Reaching the Subsistence Farmer: A Unique Challenge

Because maize has so many distinctive characteristics that affect the way in which improved germplasm is developed and disseminated to farmers, public breeding programs that work on maize face a much more difficult task than public breeding programs that work on other crops. The challenge faced by public maize breeding programs is unique in a number of respects:

- ***Stiff competition from the private sector:*** Private-sector investment in maize breeding research far exceeds public-sector investment in breeding research for any other food crop. Public maize breeding programs thus face extremely stiff competition in the form of a flourishing global maize seed industry made up of large, well-funded, multinational corporations, all of which invest enormous sums in crop improvement research. In this respect, maize differs from rice, wheat, barley, millet, and most other food crops, which have attracted little interest from the private sector.
- ***Limited scope for capturing research spillins:*** Public maize breeding programs could potentially benefit from the extensive private-sector investment in breeding research if they could take advantage of improved materials developed by the private sector. Unfortunately, the possibility of capturing "spillin" benefits is precluded by the location specificity of maize germplasm. Virtually all of the germplasm being worked on by leading private seed companies is temperate germplasm destined for the commercial production zones of North America, Western Europe, northern China, Argentina, and South Africa; this germplasm is generally of limited use in the non-temperate production zones targeted by many public breeding programs.
- C***onsiderable achievements of farmer-breeders:*** Since maize was domesticated 5,000-10,000 years ago, farmers have developed an enormous number of varieties that not only meet specialized consumption preferences but also show excellent adaptation to local growing conditions. Although farmers impose selection pressure in all crops, in the case of maize the open-pollinating characteristic has allowed progress to be achieved unusually fast. Modern maize breeding programs thus face a particularly difficult challenge in attempting to compete with landraces and farmer-bred varieties.
- ***Diversity of farmers' varietal preferences:*** Because maize has multiple end uses, maize breeders face the additional challenge of having to develop many different types of varieties to meet farmers' varietal preferences. The problem is particularly daunting for breeders who are trying to develop varieties for subsistence farmers, who typically grow several varieties with completely different characteristics. In a world of finite research resources, the greater the number of varieties being developed, the less resources that can be devoted to each cultivar, and the less progress that is likely to be achieved.
- ***High cost of hybrid seed:*** The high cost of producing hybrid seed poses a final challenge to public-sector maize breeding programs, because even when it is possible to develop hybrids that significantly outperform farmers' current varieties, often it is not possible to produce improved seed at a price that subsistence farmers will be willing and able to pay. In most developing countries, the private seed industry is now targeting commercial farmers who regularly purchase improved seed, meaning that public breeding programs for all intents and purposes are left serving those farmers who are unable to afford improved seed.

Investment in Maize Breeding Research

International maize breeding efforts are carried out on a global stage populated by many different actors. No effort will be made here to enumerate all of these actors and to describe their activities in detail. Such an exercise would in any case be pointless; the global maize breeding industry is evolving very rapidly, and the actors and their roles change practically on a daily basis. The more modest objectives of this section therefore are to provide a brief overview of international maize breeding efforts, to introduce the major institutional players, and to summarize their germplasm improvement activities.

International Agricultural Research Centers (IARCs)

Maize improvement work is carried out at two of the 16 international agricultural research centers (IARCs) that are members of the CGIAR. CIMMYT, headquartered in Mexico, holds a global mandate for maize improvement. IITA, headquartered in Nigeria, holds a regional mandate for maize improvement and targets mainly humid tropical zones of West and Central Africa. This report focuses mainly on the impacts of the CIMMYT maize breeding program, which is by far the larger of the two. Information about the impacts of the IITA maize breeding program can be found in Manyong et al. (2000).

The organization of maize breeding activities at CIMMYT is consistent with the Center's mandate to provide support to local breeding programs in developing countries. The objective of the CIMMYT maize breeding program is not to produce finished varieties that can be delivered directly to farmers. Rather, the CIMMYT maize breeding program seeks to develop intermediate products for use by local breeding programs, i.e., improved germplasm showing high yield potential, good agronomic characteristics, resistance to important biotic and abiotic stresses, and/or enhanced nutritional quality. CIMMYT scientists accomplish this goal by collecting, evaluating, and preserving a wide range of maize germplasm; by improving materials in their own breeding plots; and by managing an international testing network through which sets of experimental materials (known as "nurseries") are distributed to key sites around the world for evaluation by local collaborators. In return for growing the nurseries under specified levels of management and recording key performance data, the collaborators are free to request additional seed of promising materials for use in their own breeding programs. The CIMMYT-managed international testing networks thus provide national breeding programs with ready access to germplasm and information that they would not be able to generate on their own.

