Wheat

CIMMYT

[International maize and wheat improvement center]

1992/93 World Wheat Facts and Trends

The Wheat Breeding Industry in Developing Countries: An Analysis of Investments and Impacts

CIMMYT is an internationally funded, nonprofit scientific research and training organization. Headquartered in Mexico, the Center is engaged in a research program for maize, wheat, and triticale, with emphasis on improving the productivity of agricultural resources in developing countries. It is one of 17 nonprofit international agricultural research and training centers supported by the Consultative Group on International Agricultural Research (CGIAR), which is sponsored by the Food and Agriculture Organization (FAO) of the United Nations, the International Bank for Reconstruction and Development (World Bank), and the United Nations Development Programme (UNDP). The CGIAR consists of some 40 donor countries, international and regional organizations, and private foundations.

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Abstract: This report presents information on the level of investment in wheat breeding research in developing countries and the impact of that research, and discusses issues related to assessing returns to wheat improvement research and improving research efficiency. In 1990, the total estimated investment in wheat improvement research in developing countries was US$ 96 million. Expressed another way, developing countries spent about US$ 0.40 per ton of wheat on improvement research, or about 0.3% of the value of production. This research has had a considerable impact in the developing world. Modern varieties of wheat cover 70% of the developing country wheat area, and many farmers have replaced older improved varieties with newer ones. Research on improved spring bread wheat varieties alone has contributed an additional US$ 3 billion in benefits in developing countries in the past decade. However, results of this study suggest that national agricultural research programs have considerable scope to utilize research resources more efficiently, by rationalizing the number and size of wheat research programs and by examining opportunities to import technology or collaborate with countries sharing similar production environments.

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Foreword

This latest report in our *Facts and Trends* series is the first detailed study of investment in wheat breeding research across developing countries. It is a companion piece to our previous report, which examined similar issues for maize research. Although figures on research expenditures in the two reports cannot be compared directly because of different methods used in calculations, the publications provide a comprehensive view of the level of human resources devoted to maize and wheat research in the developing world, identify the products of that research, and estimate the magnitude of their impacts.

To date, very little information has been available on these subjects, as few countries have done in-depth analyses of the resources invested in maize or wheat research or the resulting benefits of that research. To produce this report, we assembled information from nearly 100 wheat research programs, in the public and private sectors, in virtually all wheat-producing countries of the developing world and in some high-income countries as well.

More than 1,000 scientists, supported by a total of about US$ 100 million, work under widely varying conditions to improve wheat in the developing world. Using both their own breeding materials, germplasm from other countries, and CIMMYT germplasm, they have achieved remarkable success. In the case of spring bread wheat varieties alone, adoption of new research results from 1977 to 1990 has contributed US$ 3 billion in additional benefits in 1990 in developing countries through improved yields and disease resistance.

However, our motive for undertaking the present study extends beyond simply documenting investments and their impact, regardless of how impressive they might be. We also wished to explore issues that are growing in importance for research decision makers in the 1990s, as resources for public sector agricultural research, never lavish, become increasingly limited. Stagnating or declining budgets for agricultural research restrict the effectiveness of resources invested in wheat breeding and other kinds of research and argue strongly for more attention to questions of research efficiency.

In this context, research programs will have to analyze critically their expenditures on wheat breeding research in terms of the number, size, scope, and locations of their programs. The efficiency of maize and wheat research at CIMMYT and in national programs has long been a strong concern of ours. As we see it, circumstances will compel all participants to achieve greater levels of efficiency in their work, including new ways to access the work of others, CIMMYT among them. (For my views on this subject, see "Quintessential internationalism in agricultural research," in *Agricultural Technology: Policy Issues for the International Community*, ed. J.R. Anderson, Wallingford, U.K.: CABI, 1993.)

Recent analysis suggests that significant economics of scale may be achieved in wheat breeding research. National research programs probably have considerable scope for efficiency by rationalizing the number and size of wheat research programs and by examining the opportunities to import technology or work with the private sector. A strong case can be made that small countries could benefit from broader collaboration in wheat research. At the very least, each country or breeding program should determine which kinds of breeding materials can be acquired from external sources and used effectively in their mandated research areas. The discussion that follows gives ample evidence of the benefits of such a strategy.

This report offers a good starting point to explore the spectrum of options for structuring wheat research programs. We think that decision makers will be able to use the ideas discussed here to ensure that research continues to be a "lifeline to the future" for the world's poor people and the natural resources on which they depend.

Donald L. Winkelmann
Director General

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Part 1: Wheat Breeding Research in Developing Countries: Investments and Impacts

Andrea Bohn and Derek Byerlee

Between 1961-65 and 1981-85, investment in agricultural research in developing countries rose in real terms at an annual rate of 6.2% (Pardey, Roseboom, and Anderson 1991). At least two major factors stimulated this rising investment. First, the rapid growth in rice and wheat yields that resulted from the development and adoption of semidwarf varieties provided an example of what agricultural research could accomplish. Second, a growing body of studies suggested that investment in agricultural research provided high economic payoffs and that technical change in food crop production, brought about through research, could be an "engine of growth" for developing countries.

The way that agricultural research was organized in developing countries also changed significantly between 1960 and 1980. Many agricultural research systems were reorganized into commodity research teams, usually led by a national coordinator. Now most countries in the developing world have national wheat research programs that range from one centralized group of scientists to an extended network of several hundred scientists working in more than 50 research centers. The investment in these programs has undoubtedly achieved success. Over the past three decades, wheat yields in developing countries have grown at a faster rate than yields of any other food commodity.

However, the environment in which agricultural research is conducted has changed markedly in the 1980s and early 1990s. Expenditures on agricultural research in the public sector have stagnated. In many countries, especially in sub-Saharan Africa and Latin America, real expenditures have declined. Both national research programs and international research centers, such as CIMMYT, have had to rationalize resource allocations; in some cases they have sharply curtailed research programs. Although the tasks facing agricultural research appear more challenging than ever, fewer resources are available to help researchers accomplish their objectives.

This report provides the first in-depth examination of investment in wheat breeding research in developing countries, with the aim of identifying the key policy issues that research administrators must address in the next decade if wheat research is to remain effective. Nearly 100 wheat research programs were surveyed to obtain a perspective on wheat improvement research across countries (see the box, "Sources of Information for This Report"). Our report begins with a description of the characteristics of developing country wheat research programs. We then estimate the level of resources currently invested in wheat improvement research in developing countries. Next, we describe the products of wheat improvement research, discuss the issues in computing economic returns to wheat research investments, and review evidence from studies of returns to wheat research. We conclude our study — which we regard as a first step toward measuring the costs and benefits of developing country wheat research — by identifying the types of analysis required to guide research resource allocation in a climate of growing resource scarcity for agricultural research.

A Profile of Wheat Research Programs

The results of our survey enabled us to develop a profile of wheat research programs in developing countries. Three sets of characteristics are useful for comparing these programs: the size and diversity of their mandate areas, the size and composition of their scientific staff, and their primary breeding goals. Each set of characteristics is discussed briefly below.

Size and diversity of the mandate area
All wheat research programs are responsible for a "mandate wheat area" to which they target the products of their research. Usually this area is defined by political boundaries. The average size of the mandate area of the *developing country* wheat research programs surveyed in this study is 1.3 million hectares (M ha), with a median size of 600,000 ha. However, the size of the mandate area varies tremendously from program to program, ranging from an average of 27,000 ha for the 8 smallest wheat research programs to an average of 3.9 M ha for the 11 largest ones (Figure 1).

Many of the small programs are located in sub-Saharan Africa (their average mandate area is 0.2 M ha), whereas the large programs are concentrated in Asia (Figure 1). The average mandate area of the high-income industrialized countries surveyed is 2 M ha, which is the same as the average for Asia but much larger than the average of all developing countries surveyed. In addition, the range of sizes of mandate areas is somewhat narrower for industrialized countries than for

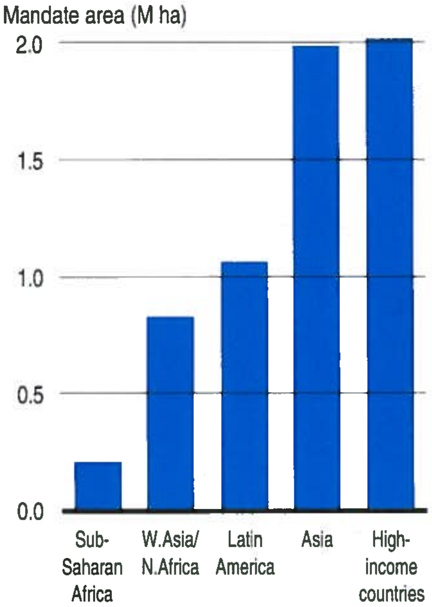


Figure 1. Average size of the mandate area of wheat research programs, by region.
Source: CIMMYT 1992 Survey of Wheat Research Programs.

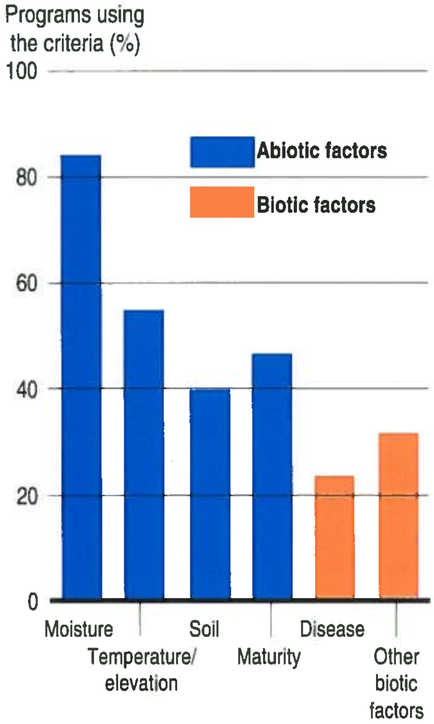


Figure 2. Use of different criteria to delineate environments for wheat improvement research.
Source: CIMMYT 1992 Survey of Wheat Research Programs.

developing countries. Only 20% of the research programs in industrialized countries have mandate areas of less than 0.5 M ha, compared to 37% of the programs in developing countries. However, it should be noted that mandate areas overlap more in industrialized countries than in developing countries, since many industrialized country programs are run by the private sector and compete in the same mandate area.

Aside from size, the complexity of a mandate area is also a significant distinguishing characteristic. The complexity of a mandate area can be measured by the number of distinct recommendations that must be made to cover the diversity of wheat types and environments in the area. This study uses the standard classification of wheat types by species — bread wheat (*Triticum aestivum*) and durum wheat (*T. turgidum* cv *durum*) — and by growth habit — spring or winter. Although many wheat research programs conduct research on triticale, barley, and sometimes other crops, most programs work on only one or two kinds of wheat. Programs in West Asia and North Africa (WANA) work on the greatest diversity of wheat types, because all four types of wheat are prevalent in the region.

In addition to working with an average of 1.6 different wheat types, each research program identifies an average of 3.4 agroclimatic environments in its mandate area (Table 1). Although the number of environments increases with the size of the mandate area, even the programs whose mandate areas are smallest average 2.4 environments.

Research programs most commonly use abiotic characteristics to delineate the agroclimatic environments in their mandate areas. Moisture availability is the most frequently mentioned defining characteristic (Figure 2). Across all of the research programs, wheat environments are divided evenly between irrigated areas, high rainfall areas, and low rainfall areas (less than 500 mm rainfall during or just prior to the wheat season). The irrigated areas are concentrated in Asia and low-rainfall areas in WANA. Soil-related factors are also mentioned more frequently than biotic stresses, such as diseases, as important characteristics for delineating environments. Time to maturity is mentioned as an important characteristic for determining agroclimatic environments by two-thirds of programs in Asia but by only a little over one-fifth of programs in WANA. (This reflects concern to fit wheat into more intensive cropping systems of Asia.)

Table 1. Average number of wheat types and environments in the mandate area of a wheat improvement program

Region	Number of wheat types[a]	Number of environments
Sub-Saharan Africa	1.3	3.2
W.Asia/N.Africa	2.2	3.0
Asia	1.3	3.4
Latin America	1.7	3.8
All developing countries	**1.6**	**3.4**
All industrialized countries	**2.1**	**2.9**

Source: CIMMYT 1992 Survey of Wheat Research Programs.
a Bread wheat (spring, winter), durum wheat (spring, winter), feed types, biscuit types, etc.

Sources of Information for This Report

To obtain the data for this report, CIMMYT conducted three surveys of wheat research programs between 1990 and 1993. In 1990 an intensive survey of research impacts covered all developing countries that produce wheat, except for most of China. The 38 countries responding to this survey provided information on varietal releases, adoption, and overall levels of scientific investment in wheat research.*

The CIMMYT 1992 Survey of Wheat Research Programs collected more detailed information on individual wheat improvement programs. (A wheat research program is a research institute, public or private, with a mandate to conduct research on wheat; it is usually identified with one experiment station.) The survey was returned by 70 programs from 35 countries, including China (see Table). The developing countries who responded cover 94% of the developing world's total wheat area and account for 97% of its total wheat production. An abridged version of the survey was sent to wheat improvement programs in industrialized countries to obtain information on key variables that would allow us to make comparisons between wheat programs in developing and industrialized countries. Where possible, these surveys included private as well as public sector research programs.

Some of the data in this report are presented as national estimates. Several research programs that responded to our second survey are the only wheat improvement programs in their countries and have the national mandate for wheat breeding research. When we received responses from all of the wheat programs in an individual country, we computed national estimates by aggregating over programs. For a few large countries where coverage was incomplete (Turkey, India, China, Mexico), estimates for the national-level variables were taken to be either the average of the responses received, assuming that the responding programs were representative of the nation, or were projected to the national level. In several cases, secondary sources were used to supplement survey responses.

* This information has been analyzed extensively and reported by Byerlee and Moya (1993). Only a summary of key results is given here.

Countries participating in the 1992 CIMMYT Survey of Wheat Research Programs

Sub-Saharan Africa	West Asia and North Africa	Asia	Latin America	Europe, USA, Australia
Burundi	Afghanistan	Bangladesh	Argentina[a,b]	Australia[a]
Ethiopia	Algeria	Bhutan	Bolivia	Belgium[b]
Kenya	Egypt	China[a]	Brazil[a,b]	Bulgaria
Lesotho	Lebanon	India[a]	Chile	Czech Rep.
Sudan	Libya	Nepal	Colombia	Denmark[b]
Tanzania	Iran	Pakistan[a]	Ecuador	Finland[b]
Zambia	Morocco		Guatemala	France[a,b]
Zimbabwe	Syria		Mexico	Germany[a,b]
	Tunisia[a]		Paraguay	Greece
	Turkey[a]		Peru	Italy[a]
			Uruguay	Poland
				Portugal
				Spain[a,b]
				Sweden[b]
				UK[a,b]
				USA[a]

a Several programs from these countries responded.
b Includes responses from private companies.

Wheat research programs in industrialized countries report a similar level of environmental diversity (an average of about 3.0 environments per program), but they tend to work on a larger number of wheat types, which they distinguish by quality (for example, quality for making bread or for animal feed).

Scientific resources

What kind of scientific resources are at the disposal of developing country wheat research programs? The average developing country wheat program employs seven full-time equivalent scientists (all staff possessing a BSc degree or above). Wheat research programs in Asia and WANA support the largest staffs, averaging more than eight scientists per program. In general the number of scientists increases with the size of the mandate wheat area, although less than proportionally. More than 70% of these scientists work in wheat improvement (that is, on research related to varietal development); the remainder conduct crop management research (including that part of crop protection that is unrelated to developing new wheat varieties). The proportion of scientists working on crop improvement is lower in the smaller programs of sub-Saharan Africa and Latin America, but even so, more than half of the scientists in these regions work in crop improvement.

Although much research on crop management in wheat production systems is conducted in soil fertility research programs and other programs that were not surveyed for this study, there is little doubt that the original motivation for establishing commodity research programs was to provide a means of conducting integrated research on all aspects of crop improvement and management (see, for example, Wortman and Cummings 1978, Hanson, Borlaug, and Anderson 1982). In fact, with few exceptions, wheat research programs today focus largely on crop improvement — specifically, on developing and disseminating improved varieties and crop management information related to those varieties (see the box, "A Short History of Wheat Breeding in Developing Countries"). The most important discipline in crop improvement research is breeding, which accounts for 70% of the full-time equivalent scientists involved in wheat improvement. The other important disciplines supporting wheat breeding are agronomy, pathology, and cereal technology.

The level of training of researchers in crop improvement programs varies among the regions. Breeders in Asia have the highest level of training (measured by the proportion of breeders holding postgraduate degrees) and those in WANA the lowest (Figure 3). With the exception of Latin America, these trends for wheat researchers parallel the levels of training observed for all agricultural scientists by Pardey, Roseboom, and Anderson (1991). However, in all regions the level of training of *wheat breeders* is higher than the average for all researchers. This discrepancy may reflect the fact that our data are more recent than the data collected by Pardey et al., but without a doubt a politically important crop such as wheat will often attract better trained scientists, especially in crop breeding.

Wheat improvement programs operate differently depending on the size of their mandate areas and the resources available. Many of the small programs, whose mandate areas encompass less than 0.5 M ha of wheat, make no crosses, preferring to evaluate and select from wheat germplasm developed by other programs in the same country or abroad. All of the large programs make their own crosses. More programs make crosses of spring bread wheat than of any other type of wheat, and only five programs maintain a crossing program for triticale. Among the research programs that make crosses, the average number of crosses increases with size of the research program; the average number of crosses made each year is 700. Even the largest research programs make only a fraction of the more than 10,000 crosses that CIMMYT makes annually.

How do the size and composition of scientific staff in wheat improvement programs in developing countries compare with staffing patterns of similar programs in industrialized countries? Wheat research programs in developing countries devote considerable resources to wheat improvement research, as measured by the number of scientists, their level of training, and the number of

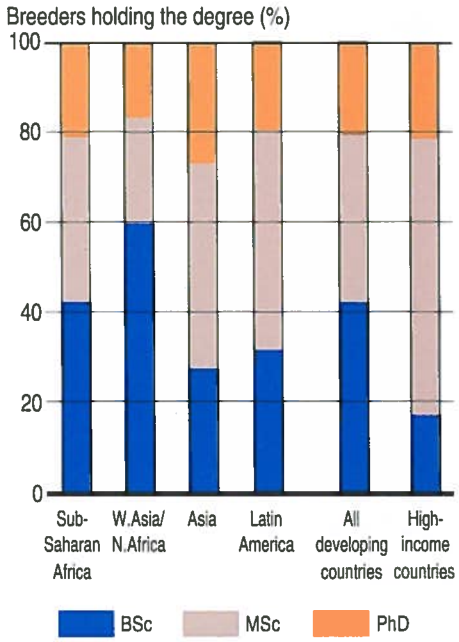


Figure 3. Training of wheat breeders, by region.
Source: CIMMYT 1992 Survey of Wheat Research Programs.

A Short History of Wheat Breeding in Developing Countries

Conscious selection of superior plants has been practiced since the beginning of agriculture, but deliberate cross-breeding began only about 170 years ago. Research on wheat breeding in developing countries commenced around the end of the 19th century. The most comprehensive of these efforts was in India, which was then an important wheat exporter. Selection began among lines introduced from Australia and elsewhere to improve the quality of wheat for the export market and to improve rust resistance (rust epidemics decimated wheat in some part of the country almost every year). Unfortunately, the introduced lines had little success. A formal wheat research program was initiated in 1906 with the appointment of Gabrielle and Albert (later Sir Albert) Howard to the research station in Pusa in northeastern India. The Howards collected local wheat varieties, selecting among them for high yield, rust resistance, and good quality.

The first successful variety was released in 1912 and eventually adopted on a significant area (Pray 1984). Soon afterward, a hybridization program was started to combine the best characteristics of the local wheats. By conducting two breeding cycles each year in two separate locations, using a summer "nursery" in Quetta for the second cycle, the Howards pioneered what was later known as "shuttle breeding." They also recognized that if superior varieties are produced they will be adopted. Writing in the early part of this century, Albert Howard observed that:

> It used to be an axiom that the Indian cultivator will adopt nothing new. This is not true. If the profit is great enough, he will adopt anything.... The difference between improved varieties is as great as that between the pictures of great artists and those of art students. Only masterpieces should be imposed on the cultivator.
>
> Howard (1953: 253)

Wheat breeding in the Punjab at Lyallpur (now Faisalabad in Pakistan) resulted in the release, in 1912, of the variety T9, a selection from local wheats that was grown on more than 0.5 M ha by 1924. At first the Lyallpur program made crosses among local varieties but later added crosses with introductions from the USSR, USA, and Australia. Multilocational testing was introduced in 1936. Only 10 varieties were released in the Punjab between 1925 and 1965 (Pray 1978) — a rate of release quite modest compared with today's standards.

In sub-Saharan Africa, one of the first wheat breeding programs was established in 1906 in Kenya by a wealthy settler, Lord Delamere. Delamere recruited a British plant breeder, G.W. Evans, to develop rust resistant varieties by crossing varieties of Italian, Australian, Egyptian, and Canadian origin. Evans and his successors found that only a few of the imported varieties could be recommended for release without further breeding and selection. The breeding program was eventually taken over by the colonial government, which established the present day Njoro Research Station, the main wheat research station in Kenya, in 1927 (NPBRC 1974). Other wheat breeding programs in sub-Saharan Africa during the colonial period included the program at Paradiso Experiment Station near Asmara in Eritrea. Established in 1929, this program tested both indigenous and imported strains of wheat (Gebre-Mariam, Tanner, and Hulluka 1991).

In Latin America, wheat breeding was not initiated until the 1920s and 1930s. Argentina's wheat program, started in 1923, produced the varieties that became the basis for the country's expanding wheat industry. As in the case of India and Kenya, wheat in Argentina was an important export crop. Research on wheat for domestic consumption did not become a priority in Latin America until the 1940s, when the Rockefeller Foundation established a collaborative program in Mexico for research on basic food grains, including wheat. By 1950 several successful wheat varieties, whose main advantage was improved rust resistance, had been released. This program, the predecessor of CIMMYT, quickly established links to Rockefeller-sponsored efforts in Colombia and Chile, leading to the first widespread exchange of germplasm in the region.

Beginning in the 1960s, wheat breeding in developing countries changed rapidly, for two reasons. First, technical assistance for increasing food crop production was initiated; to accomplish this objective, interdisciplinary commodity research teams and coordinated national research programs were formed. One of the earliest of these programs, the All India Coordinated Wheat Research Program, was established in 1961 (Tandon and Sethi 1986). Second, in the 1950s and 1960s, the first widespread movement of germplasm between countries occurred with the formation of regional and, later, international nurseries. This nursery system was formalized after CIMMYT was founded in 1966. At the same time, the first semidwarf wheat varieties were released, and they became the foundation for many of the expanding wheat breeding programs in developing countries.

support staff (Table 2). For example, developing country programs employ 10 scientists, compared to four in industrialized countries; furthermore, the mandate area of the average wheat research program in developing countries is only one-half of that in industrialized countries.

The number of scientists and number of crosses made are good indicators of the allocation of wheat research resources across wheat types. Table 3 compares the number of scientists and crosses in each region of the developing world with the relative importance of wheat, indicated by the size of the area planted to wheat. In general the allocation of resources is quite consistent with the importance of each wheat type at the global and regional levels.

Breeding goals

The heads of wheat research programs were asked to rank 14 breeding goals according to their relative importance (results of this ranking for spring bread wheat are illustrated in Figure 4). Yield and yield stability are rated as the most important goals (as one would expect), followed closely by disease resistance. Grain quality, early maturity, and drought tolerance all received medium rankings. Tolerance to abiotic stresses other than drought generally received a low priority, especially stresses related to soil problems. These results are somewhat at variance with the ranking of factors used to delineate wheat production environments, where abiotic stresses were very important. This discrepancy may reflect the relative difficulty of breeding to overcome abiotic stresses compared to biotic stresses.

