Part 2
Assessing the Benefits of International Wheat Breeding Research: An Overview of the Global Wheat Impacts Study
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In 1990, CIMMYT conducted a study to evaluate the impacts of international wheat breeding research in the developing world from 1966 to 1990. Its objectives were to provide information to researchers on the acceptance or rejection of new technologies and the underlying reasons for adoption or nonadoption, and to demonstrate the benefits of wheat research for those who fund it (Byerlee and Moya 1993).

In 1997, CIMMYT’s Economics and Wheat Programs launched a follow-up survey to update the data and analysis of the first study. Specifically, the second study sought to:

• document the use of CIMMYT-related and other improved wheat germplasm;
• document the farm-level adoption of improved wheat germplasm;
• identify factors that affect adoption of modern varieties (MVs);
• generate information for setting research priorities; and
• provide information to raise awareness of the importance and benefits of international wheat research.

Questionnaires were sent to the 41 developing-world countries that produce more than 20,000 t of wheat annually. Responses were received from 36 countries, representing just under 99% of all wheat production in the developing world. On a regional basis, coverage ranged from 94% of production in West Asia/North Africa to nearly 100% in Latin America (Table 1). The latest study differs from its predecessor in several respects. It includes South Africa for the first time, and there is more complete coverage of China’s wheat area.

Table 1. Regional coverage for global wheat impacts study, 1997

<table>
<thead>
<tr>
<th>Region</th>
<th>Coverage (% of total wheat production)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asia</td>
<td>99.7</td>
</tr>
<tr>
<td>Sub-Saharan Africa</td>
<td>98.3</td>
</tr>
<tr>
<td>West Asia and North Africa</td>
<td>94.3</td>
</tr>
<tr>
<td>Latin America</td>
<td>Nearly 100</td>
</tr>
</tbody>
</table>

This second part of our report presents preliminary results of the global wheat impacts study. The first section analyzes global wheat improvement research by national agricultural research systems (NARSs) and provides a measure of research intensity. The second section presents the pattern of release of wheat varieties over time and the use of wheat germplasm from CIMMYT. The third section presents data about varieties currently grown in farmers’ fields and compares different measures of CIMMYT’s contribution to those varieties. This preliminary assessment of the achievements of the international wheat research system concludes with a discussion of several issues that impinge upon the future effectiveness of the system.

Wheat Research Efforts by NARSs

Studies conducted in the early 1990s by Bohn and Byerlee (Bohn and Byerlee 1993; Bohn, Byerlee, and Maredia 1999) and updated more recently by CIMMYT found that research intensity, measured as the number of scientists per million tons of wheat production, tended to fall with increasing wheat production (Figure 1). This appears to be an empirical regularity: because of the inverse relationship between production level and research intensity in the developing world, small wheat-producing countries tend to have a high intensity of wheat improvement research. The resulting implications for research efficiency, particularly for small research programs, have been considered by Maredia and Byerlee (1999).

Figure 1. Wheat production and scientists per million tons of wheat production, developing countries, 1997.
Source: CIMMYT wheat impacts database.

Note that the Central Asian and Caucasus states were not included in either study.
Analysis based on the actual numbers of scientists involved in wheat improvement research must be treated with considerable caution, given the inherent constraints of an impersonal questionnaire and the difficulty of enumerating scientists outside of the national research program who conduct research related to wheat improvement (e.g., researchers in universities). These factors could lead to an underestimate. On the other hand, both the 1990 and 1997 surveys asked respondents to identify the number of full-time equivalent scientists involved in wheat breeding, even when they represented disciplines other than plant breeding. In some instances, this could lead to an overestimate of the effort devoted to wheat improvement research, as opposed to, for example, wheat crop management.

In terms of the number of scientists per million tons of wheat production, wheat research intensity across the developing world appears to be slightly greater near the end of the 1990s than it was earlier in the decade: 6.2 scientists per million tons in 1997 compared to 5.3 in 1992–93 (Bohn and Byerlee 1993) (Figure 2).

This difference arose largely because a greater number of wheat improvement scientists were reported for China in 1997. When China is excluded, the 1992–93 and 1997 figures are nearly identical.