The germplasm improvement strategy pursued by the CIMMYT Maize Program has evolved over the years in response to changes in the environment in which CIMMYT operates. During the first several decades of CIMMYT's existence, at a time when maize breeders in most industrialized countries were concentrating almost exclusively on hybrid development, CIMMYT maize breeders continued to work mainly with open-pollinating materials. The emphasis on OPVs was justified by four beliefs prevailing at the time:

(1) hybrid technology could not succeed without the support of a sophisticated seed industry, which was still lacking in most developing countries;

(2) hybrid technology was inappropriate for small-scale farmers, who could not afford to purchase new seed annually;

(3) OPV seed could be produced with simple technology, and once distributed, would travel from farmer to farmer; and

(4) improved breeding methods for population improvement offered the opportunity for OPVs to match hybrids in terms of yield potential, and, in any event, population improvement would improve the genetic base from which hybrids could later be developed.

Over time, these beliefs began to be challenged by events in farmers' fields. In many developing countries, despite large-scale efforts to promote OPVs, adoption was less extensive than expected, and even where OPVs were initially adopted, few farmers replaced seed on a regular basis. In the absence of a private seed industry, OPV seed production was left to inefficient parastatal seed companies or assigned to development projects lacking in technical expertise, long term sustainability, or both. As a result, OPV seed supply and quality were often inadequate.

As efforts to promote the use of OPVs foundered, interest in hybrids gradually increased. Despite the widely held belief that hybrid technology was not suitable for small-scale subsistence-oriented farmers, evidence was emerging to show that hybrids could be adopted successfully by smallholders. In El Salvador, Kenya, Venezuela, Zambia, and Zimbabwe, adoption of hybrids by smallholders resulted from "spillover" out of the commercial farming sector. In all of these cases, hybrids were initially targeted at large-scale commercial growers, but when the superior performance of commercial hybrids generated demand for these materials among small-scale producers, seed companies recognized a potential new market and adjusted their marketing strategies accordingly. The diffusion of hybrids by smallholders gained additional momentum following the privatization of many national seed industries, since private seed companies concentrated almost exclusively on hybrids for commercial reasons.

The shift in interest to hybrids, which also coincided with the rise of the private seed industry, led eventually to a change in the breeding strategy of the CIMMYT Maize Program (CIMMYT 1998). While the traditional population improvement work was maintained, beginning in the late 1980s, an inbreeding program was established with the goal of generating inbred lines for use in hybrid crossing programs. The inbreeding program gathered strength throughout the 1990s and currently accounts for about half of CIMMYT's total maize breeding effort.

In terms of of researchers, the IARCs are minor actors in the global maize breeding industry. The CIMMYT Maize Program currently includes about 35 scientist FTEs (full-time equivalents), of which approximately 30 are engaged in breeding or breeding support (including genetic resources conservation and management). The IITA Crop Improvement and Plant Health Management Divisions currently include about 12 maize scientist FTEs, of which approximately 8 are engaged in breeding or breeding support. Numbering less than 50 scientist FTEs between them, the CIMMYT and IITA maize breeding programs thus are considerably smaller than many national maize breeding programs.

How has CIMMYT's investment in maize genetic improvement evolved through time? The question is not as straightforward as it seems, because CIMMYT's investment in maize genetic improvement can be defined broadly or narrowly. Given that CIMMYT is first and foremost a plant breeding institute, it could be argued that CIMMYT's entire budget is ultimately dedicated to the improvement of its two mandate crops. Yet certain activities carried out by CIMMYT staff have little direct connection to plant breeding (for example, farming systems research, natural resource management research, certain types of social science research, networking and training activities), so it could also be argued that something less than the Center's entire budget is spent on crop improvement research.

