

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

Country/region	Public sector		Private sector	
	Salary and benefits	Operating budget	Salary and benefits	Operating budget
Ethiopia	3,429	-	-	-
Kenya	6,667	8,333	-	-
Uganda	5,100	-	-	-
<i>Eastern Africa</i>	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	-
<i>Southern Africa</i>	9,756	12,161	18,923	11,597
<i>Southern Africa, excluding South Africa</i>	6,590	6,520	11,021	14,497
<i>Eastern and southern Africa</i>	7,410	9,718	18,923	11,597
<i>Eastern and southern Africa, excluding South Africa</i>	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

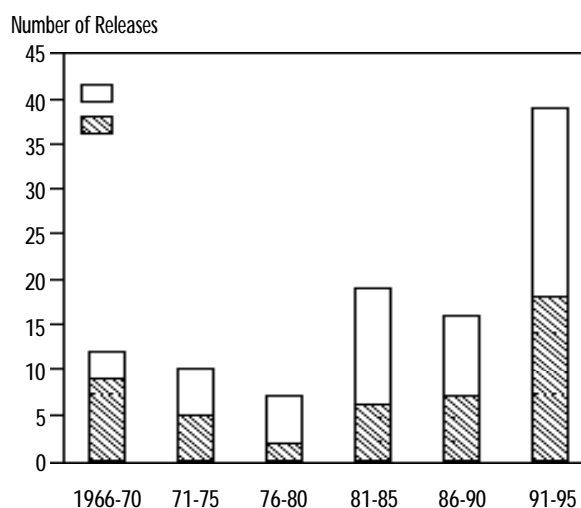


Figure 1. Public maize varietal releases, by type of cultivar, eastern and southern Africa, 1966-95
Source: CIMMYT Maize Research Impacts Survey, 1998/99.

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

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

Country/region	OPVs	Hybrids				Total	Total MVs	MVs per million ha of maize
		Single cross	Three-way cross	Double cross	Other			
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
<i>Eastern Africa</i>	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
<i>Southern Africa</i>	43	23	22	5	5	55	98	9.6
<i>Southern Africa, excluding South Africa</i>	43	23	22	5	5	55	98	13.7
<i>Eastern and southern Africa</i>	61	24	23	5	20	72	133	9.8
<i>Eastern and southern Africa, excluding South Africa</i>	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).

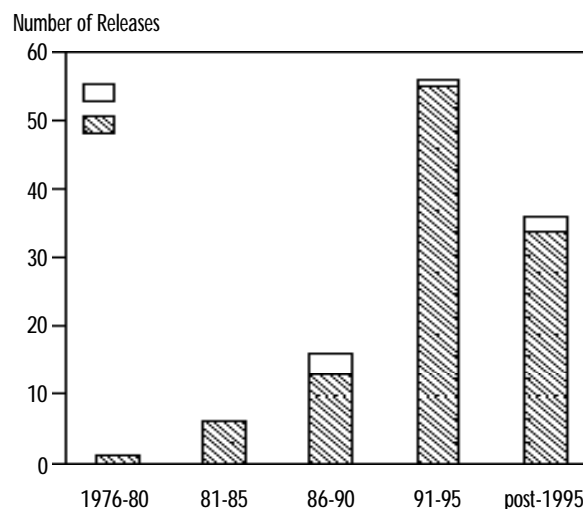


Figure 2. Private maize varietal releases, by type of cultivar, eastern and southern Africa, 1976-98
Source: CIMMYT Maize Research Impacts Survey, 1998/99.