Based on these figures, wheat research intensity may appear to be fairly stable, but it is important to note that research by the International Food Policy Research Institute (IFPRI) and the International Service for National Agricultural Research (ISNAR) has suggested that financial support for agricultural research in many NARSs has fallen in recent years. This trend has been masked at the aggregate level by continued support for research in strong national research systems such as China and India. Funding for wheat improvement research by NARSs appears to be increasingly polarized, with large wheat-producing countries continuing to support research while many smaller countries allocate fewer and fewer resources to national wheat research.

Releases of Wheat Varieties

The national research systems of developing counties released about 2,200 wheat varieties between 1966 and 1997. Of these, about one-fourth were released in 1991–97. The rate at which varieties are released, as measured by the number of varieties released per million hectares per year, seems to have increased in recent years in several regions (Figure 3). Variability in rates of release in some countries over time was particularly striking, despite the use of five-year moving averages to smooth out short-term fluctuations.

During the past 30–40 years, wheat varieties have been released at a much higher rate in Latin America and sub-Saharan Africa than in the rest of the developing world. Higher rates of release may be associated with smaller wheat areas, greater diversity in mega-environments (that is, in the target environments for wheat research; see “Wheat Mega-environments Defined,” p. 4), the rate at which disease complexes change, and greater participation of the private sector in wheat improvement.

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**Figure 2.** Wheat improvement scientists per million tons of wheat production, developing countries and regions, 1997.

Source: CIMMYT wheat impacts database.

**Figure 3.** Rate of release of wheat varieties, 1960s–1990s.

Source: CIMMYT wheat impacts database.
Although the public sector dominates wheat improvement research in developing countries, there are some exceptions. Private-sector wheat improvement research has been strong in Argentina for some time. Varieties developed by the private sector are also sown in Brazil and Uruguay, and Chile conducted some private-sector wheat research in the past. In Africa, the private sector currently appears to be important in South Africa and Zimbabwe (Heisey and Lantican 1998). Other African countries, such as Kenya and Zambia, which had no private-sector wheat researchers in 1990, reported a modest level of private-sector research activity by 1997. Across the developing world, however, less than 4% of the wheat area is planted to private-sector varieties, and most of these varieties are based on germplasm developed by the public sector.

All of the countries surveyed have made considerable use of CIMMYT wheat germplasm. China differs from most of these countries, however, by using its own material to a great extent. The extent to which the Indian and Brazilian wheat improvement programs used their own crosses was also notable, although a substantial amount of the breeding material in the Indian and Brazilian research programs was based on CIMMYT germplasm (Traxler and Pingali 1998). In most other countries, the importance of CIMMYT crosses and CIMMYT parents has not changed since the 1990 study.

Nearly all spring bread wheats released by NARSs in developing countries are semidwarfs. The pattern of spring bread wheat releases over time is reported in Figure 4. Of the 357 spring bread wheats released by national research programs between 1991 and 1997:
- 56% were CIMMYT crosses, sometimes with reselection by NARSs;
- 28% were NARS crosses with at least one CIMMYT parent;
- 5% were NARS crosses with CIMMYT ancestry;
- 8% were NARS semidwarfs with other ancestry; and
- 3% were tall varieties.

The percentage of spring bread wheat releases that were CIMMYT crosses or had at least one CIMMYT parent in 1991–97 (84%) was higher than in the earlier study period, indicating that the use of CIMMYT germplasm has not declined in recent years.

Compared with spring bread wheats, a higher proportion of spring durum wheats released by NARSs contained CIMMYT germplasm (Figure 5). Between 1991 and 1997, of 52 spring durum wheats released by national programs:
- 77% were CIMMYT crosses;
- 19% were NARS crosses with at least one CIMMYT parent;
- 2% were NARS crosses with known CIMMYT ancestry; and
- 2% were tall varieties.

Spring durum releases based on CIMMYT crosses were predominant in West Asia/North Africa and Latin America.

Of 106 winter/facultative bread wheats released by national programs in 1991–97:
- 19% were CIMMYT crosses;
- 13% were NARS crosses with at least one CIMMYT parent;
- 9% were NARS crosses with known CIMMYT ancestry;
- 41% were NARS semidwarfs with other ancestry; and
- 18% were tall varieties.

Figure 6 presents winter/facultative bread wheat releases in the developing world by time period. The number of releases was considerably higher in 1991–97 than...
in the previous study period, particularly in West Asia/North Africa. The percentage of winter/facultative releases that contained CIMMYT germplasm was also considerably higher in 1991–97 than before. Non-CIMMYT winter/facultative semidwarfs were mostly Chinese releases.