Figure 1 shows the evolution of CIMMYT's expenditures on maize improvement research under two sets of assumptions. In Scenario 1, it is assumed that CIMMYT's entire budget is dedicated to crop improvement research and that the budget can be allocated between maize and wheat

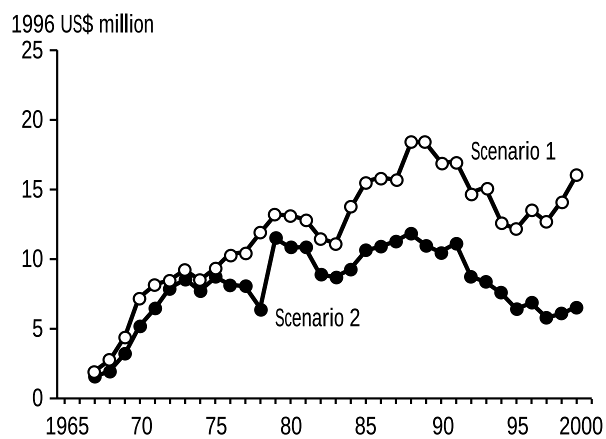

Figure 1. CIMMYT maize research expenditures, 1967-99.
Source: CIMMYT Audited Financial Statements, Annual Reports.

programs in proportion to the relative sizes of the budgets. In Scenario 2, it is assumed that the proportion of CIMMYT's entire budget that can be allocated to maize improvement research is proportional to the number of senior Maize Program staff among all senior staff (not only Maize and Wheat Program staff, but also staff of other research programs and support units). The assumptions underlying Scenario 1 are very generous, while those underlying Scenario 2 are very conservative, so the amount spent by CIMMYT on maize breeding research probably lies somewhere in between these two extremes. All expenditures have been adjusted for inflation by converting to 1996 US dollars (1996 was selected as the base year to facilitate comparison with other research investment data presented later in this report).

Under Scenario 1, CIMMYT's real investment in maize genetic improvement rose steadily throughout the 1960s, 1970s, and 1980s, peaking in 1989 at just over US $21 million per year. Thereafter, investment declined, falling to just under US $14 million per year during the mid 1990s before beginning to rise again at the end of the decade. Under Scenario 2, CIMMYT's real investment in maize genetic improvement rose throughout the 1960s and 1970s, peaked in 1978 at about US $13 million per year, remained more or less constant until the early 1990s, and subsequently declined. The marked difference between the two scenarios results from the fact that Scenario 2 figures were calculated based on staff numbers. In recent years, numbers of Maize Program staff have declined as a proportion of total staff with the diversification of CIMMYT's research portfolio and associated growth in the number of non-crop program staff.

Based on these data, it can be concluded that CIMMYT currently invests between US $8 and US $18 million per year on maize genetic improvement. In interpreting these figures, it should be noted that a portion of CIMMYT's budget (estimated at 8-15%) consists of flow-through funds that go directly to national program partners, so the amount spent by CIMMYT on its own research is actually somewhat lower.

Public National Breeding Programs

Traditionally, the principal clients of the CIMMYT Maize Program have been public maize breeding programs in developing countries. These public breeding programs vary in size, organization, and focus. Generally speaking, the level of sophistication varies as a function of the economic and political importance of maize. In countries in which maize is a relatively minor crop, the expected returns to investment in maize research are low, so national maize programs tend to be quite small. In these countries, the national breeding program often concentrates on importing materials developed elsewhere and screening them to identify those that are well adapted to local conditions. In countries in which maize is of intermediate importance, the expected returns to investment in maize research are greater, and therefore a more substantial investment in maize research is justified. In these countries, the national breeding program may take on additional functions, such as crossing inbred lines and testing the resulting hybrids. In countries in which maize is a major crop, the potential returns to investment in maize research are large, and often it will be economically efficient to establish a full-fledged national breeding program that engages in the full range of germplasm improvement activities, including germplasm conservation, population improvement and pre-breeding, inbred line development, test-crossing, and cultivar evaluation.