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

Country/region	OPVs	Hybrids				Total	Total MVs	MVs per million ha of maize
		Single cross	Three-way cross	Double cross	Other			
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
<i>Eastern Africa</i>	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
<i>Southern Africa</i>	6	17	69	30	9	125	131	12.0
<i>Southern Africa, excluding South Africa</i>	6	3	48	4	2	57	63	8.8
<i>Eastern and southern Africa</i>	6	17	71	31	12	131	137	9.4
<i>Eastern and southern Africa, excluding South Africa</i>	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

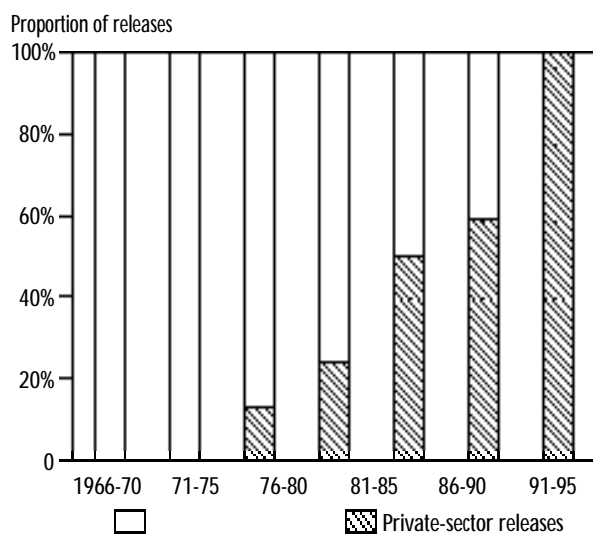


Figure 3a. Trends in maize varietal releases, by sector, eastern and southern Africa, 1966-98

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

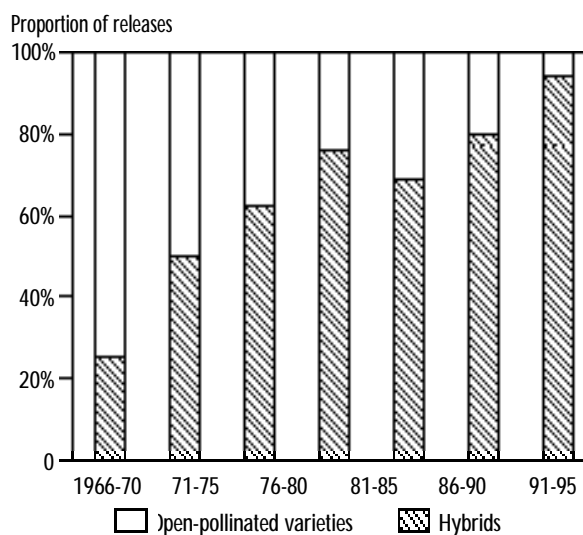


Figure 3b. Trends in maize varietal releases, by type of cultivar, eastern and southern Africa, 1966-98

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
<i>Eastern Africa</i>	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
<i>Southern Africa</i>	22	34	13	4	0
<i>Southern Africa, excluding South Africa</i>	22	34	13	4	0
<i>Eastern and southern Africa</i>	24	52	20	9	3
<i>Eastern and southern Africa, excluding South Africa</i>	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
<i>Eastern Africa</i>	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
<i>Southern Africa</i>	5	94	2	1	7
<i>Southern Africa, excluding South Africa</i>	4	40	2	1	0
<i>Eastern and southern Africa</i>	5	95	2	4	9
<i>Eastern and southern Africa, excluding South Africa</i>	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).

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

Country/region	Grain color		Grain texture			
	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
<i>Eastern Africa</i>	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
<i>Southern Africa</i>	86	12	38	15	13	32
<i>Southern Africa, excluding South Africa</i>	83	8	38	8	13	32
<i>Eastern and southern Africa</i>	121	12	47	25	27	34
<i>Eastern and southern Africa, excluding South Africa</i>	118	8	47	18	27	34

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

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

Country/region	Grain color		Grain texture			
	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
<i>Eastern Africa</i>	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
<i>Southern Africa</i>	64	51	51	46	13	5
<i>Southern Africa, excluding South Africa</i>	40	7	10	27	6	4
<i>Eastern and southern Africa</i>	70	51	53	50	13	5
<i>Eastern and southern Africa, excluding South Africa</i>	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
<i>Eastern Africa</i>	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
<i>Southern Africa</i>	3	4	19	24	23
<i>Southern Africa, excluding South Africa</i>	3	4	19	24	23
<i>Eastern and southern Africa</i>	6	6	26	32	38
<i>Eastern and southern Africa, excluding South Africa</i>	6	6	26	32	38

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