Adoption of Improved Wheat Varieties

Slightly more than 80% of the wheat area in the developing world is planted to semidwarf varieties (Figure 7). Sixty-two percent of the wheat area in the developing world is estimated to be planted to varieties with CIMMYT ancestry. Slightly less than half of the wheat area is planted to varieties produced from crosses made by CIMMYT or that have at least one CIMMYT parent. The proportion of wheat area planted to CIMMYT-related material is greater for spring bread and spring durum wheats than for winter/facultative wheat. Table 2 summarizes the area planted to different wheat types in 1997.

Table 2. Area (million hectares) grown to different wheat types in 1997, classified by the origin of the germplasm

<table>
<thead>
<tr>
<th>Wheat type</th>
<th>National research system cross</th>
<th>CIMMYT cross</th>
<th>CIMMYT parent</th>
<th>CIMMYT ancestor</th>
<th>Other semidwarf</th>
<th>Tall</th>
<th>Landraces</th>
<th>Unknown cultivars</th>
<th>All</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spring bread wheat</td>
<td>17.8</td>
<td>22.4</td>
<td>12.6</td>
<td>7.7</td>
<td>5.2</td>
<td>1.4</td>
<td>1.0</td>
<td>68.1</td>
<td></td>
</tr>
<tr>
<td>Spring durum wheat</td>
<td>3.4</td>
<td>1.2</td>
<td>0.02</td>
<td>0.11</td>
<td>0.3</td>
<td>1.5</td>
<td>0.1</td>
<td>6.7</td>
<td></td>
</tr>
<tr>
<td>W inter/facultative bread wheat</td>
<td>0.6</td>
<td>1.9</td>
<td>4.2</td>
<td>11.6</td>
<td>2.2</td>
<td>4.1</td>
<td>2.6</td>
<td>27.2</td>
<td></td>
</tr>
<tr>
<td>W inter/facultative durum wheat</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.11</td>
<td>0.1</td>
<td>1.0</td>
<td>0.1</td>
<td>1.2</td>
<td></td>
</tr>
<tr>
<td>All wheat types</td>
<td>21.8</td>
<td>25.5</td>
<td>16.8</td>
<td>19.5</td>
<td>8.7</td>
<td>7.0</td>
<td>3.8</td>
<td>103.2</td>
<td></td>
</tr>
</tbody>
</table>

Source: CIMMYT wheat impacts database.

Spring Bread Wheat

Spring bread wheat is the dominant type of wheat grown in the developing world. Nearly 68 million hectares of the developing world wheat area (including China) was planted to spring bread wheat in 1997. Of this area, about 60 million hectares were planted to semidwarfs, nearly 53 million hectares (88%) of which were sown to CIMMYT-related varieties. CIMMYT crosses or NARS crosses with at least one CIMMYT parent occupied about 40 million hectares.

The adoption of CIMMYT-related spring bread wheat in 1997 is shown for regions of the developing world in Figure 8. Excluding China, 80–90% of the spring bread wheat area in the...
developing world’s major wheat growing regions was planted to CIMMYT-related material. The use of CIMMYT crosses was greatest in West Asia/North Africa and Latin America, where more than 50% of the spring bread wheat area was planted to CIMMYT crosses. In China, about one-third of the spring bread wheat area was planted to CIMMYT-related germplasm, and an additional 40% was planted to semidwarf wheats that did not contain CIMMYT germplasm.

**Spring Durum Wheat**

Spring durum wheat area, which is relatively small compared to area sown to other wheat types, is predominantly sown to semidwarfs, primarily CIMMYT-related varieties. As was the case with adoption of spring bread wheats, Latin America and West Asia/North Africa were the major adopters of CIMMYT crosses in spring durum wheat. More than 50% of the spring durum wheat area in West Asia/North Africa, where over 80% of the developing world’s durum wheat is grown, was planted to CIMMYT crosses. In Latin America, the percentage of area planted to CIMMYT crosses was more than 90% (Figure 9).