When the productivity of research is studied, the importance of maintenance research to crop improvement programs is often overlooked. "Maintenance research" is the part of wheat improvement research directed at maintaining yields despite changing biotic and abiotic conditions. Breeding programs devote considerable resources to maintenance research, which consists mostly of maintaining disease resistance. The wheat research programs responding to our survey estimate that they devote 28% of their wheat improvement efforts to this task. By far the most important component of maintenance research is the work focusing on incorporating new sources of resistance to the evolving rust pathogens, especially leaf rust (*Puccinia recondita*). Most programs also estimate that the share of resources dedicated to maintenance research has grown over the past decade.

The international nature of most wheat breeding programs is evident from the sources of the germplasm used in their crosses (Table 4). By far the most important sources for disease resistance genes are breeding programs' own advanced lines, lines from CIMMYT nurseries, or lines from the joint breeding program of CIMMYT and the International Center for Agricultural Research in the Dry Areas (ICARDA). Breeders also make extensive use of advanced lines[1] from other programs in the same country or from other

Table 2. Size of wheat research programs in developing and industrialized countries, 1992

Region	Number of scientists per program[a]	Number of support staff per program	
		Technicians	Laborers
Sub-Saharan Africa	9.6	9.7	21.1
W. Asia/N. Africa	11.9	5.2	13.0
Asia	11.1	9.3	20.0
Latin America	8.7	5.0	6.8
All developing countries	**10.5**	**7.1**	**14.8**
Industrialized countries	**4.3**	**2.2**	**na**

Source: CIMMYT 1992 Survey of Wheat Research Programs.
a Includes all scientists, whether full or part time, both in crop improvement and in crop management research.
na not available.

Table 3. Relationship between area, percent of crosses made, and percent of scientists, by wheat type

Variable	Bread wheat		Durum wheat		All wheat types
	Spring	Winter	Spring	Winter	
Percent of area	73.5	15.2	10.9	0.4	100
Percent of crosses	73.3	13.7	11.9	1.1	100
Percent of scientists	72.3	14.7	12.5	0.5	100

Source: CIMMYT 1992 Survey of Wheat Research Programs.

1 Advanced lines are strains of wheat that have undergone considerable improvement; they are the precursors of finished varieties.

countries. They use land races only infrequently.[2] There are some differences among the regions in the use and exchange of germplasm, however. For example, in sub-Saharan Africa research programs have less opportunity to use germplasm from another program in the same country (the mandate areas and number of research programs for each area are small). Asian countries are relatively more self-sufficient in germplasm because they are larger. Furthermore, Chinese research institutes work mostly with winter wheat, whereas the bulk of CIMMYT germplasm is spring wheat.

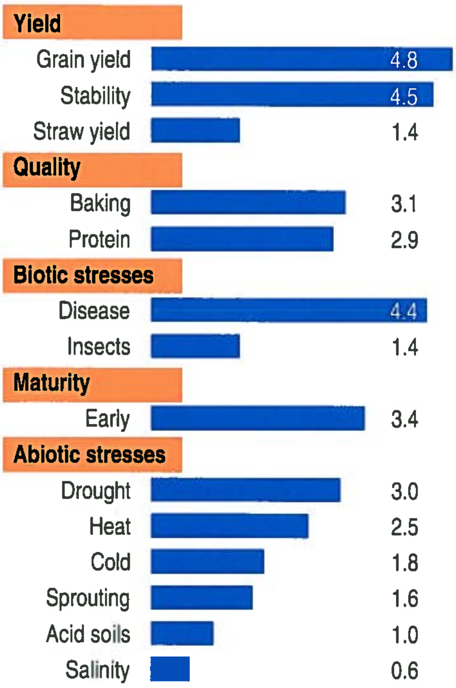


Figure 4. Average ranking of breeding priorities for spring bread wheat (5 = highest, 0 = lowest).
Source: CIMMYT 1992 Survey of Wheat Research Programs.

The Costs of Wheat Improvement Research

Estimating the cost of wheat improvement research

Only a small number of the countries we surveyed could provide a comprehensive estimate of the amount of money invested in wheat research. One reason for this is that it is not always easy to make such an estimate. The first difficulty is determining what costs to include. A comprehensive estimate of costs should include direct operating costs, salaries and fringe benefits, overheads (such as general administration), experiment station expenditures, and support services (such as laboratories and libraries). In addition, annualized capital costs of fixed assets such as buildings should be added.

A second problem is to define what to include in *wheat* research. A comprehensive definition would include *all* research related to wheat, from wheat breeding to crop and resource management and socioeconomic research. In practice, most countries identify "wheat research" with the activities of distinct wheat research programs. As we have seen, these programs usually are oriented heavily towards wheat breeding and the associated disciplines supporting the development of varieties. Much of the more basic research, such as research on wheat genetics and much of the research on crop and resource management, is done in other research programs and institutes, such as a molecular biology laboratory or a soil fertility program. For this study, we decided to focus on resources devoted to applied research on wheat aimed at developing varieties — that is, wheat improvement.

Various methods have been used to divide up research expenditures by crop, including indices based on the share of publications related to each crop (e.g., Judd, Boyce, and Evenson 1983) and the share of experiments to each crop (e.g., Traxler and Byerlee 1992). Both of these methods also provide a measure of the allocation of research resources by discipline. Another method, the one we consider most appropriate, is to identify the number of scientists involved in a particular kind of research and multiply this number by the expenditure per scientist to arrive at the total expenditure. Estimates for expenditure per researcher are available from various sources. For example, Pardey, Roseboom, and Anderson (1991) provide estimates based on the average annual expenditure per researcher and country for 1981-85. Expenditures per researcher include far more than the cost of the

Table 4. Major sources of disease resistance used in wheat breeding programs

Source	Percent of programs using as major source of genes for disease resistance
Land race varieties of local origin	15
Land race varieties of foreign origin	11
Program's own advanced lines	77
Advanced lines from other programs in the same country	37
Advanced lines from other countries	41
Lines from CIMMYT or CIMMYT/ICARDA nurseries	77

Source: CIMMYT 1992 Survey of Wheat Research Programs.

2 Land races are cultivars that have evolved through natural and human selection over a long period but have not been subject to modern scientific breeding.

researcher's salary and fringe benefits. They include a share of all the costs outlined above as well as the salaries of support staff assigned to the researcher.

Aside from the difficulties involved in obtaining these estimates, the need to compare wheat research expenditures across countries presents other complications. Expenditures can be converted to a common currency (usually the US dollar), but this is not as simple as it appears. Problems arise because of multiple exchange rates in some countries, day-to-day fluctuations in currencies, and frequent over- or undervaluation of currencies. Increasingly, the Purchasing Power Parity (PPP) exchange rate is used to make cost comparisons across countries.[3] The cost of a basket of goods in the US serves as the reference base (that is, US$ 1.0 spent in the US is worth exactly US$ 1.0 PPP). Compared to the official exchange rate, the PPP exchange rate tends to increase expenditure data in developing countries. This occurs because the cost of services is generally lower in these countries than in the US. The reverse is true for many European countries.

Obviously, estimating the number of scientists engaged in crop improvement research is the key task for arriving at an overall estimate of research costs. Even this can be difficult. First, one should include the disciplines other than plant breeding that support wheat improvement. Second, many scientists do not work full time on wheat research, so the number of scientists should be converted to full-time equivalents (FTE, or scientist-years). Third, the definition of a scientist must be standardized across countries. The survey data provided information on each scientist's disciplinary field, level of training, and time devoted to wheat breeding research, seed production, crop management research, and administration. The number of scientist-years assigned to wheat improvement research was taken to include all time spent on the first two activities as well as each researcher's relative share of administration, regardless of the researcher's disciplinary field. Only staff with a BSc degree or above were considered.

The number of scientist-years derived from the survey data were converted to 1990 US dollars using the cost per scientist at the PPP exchange rate derived from Pardey, Roseboom, and Anderson (1991).[4] This method has the disadvantage of assuming that the cost per scientist is the same for wheat research as for the research system as a whole. However, we have no reason to suspect that the cost of wheat research deviates greatly from the average cost of research for other commodities. The major advantage of this method is that it includes all overhead costs and is a better way of aggregating and comparing expenditures across countries.[5]

In the sections that follow, total expenditures on wheat research are estimated at two levels: for individual programs and for all wheat research programs in each country. The cost estimates are based on the number of FTE scientists in wheat improvement, derived from our survey data and the cost per scientist reported by Pardey et al. Although we have reasonable estimates of variables for individual research programs, the data at the country level are more problematic. This is especially true for large countries, which may have numerous wheat programs in the public research sector, universities, and the private sector, which must be aggregated to the country level. Hence country-level data should be interpreted with caution.

Program-level expenditures on wheat research

Differences in salaries are an important source of differences in costs of wheat research. One measure of these differences is the annual salary of a scientist and an unskilled laborer (Table 5). Salaries for scientists are highest in research programs in Latin America and WANA and lowest in Asia. However, the salary of a scientist relative to a laborer is highest in sub-Saharan Africa.

A researcher's salary is only a small part of the total cost of a researcher, for the reasons noted above. Latin America and WANA are still relatively high-cost regions, although the cost per scientist in sub-Saharan Africa is also high (Table 5). The cost per scientist in Asia is by far the lowest. For all the programs surveyed in developing countries, the average PPP cost per scientist was US$ 86,000, compared to a cost per

3 See Pardey and Roseboom (1989).

4 Pardey, Roseboom, and Anderson (1991) express cost per scientist-year in 1980 US dollars. Following the World Bank approach (World Bank 1993), we have approximated 1990 US dollars by inflating this cost by the US consumer price index. Our methodology assumes that expenditures on wheat improvement research have neither decreased nor increased in real terms. In actual fact, expenditures per researcher have been declining in the majority of developing countries (on average by 2.4% annually from the mid-1970s to the mid-1980s, as reported in Pardey, Roseboom, and Anderson 1991). To the extent that expenditures per scientist have continued to decline, our method will overestimate expenditures in the early 1990s.

5 This method of calculating research expenditures differs from the method used to calculate expenditures on maize research reported in the last issue of *Facts and Trends* (Morris, Clancy, and López-Pereira 1992). Thus readers should not make direct comparisons of expenditures given in the two reports.

scientist in the industrialized countries studied of US$ 133,000. When the official exchange rate is used, the cost per scientist in developing countries is US$ 53,000, about one-third of what it is in industrialized countries (US$ 152,000).

Given the PPP estimate of the cost per scientist and the number of scientists, the cost of a wheat research program is US$ 610,000 in developing countries, compared to US$ 280,000 in the sample of industrialized countries. Expressed in dollars at the official exchange rate, the cost of a wheat research program approaches US$ 380,000 in developing country programs and US$ 320,000 in industrialized countries. The lower number of scientists in industrialized country programs explains their lower overall cost.

These broad comparisons of research costs across programs do not account for differences in research costs arising from differences in the size of a program's mandate area or the level of wheat production in the mandate area. A better comparative measure of expenditures among programs is obtained by looking at research intensity indicators that take these differences into account. Table 6 expresses different measures of research intensity of wheat research programs.[6] By all measures, two factors stand out. First, the number

Table 5. Salaries of scientists and laborers in wheat research by region, 1990 (at official exchange rate)

Region	Salary (current US$/yr)			Average cost per scientist	
	PhD with 10 years of experience	BSc	Laborer	1990 US$	1990 US$ PPP
Sub-Saharan Africa	5,000	2,400	600	57,000	113,000
W. Asia/N. Africa	8,000	5,500	2,900	74,000	100,000
Asia	2,000	900	300	24,000	57,000
Latin America	18,100	5,300	2,200	78,000	117,000
All programs	**7,100**	**3,500**	**1,600**	**53,000**	**86,000**

Source: CIMMYT 1992 Survey of Wheat Research Program and Pardey, Roseboom, and Anderson (1991).

Table 6. Research intensities by program and size group

Size of mandate wheat area	Number of scientists per million tons of wheat	Research expenditure intensity		
		US$ (1990 PPP) per ton of wheat	US$ per US$ 100 value of wheat (OER 1990)[a]	Cost per variety released (000 1990 US$ PPP)
Developing country programs				
< 0.1 M ha	55.4	4.56	2.03	564
0.1 - 0.5 M ha	6.9	1.01	0.57	844
0.5 - 1.0 M ha	4.9	0.47	0.16	552
1.0 - 2.5 M ha	3.2	0.18	0.07	709
> 2.5 M ha	1.0	0.09	0.04	818
All developing countries				
Weighted	**2.5**	**0.21**	**0.09**	**696**
Unweighted	**18.0**	**1.75**	**0.79**	**1,172**
Industrialized country programs				
< 0.1 M ha	3.0	0.39	0.34	211
0.1 - 0.5 M ha	1.1	0.10	0.08	190
0.5 - 1.0 M ha	0.6	0.08	0.06	325
1.0 - 2.5 M ha	0.3	0.04	0.03	388
> 2.5 M ha	0.1	0.01	0.01	425
All industrialized country programs				
Weighted	**0.2**	**0.03**	**0.02**	**330**
Unweighted	**0.8**	**0.08**	**0.06**	**372**

Source: CIMMYT 1992 Survey of Wheat Research Programs.

a Research expenditures are expressed at the official exchange rate because the value of wheat production was calculated using a standard international wheat price.

6 Reporting research intensities for a specific wheat program assumes that the mandate area for that program is unique to that program. In fact, as noted earlier, a given region may have more than one wheat research program, and these programs may have overlapping mandates (e.g., a government research station and a university). Likewise, varieties from a given research program often are used outside of the mandate area of the program that developed the variety. For these reasons, caution must be used in interpreting research intensities at the program level presented in this report.

of researchers per million hectares decreases dramatically as the size of the mandate area increases (Figure 5), and therefore the cost of wheat research decreases as well. The relative costs of small programs whose mandate areas cover less than 100,000 ha of wheat are several times the costs of large programs. Research expenditure per ton of wheat is several times higher for small programs. This has important implications for regional comparisons, since, for example, most Asian research programs are large whereas most programs in sub-Saharan Africa are small. Second, and somewhat more surprising, research costs and intensities in developing countries, with the exception of the large programs in Asia, are higher than in industrialized countries. This is particularly true for the unweighted measures of research intensities, which are a simple average across programs. One reason for this difference is the smaller mandate area and larger number of scientists per program in developing countries, which more than compensate for their lower cost per scientist. On the other hand, mandate areas more frequently overlap in industrialized countries, which explains part of the difference in research intensities.

A common measure of research intensity is the ratio of research expenditures to the value added in wheat production.[7] In practice, it is difficult to compute value added. As an approximation, the value of wheat production is calculated by multiplying the amount of wheat produced by a standard wheat price. In the case of food grains, a share of 2.0% of the value of production is often used as a benchmark for recommending research investments (World Bank 1981). Since we are considering only the investment in wheat improvement, a more appropriate benchmark would be 1.0% of the value of production, assuming that half of all wheat research is devoted to wheat improvement (Byerlee 1993c). Programs having mandate areas of 0.1 M ha have an average share of about 2.0%, while larger programs have shares of 0.5% or less (Table 6). In contrast, all programs in industrialized countries have average research intensities that are far less than 1.0%.

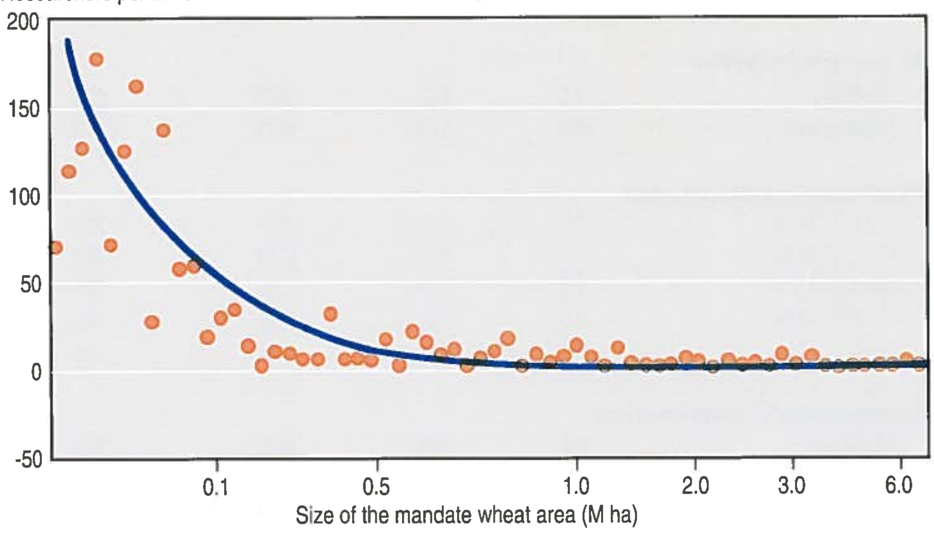


Figure 5. Economies of scale in wheat improvement research.
Source: CIMMYT 1992 Survey of Wheat Research Programs.

Another measure of research expenditure is the cost per variety developed by a program. On average, this varies from about US$ 0.3 million in industrialized countries to US$ 0.7 million in developing countries (the respective figures in dollars at the official exchange rate are US$ 0.37 million and US$ 0.44 million). The estimate for industrialized countries is consistent with other studies (Brennan 1988, Perrson 1990, and McMullen 1987). However, the relatively high cost per variety released in developing countries has not been documented previously.

Country-level expenditures on wheat research

From the survey and from secondary sources we can estimate the total expenditures on wheat improvement research for individual countries and for all developing countries. Since most countries support more than one wheat breeding program, data must be aggregated over several and sometimes many programs, and errors are likely to be greater than for estimates of expenditures at the program level. However, because mandate areas of many wheat breeding programs overlap, country-level information provides a more accurate measure of research intensities than program-level information.

Several large countries average about one wheat breeding program for each 1 million tons of wheat produced, but in smaller countries the average is

7 In calculating this ratio, research expenditures were not based on PPP dollars but were expressed in dollars at the official exchange rate because a standard international wheat price was used.

obviously much less, because total national wheat production was less than 1 million tons in 16 of the countries surveyed. We have included the USA and Australia by way of comparison. Both of these countries average about one wheat breeding program for every 1-1.5 million tons of wheat produced (Brennan 1986, James 1990).

About 1,100 scientists work in wheat improvement in developing countries (Table 7). Nearly half of them work in the two largest wheat-producing countries, India and China. The number of wheat improvement researchers in a given country is higher, the higher the level of wheat production is in that country (this is the same pattern observed at the program level). Countries in sub-Saharan Africa support an average of only four scientists in wheat improvement for an average production of 0.3 million tons. In contrast, Asian countries have an average of 142 wheat scientists for an average wheat production of 32 million tons. The number of scientists per million tons of wheat (between four and five) is similar in Asia and in the two industrialized countries for which data are available. However, 15 developing countries whose wheat areas do not reach 0.5 M ha support more than 10 scientists per million tons of wheat. As a result, the unweighted average for all developing countries is 31 scientists per million tons of wheat.

In 1990, the total estimated investment in wheat improvement research in developing countries was US$ 96 million. (For comparison, at the official exchange rate this would be US$ 58 million.) Expressed another way, developing countries spend about US$ 0.40 per ton of wheat on improvement research, or about 0.3% of the value of production. The USA spends about US$ 0.70 per ton of wheat produced. The 15 small developing countries having less than 0.5 M ha of wheat spend an average of US$ 4.0 for every ton of wheat (Figure 6).

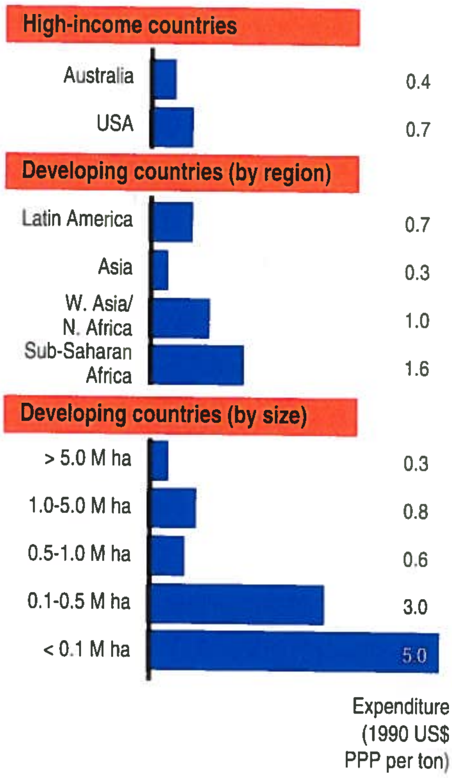


Figure 6. Research expenditure per ton of wheat produced nationally, by region and size of national wheat area.
Source: CIMMYT 1992 Survey of Wheat Research Programs.

Table 7. Country-level expenditures on wheat research, by region, 1990

	Number of countries	Number of scientists in wheat improvement	Average number of scientists in wheat improvement per country	Total wheat production (million tons)	Number of scientists per million tons of wheat produced	Total research expenditures (million 1990 US$ PPP)	Research cost per ton of wheat (1990 US$ PPP)
Sub-Saharan Africa	6	27	4	2	14.3	3	1.62
W. Asia/N. Africa	9	283	31	39	7.2	38	0.95
Asia	5	710	142	162	4.4	41	0.25
Latin America	11	123	11	20	6.0	14	0.71
All developing countries	**31**	**1,142**	**37**	**224**	**5.1** (30.5)[a]	**96**	**0.43** (3.15)[a]
Australia	1	72	72	14	5.3	6	0.43
USA	1	278	278	60	4.6	44	0.73

Source: See Bohn (1993) for details. The estimate of number of FTE scientists in the US is based on Huffman and Evenson (1993), Kalton, Richardson, and Frey (1989), as well as the survey responses, while the estimate for Australia is taken from Clements, Rosielle, and Hilton (1992).
a Unweighted averages.

These estimates confirm that developing countries invest considerable resources in wheat improvement research. However, except for the smallest countries, the difference between developing countries and industrialized countries is not as marked at the country level as at the program level, for two reasons. First, the mandate areas of industrialized country programs, especially private sector research programs, overlap. Second, national estimates for wheat research in the USA and Australia include the costs of a good deal of basic research (especially in molecular biology) and graduate training that are not included in the developing country estimates.

These data can be compared with estimates of total wheat research expenditures in developing countries in the 1970s of US$ 67 million (excluding the two large wheat producers, China and Iran) (Judd, Boyce, and Evenson 1983). Considering that we have included only wheat improvement research here, and deflating to 1980 dollars, the figures are of the same order of magnitude.

Finally, to obtain a more complete idea of expenditures on wheat improvement research in developing countries, the costs of wheat improvement by CIMMYT must be included. In 1990, CIMMYT (including the joint CIMMYT/ICARDA program) spent about US$ 8.2 million on wheat improvement research, or about US$ 0.03 per ton of wheat produced in the developing world.

The overall picture emerging from this analysis is that, on average, wheat research expenditures in developing countries are *comparable to or higher than* levels in industrialized countries. However, the aggregate data disguise the dominant role of a few large developing countries, especially China and India, where expenditures per unit of wheat output are relatively low. At the opposite end of the spectrum are the 16 countries producing less than 1 million tons of wheat, whose research expenditures are high compared to those of large producers in developing and industrialized countries. This raises questions about whether the levels of investment in wheat improvement research in smaller countries are efficient. We will return to the issue of efficiency later in this report, after discussing both the products of wheat improvement research and ways of measuring the returns to research.

The Products of Wheat Improvement Research

Having examined the level of resources that developing countries invest in wheat research, we now take a look at the products of their investment. The outputs of a wheat improvement research program can be measured by various indicators. Perhaps the simplest indicator is the rate at which new wheat varieties are released. Although a program that does not release varieties is clearly unsuccessful, a program that releases many varieties that farmers never adopt also has little impact. To be adopted by farmers, varieties must provide some tangible benefit. This benefit can take the form of higher yields or simply maintenance of yields, improved yield stability, better quality, or some other desirable characteristic. The sections that follow discuss all of these elements of research success, from the release and adoption of new varieties to the reasons for their adoption.