The level of public investment in maize research in developing countries is difficult to estimate with precision. Commodity-specific research investment data are rarely available, and when they are available, usually do not provide a full accounting of all expenses (e.g., capital investment, administrative overheads). In addition, national accounts frequently do not include funds obtained from external sources, particularly development assistance grants from foreign donors, which can be significant.

Where financial data are unavailable, a less complete but more easily quantified measure of research investment is the number of people working in research. Table 2 presents data on numbers of scientists working on maize improvement research in public institutes in developing countries. (A scientist working on maize improvement research was defined as someone who engages in breeding or directly supports germplasm improvement work.) During the late 1990s, the public sector was still a major player in the international maize breeding industry, supporting nearly 1,000 scientists. These scientists were quite evenly distributed across all developing regions, with the exception of China, which supported a disproportionately large share.[2] The organization of public breeding programs varied considerably, however. Public breeding activities in Latin America and Asia were generally more decentralized, with larger numbers of relatively small breeding programs, whereas in Eastern and Southern Africa they were generally more centralized, with fewer numbers of larger breeding programs.

The data in Table 2 also reveal some interesting patterns in the intensity of public investment in maize research. Controlling for the size of the maize sector, the number of publicly supported maize scientists was much higher in Asia than other regions, presumably reflecting the relatively low cost of human capital in Asia. Interestingly, both of the research intensity indicators shown in Table 2 (scientists/million ha planted to maize, scientists/million tons of maize production) have decreased since the first CIMMYT global impacts survey was conducted, indicating that public investment in maize breeding (measured in terms of numbers of scientists) declined during the 1990s.

Table 2. Public-sector maize research investment indicators, developing countries, late 1990s.

	Number of countries surveyed	Public maize breeding programs	Maize scientists (FTEs)	Maize scientists per program	Maize scientists per million ha maize area	Maize scientists per million t maize production
Latin America	**18**	**49**	**290**	**5.9**	**10.2**	**4.2**
Brazil		*7*	*55*	*7.9*	*4.1*	*1.7*
Mexico		*13*	*131*	*10.0*	*16.8*	*7.4*
Eastern and Southern Africa	**12**	**4**	**109**	**27.3**	**7.6**	**4.1**
East, South, and Southeast Asia	**7**	**116**	**505**	**4.4**	**26.3**	**11.0**
China (southern)		*65*	*270*	*4.2*	*65.6*	*17.5*
India		*27*	*56*	*2.1*	*9.1*	*5.7*
All regions	**37**	**169**	**904**	**5.3**	**14.6**	**6.4**

FTEs = Full-time equivalents
Source: CIMMYT maize research impacts survey.

2 Since the China data in Table 2 refer only to the five southern provinces of China in which maize is grown mainly in non-temperate production zones, they do not include an additional 1,500 Chinese breeders working in central and northern China. When these additional breeders are included, two out of every three maize breeders in the developing world are Chinese!

Table 3 presents estimates of the average annual support cost (salary and benefits) of four categories of research personnel: senior scientists, junior scientists, research technicians, and field laborers. The estimates do not include operating budgets and capital investment costs, so they significantly understate total investment costs. Even so, they provide valuable insights into the size and distribution of public investment in maize breeding research during the late 1990s. Personnel support costs varied considerably between regions, being highest in Latin America and lowest in Asia. (Average research investment costs for Asia are greatly influenced by the large national maize breeding programs of China and India, countries in which salaries and benefits paid to public-sector employees are very low by international standards.)

Private Seed Companies

Maize breeding programs are also found in the private sector. This has not always been the case, at least not in the developing world. Until quite recently, policy makers in many developing countries believed that research on maize and other staple food crops was too important to be entrusted to the private sector, and private companies were legally prohibited from engaging in maize breeding research. Over time, as the performance of many government seed organizations deteriorated, opposition to private-sector participation in the seed industry gradually subsided. Beginning in the 1970s in Latin America, in the 1980s in Asia, and in the 1990s in Africa, reforms were enacted in many countries that broke up longstanding government seed monopolies and paved the way for increased private-sector participation in plant breeding research and commercial seed production.

