data were not adjusted to allow for the fact that in most years a certain amount of seed remains unplanted, some farmers replant the same field several times in order to establish a satisfactory stand, some of the area planted to commercial seed is never harvested, etc.

Table 23. Percentage of total national maize area planted to improved OPVs and hybrids, eastern and southern Africa, 1996 (comparison of survey respondents' direct estimates and calculations based on commercial seed sales)

	OPVs		Hybrids		All MVs		
Country / region	National program estimates	Seed sales	National program estimates	Seed sales	National program estimates	Seed sales	Percentage deviation from national program estimates
Ethiopia	1.89	2.99	3.94	5.47	5.83	8.46	45.1
Kenya	7.49	9.42	64.96	61.69	72.45	71.11	-1.8
Uganda	50.00	4.42	4.68	4.46	54.68	8.88	-83.8
Eastern Africa	11.62	5.60	28.09	26.24	39.71	31.83	-19.8
Angola	25.00	11.30	0.05	-	25.50	11.80	-53.7
Lesotho	10.87	13.05	63.94	57.72	74.81	70.76	-5.4
Malawi	4.38	1.05	7.00	12.75	11.38	13.80	21.3
Mozambique	7.96	9.10	0.05	0.04	8.01	9.14	14.1
South Africa	3.06	3.66	94.5	92.23	97.56	95.90	-1.7
Swaziland	2.23	0.00	73.22	78.37	75.45	78.37	3.9
Tanzania	4.00	1.92	6.00	2.33	10.00	4.25	-57.5
Zambia	0.62	0.72	18.63	22.17	19.25	22.89	18.9
Zimbabwe	4.51	0.00	90.98	81.63	95.49	81.63	-14.5
Southern Africa	5.24	3.77	51.73	43.51	56.97	47.28	-17.0
Southern Africa, excluding South Africa	6.49	3.82	27.37	21.76	33.86	25.57	-24.5
Eastern and southern Africa	6.88	4.24	45.67	39.02	52.55	43.27	-17.7
Eastern and southern Africa, excluding South Africa	8.29	4.41	27.62	23.26	35.91	27.68	-22.9

Source: CIMMYT Maize Research Impacts Survey, 1998/99.

Generally speaking, the seed sales-based estimates of the area planted to improved germplasm were consistent with the direct estimates made by the survey respondents (Table 23). In many countries, the estimates based on seed sales data were lower than the direct estimates, but this is expected, since the seed sales-based estimates include only area planted to newly purchased seed, whereas the direct estimates additionally include area planted to recycled seed. Countries in which the direct estimates significantly exceeded the seed-sales based estimates tended to be those in which a large amount of seed recycling is known to occur (e.g., Angola, Tanzania, Uganda).

Role of the Private Sector and Importance of Hybrids

Table 24 and Figures 5a and 5b show recent trends in commercial maize seed sales in eastern and southern Africa.[7] After increasing sharply during the early 1990s, maize seed sales leveled off around 120,000 tons for several years before dropping by more than 25% between 1994 and 1996. The decline in commercial maize seed sales during the mid-1990s can be attributed to several factors. In a number of countries (e.g., Kenya, Malawi, Zimbabwe), economic reforms resulted in the removal of input subsidies and elimination of exchange rate distortions, which had the effect of significantly increasing the price of maize seed. Unfavorable weather conditions also played a role, as a prolonged drought caused the area planted to maize to drop significantly in several major maize producing countries (e.g., South Africa).

The commercial seed sales data confirm that the maize seed market in eastern and southern Africa is now almost entirely privatized. By 1996, the most recent year for which data are available, private seed companies controlled more than 90% of the total market (Table 24). The domination of the private sector was pronounced not only in southern Africa, where private seed companies are relatively numerous, but also in eastern Africa, where private seed companies are still relatively scarce.

[7] Since it was not possible to obtain complete historical seed sales data for Angola, Angola was excluded from the analysis of trends in seed sales.