Varietal releases

The number of varieties released annually in developing countries has increased steadily since 1966. In the 1980s, developing countries (excluding China) released an average of about 65 varieties every year, which translates to about one variety per million hectares of wheat. Smaller wheat producers release more varieties annually for every million hectares cropped to wheat (in other words, they have a higher *intensity* of varietal releases) than large countries,

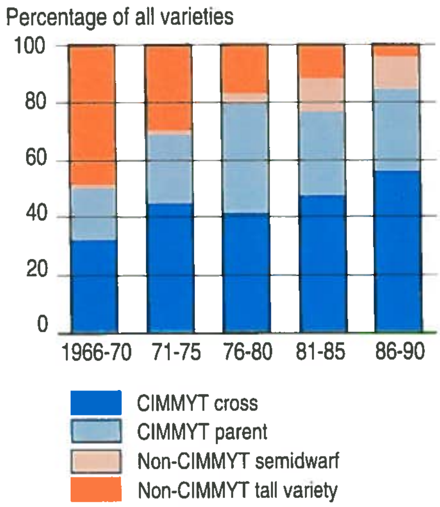


Figure 7. Trends in the origin of spring bread wheat varieties in developing countries, 1966-90.
Source: Byerlee and Moya (1993).

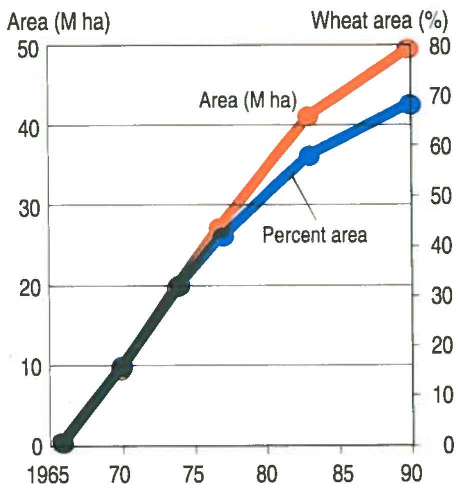


Figure 8. Adoption of semidwarf wheat varieties in developing countries, 1966-90.
Source: Byerlee and Moya (1993).
Note: Excludes China.

which have larger wheat production environments. This situation is particularly common in the small African countries, but Latin American countries also release varieties at a much higher rate than countries in other regions.

Over the past 25 years, the proportion of semidwarf wheat varieties among the wheat varieties released has kept growing. From 1966 to 1970, about half of the spring bread wheat varieties released were semidwarfs. During the 1970s and 1980s, the proportion of semidwarfs among spring durum wheat and winter wheat releases also rose rapidly, so that by 1986-90 well over 80% of all varieties released were semidwarfs. About half of spring wheat varieties were based on crosses made by CIMMYT, but with increasing frequency national research systems are producing semidwarf varieties based on their own crosses (Figure 7).

Adoption of modern wheat varieties
The adoption of improved or modern varieties (MVs) can be viewed in two stages (Morris, Dubin, and Pokhrel 1992):

- **Stage 1:** Modern high-yielding varieties are released and adopted to replace local varieties or older improved varieties that farmers have used for many years. In most cases, these MVs differ considerably from the varieties they replace because of characteristics such as higher yield potential or better disease resistance.
- **Stage 2:** Newer generations of MVs are adopted periodically (at least once a decade) to replace earlier generations of MVs and provide steady improvement in yield and other traits.

The changes that occur in Stage 1 are best illustrated by the Green Revolution in South Asia, where semidwarf varieties rapidly replaced older, mostly improved varieties released in earlier decades. When farmers grew semidwarfs under irrigation and with modest levels of fertilizer, their wheat yields jumped 35-50%. The impact of these changes inevitably lessened over time in irrigated areas as semidwarf wheats reached the peak level of adoption — 100%. However, Stage-1 varietal changes continue in the developing world's rainfed areas. Figure 8 shows current estimates of Stage-1 adoption of MVs. Since 1975 much of the increase in area planted with MVs has occurred in rainfed areas (Figure 9).

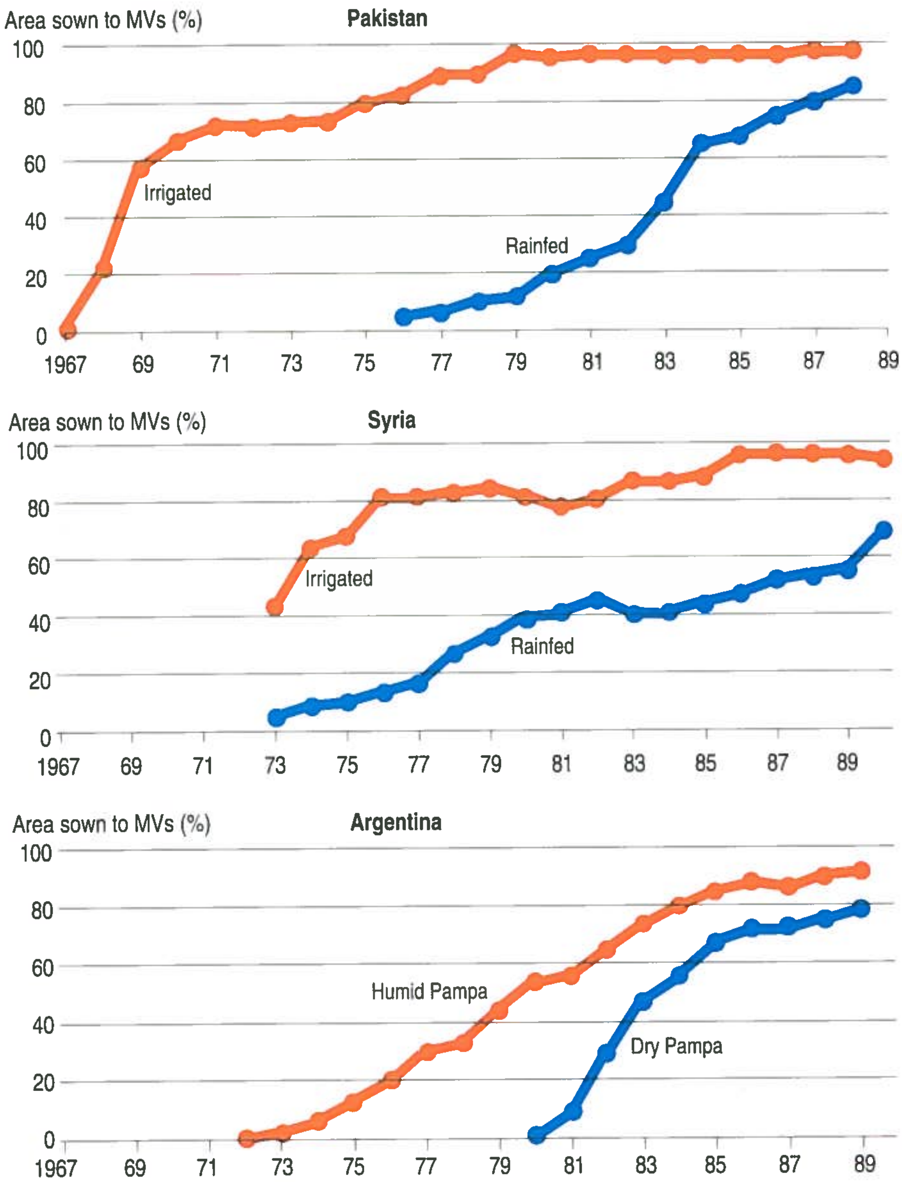


Figure 9. Adoption of modern wheat varieties (MVs) in different moisture zones.
Source: Byerlee and Moya (1993).

Farmers still grow tall varieties on 30% of the developing world wheat area and in some parts of industrialized countries. These areas generally suffer the effects of harsh climates, especially severe drought and extreme heat or cold. Even so, MVs are edging into these difficult environments. For example, in the very dry wheat-producing state of Western Australia, where annual rainfall is less than 350 mm, the adoption of MVs lagged until in the 1980s, when a newer generation of better adapted varieties was released and adopted quickly.

Most wheat-producing areas of the developing world are now characterized by Stage-2 changes (in other words, they have entered a "post-Green Revolution" phase). In these areas, farmers replace MVs with newer generations of MVs every few years. Most farmers in Pakistan and India have switched wheat varieties at least twice since adopting the original Green Revolution varieties (Figure 10). In northwestern Mexico, farmers replace varieties even more rapidly — on average once every three years.

One measure of the rate of varietal replacement is the age of varieties, measured in years since release, weighted by the area that farmers sow to each variety. This measure is referred to as the "weighted average age of varieties." Varietal age averages about seven years but varies considerably from country to country (Figure 11). A weighted age of seven years is consistent with replacing a variety once every five years, assuming that two years usually elapse between the time a variety is released and adoption begins (time is needed to multiply seed of the variety). The average age of varieties is generally lower in commercial wheat-producing areas because seed and extension systems are well developed. It is high in parts of South Asia, where many farmers have not yet substituted a new variety for the original Green Revolution variety, Sonalika. Frequent replacement of varieties is desirable, because it enables farmers to avoid the loss of disease resistance that often afflicts older varieties and to reap the benefits of traits bred into newer varieties (see the box, "Transferring Technology to Farmers").

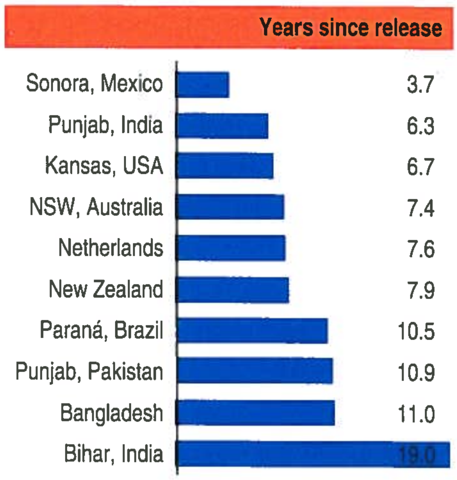


Figure 11. Weighted average age of varieties grown by farmers, 1980s.
Source: Byerlee (1993a).

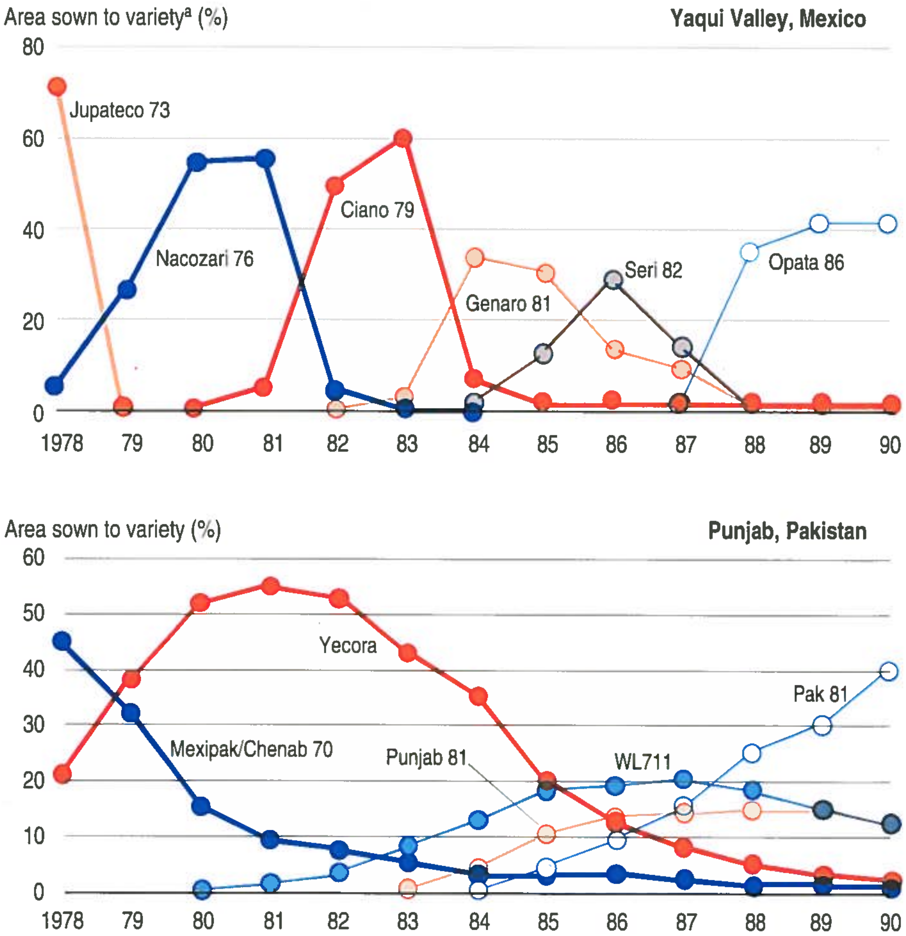


Figure 10. Patterns of varietal change in post-Green Revolution areas of Mexico and Pakistan.
Source: CIMMYT data files.
a Bread wheat varieties only. Durum area was important in Mexico in the late 1980s.

Benefits of varietal adoption
The benefits of new varieties range from broad characteristics such as higher yields to more specific quality characteristics needed by farmers. The following paragraphs describe some of the benefits of adopting new varieties.

Yield gains and stability — The major focus of wheat breeding programs has been to increase yield potential and improve yield stability. In Stage 1 of the adoption process, farmers may see a surge in yields, but the impact of Stage-1 changes diminishes over time as MVs diffuse into marginal areas, where their yield advantage is usually less. Thus yield gains for wheat in Stage 1 have declined from about 40% when MVs were adopted in the 1960s in high-potential areas to about 10% when MVs were adopted in the late 1980s in drier rainfed areas. When the impact of these varieties is expressed as absolute gains in yield, it is more modest, perhaps 800 kg/ha in the first case and only 100 kg/ha in the second.

Genetic gains in yields resulting from the release and adoption of newer generations of improved varieties in Stage 2 tend to be a steady 0.3-1.0% per year over the longer term, although considerable short-term fluctuations may be experienced (Table 8). In irrigated areas, there is substantial evidence of genetic gains in yields of about 1% annually in post-Green Revolution areas (Byerlee and Moya 1993). This translates into absolute yield gains of about 20 kg/ha/yr in Pakistan to 50 kg/ha/yr in northwestern Mexico. In rainfed areas that experience some drought stress, the long-term average rate of yield gain is only about 0.5% per year, which is usually less than 10 kg/ha/yr in absolute terms. In very dry areas, genetic gains in yield may average only 2-3 kg/ha/yr (e.g., Perry and D'Antuono 1989, Jain et al. 1993). Of course, the yield gains that farmers actually achieve are often higher than this because of improvements in crop and resource management, which in marginal areas are usually more important than genetic gains in improving yields.

The general pattern in varietal adoption that emerges is that developing countries are passing through a transition from Stage-1 adoption to Stage-2 adoption. For example, in South Asia practically all the benefits of wheat breeding from 1966 to 1977 were derived from Stage-1 changes. However, from 1977 to 1990 an estimated 78% of economic benefits came from Stage-2 changes (Table 9). In other regions, Stage-1 gains still made up half or more of the benefits between 1977 and 1990. Improvements in yield and the maintenance of disease resistance in spring wheats alone during this period added benefits of US$ 3 billion in 1990 (Byerlee and Moya 1993). In every region except sub-Saharan Africa, these benefits, expressed in average annual increments, considerably exceed the annual cost of research in 1990 (Table 9). However,

Table 8. Annual rates of genetic gains in wheat yields observed in experiments in different environments over the past two decades, developing countries

Environment and country	Rate of gain (%/yr)[a]
Irrigated	
Northwestern Mexico	0.6 - 1.1%[b]
Northwestern India	0.5 - 1.0[b]
Punjab, Pakistan	0.8[b]
Zimbabwe	1.0[b]
Irrigated hot	
Sudan	0.9[c]
Rainfed	
Brazil	0.5 - 0.8[b]
Paraguay	1.3[c]
Central India	0[c]
Rainfed acid soils	
Brazil	2.2 - 3.2%[c]

Source: Byerlee and Moya (1993).
a Period varies, but the most common period is from about 1970 to the late 1980s.
b Semidwarf varieties only.
c Includes the effect of switching from tall to semidwarf varieties.

Table 9. Estimated annual average costs and increment in benefits of wheat improvement research for spring wheats, 1977-90

Region	Estimated annual research expenditures on spring wheat, 1990 (million 1990 US$)	Average annual increment in benefits, 1977-90 (million 1990 US$)	Percent of benefits due to varietal change	
			Stage-1 varietal change	Stage-2 varietal change
Sub-Saharan Africa	3	2	62	38
W. Asia/N. Africa	22[a]	39	49	51
Asia	22[b]	143[b]	22	78
Latin America	14	51	56	44
All developing countries	61[b]	235[b]	34	66

Source: Byerlee and Moya (1993).
a Assumes that research resources are allocated between spring wheats and winter wheats in proportion to their share in regional production.
b Excludes China.

Transferring Technology to Farmers

No matter how impressive an innovation is, it is not worth much unless farmers use it. In the case of wheat improvement, the transfer of the innovation — that is, a new variety — depends on farmers knowing about new varieties and their potential benefits, and then obtaining seed of those varieties. When new management practices are required for farmers to benefit from using a new variety, farmers will also need to learn about these new practices.

Quick dissemination of "genetic innovations" is desirable so that farmers can benefit from them as soon as possible. The rapid transfer of newer wheat varieties helps increase genetic diversity over time and lower the risk of disease epidemics, particularly if the parentage of newer varieties is diverse. Without periodic replacement of older varieties with new, more disease resistant varieties, annual losses caused by disease can be substantial even before an epidemic breaks out.

Many factors influence the rate at which farmers are likely to replace wheat varieties. These include:

- *The time to test new varieties and make seed available.* Our survey suggests that this period averages about five years and is fairly uniform across countries.

- *The availability of seed of new varieties and the price of the seed.* In most developing countries, seed production and distribution are still largely done by the public sector. Although the profit margin on marketing seed of a self-pollinated crop such as wheat is small, there are probably substantial opportunities to diversify seed production and marketing away from the public sector in many countries. This may entail making a tradeoff between raising the cost of seed and improving its availability. However, prices of certified wheat seed relative to commercial grain vary over a narrow range of about 2:1 to 3:1 (see Figure A). It should also be remembered that in small-farm agriculture, most farmers obtain seed from other farmers instead of purchasing certified seed. Figure B shows results of a detailed study from the Punjab of Pakistan, where only 37% of farmers say they first obtained seed of new varieties from formal sources.

- *Extension of information about new varieties to farmers.* The speed of varietal change depends also on an effective extension system to make farmers aware of the availability of new varieties and their characteristics. On-farm demonstrations are probably the most effective way of promoting new varieties and at the same time soliciting feedback from farmers on varietal traits that they prefer.

The speed of varietal adoption is central in determining the magnitude of the benefits and the rate of return on the research. If it takes a long time for farmers to adopt a variety, the benefits of research will be delayed and the rate of return on the research will be lower. Given reasonable assumptions about the values of the variables listed above, Heisey and Brennan (1991) calculate that the optimum period for varietal replacement is between 5 and 10 years.

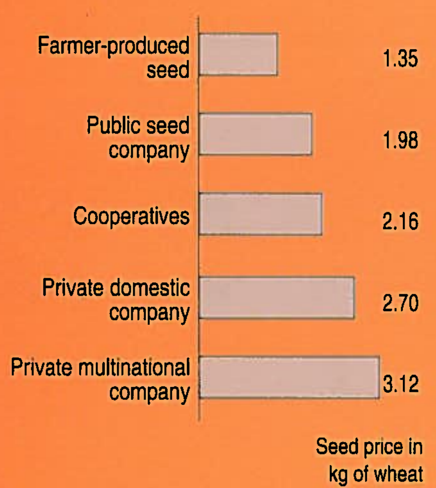


Figure A. Price of seed from different sources.
Source: CIMMYT 1992 Survey of Wheat Research Programs.

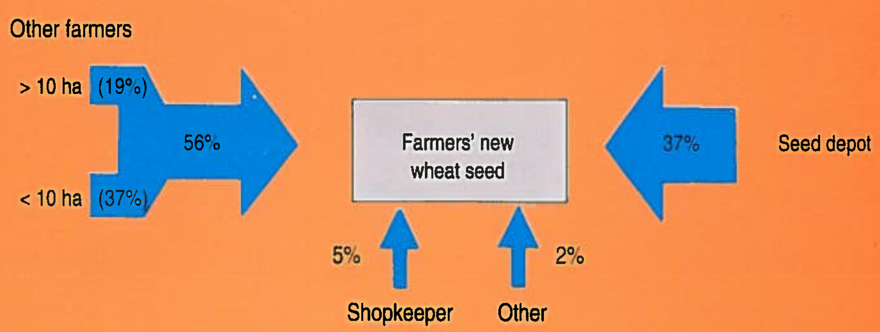


Figure B. Initial seed sources for new wheat varieties in the rice zone of the Punjab, Pakistan.
Source: Heisey (1990).

these comparisons to do not take into account the different periods in which costs and benefits of research occur. This will be discussed later in "Basic concepts in evaluating returns to research."

Disease resistance — In most environments where wheat is grown, diseases, especially the three rusts,[8] can inflict large yield losses. After yield, the objective to which breeders attach the greatest importance is improving and maintaining disease resistance in the face of evolving pathogens. In many areas, the contribution of new wheat varieties may be greater in terms of disease resistance than in terms of increased yield potential.

If resistance to rust breaks down in varieties grown by farmers and an epidemic occurs, average yield losses of up to 20% may be recorded. Figure 12 shows the role of maintenance breeding in avoiding losses to leaf rust in northwestern Mexico. Since the average life of a variety's resistance to rust is five to seven years (Khan 1987, Kirkpatrick 1975), the loss of resistance is a major force behind regular varietal replacement. Recent breakthroughs in obtaining durable resistance to leaf rust should help alleviate the problems that arise when rust resistance breaks down (Singh et al. 1991).

Gains have also been made in reducing losses from other endemic diseases, especially in warmer humid areas. Improved disease resistance has been important in reducing the use of financially and environmentally costly fungicides, especially in South America.

Maturity — Particularly where double cropping is common or the potential for double cropping exists, the length of time that it takes a variety to reach maturity is an important characteristic affecting varietal acceptance and benefits. Early maturing varieties were critical to the rapid expansion of wheat area in northeastern India, Nepal, and Bangladesh (Morris, Dubin, and Pokhrel 1992). Although progress in improving yields of early maturing varieties has been relatively slow, several varieties released in Bangladesh yield 10-20% more than the original early maturing variety of the Green Revolution period, Sonalika. These varieties are grown widely by Bangladeshi farmers. In Pakistan, progress has been achieved by developing varieties of average maturity for late planting in double-crop systems. In some cases, however, intensified cropping may have costs. In Argentina, double cropping of wheat and soybeans, which became possible with the introduction of earlier maturing semidwarf varieties, has raised concerns about soil erosion.

Quality — In general, improvements in grain quality have not been an important part of the benefits of wheat breeding in developing countries, except in durum wheat. Since there are likely to be yield-quality tradeoffs, a rational strategy may be to maintain minimum quality standards to meet consumer acceptance. Most developing countries have provided a uniform wheat support price regardless of quality, so breeders have had little incentive to improve quality. However, in Latin America wheat markets are being liberalized and price premiums given for quality, so breeding programs in this region may place greater emphasis on quality in the future.