The privatization of national maize seed industries played out differently in different countries, depending on the nature and sequencing of reforms, on the structure of the pre-existing seed industry, and on the prevailing business climate into which reforms were introduced. In many countries in which maize is economically or politically important, reforms to the maize seed industry were initially designed to favor domestic companies; restrictions were often maintained on foreign investment in the maize seed industry, ostensibly to protect national food security. Effectively sheltered from foreign competition, newly-formed domestic seed companies moved quickly to establish a presence in what initially were still largely uncontested markets. The number of seed companies that sprang up varied from country to country. In countries where the small-scale business sector was already well established, seed industry liberalization often resulted in the emergence of large numbers of small private seed companies that thanks to their low capital investment requirements, operational flexibility, and intimate knowledge of local markets were able

Table 3. Direct support costs of public-sector maize research personnel, developing countries, late 1990s.

	Senior researchers		Junior researchers		Technicians		Casual laborers		Total direct personnel costs (US $)
	Number	Cost (US $)	Number	Cost (US $)	Number	Cost (US $)	Number	Cost (US $)	
Latin America	126	39,000	164	18,000	207	10,000	312	4,000	11,079,000
Eastern and Southern Africa	83	15,000	53	8,000	165	7,000	1,045	3,000	5,878,000
East, South, and Southeast Asia	182	6,000	295	3,000	294	4,000	435	3,000	4,307,000
All regions	391	18,000	512	8,000	666	6,000	1,792	3,000	21,263,000

Source: CIMMYT maize research impacts survey.

to compete effectively with the large, inflexible, and sluggish government seed monopolies on which farmers previously depended. In countries where the small-scale business sector was less well developed, seed industry liberalization often resulted in the privatization of well-established government seed agencies, resulting in national seed industries that were populated by relatively small numbers of large players.

Lacking established breeding programs of their own, virtually all of the newly formed private companies started out producing and selling seed of varieties that had been developed by public breeding programs. A high proportion of the first-generation private seed companies in fact were founded by public-sector breeders who quit their posts in the national breeding program to form seed companies. Since all of the companies offered basically the same varieties, competition was not based on germplasm per se, but rather on seed quality, price, and availability. In many countries, private start-ups quickly wrested a significant portion of the market away from government seed agencies, which continued to be plagued by problems of poor seed quality, inadequate supplies, and late delivery.

When fears that privatization of national seed industries would bring disastrous results proved unfounded, the initial cautious policy reforms were followed by more substantial reforms that among other things opened the door to increased foreign investment. Beginning in the late 1980s, most of the leading multinational seed companies began to take advantage of the lowering of investment barriers by expanding into developing country markets from their bases in Europe and North America. Initially, these expansionary efforts targeted mainly big countries with important commercial maize sectors, such as Argentina, Brazil, and Mexico in Latin America; Kenya, Nigeria, and South Africa in Africa; and India, Indonesia, the Philippines, and Thailand in Asia. Market penetration strategies varied. Some companies chose a more conservative course and at first set up only seed production facilities, intending to produce commercial seed using imported parental lines that had been developed elsewhere. Other companies opted for a more aggressive strategy by investing immediately in local research facilities, realizing from the outset that most of the commercial hybrids being sold in North America and Europe were unlikely to perform well in tropical and non-tropical production environments.

With the rapid proliferation of national seed companies and the appearance of more multinationals, competition began to heat up. In many countries, it soon became clear that the industry had over-expanded; excess production capacity began to manifest itself at the end of every planting season in the form of increasing numbers of companies left with unsold stocks of seed. Seed companies soon realized that the only way to survive in saturated markets was by offering distinctive products, i.e., unique varieties that could be differentiated in the marketplace from those of competing companies. Since the obvious way to acquire unique varieties was by establishing an in-house breeding program, companies with access to sufficient capital began to invest in research, with the goal of developing their own proprietary hybrids. Companies that were not able to establish breeding capacity had little choice but to continue multiplying and selling seed of public varieties; unable to survive on the low margins that characterized this intensely competitive sector, many of these companies eventually folded.

Meanwhile, many multinational companies were also running into problems. Many discovered that their hybrids were not suitable for developing countries; either the germplasm was poorly adapted to local production conditions, or the grain quality was unacceptable. Even when their hybrids were suitable, often the multinationals found that it was difficult to produce and distribute seed in countries where prevailing business practices were unfamiliar. Faced with these unexpected problems, the multinationals had two basic options: withdraw from the market altogether, or adopt an alternative strategy. In some instances, they chose to withdraw, if not from all developing countries, then at least from some. Many leading multinationals have closed down operations in some developing countries, and most multinationals continue to avoid entire regions of the developing world (for example, West Africa).

