Chapter 8

Conclusion

At the beginning of the 1990s, Byerlee and Moya (1993) reached three main conclusions in their study of the impacts of international wheat breeding research in the developing world. "First, the adoption of modern wheat varieties has maintained its momentum in the post-Green Revolution period. Second, CIMMYT germplasm continues to be used extensively as source material for the varieties that have diffused in the post-Green Revolution period. Third, investment in international wheat breeding research has continued to provide high rates of return."

Our study, which updates Byerlee and Moya's work and extends its coverage to include all of China as well as South Africa, provides strong support for these conclusions. In this concluding section, we briefly recap the evidence. We also review the ways in which the international wheat breeding effort has changed during the 1990s and identify two research areas that deserve further attention.

During the 1990s, the area planted to wheat modern varieties (MVs) in developing countries continued to expand, rising from just under 70% in 1990 to just over 80% in 1997. Adoption of MVs varied by region, wheat type, and growing environment. In South Asia and Latin America, 90% or more of wheat area was planted to MVs; China's percentage was just under the aggregate figure of 80%; and two-thirds of the wheat area in WANA and sub-Saharan Africa was planted to MVs. Across the developing world, adoption of spring bread wheat MVs, the most commonly grown wheat type, stood at just under 90% of wheat area. Adoption of spring durum wheat MVs and winter bread wheat MVs was just over 70% of the area planted to each of these wheat types. Adoption of MV wheat ranged from 80% to 100% in nearly all irrigated or high rainfall environments, varied between 50% and 60% in dry spring wheat environments, and stood at around 30% to 40% in dry winter wheat environments. In areas where MV wheat has been planted for some time, older MVs are continuously replaced by newer MVs, although lengthy adoption lags continue to reduce research impacts below what they would be were new MVs to reach farmers faster.

In developing countries, the average rate of wheat varietal releases and the rate of varietal releases per million hectares planted to wheat have leveled off since the mid-1980s. Wheat breeding programs in large wheat-producing countries today are releasing fewer varieties, perhaps because they target their releases more precisely. Meanwhile, releases have increased in smaller wheat-producing countries.

CIMMYT is clearly the leading organization working in wheat breeding for the developing world. CIMMYT's wheat breeding program, which collaborates extensively with NARSs and ICARDA, can claim credit for more than one-half of the spring bread wheat crosses released in the developing world since the mid-1980s. Another

30% of spring bread wheat crosses have one or two CIMMYT parents, and when crosses with CIMMYT ancestry further back in the pedigree are included, about 90% of all spring bread wheat releases have some CIMMYT ancestry. Spring durum wheat releases feature CIMMYT material even more prominently, with about three-quarters coming from CIMMYT crosses and nearly all having some CIMMYT ancestry. On the other hand, although the use of CIMMYT material in winter bread wheat releases increased during the 1990s, particularly in Latin America and WANA, only about 15% of these were CIMMYT crosses, and about 40% percent had some CIMMYT ancestry.

The importance of CIMMYT-related varieties is evident in farmers' fields. Even including China, where CIMMYT-related materials have been used less extensively, about 62% of the total wheat area in developing countries is planted to CIMMYT-related varieties. About 20% of the total wheat area in developing countries is planted to CIMMYT crosses. These figures take into account all wheat varieties, so they include landraces and unidentified varieties that are still planted widely in durum wheat and winter bread wheat areas. Using a geometric rule that attempts to weigh contributions made by different breeding institutions to a given wheat variety, CIMMYT germplasm accounts for just under 30% of all wheat germplasm planted in the developing world. This figure is much higher when only scientifically bred wheat varieties are considered, when China is excluded, or when the focus is only on spring habit wheat.

Returns to international wheat breeding research continue to be high. For a total annual investment of US$ 100 to US$ 150 million, the international wheat breeding system produces annual benefits ranging between US$ 1.6 and US$ 6 billion or more (1990 dollars). The large difference between the "high end" estimate and the "low end" estimate results partly from assumptions made concerning the "without research" scenario. The "high end" estimate is derived by comparing post-Green Revolution yields and production with pre-Green Revolution yields and production, and the "low end" estimate is derived by comparing the results of wheat improvement research that has actually been done with wheat improvement research that presumably would have been done in the absence of the current international system. Very loosely speaking, the "high end" estimate was derived by summing average annual returns, and the "low end"estimate was derived by summing marginal returns that might be expected from continued investment in wheat improvement research. Excluding China, Byerlee and Traxler (1995) estimated a future rate of return of 37% for spring bread wheat alone even if research only maintained yields and did not increase them. Since wheat improvement research has affected all wheat types, has been very successful in China, and has increased yields at the same time that it has provided superior stress resistance, it is clear that the conditions for a high rate of return to wheat improvement research have been met.