Table 24. Evolution of commercial maize seed sales by public and private seed organizations, eastern and southern Africa, 1990-96

Region / seed agency / seed type	1990	1991	1992	1993	1994	1995	1996
Eastern Africa							
Sales by public agencies (tons)	2,957	1,136	1,529	2,384	3,610	2,632	1,889
Hybrid seed sold (%)	11.0	10.0	11.0	11.0	11.0	24.2	50.8
Sales by private agencies (tons)	19,885	21,752	19,537	17,875	22,830	13,080	18,757
Hybrid seed sold (%)	88.7	88.4	86.8	87.9	88.1	86.9	85.7
Southern Africa, excluding Angola							
Sales by public agencies (tons)	2,003	1,962	1,504	838	836	711	2,079
Hybrid seed sold (%)	47.3	53.3	48.5	35.4	24.5	36.4	8.3
Sales by private agencies (tons)	43,544	91,470	99,310	98,872	96,084	90,192	68,921
Hybrid seed sold (%)	93.5	95.7	96.3	94.0	92.4	93.6	93.7
Eastern and southern Africa, excluding Angola							
Sales by public agencies (tons)	4,960	3,098	3,033	3,222	4,446	3,343	3,968
Hybrid seed sold (%)	25.7	37.4	29.6	17.4	13.6	26.8	28.5
Sales by private agencies (tons)	63,429	113,222	118,847	116,747	118,914	108,872	87,678
Hybrid seed sold (%)	92.0	94.1	94.7	93.1	91.6	92.7	92.0

Source: CIMMYT Maize Research Impacts Survey, 1998/99.

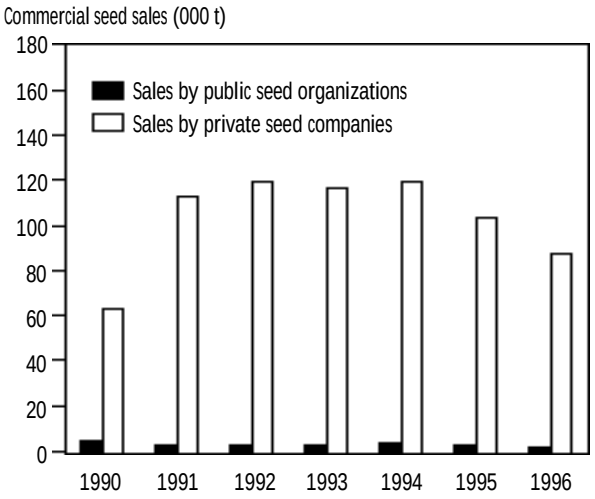

Figure 5a. Commercial maize seed sales, by sector, eastern and southern Africa, 1990-96
Source: CIMMYT Maize Research Impacts Survey, 1998/99.

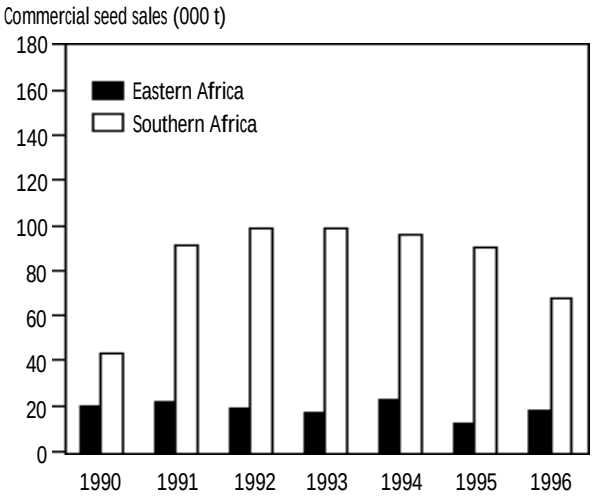

Figure 5b. Commercial maize seed sales, by region, eastern and southern Africa, 1990-96
Source: CIMMYT Maize Research Impacts Survey, 1998/99.

In terms of market size, southern Africa is a much more important market for private seed companies than eastern Africa; the volume of private-sector seed sales in southern Africa is more than three times larger than the volume of seed sales in eastern Africa (Table 24). For public seed companies, the reverse is true; public seed companies continue to sell more maize seed in eastern Africa than they do in southern Africa (Table 24).

Aggregating across the two regions, sales of hybrid seed have grown as a proportion of total seed sales. By 1996, hybrid seed accounted for more than 92% of total seed sales (Table 24 and Figure 6). The only significant exception to the trend toward greater emphasis on hybrids has occurred in southern Africa, where public-sector seed sales have become increasingly dominated by OPVs. This finding can be attributed to the fact that with Angola excluded from the analysis, the only public seed company still operating in southern Africa is in Tanzania, where public seed agencies have made a conscious decision to concentrate on OPVs. Given the current environment, most smallholders in Tanzania cannot afford to purchase hybrid seed and other inputs such as chemical fertilizer.