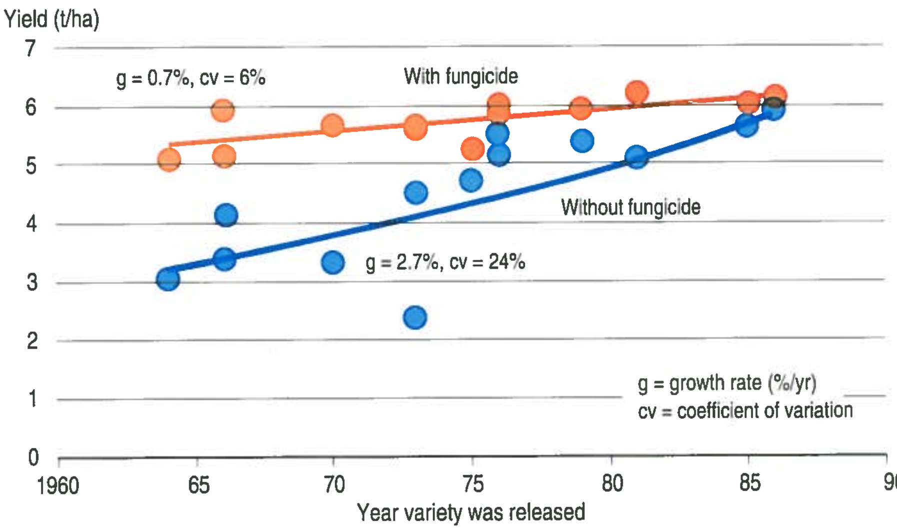


Figure 12. Yield of historically important varieties (released 1964-86) with and without fungicide, Obregón, Mexico, 1990-91.
Source: K. Sayre (pers. comm). Data for normal planting in 1990-91 and 1991-92.

Estimating the Returns to Investment in Wheat Research

Although yield gains, disease resistance, and the other products of wheat improvement contribute to the benefits that can be realized from a wheat improvement program, ultimately they must be summarized in economic terms

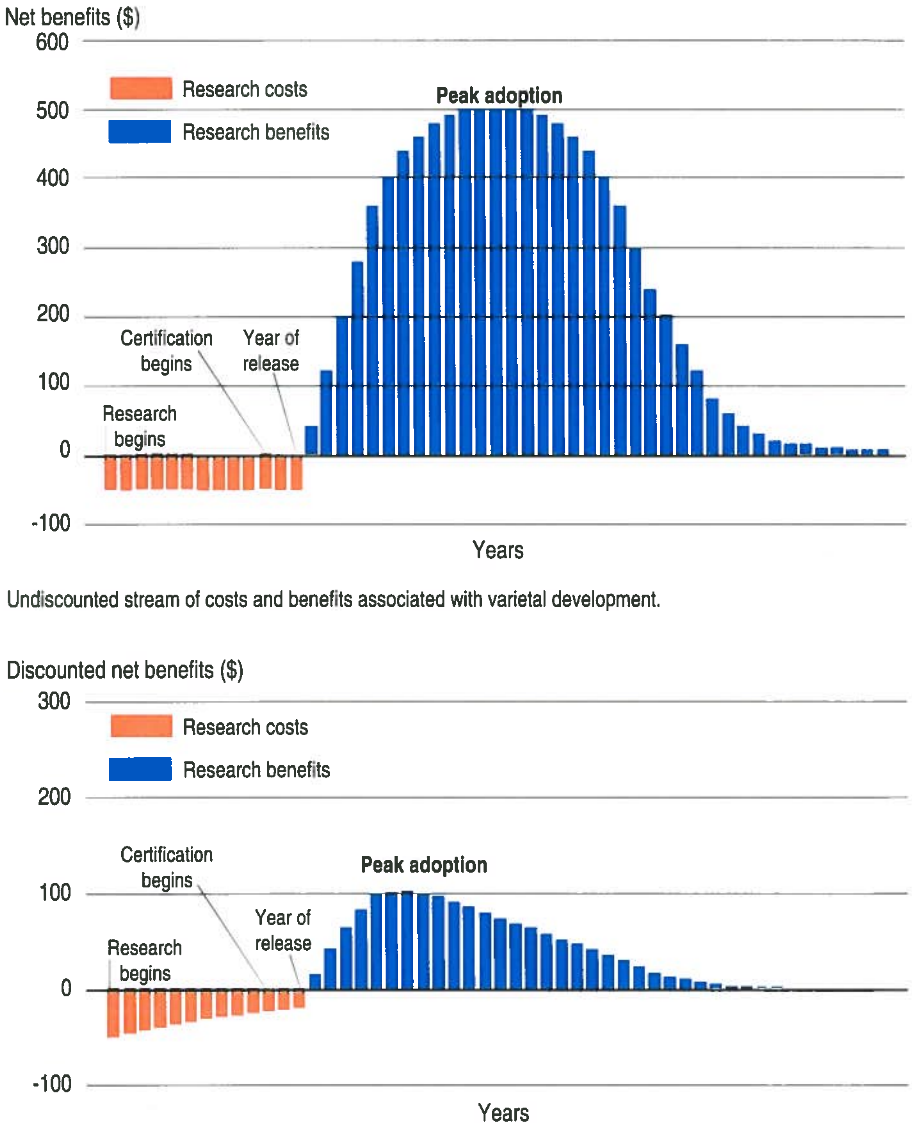
8 The three rusts are (1) leaf or brown rust (*Puccinia recondita*), (2) stem or black rust (*P. graminis* f.sp. *tritici*), and (3) stripe or yellow rust (*P. striiformis*).

if we are to compare them to the costs of wheat research. This section provides a brief overview of methods that economists use to measure the benefits of agricultural research and demonstrates how these methods have been applied to measure the benefits of wheat research.

Basic concepts in evaluating returns to research

Confronted with increasingly scarce resources in the public sector, policy makers are asking if agricultural research is a worthwhile investment. How do returns to investment in research compare with other possible uses of public monies, such as building a new road or irrigation system? Such comparisons can be made because agricultural research, just like any other investment, has identifiable costs and benefits derived from those costs. Economists have used various methods to calculate the returns to research investments, but in the case of research on a specific commodity, such as wheat, a practical method is the "economic surplus approach." The steps in this approach are:

- Identify the costs for each year of the research project or, in this case, the annual costs of the wheat improvement program.
- Identify the products of the research, the extent of their adoption by farmers, and the economic benefits derived from those products.
- Since the costs and benefits of research occur at different periods, they must be adjusted to be compared. They are adjusted by discounting to the same time period, usually the initial year of the project. Discounting reflects the fact that benefits occurring many years in the future are valued less than the same benefits received today. The same holds for costs. The typical wheat improvement program has costs and benefits related to the development of an individual variety (Figure 13). Costs occur in the early years of the project and benefits later in the project, for two reasons. First, in the research process there are lags between expenditures on breeding and the release of a new variety. Second, once a variety is released, there is another lag before it is adopted. Eventually benefits decline as a variety reaches peak adoption and is replaced by newer varieties. Figure 13 shows how an annual



Undiscounted stream of costs and benefits associated with varietal development.

Effects of discounting the stream of costs and benefits associated with varietal development.
Discount rate = 8%.

Figure 13. Generalized pattern of costs and benefits associated with developing a new variety.
Source: Morris, Clancy, and López-Pereira (1992).

discount rate of 8% reduces future benefits relative to costs. The discounting of future benefits is commonly used in appraising investments. It clearly shows why it is important to reduce lags in the research process (e.g., through two breeding cycles per year) and the adoption process (e.g., through improved seed production and extension systems).

- Generally the return on an investment is expressed as an "internal rate of return" (IRR), which is the rate of return that makes the discounted sum of costs and benefits equal. Thus an IRR of 20% indicates that the return on the research investment is equivalent to a deposit in a bank at an interest rate of 20% over the entire period of the analysis (usually greater than 20 years).

These concepts are best illustrated by a specific example of how the returns to wheat improvement research have been calculated.

An example of calculation of returns to research

The returns to wheat breeding research in Argentina from 1967 to 1992 have been calculated by Macagno and Gómez Chao (1993). First, the benefits of wheat breeding research were calculated for each of Argentina's seven major wheat-growing regions. Macagno and Gómez Chao considered two periods of varietal change: 1) the initial adoption of semidwarf wheat varieties in the 1970s (MV1s) to replace older tall varieties (TVs) and 2) the adoption of a second generation of varieties in the 1980s (MV2s) to replace the MV1s in most regions. (This process mirrors the Stage-1 and Stage-2 varietal changes described earlier.)

To estimate benefits in each region, two key parameters were needed: statistics on varietal adoption and estimates of the relative yields of MV1 and MV2 varieties. Statistics on varietal adoption were available from wheat market deliveries for each region and each year. Researchers estimated the relative yields of MV1 and MV2 varieties from the results of multilocational trials sown yearly in each region to evaluate varieties that were candidates for release. Because the trials included a series of check varieties, the yields of new varieties could be estimated in relation to the checks. In Region 1, for example, it was estimated that MV1 yielded 17% more than the TVs and that MV2 yielded 6% more than MV1. These estimates enabled Macagno and Gómez Chao to estimate K, the unit reduction in cost of production. Next, the benefits were calculated by multiplying K by the price of wheat and the baseline production level in Region 1 in 1975 (307,000 t). With the data on adoption of MV1 and MV2 varieties, aggregate annual benefits of the new varieties could be calculated for the region. These data were then aggregated over the seven regions considered in the study to give the gross benefits over regions (the third column from the right in Table 10).

Table 10. Aggregated cost and benefits of wheat research in Argentina, 1967-92

	Total costs (US$ 1990 million)					Benefits (US$ 1990 million)		
Year	Public research[a]	Private research	CIMMYT[b]	Extension	Total costs	Gross benefits over regions	Net benefits over regions	Discounted net benefits (1992 base)[c]
1967	1.91	1.0	.02		2.94		-2.9	-31
1968	1.88	1.0	.05		2.93		-2.9	-29
1969	2.15	1.0	.11		3.26		-3.3	-30
1970	1.94	1.0	.11		3.05		-3.0	-24
1971	2.05	1.0	.32		3.37		-3.4	-25
1972	1.94	1.0	.33		3.27		-3.3	-22
1973	3.33	1.0	.39		4.72		-4.7	-29
1974	2.87	1.0	.33	.94	5.14	1	-4.1	-23
1975	2.41	1.5	.33	.82	5.06	18	13	66
:	:	:	:	:	:	:	:	:
1985	3.12	1.5	.66	1.66	6.94	103	96	187
1986				1.66	1.66	100	97	172
1987				1.66	1.66	112	111	179
1988				1.66	1.66	178	176	258
1989				1.66	1.66	167	165	220
1990				1.66	1.66	83	82	99
1991				1.66	1.66	114	112	123
1992				1.66	1.66	129	127	127
Total					107	1,855	1,750	299

Source: Macagno and Gómez Chao (1993).
a Improvement research assumed to be 50% of all wheat research.
b Percent of the CIMMYT wheat improvement budget proportional to Argentina's share of wheat production.
c Discounted at 10%.

The next step was to estimate costs. Macagno and Gómez Chao included four categories of costs:

1. **Costs of the public sector breeding programs.** These programs were largely responsible for developing the MV1s. Costs were estimated taking account of salaries, overheads, and other expenses, as discussed above.

2. **Costs of private sector breeding programs.** The private sector is active in wheat breeding in Argentina, and accounts for a considerable share of the MV2s. Only rough estimates of private sector expenditures could be obtained, and these had to be extrapolated over years.

3. **A share of the costs of CIMMYT wheat research.** Because the MVs were developed through a collaborative research program between CIMMYT and Argentina, a share of CIMMYT costs proportional to Argentina's share of CIMMYT's mandate wheat area was included.

4. **Extension costs.** Extension costs for wheat were apportioned as a share of all extension costs over crops. Half of the share of wheat extension costs was attributed to disseminating the varieties. Both public sector and private sector extension (the latter is important for larger-scale farmers) were included.

Research costs were assumed to begin in 1967, when work on MVs began. Thus seven years elapsed from the beginning of the research until the first benefits were received. The cost of extension was assumed to begin in the first year of adoption of the MVs.

The rate of return on research is then simply the interest rate that makes the net present value of benefits and costs in the final column of Table 10 equal to zero. Despite the fact that this study includes costs that are not normally considered in country-specific rate of return studies, such as CIMMYT costs and extension costs, the return to research is still estimated at the high rate of 42% per annum.

Summary of estimates of returns to research

Several studies of returns to wheat research have used the method described above, and they generally show returns in the range of 25% to 80% (Table 11).

This suggests that wheat research has been a good investment. However, for several reasons, caution is needed in interpreting these results.

- Most of the studies were done during the Stage-1 adoption of improved varieties (the Green Revolution, for example). Returns to research in this period were unusually high. In Pakistan, for instance, returns exceeded 50% for 1967-81 but fell to about 25% in the post-Green Revolution period (Byerlee 1990).

- Most of the studies focused on large wheat-producing countries. Returns for smaller wheat-producing

Table 11. Summary of estimates of returns from investments in wheat research

Country or region	Scope of study	Period of analysis	Range of of returns (%)	Author(s) and year published
Argentina	Improvement	1967-92	42	Macagno and Gómez Chao (1993)
Brazil	All wheat research	1974-90	59-74	Ambrosi and da Cruz (1984)
Canada	Improvement	1946-79	30	Zentner and Peterson (1984)
Chile	All wheat research	1949-77	21-28	Yrarrazaval et al. (1982)
Colombia	Improvement	1927-76	11-12	Hertford et al. (1977)
India	All wheat research	1972-84	51	Evenson and McKinsey (1991)
Israel	Improvement	1954-73	125-150	Kislev and Hoffmann (1978)
Mexico	Improvement	1943-63	90	Ardito-Barletta (1970)
Nepal	Improvement	1960-90	75-84	Morris, Dubin, and Pokhrel (1992)
Pakistan	Improvement	1960-81	55-62	Nagy (1991)
Pakistan (Punjab)	Improvement	1978-87	16-27	Byerlee (1993b)
USA	All wheat research	1967-79	81	Otto and Havlicek (1981)
USA	All wheat research	1978-85	46	Eddleman (1977)
South America (PROCISUR)	Improvement	1979-88	110	Evenson and da Cruz (1989)
All developing countries except China (spring wheat only)	Improvement	1977-90	50-70	Byerlee and Moya (1993)

Source: CIMMYT database.

countries, such as Colombia, are much lower (although Israel is an exception to this generalization). This pattern is consistent with the evidence presented above on the relatively higher costs of conducting wheat research in small wheat-producing countries.

- Few of the studies accounted for the costs of research conducted by other countries and by CIMMYT. Since such a large share (over half) of the varieties released in developing countries originates abroad, costs of research at a global level have not been accounted for adequately.
- Few studies accounted for the benefits of maintenance research, especially research that ensures continuing disease resistance and prevents epidemics. While the factors listed above tend to exaggerate the returns to research, failing to consider maintenance research leads to an underestimate of returns, especially since we have seen that, at least in the case of wheat, maintenance research is a significant proportion of the total research effort.

In summary, studies of returns to wheat research are still rather few and selective. More studies of this kind are needed to guide the allocation of scarce research resources.

Despite the limitations of these studies, there is still no doubt that globally the investment in wheat research has been productive. A more recent study than the ones described above estimates the rate of return to research by national programs and CIMMYT on spring wheat improvement at 50-60% (Byerlee and Moya 1993).

Toward Efficient Allocation of Resources in Wheat Improvement Research

Although the few studies available show high returns to wheat breeding research, this does not necessarily imply that returns are always positive and that resources are being used most efficiently. Few countries have done a critical analysis of their expenditures on wheat breeding research in terms of the number, size, and location of their programs and the scope of those programs.

The information presented in this report suggests that there are significant economies of scale in wheat breeding research. Many small wheat-producing countries have established wheat research programs that are quite large in relation to their mandate areas. Even large wheat-producing countries may support programs that have small mandate areas — for example, a state that produces little wheat — or overlapping mandate areas. For example, in India, where more than 50 programs are dedicated to wheat improvement, the average wheat area per program is only about 0.5 M ha (Wheat Project Directorate 1988).

Many research systems seem to consider that a wheat research program requires a certain critical mass of skills — breeders, pathologists, cereal chemists, and so on. In fact, the capability of a wheat research program may vary, ranging from a part-time breeder/ pathologist screening international, regional, and national nurseries; to a full crossing program and support disciplines; to a program that has specialized disease screening facilities or, increasingly, a molecular biology laboratory.

Rather than assuming that all of the elements of a large research program are necessary, each country and/or wheat research program should take a careful look at the range of possibilities for meeting its needs efficiently. For example, varieties that might be utilized effectively in the mandate area could be acquired from an external source (see the box, "Technology Spillovers"). Common sources of varieties are other programs in the same country, other countries that have similar production environments, and widely adapted materials from international research centers such as CIMMYT.

Countries or programs should evaluate whether their wheat research capabilities are commensurate with the size of the mandate areas they serve. In a recent study, Maredia (1993) has expanded on Brennan (1991) and developed guidelines on the minimum size of a mandate production area that is required to justify investment in wheat breeding programs of different capabilities. She estimated the major technical and economic variables for a typical developing country program for two levels of research capacity — testing only introduced lines, and conducting a full crossing program (Table 12). She assumes that a crossing program increases the rate of yield progress by 50%, but estimates that a full-time crossing program requires three full-time scientists, versus only one for a testing program.

Technology Spillovers

It is widely assumed that agricultural technology, including wheat varieties, is quite site specific. Technology developed abroad must be adapted to local conditions before it is really useful. In crop breeding, this "adaptive research" usually involves crossing imported materials with locally developed materials to obtain the required traits.

In fact, there is growing evidence that varieties developed in one country perform well in other countries with similar environments. CIMMYT views global wheat production environments in terms of 12 "megaenvironments" (ME), which are classified by such factors as moisture, temperature, latitude, and disease stress. In one megaenvironment alone, ME1 (irrigated spring bread wheat), some 45 MT of wheat are produced in 13 countries, dominated by India, Pakistan, and China.

Generally materials developed in a country for a given ME will perform well in similar environments in other countries. This is borne out by an analysis of the International Spring Wheat Yield Nursery trials, which CIMMYT and national research systems conduct annually (see Table). The highest yields in an ME are obtained by varieties originating in that ME (that is, the relative yields along the diagonal in the Table are nearly always higher than the yields in the off-diagonal elements of the Table). In particular, varieties developed for ME1 and ME2, where there are few abiotic stresses, do relatively poorly in megaenvironments characterized by abiotic stresses (ME3 and ME4A).

CIMMYT, because it develops widely adapted materials through multilocational testing in collaboration with national research systems, produces materials that perform well in several MEs. These materials do especially well in irrigated and high rainfall environments where CIMMYT has had the longest experience. For example, CIMMYT cultivars released in Mexico provide a yield gain of 11% in ME1 over cultivars developed by others for the same environment.

These data provide evidence of the potential for "spillovers" — for wheat varieties to grow well outside the location for which they were developed. Spillovers are actually quite common. More than 10% of the varieties released in developing countries were developed in another country. Varieties developed in India have been released in 14 countries, including Sudan, Egypt, Pakistan, Afghanistan, Bangladesh, and Nepal. CIMMYT materials have been used even more widely around the world. About half of the varieties released in developing countries in the 1980s were derived from CIMMYT crosses. These varieties underwent various levels of selection by national programs, ranging from direct introduction to a longer process of selection from early generation (F2 or F3) breeding lines (Byerlee and Moya 1993).

Even within countries, germplasm often travels extensively. For example, although breeding programs in Australia target the state in which they are located, over half of the national wheat area in 1990 was planted to varieties developed in other states (Marshall and Brennan 1993). Although in some countries provincial pride and politics unfortunately prevent these kinds of useful spillovers from being realized, some spillovers are inevitable. After all, for thousands of years farmers have quietly ignored political boundaries where seed is concerned, and they continue to acquire and use seed from other farmers and regions.

Relative yield performance of spring wheat cultivars of different origins in various megaenvironments, 1980-89

Megaenvironment of variety origin	Relative yield in megaenvironment where tested[a]						
	1 Irrigated	2 High rainfall	3 Acid soils	4A Winter drought	4B Early drought	5A High temperature	6 High latitude
1. Irrigated	**100**	95	84	90	88	102	94
2. High rainfall	95	**100**	81	92	90	89	96
3. Acid soils	89	96	**100**	85	90	98	100
4A. Winter drought	99	94	78	**100**	83	91	93
4B. Early drought	90	97	89	91	**100**	90	99
5A. High temperature	88	86	92	82	89	**100**	92
6. High latitude	88	89	84	87	91	84	**100**
CIMMYT/Mexico[b]	111	113	99	101	101	101	98

Source: Maredia (1993), based on analysis of the yield data in the International Spring Wheat Yield Nursery.
a Yield expressed relative to the yield of cultivars originating in that megaenvironment (=100).
b Cultivars derived from CIMMYT crosses and released in Mexico.

Some of the results reported by Maredia (Figure 14) confirm what one would expect. For example, to justify allocating one FTE scientist to wheat research requires an industry size of 200,000 t, considerably higher than the level of wheat production in the mandate areas of a significant number of the programs surveyed in this study. Regions or countries that have programs smaller than this should consider assigning part-time researchers to work in wheat improvement, unless they expect wheat area to expand dramatically in the future.[9]

It is important to note that although a crossing program becomes profitable at an industry size of 460,000 t, it remains *less profitable* than testing until the threshold of 1.4 million tons is reached. Even if a crossing program doubles the rate of yield gains relative to a testing program, the threshold size for a crossing program to be the best alternative is still 800,000 t. Maredia calculates that about half of the wheat research programs in developing countries operate below these thresholds.

These results are only indicative, but they suggest that with increasingly tight budgets, national research systems probably have considerable scope to use their research resources more efficiently by rationalizing the number and size of wheat research programs and by examining the opportunities to import technology. At the same time, there is a strong case (at least on economic grounds) for small countries sharing similar production environments to establish collaborative regional wheat research or close links with international research centers.

9 Even without a wheat varietal testing program, new varieties can spread from other regions in a country and across national boundaries. However, a minimal investment in screening suitable materials may give high payoffs (Morris, Dubin, and Pokhrel 1992).

Conclusions

Over the years wheat breeding research has attracted considerable resources, as measured in terms of the number and training of scientists and the budgets allocated to wheat research. Most countries now have well-established wheat research programs; currently more than 1,000 scientists, supported by a total of about US$ 100 million, conduct research related to wheat improvement in developing countries. Overall these programs have been highly successful, continuously releasing superior wheat varieties that farmers use. More than 70% of the wheat area in developing countries is planted to modern wheat varieties, and on much of that area, farmers replace older varieties with new ones every few years. Research on improved spring bread wheat varieties alone has contributed an additional US$ 3 billion in benefits in developing countries in the past decade.

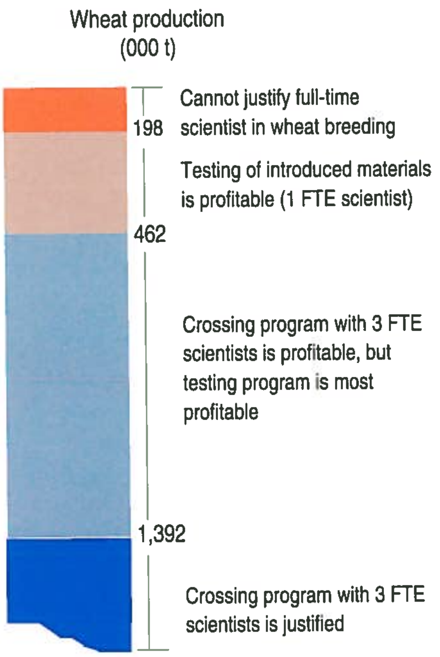


Figure 14. Threshold size of wheat production in a mandate area needed to justify different types of wheat research programs.
Source: Maredia (1993).
Note: FTE = full-time equivalent.

In looking to the next decade, however, it is clear that several policy issues affecting wheat research require the close attention of research decision makers. Budgets for wheat research in many countries and at the international level appear to be stagnating or declining. Frequently this decline is not reflected in an overall reduction in the number of scientists, but in shrinking operating budgets for scientists. Tighter operating budgets reduce the effectiveness of the human resources invested in wheat breeding. At the same time, it seems clear that many countries may actually have overinvested in wheat improvement research, particularly smaller countries and in smaller regions within countries.