**Winter/Facultative Bread Wheat**

In contrast to spring bread wheat and spring durum wheat regions, areas planted to winter/facultative bread wheat are dominated by semidwarf wheats that are unrelated to CIMMYT wheats. Among the regions where winter/facultative bread wheat is grown, Latin America was the only region where CIMMYT material was dominant (Figure 10). In China, where winter/facultative bread wheat occupies more than half of the wheat area, nearly two-thirds of the winter/facultative bread wheat area (36% of the total wheat area) consisted of non-CIMMYT winter/facultative semidwarfs. In the other region with a large winter/facultative wheat area, West Asia/North Africa, nearly 40% of the winter/facultative wheat area was planted to landraces and another 35% was sown to varieties with some CIMMYT ancestry. In South Africa, which is the only country in sub-Saharan Africa growing winter/facultative wheat, two-thirds of the area was planted to tall varieties with pedigrees (versus tall varieties whose pedigrees are unknown).

**Landraces**

Relatively little spring bread wheat area remains in landraces. Unlike spring bread wheat, large proportions of both the spring durum wheat area and the winter/facultative bread wheat area were still planted to landraces in 1997. Seven million hectares of the developing world’s wheat area were sown to landraces and 3.8 million hectares were planted to unknown cultivars (i.e., their pedigrees and origin were unknown).

Landraces tended to be concentrated geographically in West Asia/North Africa. Landraces covered slightly less than 20% of the spring durum wheat area in West Asia/North Africa. In Ethiopia, the only country in sub-Saharan Africa where durum wheat is planted, landraces covered nearly 80% of the wheat area. As noted, landraces occupied nearly 40% of the winter/facultative wheat area in West Asia/North Africa.

**CIMMYT/NARS Collaboration**

The data for numbers of released varieties and area planted indicate that CIMMYT plays a major role in wheat improvement research for developing countries.
countries. It is important to recall that the Center’s contribution is not the result of independent activity; international wheat improvement research is collaborative and progress depends on international testing by a network formed by CIMMYT and national research systems worldwide (Maredia and Byerlee 1999). Furthermore, every cross is the result of a conscious decision by the breeder and institution that made the cross, of decisions made earlier by other breeders, and ultimately of breeding decisions made by the farmers who tended landraces over the centuries.

**Trends and Observations**

The extensive data collected for the 1990 and 1997 studies allow us to look for longitudinal trends, albeit using a rather short time frame. Our estimates of wheat area have relied on fairly simple ways of assessing the CIMMYT contribution. Here, we recapitulate some of those measures and present an additional one based on a geometric rule developed by Pardey et al. (1996). This additional measure analyzes a variety’s pedigree by applying geometrically declining weights to each level of crossing for as many generations as desired. The weights applied to the earliest generation included in the analysis are increased to make the total of all weights sum to 1.  

For comparison, we present estimates for 1990 based on the data analyzed by Byerlee and Moya (1993). In presenting the 1997 data, we provide figures that both include and exclude China, because only a few spring bread wheat zones in China were covered in the 1990 study and because China does not use CIMMYT germplasm as extensively as other developing countries. Calculations for spring bread wheat are presented in Figure 11 and for winter/facultative bread wheat in Figure 12.  

Excluding China, spring bread wheat area planted to CIMMYT crosses declined between 1990 and 1997. During the same time, however, area planted to NARS crosses with CIMMYT parents increased, as did the area planted to spring bread wheat with any CIMMYT ancestry. The decline in spring bread wheat area planted to CIMMYT crosses can be explained by somewhat lower planting of direct CIMMYT crosses in India, Turkey, and Pakistan—three large developing-country wheat producers. By the geometric rule, in 1990, approximately 45% of the genetic contribution to spring bread wheat could be attributed to CIMMYT. In the 1997 data, this figure fell to slightly more than 40%, because of the decline in area planted to CIMMYT crosses (as crosses are given the most weight in the geometric index).  

As expected, when China is included the CIMMYT contribution declines by all measures; the decline is proportionately the lowest when using the “any ancestor” rule (Figure 11). The reason for this finding is that, compared to other breeding programs, the Chinese wheat program often uses CIMMYT material at an earlier stage of the crossing process.

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2 For example, if the analysis were carried back to the level of great-grandparents, the source of the final cross would be given a weight of 1/2, the source of each of the parents would be given a weight of 1/8, and the source of each of the grandparents would be given a weight of 1/32. The next fraction in this series is 1/128, but the source of each of the great-grandparents would be given a weight of 1/64 to ensure that the weights sum to 1.

3 Calculations for spring durum wheat are being revised. As a result, estimates for spring durum wheat and for “all wheat” are not presented; however the patterns for spring durum and all wheat are fairly clear.