The rise of the private maize seed industry and the related increase in the production of hybrid seed raises difficult questions for policy makers. In particular, it is justifiable to ask whether current trends will lead eventually to further marginalization of small-scale, subsistence-oriented farmers, many of whom are likely to find it difficult

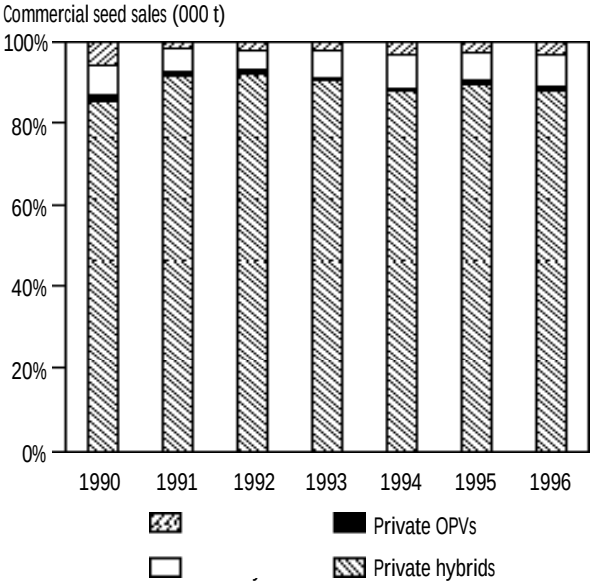

Figure 6. Compostion of commercial maize seed sales, eastern and southern Africa, 1990-96
Source: CIMMYT Maize Research Impacts Survey, 1998/99.

to buy fresh hybrid seed every year. To date, no definitive answer has emerged to this important question. Despite the widespread belief that hybrid technology is inappropriate for smallholders, evidence from a number of countries in the region suggests that hybrids can be adopted successfully by small-scale producers. In Kenya (Hassan et al. 1998b), Zimbabwe (Eicher and Kupfuma 1997, Eicher 1995), Lesotho, Swaziland and South Africa, smallholders have achieved rates of adoption of hybrid maize that are comparable to those achieved by large commercial farmers.

Estimates of Area Under CIMMYT Germplasm

How extensive is the area planted in eastern and southern Africa to maize varieties that were developed using CIMMYT germplasm? In the absence of detailed information about the area planted to individual varieties, the area planted to varieties containing CIMMYT germplasm had to be calculated indirectly based on (1) estimates of the area planted to all modern varieties, (2) quantitative data on the use of CIMMYT germplasm in all varietal releases, and (3) qualitative information provided by public- and private-sector breeders. For most countries, it was assumed that of the total area planted to modern varieties, the proportion planted to varieties containing CIMMYT germplasm was identical to the proportion of all varietal releases that have contained CIMMYT germplasm. Implicit in this approach is the assumption that on average, varieties developed using CIMMYT germplasm have been adopted at the same rate as varieties developed without the use of CIMMYT germplasm. For five countries in which only limited information was available about the CIMMYT germplasm content of varietal releases (Angola, Lesotho, South Africa, Swaziland, Uganda), the proportion of modern varieties containing CIMMYT germplasm was subjectively estimated based on information provided by breeders in the public and private sectors about the use of CIMMYT source materials in their breeding programs.

Based on these estimates, it is estimated that in 1996 over 1.6 million hectares in eastern and southern Africa were planted to varieties containing CIMMYT germplasm (Table 25). Of this amount, 0.32 million ha were located in eastern Africa (representing 8% of the total maize area in that region, and 21% of the area planted to modern varieties) and 1.31 million ha were located in southern Africa (representing 12% of the total maize area in that region, and 21% of the area planted to modern varieties). Excluding South Africa, where maize is grown mainly in temperate production environments that are not directly targeted by CIMMYT's breeding program, 16% of the total maize area in southern Africa was planted to CIMMYT derived varieties, representing 47% of the area planted to modern varieties.