How can decision makers respond to this situation? A rule of thumb provided by this analysis is that any country or region within a country that produces less than 1 million tons of wheat should evaluate its options carefully to ensure the efficiency of investments in wheat improvement research. These options include centralizing programs within a country or forming regional collaborative programs across countries. Another option is to identify the minimum number of scientists and specific disciplines needed for a region in terms of the type of research program (for example, a program that evaluates and selects from national or international nurseries versus a crossing program). Even programs with large mandate wheat areas may have opportunities for enhanced efficiency, given that wheat research programs in developing countries typically employ more scientists than equivalent programs in industrialized countries. Upgrading the technical skills of support staff may be one way of increasing efficiency and reducing costs.

In addition, countries must determine their comparative advantage in conducting different types of research. Although we have not analyzed investments in crop and resource management research in this report, we observe that many countries have emphasized investment in wheat improvement research over investment in crop and resource management research. Given that it may be easier to import germplasm to many environments than to import more site-specific crop and resource management research recommendations, the relative priority that should be given to each type of research ought to be evaluated. This is particularly true in more marginal environments, where investment in wheat improvement research has had less of an impact.

On the output side, steady gains have been made in wheat in most environments since the initial Green Revolution successes. However, one factor that does reduce returns to wheat research is slow replacement of varieties, especially in some areas of small-farm agriculture where extension and seed systems are not well developed. Slow turnover not only reduces returns because gains in the distant future are valued less than gains in the near future, but also because frequent varietal replacement is an important means of preventing disease losses.

Few in-depth analyses have been done of the resources invested in wheat research or of the benefits resulting from that research, especially in smaller countries. In addition, there has been little effort to evaluate alternative ways of organizing individual wheat improvement research programs and groups of programs that exploit complementarities between them. Nor has the potential role of private sector research been explored thoroughly (see the box, "Private Sector Investment in Wheat Improvement Research"). We hope this report will provide some important benchmarks for evaluating resource investments and progress achieved, and will stimulate more studies of the returns to investment in wheat research and the efficiency of wheat breeding programs in developing countries. In a global climate of scarce research resources, such studies can provide valuable information for insuring that investments in research remain productive.

Private Sector Investment in Wheat Improvement Research

The public sector is largely responsible for wheat improvement research in developing countries. More than 80% of the wheat research programs surveyed state that there are no private sector research programs in their mandate areas (the main exceptions are in South America).

This situation contrasts with the changing roles of private and public sector wheat research in industrialized countries. Although private breeders (usually farmers) once led the development of new wheat cultivars, with the establishment of public agricultural research institutes toward the end of the 19th century, the public sector came to dominate wheat breeding efforts.

Because wheat is a self-pollinated crop, farmers can save seed from year to year and pass seed to other farmers without risking any loss of the seed's genetic purity. This means that the market for wheat seed usually has a low profit margin. In developing countries, the public sector usually produces and distributes seed. To provide incentives for private sector investment in crop breeding, two approaches have been used. Hybrid seed providing increased yields only in the first generation in which it is sown has been the vehicle for privatizing research on maize and some other crops. In the 1960s and 1970s, several private companies invested heavily in research on hybrid wheat (Knudson 1986).* However, this approach has had little commercial success, although small amounts of hybrid wheat seed are sold in several countries (e.g., in Europe, the USA, Australia, and Argentina).

* CIMMYT had a hybrid wheat program until 1971.

Progress with hybrid wheat has been slow for several reasons: the relatively low yield advantage of hybrids over conventional varieties, high seed rates, lack of efficient technology for producing hybrid seed, and the fact that steady progress in yield has been achieved through conventional breeding. Recently developed genetic approaches to male sterility and fertility restoration through biotechnology have the potential to alleviate one of these constraints — the high cost of seed (Mariani et al. 1990).

A second approach to encouraging private sector investment in breeding research is the establishment of plant variety rights (PVRs). In most industrialized countries and a few developing countries, PVRs have been introduced to encourage private sector investment in breeding of self-pollinated crops such as wheat (Pray 1992). Plant variety rights enable seed companies to collect royalties on seed sales and legally restrain others from producing and selling seed of PVR-protected varieties.

Since the 1930s, PVRs have existed in some form in Europe, where most wheat breeding research is now conducted in the private sector. In the UK, for example, farmers pay a royalty of about US$ 0.035 per kilogram of seed purchased, or about US$ 5.00/ha, which sustains breeding research by several private companies (Perrson 1990). The use of PVRs has also been effective in some South American wheat-producing countries, especially Argentina, where most wheat area is sown to varieties from the private sector.

Nonetheless PVRs have been less effective in stimulating the switch to private sector breeding in the USA and Australia, although the trend is clearly toward the private sector.[†] In the USA, for example, the number of wheat breeders in the private sector is now similar to that in the public sector (James 1990; Kalton, Richardson, and Frey 1989).[‡] The number of wheat varieties registered under PVRs grew from 13 in 1971-75, just after PVR legislation was enacted, to more than 100 in 1986-90 (Huffman and Evenson 1993). The public sector also increasingly uses PVRs to earn royalties from its plant breeding programs and to pay at least a portion of the research costs.

However, PVRs and other forms of intellectual property protection will be successful for self-pollinated crops only if two conditions are met. First, farmers will have to purchase seed frequently, rather than save seed from their own harvest.[§] Second, violations of PVRs will have to be enforced cost effectively. Neither of these situations is characteristic of small-farm agriculture in developing countries. If companies seek to collect royalties on seed sold by unauthorized dealers, the cost of litigation against thousands or millions of small farmers, each sowing only a few hectares of wheat, will be extremely high. Also, the royalties are likely to be less than the US$ 5.00/ha collected in the UK. Nonetheless, in some commercial wheat-growing areas in developing countries (Argentina, Brazil, Mexico, and Turkey), the use of PVRs will become more common, and the private sector will play a greater role in wheat improvement research.

Despite these limitations on private sector investment in wheat research, the participation of the private sector in wheat research — especially the participation of farmers themselves — can be increased in other ways. In some places, including northwestern Mexico and Zimbabwe, farmers pay a small percentage of wheat sales to support wheat research in the public sector. In Brazil, farmers have formed cooperatives to conduct wheat research. While these examples come largely from commercial farming areas, they could be extended to small-farm agriculture by charging farmers the research levy only on wheat sales (in which case larger-scale farmers would pay a higher proportion of the levy). Since wheat is nearly always an important food for urban consumers and enters the formal market, the administrative costs for such a levy should be lower than for levies on crops that are marketed through informal channels or mostly consumed on the farm. In addition, when farmers pay part of the cost of wheat research and influence the allocation of those funds, research is more likely to be directed to farmers' priorities.

† However, a major private company in Kansas closed recently and donated its breeding materials to the public sector.

‡ However, the public sector has more total scientists, including nonbreeders, in wheat improvement.

§ Recent changes in PVR rules at the international level may prevent farmers from saving seed of protected varieties in the future.

Part 2: The World Wheat Situation: Current Developments and Emerging Trends

Andrea Bohn

Production

In 1992, 564 million tons of wheat were produced on 220 M ha worldwide; the average yield was 2.6 t/ha. The share of developing countries in global wheat production is now around 43%, a substantial increase from less than 30% in the early 1950s (Figure 15). In developing countries, the average annual growth rate of production over the whole period has been almost twice as high as in the rest of the world (4.1% vs. 2.2%) (Figure 16).

Wheat production continues to expand, but at a slower pace, and the source and composition of production increases have changed over time (Figure 16). In developing countries, the 1960s was the period of highest annual production growth (5.2%/yr, composed of 3.4% growth in yields and 1.8% expansion in area). During the 1960s and 1970s area expansion in China, now the world's largest wheat producer, was slower than in the rest of the developing world, although yield gains tended to be somewhat higher.

As annual growth in yields peaked in developing countries in the 1970s, area expansion began to slow. The latest FAO cereal statistics confirm the trends discussed in the last issue of *Wheat Facts and Trends.* In developing countries, annual growth in yields from 1983 to 1992 slowed to 2.0% (2.4% if China is excluded), whereas in industrialized countries it has picked up from the 1.3% recorded during the 1970s to 1.9% today. Wheat area in the industrialized world has actually diminished as land is taken out of production. This trend will likely continue, particularly in the European Community (EC), because of land set-aside programs inspired by overproduction and environmental concerns about intensive farming. At least in the economically more advanced producer countries, greater public awareness of ecological and food policy issues, as well as of the cost of agricultural subsidies, may create a production and marketing environment for cereal producers during the 1990s that differs greatly from the environment of past decades.

Consumption

World wheat consumption is estimated at 555 million tons for 1992-93, 20 million tons below the peak recorded in 1990-91, which came about because prices were extremely low and much wheat was used as feed. Wheat consumption in developing countries has been growing at a rate of 4.8% over the last three decades (1961-90), compared to only 3.5% for all cereals (Table 12). Growth in demand worldwide will slow to around 2.1% from 1990 to 2005, but consumption of wheat in developing countries will grow much faster (3.0%/yr, headed by sub-Saharan Africa at 3.3%/yr) than in industrialized

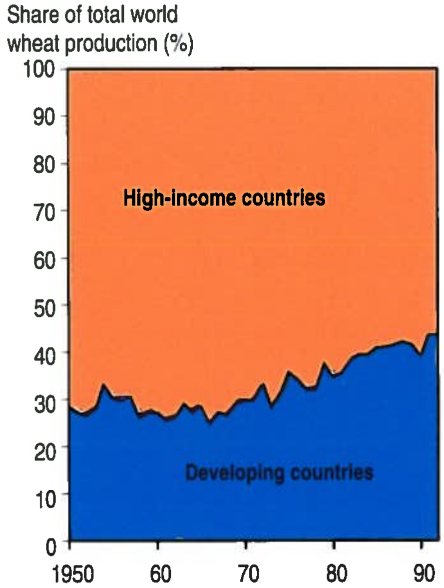


Figure 15. World wheat production, 1950-92.

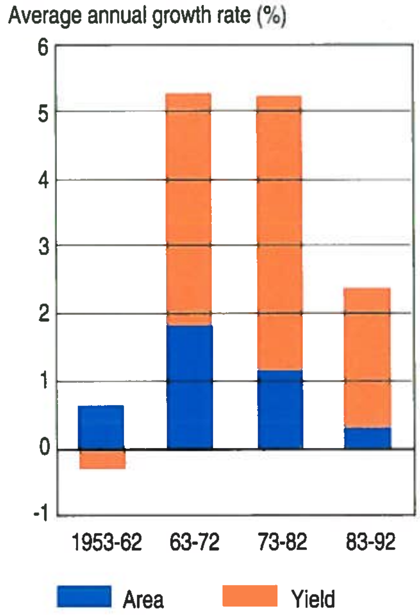


Figure16. Sources of growth in wheat production in developing countries, 1953-92.

Table 12. Growth in consumption of cereals in developing countries, 1961-90

Cereal	Growth in consumption (%)
Wheat	4.8
Maize	4.3
Rice	3.1
Other cereals	1.5
All cereals	**3.5**

Source: CIMMYT database.

countries (1.0%/yr). As a result, developing countries will probably consume three-fifths of the world's wheat by 2005, while their share today is only half. Most of the growth in demand will come from Asia.

By 2005, wheat will challenge rice as the major food staple in developing countries because of a relatively higher increase in demand (3.0% vs. 2.1%). Per capita rice consumption is projected to be around 97 kg/yr compared to 86 kg/yr of wheat in 2005 (CIMMYT Economics Program database).

Trade

A volume of 115 million tons (21% of world wheat production) was traded in 1991. Despite rapid growth in wheat yields, the developing country share of world wheat imports has increased steadily from 47% in 1972 to around 61% in 1991 (Figure 17). Although their share of world wheat production has been increasing, developing countries have not substantially strengthened their position as exporters.

The volume of world wheat trade usually depends very much on the level of demand from the two main importers, the former Soviet Union (FSU) and China. Uncertainty about demand from China stems from the unpredictable effect of recently introduced market reforms and decentralization efforts (USDA 1992).

Wheat Aid

Wheat food aid fluctuates greatly from year to year. In 1989 Asia, sub-Saharan Africa, Latin America, and WANA each received 1.3-2.3 million tons of wheat, although these regions differ greatly in size and population (Figure 18). As Asia has become more self-sufficient and wealthy enough to purchase the additional food it needs, its share in wheat aid has declined. The opposite trend has prevailed in sub-Saharan Africa, which since 1980 has received about 20% of total wheat aid. The share of Latin America, albeit small, has been growing since the mid-1970s. The main recipients are Central American countries, but Peru and Bolivia also have received substantial amounts.

In 1989, nearly 1.3 million tons of wheat aid went to Poland; consequently, the share of aid going to industrialized countries rose from less than 5% to 16%. At the same time, aid to developing countries dropped to its lowest absolute level (6.4 million tons) since 1982-83. In the short term the industrialized countries' share of aid will probably remain high, due to the increasing need from former socialist bloc countries and the simultaneous concern of donors for stabilizing those new market economies.

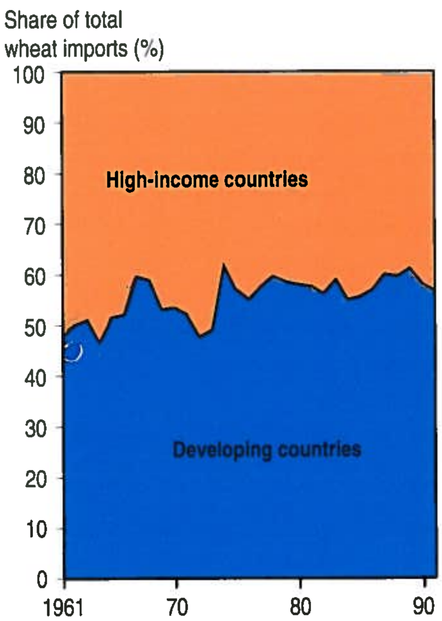


Figure 17. World wheat imports, 1961-91.

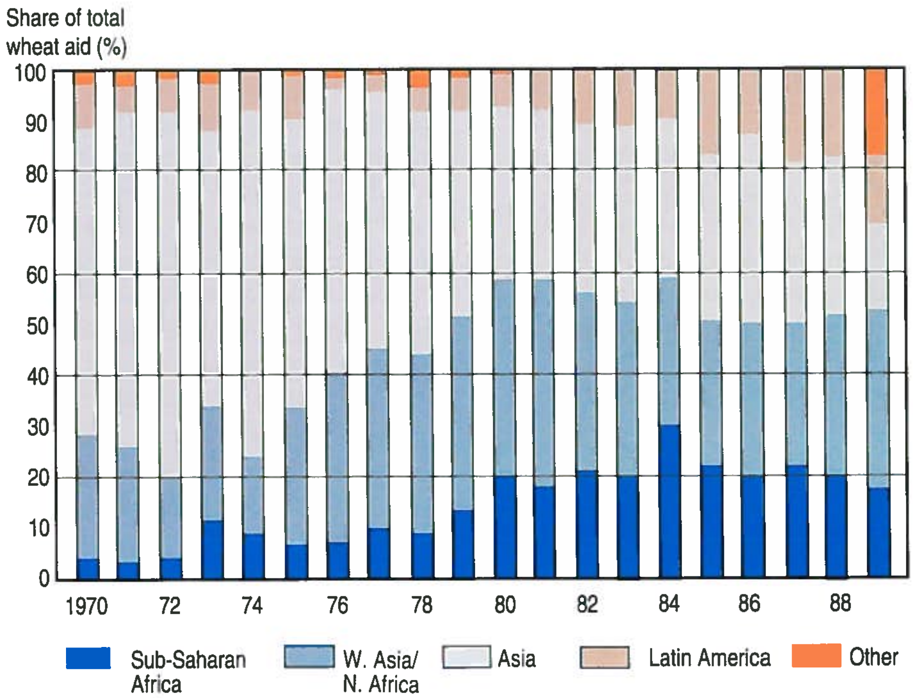


Figure 18. Wheat aid to developing countries, 1970-89.

The Proposed European Community Policy Reform

The reform of the EC Common Agricultural Policy (CAP) is scheduled to begin with the 1993-94 (July-June) marketing year and will be phased in over three years. The reform consists of five key changes. First, the internal market will be slightly more accessible to imported, non-EC wheat. Second, the price guaranteed to farmers will be lowered. Third, large producers will have to take land out of production, including land usually sown to wheat. Fourth, producers hard hit by these measures will receive compensation in the form of direct cash payments. Finally, new programs will be put into place to discourage the intensification of production and the use of environmentally harmful practices. As a result, wheat production and area are expected to decline, whereas consumption is likely to increase due to a decline in wheat prices.

Effects of Change in Eastern Europe and the Former Soviet Union

The 1990s got off to a turbulent start in Eastern Europe and the FSU as old borders fell and new ones were created, old regimes were displaced, and fledgling democracies struggled to come to terms with more market-oriented systems. All of these changes have implications for the world wheat situation.

As markets were liberalized, food prices rose, making the still relatively cheap wheat products preferred food items and drastically reducing the feeding of bread to livestock. At the same time, livestock numbers began to decline, lowering demand for wheat as feed. Overall, wheat consumption and demand for imports fell, with the principle exception of Russia.

Following 1992's drought and uncertain grain prices, Eastern Europe is recovering from its lowest level of grain production in more than 10 years (USDA 1993). Imports by Eastern Europe are projected to fall for 1992-93, but FSU imports will probably rise. Whether production in these regions will stabilize or even grow in the next few years depends on renewed economic growth as well as the dissemination of better production technologies. The former Eastern Bloc is challenged with implementing much-needed land reform, which will certainly influence cropping patterns, although the effect on wheat production is uncertain.

Many former socialist countries will continue to rely heavily on wheat imports, particularly Russia. The FSU once paid cash for all its imported grain, but barter ("ores for ears") now constitutes an estimated 20% of the value of the grain trade. The rest is paid for mainly with credits and to a small extent is given as food aid. Western wheat exporters are still trying to establish long-term, viable trade arrangements. Meanwhile, the EC has begun to dominate the East European wheat market through preferential tariffs, association agreements, credit allocations, and the EC's transportation advantage.

What lies ahead for the FSU? Ensuring sufficient food supplies in the FSU is a major concern to Western countries, who want to ensure political stability and to support democratization, seeing the long-term benefits of reduced military spending and potential export markets. The question remains of whether this is best done through directly supporting the food sector (import credits being a transitory instrument) or investing in other sectors of the economy to increase export opportunities and foreign currency income, which in turn will permit a return to purchasing grain on commercial terms.

Conclusions

As indicated above, growth in wheat yields and area has slowed considerably throughout the world, especially in developing countries. At the same time, demand for wheat has been growing faster than demand for any other cereal (Table 12). Although growth in consumption is expected to decline eventually, it is not certain to what extent developing countries will be able to produce the wheat they need. Wheat aid continues to be delivered to developing nations, but since the late 1980s former socialist countries have also emerged as major aid recipients. All of these trends presage significant change in the world wheat economy.

Part 3: Selected Wheat Statistics

Laura Saad

The tables that follow present 33 statistics related to wheat production, trade, consumption, research, and prices, as well as some basic economic indicators. The statistics were selected to provide the latest available information.

Countries listed in the tables are classified either as wheat consumers or producers. Wheat consumers include developing countries consuming over 100,000 t of wheat per year, and industrialized countries consuming more than 1 million tons of wheat per year. Wheat producers include developing countries in which wheat production exceeded 100,000 t/yr (or accounted for at least 50% of total wheat consumption) and industrialized countries in which wheat production exceeded 1 million tons per year (or accounted for 50% of total wheat consumption). Average 1989-91 data were used in the classification.

Unless otherwise indicated, the regional aggregates include all of the countries of a particular region, even countries for which data have not been reported individually (for a list of countries belonging to each region, see Annex 1, inside back cover).

All prices reported in the tables were converted to US dollars at official exchange rates.

Notes on the Variables

Variable 1: The source of this information was the FAO Agrostat/PC diskette of population statistics (1992).

Variables 2-3: These data were obtained from the World Bank *World Development Report* (1993).

Variables 4, 5, 9-17, 20: The source of these variables was the FAO *World Crop and Livestocks Statistics, 1948-85* (1987), FAO.DIF files on diskette (1987 and 1988), and FAO Agrostat/PC diskettes of production statistics (1993). Growth rates were calculated by semilog regression.

Variables 6-8, 18, 19: These variables were obtained from the FAO Agrostat/PC diskettes of production statistics (1993).

Variables 21-24: These data were obtained from the FAO diskettes of trade statistics (1992). Net imports were calculated as imports minus exports. Negative numbers indicate that a country is a net exporter. Consumption was calculated as production plus net imports. Growth rates were calculated by semilog regression.

Variables 25-29: These data (which are for 1966-92) were collected through two surveys sent to knowledgeable wheat scientists worldwide (see the box in Part 1, "Sources of Information for This Report"). In nearly all cases, modern varieties are defined as varieties carrying one or more semidwarf genes. Data on the number of researchers refer to full-time equivalent scientists in wheat improvement in 1992, although in some cases the late 1980s are the reference years. Some data were estimated by CIMMYT staff based on secondary sources. Data on the number of full-time equivalent researchers (variable 28) are for researchers in the public sector only. Variable 29 was calculated using average 1988-92 production data. Regional totals and regional averages in some instances were based on data from a subset of countries in the region. Regional data are reported only when information is available for at least 50% of the area in the region (or 50% of wheat production, depending on the variable).

Variable 30: The source of this information was the FAO *Fertilizer Yearbook* (1990) and FAO Agrostat/PC files of land use statistics (1992). Fertilizer applied per hectare of arable land was calculated dividing the total consumption of fertilizer by total arable land and permanent crop area.

Variables 31-33: These data were collected through a general country survey of wheat scientists and economists and refer to an important producing region within the country. Data for the majority of the countries refer to the wheat crop harvested in 1991-92, although in some cases 1992-93 is the reference year. The wheat price is the average post-harvest price received by farmers. The nitrogen price is usually the price paid by farmers for the most common nitrogenous fertilizer (usually urea). In some countries, only the price of compound fertilizer was available; in these cases the variable refers to the average price of all nutrients, whether N, $P_2 0_5$, and/or $K_2 0$.