4 Although the estimates for spring durum wheat are being recalculated, it is likely that in comparison with spring bread wheat, CIMMYT crosses are more important in terms of area planted in spring durum than in spring bread wheat; NARS crosses with at least one CIMMYT parent, and NARS crosses with earlier CIMMYT ancestry, are less important in durum wheat. Genetic contribution as measured by the geometric rule is greater in spring durum wheat than in spring bread wheat, again because of the higher weight given to the final cross. Slightly more than 50% of the genetic contribution to spring durum wheat planted in developing countries would be attributed to CIMMYT by this rule.
As expected, the data on releases and area planted show that CIMMYT has made a smaller contribution to winter/facultative wheat breeding in developing countries relative to its contributions to spring bread or spring durum wheat breeding. Even so, CIMMYT’s contribution to winter/facultative wheat has grown substantially since 1990. No CIMMYT winter/facultative crosses were planted in 1990; in 1997, a small area was planted to such crosses. Excluding China, the proportion of winter/facultative wheat planted to varieties with some CIMMYT ancestry tripled between 1990 and 1997 (Figure 12). Within China in 1997, a little more than 10% of the winter/facultative wheat area was planted to a variety with some CIMMYT ancestry.

The final figures for all wheats taken together are not yet available, but they will most likely parallel the estimates for spring bread wheat, because that is the dominant wheat type in the developing world. It then follows that the area planted to CIMMYT crosses is likely to have declined somewhat between 1990 and 1997, while the area planted to NARS varieties with at least one CIMMYT parent and to NARS varieties with earlier CIMMYT ancestry increased. By the geometric rule, it appears that in 1990 and 1997 CIMMYT accounted for just under 40% of the genetic contribution to all wheat planted in the developing world (excluding China). If China is included, the 1997 CIMMYT contribution would probably be less than 30%.

### Outstanding Issues

In assessing the impacts of international wheat breeding research in the developing world, several issues merit further study and analysis. These include the rate at which varieties are replaced in farmers’ fields, the rates of genetic gain in wheat yield and yield gain in farmers’ fields, and the future of international collaboration in wheat improvement research.

### Varietal Replacement

Our most recent data indicate that, as reported in the 1990 study by Byerlee and Moya (1993), a significant proportion of the total wheat area is still planted to older improved varieties. Despite the fact that farmers in developing countries have widely adopted improved varieties, the rate at which older improved seed is replaced by seed of newer improved varieties remains unacceptably slow. Farmers benefit neither from the improved yield potential of newer varieties nor from their superior disease resistance.

One measure of the rate at which varieties are being replaced is the age of varieties in farmers’ fields, measured in years since release and weighted by the area planted to each variety (Brennan and Byerlee 1991). Based on this indicator for 1990 and 1997, varietal replacement had become more rapid by 1997 in only 12 of the 31 countries for which comparisons could be made.

Table 3 presents a classification of countries by weighted average age of improved varieties in farmers’ fields in 1997. Note that only improved varieties (semidwarfs and improved tall varieties) are included in these calculations. Among developing countries, only two, Zimbabwe and Afghanistan, had an average age of varieties in farmers’ fields within less than six years. This length of time is important because it is the period estimated (based on weighted averages) in which rust resistance derived from a single resistance gene can be maintained (Kilpatrick 1975). (Rust is the most important disease of wheat worldwide; for a discussion of the importance of rust resistance, see “CIMMYT’s strategy to achieve durable rust resistance in wheat,” p. 10.) In Zimbabwe, it appears that the private sector’s involvement in wheat research may have played a role in the rapid turnover of wheat varieties. In Afghanistan, external aid following the Russian withdrawal included widespread distribution of wheat seed.

Most Latin American countries, with the exception of Peru and Mexico, seem to replace their varieties in the field more rapidly than other developing countries, which is consistent with earlier findings (Byerlee and Moya 1993). In Mexico, however, varietal replacement was much more rapid in the past (Brennan and Byerlee 1991), primarily because of a shift in the major wheat-growing areas of northwestern Mexico from bread wheat to older durum wheat varieties.