More commonly, however, the multinationals adopted an alternative strategy. Usually this involved joining forces with an established local partner, whether through a joint-operating agreement, a partnership, or an outright acquisition. Typically the multinational brought to the partnership a strong breeding program, a steady supply of improved germplasm products, and investment capital, while the local partner (more often than not a seed company) brought an established distribution network, knowledge of local markets, and the ability to operate effectively in the prevailing business climate.

These twin pressures—the pressure on national seed companies to come up with improved germplasm products that can be differentiated in the market from those of competitors, and the pressure on multinationals to gain access to effective distribution networks for their proprietary hybrids—have led to a structural transformation of most national seed industries. During the past decade, many small national seed companies have been swallowed by larger competitors, which themselves have formed alliances with multinational partners who can provide improved germplasm and capital.

One result of this structural transformation, which is still very much underway, has been a blurring of the distinction between "domestic seed companies" and "multinationals." Although at the extremes it is often possible to differentiate between the two categories, in between the small family-owned local seed companies that populate one end of the spectrum and the large multinationals that populate the other are a large number of medium-sized companies that may be registered as domestic corporations and operate within the boundaries of a single country but that share financial assets, germplasm, and/or business services with an overseas partner.

Table 4 presents data on private-sector maize research investment indicators for developing countries during the late 1990s. Subject to the caveat described above, the data are disaggregated into two categories, national companies and multinationals. By the late 1990s, the private sector

Table 4. Private-sector maize research investment indicators, developing countries, late 1990s.

	Number of countries surveyed	Private seed companies with breeding programs		Private-sector maize researchers		Maize scientists per million ha maize area	Maize scientists per million t maize production
		National	Multinational	National	Multinational		
Latin America	**18**	**65**	**27**	**101**	**109**	**7.4**	**3.1**
Brazil		*14*	*5*	*24*	*42*	*4.9*	*2.1*
Mexico		*20*	*4*	*23*	*20*	*5.5*	*2.4*
Eastern and Southern Africa	**12**	**10**	**2**	**10**	**35**	**3.1**	**1.7**
East, South, and Southeast Asia	**7**	**24**	**22**	**64**	**96**	**8.3**	**3.5**
China (southern)		*1*	*1*	*n.a.*	*n.a.*	*n.a*	*n.a*
India		*18*	*10*	35	40	*12.2*	*7.7*
All regions	**37**	**99**	**51**	**174**	**240**	**6.7**	**3.0**

Source: CIMMYT maize research impacts survey.

had become a major player in the maize breeding industries of most developing countries, employing over 400 senior breeders. Nearly 60% of these were employed by multinational companies, a marked increase from earlier years, when most maize breeding work was still being carried out in national companies. In contrast with the public sector, however, breeding capacity in the private sector was not distributed evenly throughout the developing world. Latin America and Asia (with the exception of China) supported a large number of private seed companies, reflecting not only the presence in those regions of important commercial maize sectors, but also a friendlier business climate. Private seed companies were much less common in Eastern and Southern Africa, reflecting the relative scarcity in this region of commercial maize sectors, as well as generally more challenging business environments.

Regional differences in numbers of private seed companies and numbers of private-sector maize breeders were reflected in similar differences in the intensity of private-sector investment in maize research. Controlling for the size of the maize sector, the number of private maize breeders was more than twice as high in Latin America and Asia than in Eastern and Southern Africa. Both research intensity indicators (scientists/million ha planted to maize, scientists/million tons of maize production) have risen significantly since the first CIMMYT survey was conducted, indicating that private investment in maize breeding (measured in terms of numbers of scientists) increased during the 1990s.

Table 5 presents estimates of the direct costs reported by private seed companies of supporting four categories of maize researchers: senior scientists, junior scientists, research technicians, and field laborers. Direct personnel support costs varied between regions. As in the public sector, personnel support costs in the private sector were highest in Latin America, but for private companies the cost of supporting research personnel was also relatively high in Asia. In all three developing regions, researchers employed by multinationals cost approximately twice as much to support as researchers employed by national companies, a difference attributable partly to differences in salaries and partly to differences in benefits (for example, international relocation costs).