Eastern and Southern Africa

		Producers				
		Ethiopia	Kenya	Sudan	Tanzania	Zambia
General indicators	1. Estimated population, 1992 (million)	52.1	25.9	26.7	29.4	9.1
	2. Estimated growth rate of population, 1991-2000 (%/yr)	2.7	3.5	3.0	3.0	3.0
	3. Per capita income 1991 (US $)	120	340	..	100	..
	4. Per capita cereal production, 1990-92 (kg/yr)	130	114	154	131	115
	5. Growth rate of per capita cereal production, 1983-92 (%/yr)	1.3	-1.2	3.8	-1.2	4.2
Production of wheat and all cereals	6. Wheat area harvested, 1990-92 (000 ha)	687	102	368	46	14
	7. Wheat yield, 1990-92 (t/ha)	1.3	1.9	1.8	1.7	..
	8. Wheat production, 1990-92 (000 t)	886	195	661	76	..
	9. Growth rate of wheat area, 1951-92 (%)	-1.0	0.2	8.6	4.2	..
	10. Growth rate of wheat area, 1973-92 (%)	0.9	0.8	0.8	0.0	..
	11. Growth rate of wheat area, 1983-92 (%)	0.4	-1.3	16.1	-1.6	..
	12. Growth rate of wheat yield, 1951-92 (%)	2.2	1.6	-0.1	2.8	..
	13. Growth rate of wheat yield, 1973-92 (%)	2.0	0.6	2.5	0.6	..
	14. Growth rate of wheat yield, 1983-92 (%)	2.8	1.4	5.3	3.3	..
	15. Growth rate of wheat production, 1951-92 (%)	1.2	1.8	8.5	7.0	..
	16. Growth rate of wheat production, 1973-92 (%)	2.8	1.4	3.2	0.6	..
	17. Growth rate of wheat production, 1983-92 (%)	3.2	0.1	21.4	1.6	..
	18. Wheat area as percent of total cereal area, 1990-92 (%)	13	6	6	2	2
	19. Average yield of all cereals, 1990-92 (t/ha)	1.3	1.6	0.7	1.3	1.3
	20. Growth rate of yields of all cereals, 1951-92 (%/yr)	1.8	1.2	-1.4	1.6	2.5
Trade and utilization	21. Net imports of wheat, 1989-91 (000 t)	622	222	663	60	12
	22. Net imports of wheat per capita, 1989-91 (kg/yr)	13	9	26	2	1
	23. Per capita total wheat consumption, 1989-91 (kg/yr)	30	18	44	5	8
	24. Growth rate of per capita wheat consumption, 1983-91 (%/yr)	3.5	-0.1	4.9	0.0	-10.0
Measures of research efforts	25. Percent area under modern wheat varieties, 1990	12	100	95	100	100
	26. Number of wheat varieties released, 1966-90	35	34	8	16	14
	27. Wheat varietal releases per million ha wheat area, 1966-90	2.1	11	2.0	12	205
	28. Number of full-time wheat improvement researchers, 1992	13	4	2	..	5
	29. Wheat improvement researchers per million t wheat production, 1992	15	17	5	..	85
Fertilizer use	30. Fertilizer applied per hectare of arable land, 1988-90 (kg nutrients/ha)	6	47	4	14	17
Prices	31. Farm price of wheat, 1991-92 (US$/t)	338	196	..	..	233
	32. Ratio of farm-level nitrogen price to wheat price, 1991-92	2.7	3.0	..	..	1.5
	33. Farm wage in kg of wheat per day, 1991-92	4	6	..	..	4

Eastern and Southern Africa
(continued)

		Producer	Consumers		
		Zimbabwe	Mozambique	Somalia	Regional total or average
General indicators	1. Estimated population, 1992 (million)	10.3	16.5	7.9	242.2
	2. Estimated growth rate of population, 1991-2000 (%/yr)	2.3	2.9	..	2.9
	3. Per capita income 1991 (US $)	650	80	..	255
	4. Per capita cereal production, 1990-92 (kg/yr)	171	31	45	116
	5. Growth rate of per capita cereal production, 1983-92 (%/yr)	-7.3	-7.1	-8.5	-0.6
Production of wheat and all cereals	6. Wheat area harvested, 1990-92 (000 ha)	41	3	2	1,308
	7. Wheat yield, 1990-92 (t/ha)	5.5	..	..	1.7
	8. Wheat production, 1990-92 (000 t)	222	..	..	2,160
	9. Growth rate of wheat area, 1951-92 (%)	12.3	..	..	0.2
	10. Growth rate of wheat area, 1973-92 (%)	1.4	..	..	0.7
	11. Growth rate of wheat area, 1983-92 (%)	5.5	..	..	3.1
	12. Growth rate of wheat yield, 1951-92 (%)	5.0	..	..	2.5
	13. Growth rate of wheat yield, 1973-92 (%)	2.0	..	..	2.2
	14. Growth rate of wheat yield, 1983-92 (%)	-0.7	..	..	3.7
	15. Growth rate of wheat production, 1951-92 (%)	17.2	..	..	2.6
	16. Growth rate of wheat production, 1973-92 (%)	3.4	..	..	2.9
	17. Growth rate of wheat production, 1983-92 (%)	4.8	..	..	7.0
	18. Wheat area as percent of total cereal area, 1990-92 (%)	3	<1	<1	5
	19. Average yield of all cereals, 1990-92 (t/ha)	1.2	0.3	0.7	1.1
	20. Growth rate of yields of all cereals, 1951-92 (%/yr)	1.3	-1.9	2.0	0.9
Trade and utilization	21. Net imports of wheat, 1989-91 (000 t)	63	118	108	2,279
	22. Net imports of wheat per capita, 1989-91 (kg/yr)	6	8	14	10
	23. Per capita total wheat consumption, 1989-91 (kg/yr)	36	8	15	19
	24. Growth rate of per capita wheat consumption, 1983-91 (%/yr)	6.5	-0.8	0.1	2.6
Measures of research efforts	25. Percent area under modern wheat varieties, 1990	100	..	..	47
	26. Number of wheat varieties released, 1966-90	25	..	..	138
	27. Wheat varietal releases per million ha wheat area, 1966-90	34	..	..	5.2
	28. Number of full-time wheat improvement researchers, 1992	1	..	..	27
	29. Wheat improvement researchers per million t wheat production, 1992	6	..	..	14
Fertilizer use	30. Fertilizer applied per hectare of arable land, 1988-90 (kg nutrients/ha)	57	1	3	10
Prices	31. Farm price of wheat, 1991-92 (US$/t)	195	..	..	..
	32. Ratio of farm-level nitrogen price to wheat price, 1991-92	1.8	..	..	..
	33. Farm wage in kg of wheat per day, 1991-92	..	..	..	..

Western and Central Africa

		Angola	Cameroon	Côte d'Ivoire	Ghana	Guinea
		Consumers				
General indicators	1. Estimated population, 1992 (million)	10.6	12.7	12.9	16.0	6.1
	2. Estimated growth rate of population, 1991-2000 (%/yr)	..	3.1	3.3	3.2	2.9
	3. Per capita income 1991 (US $)	..	850	690	400	460
	4. Per capita cereal production, 1990-92 (kg/yr)	36	75	99	70	155
	5. Growth rate of per capita cereal production, 1983-92 (%/yr)	-1.6	-3.1	-0.4	4.7	3.6
Production of wheat and all cereals	6. Wheat area harvested, 1990-92 (000 ha)	3	0	0	0	0
	7. Wheat yield, 1990-92 (t/ha)	..	..	..	..	..
	8. Wheat production, 1990-92 (000 t)	..	..	..	..	..
	9. Growth rate of wheat area, 1951-92 (%)	..	..	..	..	..
	10. Growth rate of wheat area, 1973-92 (%)	..	..	..	..	..
	11. Growth rate of wheat area, 1983-92 (%)	..	..	..	..	..
	12. Growth rate of wheat yield, 1951-92 (%)	..	..	..	..	..
	13. Growth rate of wheat yield, 1973-92 (%)	..	..	..	..	..
	14. Growth rate of wheat yield, 1983-92 (%)	..	..	..	..	..
	15. Growth rate of wheat production, 1951-92 (%)	..	..	..	..	..
	16. Growth rate of wheat production, 1973-92 (%)	..	..	..	..	..
	17. Growth rate of wheat production, 1983-92 (%)	..	..	..	..	..
	18. Wheat area as percent of total cereal area, 1990-92 (%)	<1	0	0	0	0
	19. Average yield of all cereals, 1990-92 (t/ha)	0.4	1.1	0.9	1.1	0.8
	20. Growth rate of yields of all cereals, 1951-92 (%/yr)	-1.8	1.0	1.5	0.4	0.6
Trade and utilization	21. Net imports of wheat, 1989-91 (000 t)	146	180	226	204	100
	22. Net imports of wheat per capita, 1989-91 (kg/yr)	15	15	19	14	17
	23. Per capita total wheat consumption, 1989-91 (kg/yr)	15	15	19	14	17
	24. Growth rate of per capita wheat consumption, 1983-91 (%/yr)	-3.7	3.6	-2.4	9.6	9.4
Measures of research efforts	25. Percent area under modern wheat varieties, 1990	..	..	..	..	..
	26. Number of wheat varieties released, 1966-90	..	..	..	..	..
	27. Wheat varietal releases per million ha wheat area, 1966-90	..	..	..	..	..
	28. Number of full-time wheat improvement researchers, 1992	..	..	..	..	..
	29. Wheat improvement researchers per million t wheat production, 1992	..	..	..	..	..
Fertilizer use	30. Fertilizer applied per hectare of arable land, 1988-90 (kg nutrients/ha)	5	6	10	4	1
Prices	31. Farm price of wheat, 1991-92 (US$/t)	..	..	..	..	..
	32. Ratio of farm-level nitrogen price to wheat price, 1991-92	..	..	..	..	..
	33. Farm wage in kg of wheat per day, 1991-92	..	..	..	..	..

Western and Central Africa
(continued)

		Consumers				
		Mauritania	Nigeria	Senegal	Zaire	Regional total or average
General indicators	1. Estimated population, 1992 (million)	2.1	115.9	7.7	37.9	281.7
	2. Estimated growth rate of population, 1991-2000 (%/yr)	2.9	2.8	2.8	..	2.9
	3. Per capita income 1991 (US $)	510	340	720	..	467
	4. Per capita cereal production, 1990-92 (kg/yr)	45	117	123	37	107
	5. Growth rate of per capita cereal production, 1983-92 (%/yr)	2.2	1.0	0.6	0.2	1.0
Production of wheat and all cereals	6. Wheat area harvested, 1990-92 (000 ha)	1	57	0	7	80
	7. Wheat yield, 1990-92 (t/ha)	..	1.2	..	..	1.2
	8. Wheat production, 1990-92 (000 t)	..	70	..	..	96
	9. Growth rate of wheat area, 1951-92 (%)	..	4.2	..	..	3.0
	10. Growth rate of wheat area, 1973-92 (%)	..	9.0	..	..	-0.5
	11. Growth rate of wheat area, 1983-92 (%)	..	23.1	..	..	5.7
	12. Growth rate of wheat yield, 1951-92 (%)	..	-0.5	..	..	1.7
	13. Growth rate of wheat yield, 1973-92 (%)	..	-1.7	..	..	-5.4
	14. Growth rate of wheat yield, 1983-92 (%)	..	-6.9	..	..	-4.7
	15. Growth rate of wheat production, 1951-92 (%)	..	3.7	..	..	4.7
	16. Growth rate of wheat production, 1973-92 (%)	..	7.3	..	..	-6.0
	17. Growth rate of wheat production, 1983-92 (%)	..	16.2	..	..	1.0
	18. Wheat area as percent of total cereal area, 1990-92 (%)	1	1	0	<1	<1
	19. Average yield of all cereals, 1990-92 (t/ha)	0.7	1.2	0.8	0.8	0.9
	20. Growth rate of yields of all cereals, 1951-92 (%/yr)	1.8	1.7	1.4	-0.4	0.9
Trade and utilization	21. Net imports of wheat, 1989-91 (000 t)	181	317	263	214	2,462
	22. Net imports of wheat per capita, 1989-91 (kg/yr)	90	3	36	6	9
	23. Per capita total wheat consumption, 1989-91 (kg/yr)	90	3	36	6	10
	24. Growth rate of per capita wheat consumption, 1983-91 (%/yr)	-1.1	-21.0	9.5	-0.9	-4.0
Measures of research efforts	25. Percent area under modern wheat varieties, 1990	..	86	..	..	86
	26. Number of wheat varieties released, 1966-90	..	6	..	..	6
	27. Wheat varietal releases per million ha wheat area, 1966-90	..	15	..	..	15
	28. Number of full-time wheat improvement researchers, 1992	..	..	..	..	..
	29. Wheat improvement researchers per million t wheat production, 1992	..	..	..	..	..
Fertilizer use	30. Fertilizer applied per hectare of arable land, 1988-90 (kg nutrients/ha)	10	10	11	1	17
Prices	31. Farm price of wheat, 1991-92 (US$/t)	..	..	..	..	
	32. Ratio of farm-level nitrogen price to wheat price, 1991-92	..	..	..	..	..
	33. Farm wage in kg of wheat per day, 1991-92	..	..	..	..	..

North Africa

Section	Indicator	Algeria	Egypt	Libya	Morocco	Tunisia	Regional total or average
		Producers					
General indicators	1. Estimated population, 1992 (million)	26.4	54.8	4.9	26.4	8.5	121.0
	2. Estimated growth rate of population, 1991-2000 (%/yr)	2.7	2.1	..	2.2	1.9	2.2
	3. Per capita income 1991 (US $)	1,980	610	..	1,030	1,500	1,179
	4. Per capita cereal production, 1990-92 (kg/yr)	110	258	61	232	255	212
	5. Growth rate of per capita cereal production, 1983-92 (%/yr)	3.6	4.3	-4.8	0.7	4.1	3.4
Production of wheat and all cereals	6. Wheat area harvested, 1990-92 (000 ha)	1,633	877	128	2,530	954	6,122
	7. Wheat yield, 1990-92 (t/ha)	0.9	5.1	1.1	1.3	1.6	1.8
	8. Wheat production, 1990-92 (000 t)	1,422	4,456	143	3,372	1,497	10,890
	9. Growth rate of wheat area, 1951-92 (%)	-0.5	0.0	0.8	1.0	-1.1	0.0
	10. Growth rate of wheat area, 1973-92 (%)	-2.6	1.8	-1.1	1.9	-1.7	-0.1
	11. Growth rate of wheat area, 1983-92 (%)	0.8	7.2	-8.9	3.6	-0.5	2.2
	12. Growth rate of wheat yield, 1951-92 (%)	0.4	2.1	6.0	1.9	2.7	1.9
	13. Growth rate of wheat yield, 1973-92 (%)	2.4	2.6	6.8	2.6	2.6	3.7
	14. Growth rate of wheat yield, 1983-92 (%)	4.0	4.7	5.5	0.7	7.6	5.5
	15. Growth rate of wheat production, 1951-92 (%)	-0.2	2.2	6.9	2.9	1.6	2.0
	16. Growth rate of wheat production, 1973-92 (%)	-0.3	4.4	5.6	4.5	0.8	3.6
	17. Growth rate of wheat production, 1983-92 (%)	4.9	11.8	-3.4	4.2	7.1	7.8
	18. Wheat area as percent of total cereal area, 1990-92 (%)	54	36	30	47	64	48
	19. Average yield of all cereals, 1990-92 (t/ha)	0.9	5.7	0.7	1.1	1.4	2.0
	20. Growth rate of yields of all cereals, 1951-92 (%/yr)	0.5	2.0	4.5	1.2	2.7	1.9
Trade and utilization	21. Net imports of wheat, 1989-91 (000 t)	4,679	6,564	1,050	1,419	895	14,605
	22. Net imports of wheat per capita, 1989-91 (kg/yr)	187	125	231	57	109	127
	23. Per capita total wheat consumption, 1989-91 (kg/yr)	238	201	265	223	245	219
	24. Growth rate of per capita wheat consumption, 1983-91 (%/yr)	2.2	1.2	3.4	2.3	1.8	1.9
Measures of research efforts	25. Percent area under modern wheat varieties, 1990	25	76	60	60	80	56
	26. Number of wheat varieties released, 1966-90	25	18	22	28	14	107
	27. Wheat varietal releases per million ha wheat area, 1966-90	0.5	1.3	4.1	0.6	0.7	0.8
	28. Number of full-time wheat improvement researchers, 1992	15	30	12	19	9	85
	29. Wheat improvement researchers per million t wheat production, 1992	12	8	66	5	8	9
Fertilizer use	30. Fertilizer applied per hectare of arable land, 1988-90 (kg nutrients/ha)	27	383	40	35	23	66
Prices	31. Farm price of wheat, 1991-92 (US$/t)	417	..	..	258	271	..
	32. Ratio of farm-level nitrogen price to wheat price, 1991-92	1.1	..	..	3.0	2.7	..
	33. Farm wage in kg of wheat per day, 1991-92	17	..	..	19	17	..

West Asia

		Producers					
		Afghanistan	Iran	Iraq	Saudi Arabia	Syria	Turkey
General indicators	1. Estimated population, 1992 (million)	18.5	57.2	20.2	15.3	13.5	58.2
	2. Estimated growth rate of population, 1991-2000 (%/yr)	..	3.4	..	3.5	3.4	1.9
	3. Per capita income 1991 (US $)	..	2,170	..	7,820	1,160	1,780
	4. Per capita cereal production, 1990-92 (kg/yr)	150	267	127	306	276	528
	5. Growth rate of per capita cereal production, 1983-92 (%/yr)	-9.0	2.4	-1.7	13.1	2.1	-0.5
Production of wheat and all cereals	6. Wheat area harvested, 1990-92 (000 ha)	1,620	6,357	1,338	761	1,330	9,410
	7. Wheat yield, 1990-92 (t/ha)	1.0	1.4	0.8	5.1	1.8	2.1
	8. Wheat production, 1990-92 (000 t)	1,675	9,002	1,091	3,894	2,419	19,919
	9. Growth rate of wheat area, 1951-92 (%)	-0.5	2.7	-0.5	6.7	-0.1	1.0
	10. Growth rate of wheat area, 1973-92 (%)	-2.5	0.7	-1.5	18.3	-1.5	0.2
	11. Growth rate of wheat area, 1983-92 (%)	-3.6	0.7	2.6	10.2	1.3	0.3
	12. Growth rate of wheat yield, 1951-92 (%)	0.6	0.9	1.2	3.3	3.0	2.1
	13. Growth rate of wheat yield, 1973-92 (%)	-0.6	2.2	0.6	6.8	4.4	2.2
	14. Growth rate of wheat yield, 1983-92 (%)	-2.3	3.8	-1.3	5.4	4.6	1.6
	15. Growth rate of wheat production, 1951-92 (%)	0.2	3.6	0.7	9.9	2.8	3.1
	16. Growth rate of wheat production, 1973-92 (%)	-3.1	2.9	-0.8	25.1	2.9	2.3
	17. Growth rate of wheat production, 1983-92 (%)	-5.9	4.6	1.3	15.6	5.9	1.8
	18. Wheat area as percent of total cereal area, 1990-92 (%)	72	67	46	76	35	69
	19. Average yield of all cereals, 1990-92 (t/ha)	1.2	1.6	0.9	4.5	0.9	2.2
	20. Growth rate of yields of all cereals, 1951-92 (%/yr)	0.7	1.0	0.5	2.6	1.2	2.0
Trade and utilization	21. Net imports of wheat, 1989-91 (000 t)	246	3,854	2,205	-1,447	1,374	81
	22. Net imports of wheat per capita, 1989-91 (kg/yr)	15	71	116	-102	110	1
	23. Per capita total wheat consumption, 1989-91 (kg/yr)	119	210	172	158	249	339
	24. Growth rate of per capita wheat consumption, 1983-91 (%/yr)	-6.6	1.5	-5.9	-0.5	-0.5	-0.3
Measures of research efforts	25. Percent area under modern wheat varieties, 1990	..	33	..	100	68	31
	26. Number of wheat varieties released, 1966-90	..	16	..	9	11	78
	27. Wheat varietal releases per million ha wheat area, 1966-90	..	0.1	..	1.6	0.3	0.3
	28. Number of full-time wheat improvement researchers, 1992	..	71	..	..	..	51
	29. Wheat improvement researchers per million t wheat production, 1992	..	9	..	..	..	3
Fertilizer use	30. Fertilizer applied per hectare of arable land, 1988-90 (kg nutrients/ha)	8	71	39	202	45	62
Prices	31. Farm price of wheat, 1991-92 (US$/t)	300	250	..	..	591	202
	32. Ratio of farm-level nitrogen price to wheat price, 1991-92	1.9	..	..	..	1.3	1.6
	33. Farm wage in kg of wheat per day, 1991-92	10	..	..	..	..	35

West Asia
(continued)

		Consumers					
		Jordan	Lebanon	Oman	United Arab Emirates	Yemen	Regional total or average
General indicators	1. Estimated population, 1992 (million)	3.5	2.8	1.6	1.7	12.6	207.9
	2. Estimated growth rate of population, 1991-2000 (%/yr)	4.0	..	3.9	..	3.7	2.9
	3. Per capita income 1991 (US $)	1,050	..	6,120	20,140	520	2,544
	4. Per capita cereal production, 1990-92 (kg/yr)	37	29	3	5	56	293
	5. Growth rate of per capita cereal production, 1983-92 (%/yr)	0.0	14.9	7.3	1.4	-0.5	0.2
Production of wheat and all cereals	6. Wheat area harvested, 1990-92 (000 ha)	59	26	1	2	92	21,002
	7. Wheat yield, 1990-92 (t/ha)	1.3	2.2	..	..	1.5	1.8
	8. Wheat production, 1990-92 (000 t)	75	56	..	..	136	38,281
	9. Growth rate of wheat area, 1951-92 (%)	-4.3	-3.7	..	..	5.2	1.1
	10. Growth rate of wheat area, 1973-92 (%)	-5.9	-4.3	..	..	0.9	0.0
	11. Growth rate of wheat area, 1983-92 (%)	-4.8	5.9	..	..	3.8	0.5
	12. Growth rate of wheat yield, 1951-92 (%)	1.8	2.4	..	..	0.0	1.9
	13. Growth rate of wheat yield, 1973-92 (%)	5.7	3.7	..	..	2.1	2.6
	14. Growth rate of wheat yield, 1983-92 (%)	5.0	8.3	..	..	8.1	2.7
	15. Growth rate of wheat production, 1951-92 (%)	-2.5	-1.3	..	..	5.1	3.0
	16. Growth rate of wheat production, 1973-92 (%)	-0.1	-0.5	..	..	3.0	2.6
	17. Growth rate of wheat production, 1983-92 (%)	0.1	14.2	..	..	11.9	3.2
	18. Wheat area as percent of total cereal area, 1990-92 (%)	44	64	50	83	13	62
	19. Average yield of all cereals, 1990-92 (t/ha)	1.0	2.0	2.0	4.0	0.9	1.7
	20. Growth rate of yields of all cereals, 1951-92 (%/yr)	1.2	1.6	1.5	-3.6	0.4	1.6
Trade and utilization	21. Net imports of wheat, 1989-91 (000 t)	485	286	122	125	1,363	9,017
	22. Net imports of wheat per capita, 1989-91 (kg/yr)	149	106	81	79	117	46
	23. Per capita total wheat consumption, 1989-91 (kg/yr)	170	127	82	80	129	224
	24. Growth rate of per capita wheat consumption, 1983-91 (%/yr)	0.3	0.5	1.9	-5.4	5.3	-0.6
Measures of research efforts	25. Percent area under modern wheat varieties, 1990	25	50	..	..	50	38
	26. Number of wheat varieties released, 1966-90	13	10	..	..	12 [a]	149
	27. Wheat varietal releases per million ha wheat area, 1966-90	3.9	11	..	..	9.4 [a]	0.4
	28. Number of full-time wheat improvement researchers, 1992	..	3	..	..	..	198
	29. Wheat improvement researchers per million t wheat production, 1992	..	61	..	..	..	7
Fertilizer use	30. Fertilizer applied per hectare of arable land, 1988-90 (kg nutrients/ha)	61	79	69	120	6	58
Prices	31. Farm price of wheat, 1991-92 (US$/t)	..	..	..	..	..	..
	32. Ratio of farm-level nitrogen price to wheat price, 1991-92	..	..	..	..	..	..
	33. Farm wage in kg of wheat per day, 1991-92	..	..	..	..	..	..

a Data refer to former Yemen Arab Republic.