What has changed in international wheat improvement research since 1990 when the first study was undertaken? First, there have been notable changes in research funding. These changes have been exemplified by the decline since the late 1980s in real resources committed to wheat improvement research at CIMMYT. CIMMYT wheat improvement research constitutes a relatively small part of the international breeding effort in expenditure terms, but its influence nonetheless is large.

It is often claimed that resources devoted to wheat breeding research in developing countries have declined in real terms. At the level of the NARSs, there is relatively little evidence to support this view. Declines in NARS public-sector investments in wheat breeding research may be easiest to document in sub-Saharan Africa and possibly parts of Latin America, with anecdotal evidence from other developing countries. Increases in wheat breeding investment in large producers such as China may have masked declines in smaller producers, but this remains conjecture rather than demonstrable fact. For many countries, even those in which real resources allocated to wheat research have not declined, two additional features may be important. First, a very high proportion of the investment often goes to salaries, with limited funds left over for operational budgets crucial to conducting research. Second, it might be possible to increase breeding efficiency by relying more heavily on the international system or by reallocating resources within larger countries (Maredia and Byerlee 1999).

It is too soon to say how the real decline in breeding resources at CIMMYT will affect the international wheat breeding system. In recent years, the pivotal role of CIMMYT in many developing country wheat releases has been maintained, and the influence of CIMMYT in winter wheat breeding has actually increased (it should be recalled, however, that CIMMYT began targeting winter wheat only in the mid-1980s). Since lag times in agricultural research tend to be long, however, it is possible that the real decline in CIMMYT funding may in the future have an adverse effect on the number of wheat varieties that NARSs will release.

A second significant feature of developing country wheat production over the past 10 or 15 years has been the slow rate of growth of wheat yields. On the one hand, there is little hard evidence that breeders are making slower progress in increasing wheat yield potential than they have over the entire post-Green Revolution period. Furthermore, breeders have been making gains both in wheat yield potential and particularly in disease resistance while increasing, not decreasing, the genetic diversity of released varieties (Smale et al. 2001). There is also evidence that although yield growth has slowed in favored wheat production environments, it has grown faster over some periods in some marginal environments due to increased MV adoption and faster MV yield growth. Increased adoption and faster yield growth in marginal environments have resulted in large part from spillovers from research conducted in more favored areas. Evidence to support these conclusions comes from experimental trials, yields observed in farmers' fields, and a few micro-level studies in favorable wheat-growing areas that have been characterized by early MV adoption and relatively high yields. Because it is hard to estimate aggregate yields based on environments rather than political units, the evidence is not completely conclusive, but it does deserve further scrutiny.

The fact that yield growth has varied by environment raises several important methodological issues that will have to be addressed in future studies of impacts of wheat breeding research. In the first place, it will become harder to assume that experimental yield gains translate directly to industry supply shifts in every environment. To sort out how research affects different environments, several thing will be required—better data on wheat areas, wheat yields, and wheat production in major wheat-growing environments in the developing world; consistent experimental data such as the ISWYN and ESWYT data; and the combination of the secondary data with GIS data. In the interim, updating the CIMMYT ME database using expert opinion appears a worthwhile first step.

Next, impacts assessment research will have to make more explicit assumptions about the "with research" and "without research" scenarios. In distinguishing between the two, it will be necessary to consider the research lags that exist in the international wheat breeding system. It will also be necessary to determine what proportion of current and future benefits of wheat breeding research results from increases in yield potential and what proportion results from maintaining or improving resistance to disease or other stresses. It will be important eventually to integrate the evaluation of components of breeding strategies, such as those directed at disease resistance, nitrogen-use efficiency, or improved end-use quality, into the overall evaluation of impacts of wheat breeding research. In addition, the assumptions and results of impact assessment models will have to be continually evaluated to ensure that they are consistent with observed patterns of wheat supply and demand in the countries, environments, or regions to which they are applied.

Finally, research managers will have to continue to scrutinize breeding priorities within the international wheat breeding community, particularly within the CIMMYT/NARS agenda. The evidence to date suggests that the strategy should be continued of directing more breeding research efforts toward favorable wheat-growing environments, at the same time that some resources are devoted to maximizing spillovers into less favorable environments. Furthermore, payoffs to investments in disease resistance are likely to continue to be high. What is less clear is what combination of tactics will be most successful in continuing to advance yield potential in wheat—conventional breeding, hybrid wheat, wide crossing, biotechnology (including functional genomics), and the like. It will also be useful to further analyze the apparent slowdown in wheat yield gains in highly productive environments to determine possible environmental factors in this slowdown. Last but not least, it will be important to consider what combination of breeding research, crop management research, and policy research will best advance wheat yields, wheat production, and wheat productivity worldwide.