Table 5. Direct support costs of private-sector maize research personnel, developing countries, late 1990s.

	Senior researchers		Junior researchers		Technicians		Casual laborers		Total direct personnel costs (US $)
	Number	Cost (US $)	Number	Cost (US $)	Number	Cost (US $)	Number	Cost (US $)	
Latin America									
National companies	47	71,000	54	29,000	84	14,000	238	4,000	7,095,000
Multinationals	52	137,000	57	60,000	241	29,000	318	6,000	19,531,000
Eastern and Southern Africa									
National companies	28	19,000	5	8,000	21	3,000	172	1,000	814,000
Multinationals	19	46,000	16	16,000	41	5,000	150	2,000	1,562,000
East, South, and Southeast Asia									
National companies	35	20,000	35	11,000	45	6,000	158	3,000	1,858,000
Multinationals	51	75,000	37	45,000	105	15,000	153	5,000	7,830,000
All regions									
National companies	109	42,000	93	21,000	150	10,000	568	3,000	9,767,000
Multinationals	123	97,000	110	49,000	386	23,000	621	5,000	28,923,000

Source: CIMMYT maize research impacts survey.

Importance of the Public and Private Sectors

Even though they represent an incomplete measure, these data on direct personnel support costs still provide a basis for comparing the relative size of public and private investment in maize breeding research. Summarizing across all three developing regions, during the late 1990s public expenditure on maize research personnel totaled approximately US $ 21.3 million per year. Over half of this amount was spent in Latin America (US $ 11.1 million), while the rest was spent in Africa (US $ 5.9 million) and Asia (US $ 4.3 million).

During the same period, private-sector expenditures on maize breeding research were considerably higher. Summarizing across all three developing regions, private-sector expenditures on direct personnel support costs totaled about US $ 38.7 million per year, of which about US $ 25.6 million was spent in Latin America, US $9.7 million in Asia, and US $ 2.4 million in Africa. Multinational seed companies outspent national seed companies by nearly 3:1, confirming the increasingly dominant role of multinationals in the developing world's maize seed industry. The investment advantage enjoyed by multinationals was even larger than these figures suggest, because no attempt has been made to factor in the cost of research carried out in industrialized countries. In breeding hybrids destined for developing-country markets, all multinationals draw heavily on technology and improved germplasm produced in their advanced laboratories and breeding stations located in North America and Europe.

Case study evidence from several countries suggests that direct personnel support costs make up 40-50% of total operating costs of a typical maize breeding program, so these figures can be doubled to arrive at a rough approximation of total investment in maize breeding research.

Products of Maize Breeding Research

The principal product of any maize breeding program is improved germplasm, so an important first step in assessing the impacts of international maize breeding research in developing countries is to compile a complete inventory of germplasm products.

Information about maize varieties developed by public breeding programs was collected in 1992 during the original CIMMYT global impacts survey. The public-sector varietal releases database was updated and expanded during the more recent survey. The database currently contains descriptive information about approximately 1,350 varieties and hybrids released since the mid-1950s by public breeding programs in 37 developing countries.[3] Collectively, these countries account for more than 75% of the area planted to maize in Latin America, Eastern and Southern Africa, and Asia and for more than 95% of the area planted to maize in non-temperate environments.

Information about maize varieties developed by private seed companies was collected through direct interviews carried out over a three-year period (1997-99). The CIMMYT maize impacts database currently contains information about nearly 1,900 varieties sold by private seed companies during the late 1990s in the 37 developing countries that participated in the CIMMYT survey. Approximately 1,100 of these were proprietary varieties that had been developed by private breeding programs.[4] Unlike the public sector, it was not possible to compile a complete list of all varieties developed by the private sector since 1966, the year in which CIMMYT was established.

[3] Since a major objective of this study is to assess CIMMYT's contribution to international maize breeding efforts, the following discussion relates only to the approximately 1,200 varieties released since 1966, the year in which CIMMYT was officially established.