South Asia

		Producers					Consumer	
		Bangladesh	India	Myanmar	Nepal	Pakistan	Sri Lanka	Regional total or average
General indicators	1. Estimated population, 1992 (million)	121.9	889.3	43.5	20.1	130.6	17.7	1,224.9
	2. Estimated growth rate of population, 1991-2000 (%/yr)	1.9	1.8	..	2.5	2.8	1.1	1.9
	3. Per capita income 1991 (US $)	220	330	..	180	400	500	327
	4. Per capita cereal production, 1990-92 (kg/yr)	238	225	332	273	169	139	224
	5. Growth rate of per capita cereal production, 1983-92 (%/yr)	0.0	0.5	-3.0	0.6	-1.3	-2.4	0.0
Production of wheat and all cereals	6. Wheat area harvested, 1990-92 (000 ha)	589	23,486	138	589	7,878	<1	32,686
	7. Wheat yield, 1990-92 (t/ha)	1.7	2.3	1.0	1.4	1.9	..	2.1
	8. Wheat production, 1990-92 (000 t)	986	53,152	131	823	14,855	..	69,954
	9. Growth rate of wheat area, 1951-92 (%)	8.3	2.4	5.4	4.8	1.7	..	2.3
	10. Growth rate of wheat area, 1973-92 (%)	9.7	1.2	4.3	4.5	1.6	..	1.5
	11. Growth rate of wheat area, 1983-92 (%)	0.8	-0.2	2.5	3.2	0.9	..	0.2
	12. Growth rate of wheat yield, 1951-92 (%)	4.0	3.3	3.5	0.8	2.7	..	3.1
	13. Growth rate of wheat yield, 1973-92 (%)	3.0	3.5	4.1	1.2	2.2	..	3.1
	14. Growth rate of wheat yield, 1983-92 (%)	-3.3	3.0	-6.6	0.6	2.3	..	2.6
	15. Growth rate of wheat production, 1951-92 (%)	12.3	5.7	8.9	5.6	4.4	..	5.4
	16. Growth rate of wheat production, 1973-92 (%)	12.7	4.7	8.4	5.8	3.8	..	4.6
	17. Growth rate of wheat production, 1983-92 (%)	-2.5	2.8	-4.1	3.8	3.2	..	2.8
	18. Wheat area as percent of total cereal area, 1990-92 (%)	5	23	3	20	67	<1	25
	19. Average yield of all cereals, 1990-92 (t/ha)	2.6	1.9	2.7	1.9	1.8	2.9	2.0
	20. Growth rate of yields of all cereals, 1951-92 (%/yr)	1.5	2.4	2.0	-0.2	2.6	2.0	2.2
Trade and utilization	21. Net imports of wheat, 1989-91 (000 t)	1,643	-156	7	3	1,730	789	4,032
	22. Net imports of wheat per capita, 1989-91 (kg/yr)	14	0	0	0	14	46	3
	23. Per capita total wheat consumption, 1989-91 (kg/yr)	23	62	3	44	132	46	63
	24. Growth rate of per capita wheat consumption, 1983-91 (%/yr)	-4.4	0.0	-6.0	1.9	0.4	1.6	0.1
Measures of research efforts	25. Percent area under modern wheat varieties, 1990	100	87	46	90	91	..	88
	26. Number of wheat varieties released, 1966-90	16	161	10	14	50	..	251
	27. Wheat varietal releases per million ha wheat area, 1966-90	2.0	0.3	4.2	1.6	0.3	..	0.4
	28. Number of full-time wheat improvement researchers, 1992	13	200	..	7	80	..	300
	29. Wheat improvement researchers per million t wheat production, 1992	13	4	..	8	6	..	4
Fertilizer use	30. Fertilizer applied per hectare of arable land, 1988-90 (kg nutrients/ha)	87	62	..	23	85	107	62
Prices	31. Farm price of wheat, 1991-92 (US$/t)	166	136	..	117	120	..	..
	32. Ratio of farm-level nitrogen price to wheat price, 1991-92	1.8	3.4	..	3.3	2.9	..	..
	33. Farm wage in kg of wheat per day, 1991-92	5	7	..	5	17	..	..

Southeast Asia and Pacific

		Consumers						
		Indonesia	Malaysia	Philippines	Singapore	Thailand	Vietnam	Regional total or average
General indicators	1. Estimated population, 1992 (million)	191.3	18.8	65.4	2.8	57.2	69.7	431.9
	2. Estimated growth rate of population, 1991-2000 (%/yr)	1.4	2.2	1.9	1.5	1.4	..	1.6
	3. Per capita income 1991 (US $)	610	2,520	730	14,210	1,570	..	1,087
	4. Per capita cereal production, 1990-92 (kg/yr)	282	105	220	..	397	306	274
	5. Growth rate of per capita cereal production, 1983-92 (%/yr)	1.3	-1.2	0.1	..	-2.1	1.9	0.4
Production of wheat and all cereals	6. Wheat area harvested, 1990-92 (000 ha)	0	0	0	0	<1	0	0
	7. Wheat yield, 1990-92 (t/ha)	..	..	..	..	..	..	..
	8. Wheat production, 1990-92 (000 t)	..	..	..	..	..	..	..
	9. Growth rate of wheat area, 1951-92 (%)	..	..	..	..	..	..	..
	10. Growth rate of wheat area, 1973-92 (%)	..	..	..	..	..	..	..
	11. Growth rate of wheat area, 1983-92 (%)	..	..	..	..	..	..	..
	12. Growth rate of wheat yield, 1951-92 (%)	..	..	..	..	..	..	..
	13. Growth rate of wheat yield, 1973-92 (%)	..	..	..	..	..	..	..
	14. Growth rate of wheat yield, 1983-92 (%)	..	..	..	..	..	..	..
	15. Growth rate of wheat production, 1951-92 (%)	..	..	..	..	..	..	..
	16. Growth rate of wheat production, 1973-92 (%)	..	..	..	..	..	..	..
	17. Growth rate of wheat production, 1983-92 (%)	..	..	..	..	..	..	..
	18. Wheat area as percent of total cereal area, 1990-92 (%)	0	0	0	..	<1	0	0
	19. Average yield of all cereals, 1990-92 (t/ha)	3.9	2.8	2.0	..	2.1	3.1	2.8
	20. Growth rate of yields of all cereals, 1951-92 (%/yr)	2.9	1.3	2.2	..	1.2	1.7	2.1
Trade and utilization	21. Net imports of wheat, 1989-91 (000 t)	1,965	864	1,532	221	402	208	5,698
	22. Net imports of wheat per capita, 1989-91 (kg/yr)	11	48	25	81	7	3	14
	23. Per capita total wheat consumption, 1989-91 (kg/yr)	11	48	25	81	7	3	14
	24. Growth rate of per capita wheat consumption, 1983-91 (%/yr)	1.9	5.0	8.3	5.5	12.0	3.0	4.8
Measures of research efforts	25. Percent area under modern wheat varieties, 1990	..	..	..	..	..	..	..
	26. Number of wheat varieties released, 1966-90	..	..	..	..	..	..	..
	27. Wheat varietal releases per million ha wheat area, 1966-90	..	..	..	..	..	..	..
	28. Number of full-time wheat improvement researchers, 1992	..	..	..	..	..	..	..
	29. Wheat improvement researchers per million t wheat production, 1992	..	..	..	..	..	..	..
Fertilizer use	30. Fertilizer applied per hectare of arable land, 1988-90 (kg nutrients/ha)	111	150	64	..	33	79	74
Prices	31. Farm price of wheat, 1991-92 (US$/t)	..	..	..	..	242	..	..
	32. Ratio of farm-level nitrogen price to wheat price, 1991-92	..	..	..	..	1.6	..	..
	33. Farm wage in kg of wheat per day, 1991-92	..	..	..	..	8	..	..

East Asia

Section	Indicator	Producers: China	Producers: North Korea	Producers: Mongolia	Consumer: South Korea	Regional total or average
General indicators	1. Estimated population, 1992 (million)	1,173.0	22.6	2.3	43.5	1,241.5
	2. Estimated growth rate of population, 1991-2000 (%/yr)	1.3	..	..	0.8	1.3
	3. Per capita income 1991 (US $)	370	..	..	6,330	605
	4. Per capita cereal production, 1990-92 (kg/yr)	346	455	239	187	342
	5. Growth rate of per capita cereal production, 1983-92 (%/yr)	0.4	-1.9	-7.5	-1.9	0.4
Production of wheat and all cereals	6. Wheat area harvested, 1990-92 (000 ha)	30,785	51	512	<1	31,348
	7. Wheat yield, 1990-92 (t/ha)	3.2	4.0	1.0	..	3.2
	8. Wheat production, 1990-92 (000 t)	98,396	203	488	..	99,088
	9. Growth rate of wheat area, 1951-92 (%)	0.5	0.7	7.0	..	0.5
	10. Growth rate of wheat area, 1973-92 (%)	0.6	-6.8	2.9	..	0.6
	11. Growth rate of wheat area, 1983-92 (%)	0.7	-16.4	1.6	..	0.6
	12. Growth rate of wheat yield, 1951-92 (%)	4.2	2.9	1.7	..	4.2
	13. Growth rate of wheat yield, 1973-92 (%)	4.8	4.0	1.5	..	4.8
	14. Growth rate of wheat yield, 1983-92 (%)	1.3	2.2	-4.3	..	1.3
	15. Growth rate of wheat production, 1951-92 (%)	4.8	3.6	8.7	..	4.7
	16. Growth rate of wheat production, 1973-92 (%)	5.4	-2.8	4.4	..	5.4
	17. Growth rate of wheat production, 1983-92 (%)	2.0	-14.2	-2.7	..	1.9
	18. Wheat area as percent of total cereal area, 1990-92 (%)	33	3	86	<1	33
	19. Average yield of all cereals, 1990-92 (t/ha)	4.3	6.5	0.9	5.8	4.4
	20. Growth rate of yields of all cereals, 1951-92 (%/yr)	3.3	3.6	1.3	2.8	3.2
Trade and utilization	21. Net imports of wheat, 1989-91 (000 t)	14,245	467	19	3,189	17,920
	22. Net imports of wheat per capita, 1989-91 (kg/yr)	13	21	9	75	15
	23. Per capita total wheat consumption, 1989-91 (kg/yr)	96	31	241	75	94
	24. Growth rate of per capita wheat consumption, 1983-91 (%/yr)	0.9	-4.3	-4.0	4.0	1.2
Measures of research efforts	25. Percent area under modern wheat varieties, 1990	..	..	..	..	..
	26. Number of wheat varieties released, 1966-90	..	..	..	..	..
	27. Wheat varietal releases per million ha wheat area, 1966-90	..	..	..	..	..
	28. Number of full-time wheat improvement researchers, 1992	410	..	..	..	410
	29. Wheat improvement researchers per million t wheat production, 1992	4	..	..	..	4
Fertilizer use	30. Fertilizer applied per hectare of arable land, 1988-90 (kg nutrients/ha)	254	396	15	412	256
Prices	31. Farm price of wheat, 1991-92 (US$/t)	148	..	..	..	..
	32. Ratio of farm-level nitrogen price to wheat price, 1991-92	2.8	..	..	..	..
	33. Farm wage in kg of wheat per day, 1991-92	5	..	..	..	..

Mexico, Central America, and the Caribbean

		Producer	Consumers			
		Mexico	Costa Rica	Cuba	Dominican Republic	El Salvador
General indicators	1. Estimated population, 1992 (million)	92.3	3.2	10.8	7.5	5.5
	2. Estimated growth rate of population, 1991-2000 (%/yr)	1.9	2.0	..	1.6	2.0
	3. Per capita income 1991 (US $)	3,030	1,850	..	940	1,080
	4. Per capita cereal production, 1990-92 (kg/yr)	273	86	46	71	158
	5. Growth rate of per capita cereal production, 1983-92 (%/yr)	-2.1	-7.7	-4.7	-4.0	1.9
Production of wheat and all cereals	6. Wheat area harvested, 1990-92 (000 ha)	945	0	0	0	0
	7. Wheat yield, 1990-92 (t/ha)	4.1	..	..	..	..
	8. Wheat production, 1990-92 (000 t)	3,866	..	..	..	..
	9. Growth rate of wheat area, 1951-92 (%)	0.7	..	..	..	..
	10. Growth rate of wheat area, 1973-92 (%)	2.3	..	..	..	..
	11. Growth rate of wheat area, 1983-92 (%)	-0.8	..	..	..	..
	12. Growth rate of wheat yield, 1951-92 (%)	3.8	..	..	..	..
	13. Growth rate of wheat yield, 1973-92 (%)	1.0	..	..	..	..
	14. Growth rate of wheat yield, 1983-92 (%)	-0.6	..	..	..	..
	15. Growth rate of wheat production, 1951-92 (%)	4.5	..	..	..	..
	16. Growth rate of wheat production, 1973-92 (%)	3.2	..	..	..	..
	17. Growth rate of wheat production, 1983-92 (%)	-1.3	..	..	..	..
	18. Wheat area as percent of total cereal area, 1990-92 (%)	9	0	0	0	0
	19. Average yield of all cereals, 1990-92 (t/ha)	2.4	3.0	2.3	3.7	1.9
	20. Growth rate of yields of all cereals, 1951-92 (%/yr)	3.0	2.7	2.3	2.6	1.9
Trade and utilization	21. Net imports of wheat, 1989-91 (000 t)	387	124	1,336	207	129
	22. Net imports of wheat per capita, 1989-91 (kg/yr)	4	41	126	29	25
	23. Per capita total wheat consumption, 1989-91 (kg/yr)	51	41	126	29	25
	24. Growth rate of per capita wheat consumption, 1983-91 (%/yr)	-2.5	-1.8	-2.2	0.3	-3.1
Measures of research efforts	25. Percent area under modern wheat varieties, 1990	95	..	..	..	..
	26. Number of wheat varieties released, 1966-90	85	..	..	..	..
	27. Wheat varietal releases per million ha wheat area, 1966-90	4.0	..	..	..	..
	28. Number of full-time wheat improvement researchers, 1992	5	..	..	..	..
	29. Wheat improvement researchers per million t wheat production, 1992	1	..	..	..	..
Fertilizer use	30. Fertilizer applied per hectare of arable land, 1988-90 (kg nutrients/ha)	72	191	191	50	121
Prices	31. Farm price of wheat, 1991-92 (US$/t)	194	..	..	..	..
	32. Ratio of farm-level nitrogen price to wheat price, 1991-92	2.0	..	..	..	..
	33. Farm wage in kg of wheat per day, 1991-92	40	..	..	..	..

Mexico, Central America, and the Caribbean
(continued)

		Consumers					Regional total or average
		Guatemala	Haiti	Honduras	Jamaica	Trinidad and Tobago	
General indicators	1. Estimated population, 1992 (million)	9.7	6.8	5.5	2.5	1.3	154.1
	2. Estimated growth rate of population, 1991-2000 (%/yr)	2.9	1.7	2.9	0.5	0.9	2.0
	3. Per capita income 1991 (US $)	930	370	580	1,380	3,670	2,398
	4. Per capita cereal production, 1990-92 (kg/yr)	146	47	130	1	13	199
	5. Growth rate of per capita cereal production, 1983-92 (%/yr)	-1.2	-7.0	-0.3	-14.8	11.6	-2.0
Production of wheat and all cereals	6. Wheat area harvested, 1990-92 (000 ha)	14	0	1	0	0	960
	7. Wheat yield, 1990-92 (t/ha)	1.7	..	..	..	..	4.1
	8. Wheat production, 1990-92 (000 t)	25	..	..	..	..	3,892
	9. Growth rate of wheat area, 1951-92 (%)	-1.0	..	..	..	..	0.6
	10. Growth rate of wheat area, 1973-92 (%)	-5.4	..	..	..	..	2.0
	11. Growth rate of wheat area, 1983-92 (%)	-12.3	..	..	..	..	-1.0
	12. Growth rate of wheat yield, 1951-92 (%)	3.2	..	..	..	..	3.9
	13. Growth rate of wheat yield, 1973-92 (%)	2.6	..	..	..	..	1.1
	14. Growth rate of wheat yield, 1983-92 (%)	1.7	..	..	..	..	-0.4
	15. Growth rate of wheat production, 1951-92 (%)	2.3	..	..	..	..	4.5
	16. Growth rate of wheat production, 1973-92 (%)	-2.8	..	..	..	..	3.1
	17. Growth rate of wheat production, 1983-92 (%)	-10.6	..	..	..	..	-1.4
	18. Wheat area as percent of total cereal area, 1990-92 (%)	2	0	<1	0	0	7
	19. Average yield of all cereals, 1990-92 (t/ha)	1.9	1.0	1.4	1.0	2.8	2.3
	20. Growth rate of yields of all cereals, 1951-92 (%/yr)	2.8	0.5	1.6	1.1	1.2	2.8
Trade and utilization	21. Net imports of wheat, 1989-91 (000 t)	187	215	130	119	118	3,278
	22. Net imports of wheat per capita, 1989-91 (kg/yr)	20	33	25	50	92	22
	23. Per capita total wheat consumption, 1989-91 (kg/yr)	24	33	25	50	92	50
	24. Growth rate of per capita wheat consumption, 1983-91 (%/yr)	1.3	0.7	4.1	-7.3	0.7	-2.2
Measures of research efforts	25. Percent area under modern wheat varieties, 1990	100	..	..	..	..	95
	26. Number of wheat varieties released, 1966-90	18	..	..	..	..	103
	27. Wheat varietal releases per million ha wheat area, 1966-90	20	..	..	..	..	4.6
	28. Number of full-time wheat improvement researchers, 1992	2	..	..	..	..	8
	29. Wheat improvement researchers per million t wheat production, 1992	67	..	..	..	..	2
Fertilizer use	30. Fertilizer applied per hectare of arable land, 1988-90 (kg nutrients/ha)	69	3	20	105	28	80
Prices	31. Farm price of wheat, 1991-92 (US$/t)	181	..	..	..	..	..
	32. Ratio of farm-level nitrogen price to wheat price, 1991-92	6.3	..	..	..	..	..
	33. Farm wage in kg of wheat per day, 1991-92	13	..	..	..	..	..

Andean Region, South America

		Producer	Consumers				
		Peru	Bolivia	Colombia	Ecuador	Venezuela	Regional total or average
General indicators	1. Estimated population, 1992 (million)	22.4	7.7	34.2	11.1	20.7	97.6
	2. Estimated growth rate of population, 1991-2000 (%/yr)	1.9	2.4	1.5	2.1	1.9	1.8
	3. Per capita income 1991 (US $)	1,070	650	1,260	1,000	2,730	1,456
	4. Per capita cereal production, 1990-92 (kg/yr)	77	113	118	135	99	109
	5. Growth rate of per capita cereal production, 1983-92 (%/yr)	-2.7	-0.3	0.9	7.5	1.2	0.6
Production of wheat and all cereals	6. Wheat area harvested, 1990-92 (000 ha)	85	93	49	35	1	263
	7. Wheat yield, 1990-92 (t/ha)	1.2	0.8	1.9	0.8	..	1.1
	8. Wheat production, 1990-92 (000 t)	100	79	91	28	..	298
	9. Growth rate of wheat area, 1951-92 (%)	-1.8	1.6	-4.6	-2.0	..	-1.8
	10. Growth rate of wheat area, 1973-92 (%)	-2.0	1.1	1.3	-2.4	..	-0.7
	11. Growth rate of wheat area, 1983-92 (%)	0.8	0.9	0.7	4.7	..	1.3
	12. Growth rate of wheat yield, 1951-92 (%)	0.7	0.8	2.4	0.9	..	0.9
	13. Growth rate of wheat yield, 1973-92 (%)	1.7	0.2	2.6	-1.4	..	1.3
	14. Growth rate of wheat yield, 1983-92 (%)	1.6	2.5	1.9	-3.4	..	1.4
	15. Growth rate of wheat production, 1951-92 (%)	-1.1	2.4	-2.3	-1.1	..	-1.0
	16. Growth rate of wheat production, 1973-92 (%)	-0.3	1.3	4.0	-3.8	..	0.6
	17. Growth rate of wheat production, 1983-92 (%)	2.4	3.4	2.6	1.3	..	2.7
	18. Wheat area as percent of total cereal area, 1990-92 (%)	12	16	3	4	<1	6
	19. Average yield of all cereals, 1990-92 (t/ha)	2.5	1.4	2.5	1.8	2.5	2.2
	20. Growth rate of yields of all cereals, 1951-92 (%/yr)	1.7	1.1	2.5	1.9	2.0	1.9
Trade and utilization	21. Net imports of wheat, 1989-91 (000 t)	792	210	669	371	985	3,113
	22. Net imports of wheat per capita, 1989-91 (kg/yr)	37	29	20	35	50	33
	23. Per capita total wheat consumption, 1989-91 (kg/yr)	43	39	23	38	50	37
	24. Growth rate of per capita wheat consumption, 1983-91 (%/yr)	-3.9	-6.2	-1.5	4.0	-1.4	-1.8
Measures of research efforts	25. Percent area under modern wheat varieties, 1990	60	33	16	44	..	39
	26. Number of wheat varieties released, 1966-90	25	22	11	12	..	70
	27. Wheat varietal releases per million ha wheat area, 1966-90	9	11	9	10	..	10
	28. Number of full-time wheat improvement researchers, 1992	7	11	6	2	..	26
	29. Wheat improvement researchers per million t wheat production, 1992	55	155	77	70	..	86
Fertilizer use	30. Fertilizer applied per hectare of arable land, 1988-90 (kg nutrients/ha)	54	3	90	29	..	42
Prices	31. Farm price of wheat, 1991-92 (US$/t)	184	214	236	189	..	..
	32. Ratio of farm-level nitrogen price to wheat price, 1991-92	4.9	4.8	2.7	5.0	..	..
	33. Farm wage in kg of wheat per day, 1991-92	8	..	9	15	..	..

Southern Cone, South America

		Producers					
		Argentina	Brazil	Chile	Paraguay	Uruguay	Regional total or average
General indicators	1. Estimated population, 1992 (million)	33.1	156.3	13.6	4.5	3.1	210.6
	2. Estimated growth rate of population, 1991-2000 (%/yr)	1.0	1.4	1.3	2.6	0.6	1.3
	3. Per capita income 1991 (US $)	2,790	2,940	2,160	1,270	2,840	2,829
	4. Per capita cereal production, 1990-92 (kg/yr)	669	247	218	231	393	313
	5. Growth rate of per capita cereal production, 1983-92 (%/yr)	-6.1	0.7	4.5	-2.5	2.2	-2.0
Production of wheat and all cereals	6. Wheat area harvested, 1990-92 (000 ha)	4,858	2,224	503	188	166	7,940
	7. Wheat yield, 1990-92 (t/ha)	2.1	1.3	3.2	1.4	2.0	1.9
	8. Wheat production, 1990-92 (000 t)	10,094	2,951	1,621	271	335	15,272
	9. Growth rate of wheat area, 1951-92 (%)	0.4	3.6	-1.4	10.9	-3.5	0.8
	10. Growth rate of wheat area, 1973-92 (%)	0.3	-0.2	-0.9	14.1	-5.2	0.0
	11. Growth rate of wheat area, 1983-92 (%)	-3.5	0.6	1.5	6.0	-5.0	-2.2
	12. Growth rate of wheat yield, 1951-92 (%)	1.4	2.0	2.1	2.2	2.1	1.4
	13. Growth rate of wheat yield, 1973-92 (%)	1.7	3.8	5.1	3.1	4.7	2.6
	14. Growth rate of wheat yield, 1983-92 (%)	1.4	1.2	7.1	1.5	4.3	1.5
	15. Growth rate of wheat production, 1951-92 (%)	1.8	5.6	0.7	13.1	-1.4	2.2
	16. Growth rate of wheat production, 1973-92 (%)	2.0	3.6	4.2	17.1	-0.5	2.7
	17. Growth rate of wheat production, 1983-92 (%)	-2.1	1.9	8.6	7.7	-0.7	-0.7
	18. Wheat area as percent of total cereal area, 1990-92 (%)	58	11	68	33	33	27
	19. Average yield of all cereals, 1990-92 (t/ha)	2.6	1.9	3.9	1.8	2.5	2.2
	20. Growth rate of yields of all cereals, 1951-92 (%/yr)	2.1	12.1	2.7	0.9	3.2	1.5
Trade and utilization	21. Net imports of wheat, 1989-91 (000 t)	-5384	2,736	90	-100	-158	-2816
	22. Net imports of wheat per capita, 1989-91 (kg/yr)	-167	18	7	-23	-51	-14
	23. Per capita total wheat consumption, 1989-91 (kg/yr)	155	44	135	52	87	68
	24. Growth rate of per capita wheat consumption, 1983-91 (%/yr)	1.3	-3.2	-1.7	-3.0	-11.4	-0.3
Measures of research efforts	25. Percent area under modern wheat varieties, 1990	90	64	90	100	72	82
	26. Number of wheat varieties released, 1966-90	104	179	106	21	20	430
	27. Wheat varietal releases per million ha wheat area, 1966-90	0.8	2.9	7.1	10	2.7	2.0
	28. Number of full-time wheat improvement researchers, 1992	23	47	9	7	3	89
	29. Wheat improvement researchers per million t wheat production, 1992	2	12	5	18	7	6
Fertilizer use	30. Fertilizer applied per hectare of arable land, 1988-90 (kg nutrients/ha)	6	62	74	6	48	45
Prices	31. Farm price of wheat, 1991-92 (US$/t)	93	201	179	106	110	..
	32. Ratio of farm-level nitrogen price to wheat price, 1991-92	6.1	4.5	3.2	7.0	4.6	..
	33. Farm wage in kg of wheat per day, 1991-92	..	21	23	..	..	..