Table 25. Area planted to maize varieties developed using CIMMYT germplasm, eastern and southern Africa, 1996

Country / region	Area planted to materials containing CIMMYT germplasm (000 / ha)	Percentage of total area under MVs
Ethiopia	36.4	36.4
Kenya	121.1	11.1
Uganda	163.5	50.0
Eastern Africa	*321.1*	*21.2*
Angola	52.7	33.3
Lesotho	5.4	5.0
Malawi	78.0	55.6
Mozambique	69.3	75.0
South Africa	196.3	5.0
Swaziland	2.3	5.0
Tanzania	52.1	33.3
Zambia	17.0	13.6
Zimbabwe	835.3	53.3
Southern Africa	*1,308.4*	*20.7*
Southern Africa, excluding South Africa	*1,112.1*	*46.5*
Eastern and southern Africa	*1,629.4*	*20.8*
Eastern and southern Africa, excluding South Africa	*1,433.2*	*36.7*

Source: CIMMYT Maize Research Impacts Survey, 1998/99.

Summary and Conclusions

In 1997, CIMMYT launched a major study designed to document the impacts of international maize breeding research in developing countries. The study was intended to update and extend the findings of CIMMYT's first global research impacts study, which had been published three years earlier in a report entitled *Impacts of International Maize Breeding Research in the Developing World, 1966-90* (López-Pereira and Morris 1994). Due to the enormity of the data collection task, the follow-up study was divided into three regional impacts studies. This report has presented the results of the regional impacts study carried out for eastern and southern Africa.

The results presented in this report are based on information collected during 1998 and 1999 through a comprehensive survey of public and private maize breeding organizations and seed production agencies in 12 countries of eastern and southern Africa. The survey generated information on many aspects of maize research, seed production, and seed distribution (e.g., maize breeding activities, products of breeding programs, maize seed production and sales operations, seed industry regulations and policies). The countries covered by the survey accounted for more than 95% of all maize produced in the region. The organizations contacted as part of the survey currently control about 97% of the total maize seed market in the 12 countries.

Major findings of the study are summarized below.

Policy reforms have led to increased private-sector participation in many national maize seed industries

During the past decade, national maize seed industries in eastern and southern Africa have undergone major structural changes. In most countries, policy reforms introduced in an effort to scale back the role of the state have paved the way for increased private sector participation in seed research, seed production, and seed distribution activities. These policy reforms have induced marked changes in the organization and performance of national maize seed industries.

The most obvious change has been the emergence of a flourishing private maize seed sector. Private maize seed companies currently operate in every country in the region. This represents a major difference compared to earlier years, when maize research and maize seed production were largely restricted to monopolistic government agencies and parastatals. Major reforms that were instrumental in bringing about this change included the lifting of prohibitions on private seed companies, removal of restrictions on importation of commercial maize seed, and elimination of direct seed price controls.

Despite the recent liberalization measures, however, in many countries the participation of private seed companies continues to be constrained by implicit restrictions in the form of cumbersome seed certification requirements and lengthy varietal registration procedures. Moreover, a number of governments are still trying to influence maize seed prices indirectly, for example by subsidizing maize seed production. This practice is especially prevalent in countries in which public agencies continue to operate and control large shares in the seed market.

Interestingly, the rise of the private seed industry appears to have happened in the absence of well-defined intellectual property regimes. In most countries of eastern and southern Africa, little progress has been achieved in establishing intellectual property rights and implementing plant varietal protection legislation. Private seed companies apparently are relying mainly on trade secrets approaches to keep their most valuable germplasm out of the hands of potential competitors, thereby protecting the investments they have made in maize breeding research.

Rapid growth in private-sector investment in maize breeding research has been accompanied by changes in varietal release patterns

The recent policy reforms have had a pronounced effect on research investment patterns. Although data on research investment are difficult to come by, private investment in maize breeding research clearly has increased as a share of total research investment in many countries. In eastern Africa, public-sector maize breeders still outnumber private-sector breeders, but in southern Africa the number of breeders is now roughly the same. Numbers of scientists provide an imperfect measure of total research investment, however, since they reveal very little about the cost of supporting each researcher. In eastern and southern Africa, as elsewhere in the developing and developed world, the cost of supporting a senior scientist (salary and benefits plus operating funds) tends to be considerably higher in the private sector. Adjusting for the difference in support costs, total research investment by the private sector probably exceeds total research investment by the public sector, certainly in southern Africa and probably for both regions.

The productivity of investments in breeding research can be judged by examining the rate at which breeding programs release new varieties. In both eastern and southern Africa, maize breeders employed by private seed companies have on average released more varieties than maize breeders working in public research organizations. This difference in varietal release rates can be attributed to differences in the quantity and quality of investment, as well as to the commercial orientation of private seed companies compared to public breeding programs, which focus more on non-commercial breeding objectives.