### Table 3. Weighted average age (years) of improved varieties in farmers’ fields, 1997

<table>
<thead>
<tr>
<th>Country</th>
<th>Age of varieties</th>
</tr>
</thead>
<tbody>
<tr>
<td>Afghanistan, Zimbabwe</td>
<td>&lt;6</td>
</tr>
<tr>
<td>Argentina, Brazil, Chile, China, Guatemala, Pakistan</td>
<td>6-8</td>
</tr>
<tr>
<td>Bolivia, Columbia, Iran, Nigeria, Uruguay, Zambia</td>
<td>8-10</td>
</tr>
<tr>
<td>Ecuador, Morocco, Paraguay, South Africa, Tanzania</td>
<td>10-12</td>
</tr>
<tr>
<td>India, Kenya, Lebanon, Mexico, Syria, Yemen</td>
<td>12-14</td>
</tr>
<tr>
<td>Algeria, Bangladesh, Ethiopia, Egypt, Jordan, Nepal, Peru, Sudan, Tunisia, Turkey</td>
<td>&gt;14</td>
</tr>
</tbody>
</table>

Source: CIMMYT wheat impacts database.
In contrast to Latin America, in most nations of West Asia/North Africa the weighted average ages of varieties in the field exceeded 14 years. Interestingly, even some large wheat-producing countries such as India had weighted varietal ages exceeding 12 years, although wheat varieties were replaced much more rapidly in some regions of India, particularly the northwest (Byerlee and Moya 1993). Factors affecting the rate of varietal replacement in wheat are discussed from a theoretical perspective by Heisey and Brennan (1991) and empirically by Heisey (1990) and by Mwangi and colleagues (see, for example, Alemu Hailye et al. 1998; Regassa Ensermu et al. 1998; and Hailu Beyene, Verkuijl, and Mwangi 1998).

**Genetic Gains in Wheat Yields and Yields in Farmers’ Fields**

Considerable debate has surrounded the question of whether breeders are continuing to make genetic gains in yield potential in the major cereals or whether most recent progress has come from raising the bottom of the yield distribution by increasing resistance to stress (see Evans and Fischer, forthcoming; Mann 1999). It appears that the genetic yield potential of wheat has continued to increase (Evans and Fischer, forthcoming; Sayre, Rajaram and Fischer 1997). An extensive review of studies about gains in wheat yields in developed and developing countries also concluded that there is no convincing evidence that genetic gains in wheat yield potential have leveled off (Rejesus, Heisey, and Smale 1999). As is apparently the case in rice and maize, in wheat the larger proportion of genetic gains in yield also results from increased stress tolerance rather than gains in yield potential per se. Much of the progress in developing stress tolerance in wheat has come from dramatically improved resistance to wheat diseases, particularly the rusts (Sayre et al. 1998).

Meanwhile, there is ample evidence that yield advances in farmers’ wheat fields have slowed. Worldwide, some of this slowdown may be partially explained by reduced growth in demand for wheat, but it is noteworthy that yield increases in advanced wheat-producing areas of developing countries (e.g., northwestern Mexico and the Punjab of India and Pakistan) have also slowed in the past 10–15 years. The reasons for slower growth in yield gains in farmers’ fields are many and complex; it is quite likely that crop management issues and resource degradation play important roles (see Part I of this report for a discussion of the opportunities and constraints related to improving wheat productivity).

**The Future of International Collaboration in Wheat Improvement Research**

During the 1990s, the framework and dynamics of crop improvement research entered a period of rapid change. Increased private-sector investment in crop improvement, changes in intellectual property rights regimes, and potential technical changes came together to alter the ways that breeders and farmers can use seed. These developments continue to transform the dynamics of germplasm exchange, in some cases limiting the free exchange of germplasm on which the success of the CIMMYT/NARS international wheat breeding effort was built. Although many of these changes are taking place primarily in industrialized countries, it is clear that the impacts will be global.

During this same period, research intensity for wheat breeding in the developing world seems to have increased, as has the rate at which wheat varieties are released. Despite these indicators of progress, ancillary evidence on the funding and organization of wheat research in all but a few of the largest NARSs and in CIMMYT’s own wheat program suggests that the international system for wheat improvement research faces continuing challenges in the years ahead.

The structure and organization of the international wheat breeding effort was discussed in Part I of this report and has been extensively analyzed by Maredia and Byerlee (1999), Byerlee and Traxler (1996), and Traxler and Pingali (1998). It is clear from these analyses and from the data presented here that the CIMMYT/NARS collaborative effort in wheat improvement could remain central to producing significant benefits for wheat-producing nations and farmers well into the next century. Whether the political will and financial resources to sustain that effort will be available, however, remains an open question.