The composition of varietal releases reflects steady growth in the role of the private sector. By the late 1990s, all maize varieties released in eastern and southern Africa were originating from private companies. The recent decline in public-sector varietal releases no doubt also reflects reductions in public funding for agricultural research that have occurred in many countries in the region.

Increased private-sector participation in the maize seed industry has been accompanied by greater concentration of the industry

Seed industry liberalization has led to a significant decline in the role of public seed agencies throughout eastern and southern Africa. Seed sales data make clear that the private sector has effectively taken over the maize seed market in many countries. In 1996, the most recent year for which seed sales data are available, more than 90% of total commercial seed sales were made by private companies. It is important to note, however, that in a number of major maize producing countries (e.g., Kenya, Zambia, Zimbabwe), the leading private seed company is simply a transformed version of a previously public or parastatal seed agency that had long monopolized the local seed market. In several instances, these privatized parastatals continue to control more than 80% of the national seed market. At the time of their creation, these companies already had an edge over potential competitors because they inherited well established networks of seed production facilities, conditioning plants, and distribution depots.

With privatization, the maize seed industry is becoming more concentrated as a relatively small number of large multinationals acquire, merge with, or buy large shares in local seed companies. While consolidation could lead to scale economies, reduced competition is a concern to farmers, who worry that they may eventually face restricted choices and have to pay higher prices. The fact that seed prices in many countries have not risen significantly may reflect continued attempts by governments to keep maize seed prices low through the supply of subsidized public maize seed.

Hybrids now dominate varietal releases and seed sales

Since private seed companies have strong commercial incentives to concentrate on hybrids, it is not surprising that the emergence of a flourishing private seed industry has been accompanied by a rising share of hybrids in new varietal releases and seed sales. Because many public breeding programs are now also concentrating on hybrids (because of their superior performance), this has led to a situation in which varietal releases and seed sales are now completely dominated by hybrids.

Some observers have raised questions about the increasing popularity of hybrids, pointing out that hybrid technologies may not be suitable for small-scale, subsistence-oriented farmers, many of whom lack the resources needed to buy fresh seed every season. Little empirical evidence has emerged to indicate that small-scale farmers have been adversely affected by the shift to hybrids, but the matter will require careful attention, because supplying seed to smallholders may not be of interest to profit-motivated private firms.

Adoption of improved maize varieties increased during the 1990s

Commercial maize seed sales data support estimates made by researchers and seed industry insiders that adoption of improved varieties increased during the 1990s in most countries of eastern and southern Africa. However, significant differences in adoption patterns are evident between countries and regions. Total sales of improved maize seed have fluctuated around a modest 20,000 tons per year in eastern Africa, whereas in southern Africa total maize seed sales grew during the early 1990s to peak at just over 100,000 tons in 1992 before declining. Within individual countries, the area planted to modern varieties varies from less than 10% to nearly 100%. The large differences between countries in adoption rates can be attributed partly to differences in economic, institutional, and policy factors that affect the availability and affordability of improved seed.

Use by researchers of CIMMYT germplasm continues to increase, as does adoption by farmers of CIMMYT-derived varieties

CIMMYT's maize breeding program has had significant impacts in eastern and southern Africa. Of all maize varieties released by public and private breeding programs since 1966 and whose parentage is known, 24% were developed using CIMMYT source materials (35% if South Africa is excluded). Use of CIMMYT germplasm increased steadily over time; of the varieties released since 1990 and whose parentage is known, over 31% were developed using CIMMYT source materials (55% if South Africa is excluded). In 1996, approximately 1.6 million ha in eastern and southern Africa were planted to varieties that had been developed using CIMMYT germplasm, representing nearly 21% of the area planted to all modern varieties. Excluding South Africa, where farmers grow mainly temperate materials not targeted by CIMMYT's breeding program, nearly 37% of the area planted to modern varieties in eastern and southern Africa was planted to varieties containing CIMMYT germplasm. Taken together, the varietal release data and the adoption data indicate growing demand for CIMMYT source materials on the part of public and private breeding programs, as well as growing acceptance by farmers of varieties developed using those materials. The observed growth in demand for and use of CIMMYT germplasm in eastern and southern Africa over recent years validates the decision by the CIMMYT Maize Program to establish regional maize breeding programs in eastern and southern Africa and to allocate increased resources to local adaptive breeding.

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