Eastern Europe and Former USSR*

		Producers			
		Albania	Bulgaria	Former Czechoslovakia	Hungary
General indicators	1. Estimated population, 1992 (million)	3.4	9.0	15.7	10.3
	2. Estimated growth rate of population, 1991-2000 (%/yr)	..	-0.2	..	-0.4
	3. Per capita income 1991 (US $)	..	1,840	2,470	2,720
	4. Per capita cereal production, 1990-92 (kg/yr)	212	887	739	1,250
	5. Growth rate of per capita cereal production, 1983-92 (%/yr)	-7.8	0.5	-0.2	-1.4
Production of wheat and all cereals	6. Wheat area harvested, 1990-92 (000 ha)	158	1,104	1,185	1,064
	7. Wheat yield, 1990-92 (t/ha)	2.6	3.9	5.1	4.9
	8. Wheat production, 1990-92 (000 t)	414	4,353	6,050	5,211
	9. Growth rate of wheat area, 1951-92 (%)	1.9	-0.8	1.7	0.0
	10. Growth rate of wheat area, 1973-92 (%)	-0.3	1.3	-0.1	-0.8
	11. Growth rate of wheat area, 1983-92 (%)	-3.0	-0.3	-0.2	-3.9
	12. Growth rate of wheat yield, 1951-92 (%)	3.6	3.1	2.8	3.8
	13. Growth rate of wheat yield, 1973-92 (%)	1.6	0.7	2.0	2.0
	14. Growth rate of wheat yield, 1983-92 (%)	-2.4	1.6	0.4	0.1
	15. Growth rate of wheat production, 1951-92 (%)	5.5	2.3	4.5	3.7
	16. Growth rate of wheat production, 1973-92 (%)	1.4	2.0	1.8	1.2
	17. Growth rate of wheat production, 1983-92 (%)	-5.4	1.3	0.1	-3.8
	18. Wheat area as percent of total cereal area, 1990-92 (%)	59	53	49	39
	19. Average yield of all cereals, 1990-92 (t/ha)	2.6	3.8	4.8	4.8
	20. Growth rate of yields of all cereals, 1951-92 (%/yr)	3.5	3.0	2.8	3.5
Trade and utilization	21. Net imports of wheat, 1989-91 (000 t)	124	-131	-113	-1298
	22. Net imports of wheat per capita, 1989-91 (kg/yr)	38	-15	-7	-125
	23. Per capita total wheat consumption, 1989-91 (kg/yr)	195	549	403	478
	24. Growth rate of per capita wheat consumption, 1983-91 (%/yr)	-0.7	5.1	0.7	0.0
Measures of research efforts	25. Percent area under modern wheat varieties, 1990	..	..	..	..
	26. Number of wheat varieties released, 1966-90	..	..	..	..
	27. Wheat varietal releases per million ha wheat area, 1966-90	..	..	..	..
	28. Number of full-time wheat improvement researchers, 1992	..	..	..	..
	29. Wheat improvement researchers per million t wheat production, 1992	..	..	..	..
Fertilizer use	30. Fertilizer applied per hectare of arable land, 1988-90 (kg nutrients/ha)	141	199	313	258
Prices	31. Farm price of wheat, 1991-92 (US$/t)	..	..	..	89
	32. Ratio of farm-level nitrogen price to wheat price, 1991-92	..	..	..	4.0
	33. Farm wage in kg of wheat per day, 1991-92	..	..	..	71

* Data cover the same area previously designated as the USSR.

Eastern Europe and Former USSR*
(continued)

		Producer: Poland	Producer: Romania	Producer: Former USSR	Producer: Former Yugoslavia	Regional total or average
General indicators	1. Estimated population, 1992 (million)	38.5	23.1	293.6	24.0	417.6
	2. Estimated growth rate of population, 1991-2000 (%/yr)	0.3	0.2	0.4	..	0.4
	3. Per capita income 1991 (US $)	1,790	1,390	2,697	..	2,349
	4. Per capita cereal production, 1990-92 (kg/yr)	660	702	630	623	659
	5. Growth rate of per capita cereal production, 1983-92 (%/yr)	0.0	-4.0	-0.7	-3.2	-1.0
Production of wheat and all cereals	6. Wheat area harvested, 1990-92 (000 ha)	2,374	1,930	46,599	1,352	55,766
	7. Wheat yield, 1990-92 (t/ha)	3.6	2.8	1.9	4.0	2.2
	8. Wheat production, 1990-92 (000 t)	8,555	5,320	87,939	5,452	123,294
	9. Growth rate of wheat area, 1951-92 (%)	1.0	-1.0	-0.4	-1.0	-0.4
	10. Growth rate of wheat area, 1973-92 (%)	1.4	-0.7	-1.9	-1.4	-1.6
	11. Growth rate of wheat area, 1983-92 (%)	4.7	-3.0	-1.2	-1.8	-1.1
	12. Growth rate of wheat yield, 1951-92 (%)	2.7	3.0	2.0	3.4	2.3
	13. Growth rate of wheat yield, 1973-92 (%)	1.4	1.2	1.3	1.6	1.6
	14. Growth rate of wheat yield, 1983-92 (%)	0.3	0.2	2.9	1.1	2.3
	15. Growth rate of wheat production, 1951-92 (%)	3.7	2.0	1.5	2.4	1.9
	16. Growth rate of wheat production, 1973-92 (%)	2.9	0.4	-0.6	0.1	0.0
	17. Growth rate of wheat production, 1983-92 (%)	5.0	-2.8	1.7	-0.7	1.3
	18. Wheat area as percent of total cereal area, 1990-92 (%)	28	33	45	34	43
	19. Average yield of all cereals, 1990-92 (t/ha)	3.0	2.8	1.8	3.8	2.2
	20. Growth rate of yields of all cereals, 1951-92 (%/yr)	2.4	3.0	2.0	3.3	2.2
Trade and utilization	21. Net imports of wheat, 1989-91 (000 t)	1,010	152	15,609	-559	14,794
	22. Net imports of wheat per capita, 1989-91 (kg/yr)	27	7	54	-23	36
	23. Per capita total wheat consumption, 1989-91 (kg/yr)	261	303	355	235	344
	24. Growth rate of per capita wheat consumption, 1983-91 (%/yr)	2.7	1.5	-0.3	0.4	0.2
Measures of research efforts	25. Percent area under modern wheat varieties, 1990	..	..	..	..	..
	26. Number of wheat varieties released, 1966-90	..	..	..	..	..
	27. Wheat varietal releases per million ha wheat area, 1966-90	..	..	..	..	..
	28. Number of full-time wheat improvement researchers, 1992	..	..	..	..	..
	29. Wheat improvement researchers per million t wheat production, 1992	..	..	..	..	..
Fertilizer use	30. Fertilizer applied per hectare of arable land, 1988-90 (kg nutrients/ha)	224	136	114	126	129
Prices	31. Farm price of wheat, 1991-92 (US$/t)	..	81	..	..	..
	32. Ratio of farm-level nitrogen price to wheat price, 1991-92	..	0.6	..	..	..
	33. Farm wage in kg of wheat per day, 1991-92	..	24	..	..	..

* Data cover the same area previously designated as the USSR.

Western Europe, North America, and Other Industrialized Countries

		Producers					
		Australia	Austria	Belgium/ Luxembourg	Canada	Denmark	Finland
General indicators	1. Estimated population, 1992 (million)	17.5	7.8	10.4	27.2	5.2	5.0
	2. Estimated growth rate of population, 1991-2000 (%/yr)	1.3	0.4	0.2	0.8	0.2	0.3
	3. Per capita income 1991 (US $)	17,050	20,140	18,950	20,440	23,700	23,980
	4. Per capita cereal production, 1990-92 (kg/yr)	1,284	626	214	1,975	1,679	713
	5. Growth rate of per capita cereal production, 1983-92 (%/yr)	-4.8	-1.7	0.0	0.0	1.3	-1.3
Production of wheat and all cereals	6. Wheat area harvested, 1990-92 (000 ha)	8,501	265	219	14,030	548	129
	7. Wheat yield, 1990-92 (t/ha)	1.6	5.0	6.6	2.2	6.9	3.6
	8. Wheat production, 1990-92 (000 t)	13,586	1,326	1,437	31,305	3,757	461
	9. Growth rate of wheat area, 1951-92 (%)	2.5	0.5	-0.1	0.9	4.5	-0.6
	10. Growth rate of wheat area, 1973-92 (%)	-0.2	0.2	0.4	2.4	10.0	-2.0
	11. Growth rate of wheat area, 1983-92 (%)	-5.2	-2.7	1.5	0.4	8.4	-4.3
	12. Growth rate of wheat yield, 1951-92 (%)	0.7	2.5	2.0	1.1	1.6	2.0
	13. Growth rate of wheat yield, 1973-92 (%)	1.2	1.9	2.4	0.7	2.2	1.3
	14. Growth rate of wheat yield, 1983-92 (%)	0.4	1.1	1.4	2.2	0.8	0.0
	15. Growth rate of wheat production, 1951-92 (%)	3.3	3.0	1.8	2.0	6.2	1.4
	16. Growth rate of wheat production, 1973-92 (%)	1.0	2.1	2.9	3.1	12.2	-0.7
	17. Growth rate of wheat production, 1983-92 (%)	-4.8	-1.6	2.9	2.5	9.2	-4.3
	18. Wheat area as percent of total cereal area, 1990-92 (%)	65	29	62	67	35	12
	19. Average yield of all cereals, 1990-92 (t/ha)	1.7	5.4	6.3	2.6	5.5	3.4
	20. Growth rate of yields of all cereals, 1951-92 (%/yr)	1.1	2.9	2.0	1.5	1.3	1.9
Trade and utilization	21. Net imports of wheat, 1989-91 (000 t)	-11,412	-403	446	-17,709	-1,239	26
	22. Net imports of wheat per capita, 1989-91 (kg/yr)	-668	-52	43	-665	-241	5
	23. Per capita total wheat consumption, 1989-91 (kg/yr)	112	127	182	447	462	117
	24. Growth rate of per capita wheat consumption, 1983-91 (%/yr)	-12.8	1.1	2.7	9.2	3.9	0.0
Measures of research efforts	25. Percent area under modern wheat varieties, 1990	..	..	..	..	..	..
	26. Number of wheat varieties released, 1966-90	..	..	..	..	..	..
	27. Wheat varietal releases per million ha wheat area, 1966-90	..	..	..	..	..	..
	28. Number of full-time wheat improvement researchers, 1992	72	..	..	..	..	..
	29. Wheat improvement researchers per million t wheat production, 1992	5	..	..	..	..	..
Fertilizer use	30. Fertilizer applied per hectare of arable land, 1988-90 (kg nutrients/ha)	27	211	507	47	242	206
Prices	31. Farm price of wheat, 1991-92 (US$/t)	96	..	..	..	160	..
	32. Ratio of farm-level nitrogen price to wheat price, 1991-92	7.0	..	..	..	3.0	..
	33. Farm wage in kg of wheat per day, 1991-92	469	..	..	..	480	..

Western Europe, North America, and Other (continued)

		Producers					
		France	Germany[a]	Greece	Ireland	Italy	Netherlands
General indicators	1. Estimated population, 1992 (million)	56.8	79.8	10.1	3.6	57.8	15.2
	2. Estimated growth rate of population, 1991-2000 (%/yr)	0.4	0.0	0.1	0.3	0.1	0.8
	3. Per capita income 1991 (US $)	20,380	23,650 [b]	6,340	11,120	18,520	18,780
	4. Per capita cereal production, 1990-92 (kg/yr)	1,035	467	537	593	325	87
	5. Growth rate of per capita cereal production, 1983-92 (%/yr)	1.4	0.1	1.4	-0.4	-0.2	-0.4
Production of wheat and all cereals	6. Wheat area harvested, 1990-92 (000 ha)	5,106	2,241	987	83	2,658	130
	7. Wheat yield, 1990-92 (t/ha)	6.5	6.4	2.7	8.0	3.3	7.8
	8. Wheat production, 1990-92 (000 t)	33,437	14,402	2,621	669	8,823	1,012
	9. Growth rate of wheat area, 1951-92 (%)	0.5	1.3	-0.4	-2.3	-1.5	0.8
	10. Growth rate of wheat area, 1973-92 (%)	1.4	0.5	0.0	2.7	-1.5	0.0
	11. Growth rate of wheat area, 1983-92 (%)	0.5	0.8	0.9	2.3	-2.8	-0.9
	12. Growth rate of wheat yield, 1951-92 (%)	3.2	2.2	2.3	3.0	1.6	2.1
	13. Growth rate of wheat yield, 1973-92 (%)	2.6	2.4	1.0	3.9	1.4	2.3
	14. Growth rate of wheat yield, 1983-92 (%)	2.0	1.5	2.6	2.5	2.1	0.9
	15. Growth rate of wheat production, 1951-92 (%)	3.6	3.5	1.9	0.7	0.1	2.9
	16. Growth rate of wheat production, 1973-92 (%)	4.1	2.9	1.1	6.6	-0.2	2.2
	17. Growth rate of wheat production, 1983-92 (%)	2.5	2.2	3.5	4.8	-0.7	0.0
	18. Wheat area as percent of total cereal area, 1990-92 (%)	56	37	68	25	61	72
	19. Average yield of all cereals, 1990-92 (t/ha)	6.4	5.6	3.7	6.2	4.3	7.1
	20. Growth rate of yields of all cereals, 1951-92 (%/yr)	3.3	2.1	3.4	2.4	2.3	2.3
Trade and utilization	21. Net imports of wheat, 1989-91 (000 t)	-18368	-1141	-746	207	3,295	700
	22. Net imports of wheat per capita, 1989-91 (kg/yr)	-326	-18	-74	59	57	47
	23. Per capita total wheat consumption, 1989-91 (kg/yr)	262	176	186	230	201	115
	24. Growth rate of per capita wheat consumption, 1983-91 (%/yr)	2.1	-0.2	9.7	1.3	0.1	-1.0
Measures of research efforts	25. Percent area under modern wheat varieties, 1990	..	..	..	..	..	..
	26. Number of wheat varieties released, 1966-90	..	..	..	..	..	..
	27. Wheat varietal releases per million ha wheat area, 1966-90	..	..	..	..	..	..
	28. Number of full-time wheat improvement researchers, 1992	..	..	..	..	..	..
	29. Wheat improvement researchers per million t wheat production, 1992	..	..	..	..	..	..
Fertilizer use	30. Fertilizer applied per hectare of arable land, 1988-90 (kg nutrients/ha)	312	384	165	717	172	665
Prices	31. Farm price of wheat, 1991-92 (US$/t)	183	..	..	196	..	..
	32. Ratio of farm-level nitrogen price to wheat price, 1991-92	..	..	..	2.8	..	..
	33. Farm wage in kg of wheat per day, 1991-92	273	..	..	186	..	..

[a] Includes data from the Federal Republic of Germany and the former German Democratic Republic.
[b] Data refer to the Federal Republic of Germany before unification.

Western Europe, North America, and Other
(continued)

		Producers					
		New Zealand	South Africa	Spain	Sweden	Switzerland	United Kingdom
General indicators	1. Estimated population, 1992 (million)	3.5	36.9	39.4	8.6	6.8	57.9
	2. Estimated growth rate of population, 1991-2000 (%/yr)	0.8	2.2	0.1	0.6	0.7	0.2
	3. Per capita income 1991 (US $)	12,350	2,560	12,450	25,110	33,610	16,550
	4. Per capita cereal production, 1990-92 (kg/yr)	243	246	446	592	188	389
	5. Growth rate of per capita cereal production, 1983-92 (%/yr)	-4.7	-1.6	-0.3	-3.4	3.1	-0.9
Production of wheat and all cereals	6. Wheat area harvested, 1990-92 (000 ha)	39	1,237	2,175	288	98	2,020
	7. Wheat yield, 1990-92 (t/ha)	4.6	1.4	2.3	5.9	5.8	7.0
	8. Wheat production, 1990-92 (000 t)	179	1,701	4,902	1,712	566	14,194
	9. Growth rate of wheat area, 1951-92 (%)	0.5	1.7	-2.1	-0.3	-0.3	2.6
	10. Growth rate of wheat area, 1973-92 (%)	-4.3	-1.0	-1.9	-0.7	0.6	3.8
	11. Growth rate of wheat area, 1983-92 (%)	-9.3	-6.9	-0.7	-1.9	0.5	1.4
	12. Growth rate of wheat yield, 1951-92 (%)	1.2	2.0	2.7	2.7	2.0	2.3
	13. Growth rate of wheat yield, 1973-92 (%)	1.6	1.7	3.3	1.5	2.3	2.7
	14. Growth rate of wheat yield, 1983-92 (%)	0.1	4.6	0.6	1.5	1.2	0.4
	15. Growth rate of wheat production, 1951-92 (%)	1.7	3.7	0.6	2.3	1.7	4.9
	16. Growth rate of wheat production, 1973-92 (%)	-2.7	0.7	1.4	0.8	2.9	6.6
	17. Growth rate of wheat production, 1983-92 (%)	-9.2	-2.3	0.0	-0.4	1.7	1.8
	18. Wheat area as percent of total cereal area, 1990-92 (%)	24	22	29	24	47	57
	19. Average yield of all cereals, 1990-92 (t/ha)	5.1	1.6	2.3	4.3	6.1	6.3
	20. Growth rate of yields of all cereals, 1951-92 (%/yr)	1.7	1.7	2.5	2.0	2.2	2.2
Trade and utilization	21. Net imports of wheat, 1989-91 (000 t)	167	-71	456	-599	244	-3181
	22. Net imports of wheat per capita, 1989-91 (kg/yr)	49	-2	12	-70	36	-55
	23. Per capita total wheat consumption, 1989-91 (kg/yr)	99	53	145	143	127	190
	24. Growth rate of per capita wheat consumption, 1983-91 (%/yr)	-2.9	-2.1	2.9	0.2	-1.0	-1.6
Measures of research efforts	25. Percent area under modern wheat varieties, 1990	..	..	..	..	..	..
	26. Number of wheat varieties released, 1966-90	..	..	..	..	..	..
	27. Wheat varietal releases per million ha wheat area, 1966-90	..	..	..	..	..	..
	28. Number of full-time wheat improvement researchers, 1992	..	..	..	..	..	..
	29. Wheat improvement researchers per million t wheat production, 1992	..	..	..	..	..	..
Fertilizer use	30. Fertilizer applied per hectare of arable land, 1988-90 (kg nutrients/ha)	811	58	101	134	430	357
Prices	31. Farm price of wheat, 1991-92 (US$/t)	..	..	274	..	..	247
	32. Ratio of farm-level nitrogen price to wheat price, 1991-92	..	..	2.2	..	..	2.2
	33. Farm wage in kg of wheat per day, 1991-92	..	..	145	..	..	271

Western Europe, North America, and Other
(continued)

		Producer	Consumers			
		United States	Israel	Japan	Norway	Portugal
General indicators	1. Estimated population, 1992 (million)	253.6	5.1	124.4	4.3	10.3
	2. Estimated growth rate of population, 1991-2000 (%/yr)	0.9	2.8	0.3	0.4	0.0
	3. Per capita income 1991 (US $)	22,240	11,950	26,930	24,220	5,930
	4. Per capita cereal production, 1990-92 (kg/yr)	1,253	52	113	308	143
	5. Growth rate of per capita cereal production, 1983-92 (%/yr)	0.8	-2.7	-1.7	-0.6	1.1
Production of wheat and all cereals	6. Wheat area harvested, 1990-92 (000 ha)	25,548	90	238	50	269
	7. Wheat yield, 1990-92 (t/ha)	2.5	2.7	3.5	4.3	1.5
	8. Wheat production, 1990-92 (000 t)	65,103	244	837	218	405
	9. Growth rate of wheat area, 1951-92 (%)	0.6	2.2	-3.7	3.6	-3.1
	10. Growth rate of wheat area, 1973-92 (%)	-0.4	-0.9	7.1	9.2	-2.7
	11. Growth rate of wheat area, 1983-92 (%)	-0.3	-0.2	0.4	6.6	-1.4
	12. Growth rate of wheat yield, 1951-92 (%)	1.8	2.9	1.4	2.2	1.7
	13. Growth rate of wheat yield, 1973-92 (%)	1.3	0.8	1.6	0.5	2.3
	14. Growth rate of wheat yield, 1983-92 (%)	-0.5	2.9	1.1	-1.4	1.4
	15. Growth rate of wheat production, 1951-92 (%)	2.4	5.1	-2.3	5.7	-1.4
	16. Growth rate of wheat production, 1973-92 (%)	0.9	0.0	8.7	9.7	-0.4
	17. Growth rate of wheat production, 1983-92 (%)	-0.8	2.6	1.4	5.2	0.0
	18. Wheat area as percent of total cereal area, 1990-92 (%)	40	84	10	14	34
	19. Average yield of all cereals, 1990-92 (t/ha)	4.9	2.4	5.7	3.7	1.9
	20. Growth rate of yields of all cereals, 1951-92 (%/yr)	2.6	2.4	1.4	1.5	1.9
Trade and utilization	21. Net imports of wheat, 1989-91 (000 t)	-32607	621	5,158	219	570
	22. Net imports of wheat per capita, 1989-91 (kg/yr)	-130	132	42	52	55
	23. Per capita total wheat consumption, 1989-91 (kg/yr)	115	180	49	100	105
	24. Growth rate of per capita wheat consumption, 1983-91 (%/yr)	-4.2	0.0	-1.0	1.8	-0.4
Measures of research efforts	25. Percent area under modern wheat varieties, 1990	..	..	..	..	..
	26. Number of wheat varieties released, 1966-90	..	..	..	..	..
	27. Wheat varietal releases per million ha wheat area, 1966-90	..	..	..	..	..
	28. Number of full-time wheat improvement researchers, 1992	278	..	..	..	..
	29. Wheat improvement researchers per million t wheat production, 1992	5	..	..	..	..
Fertilizer use	30. Fertilizer applied per hectare of arable land, 1988-90 (kg nutrients/ha)	95	233	425	253	90
Prices	31. Farm price of wheat, 1991-92 (US$/t)	138	..	..	..	..
	32. Ratio of farm-level nitrogen price to wheat price, 1991-92	4.7	..	..	..	..
	33. Farm wage in kg of wheat per day, 1991-92	348	..	..	..	..

Regional Aggregates

		Developing Countries	Western Europe, North America, and Other	Eastern Europe and Former USSR	World
General indicators	1. Estimated population, 1992 (million)	4,213.5	847.9	417.6	5,478.9
	2. Estimated growth rate of population, 1991-2000 (%/yr)	1.8	0.6	0.4	1.5
	3. Per capita income 1991 (US $)	858	20,252	2,349	3,983
	4. Per capita cereal production, 1990-92 (kg/yr)	254	720	659	358
	5. Growth rate of per capita cereal production, 1983-92 (%/yr)	0.0	0.3	-1.0	-0.4
Production of wheat and all cereals	6. Wheat area harvested, 1990-92 (000 ha)	101,710	67,204	55,766	224,680
	7. Wheat yield, 1990-92 (t/ha)	2.4	3.0	2.2	2.5
	8. Wheat production, 1990-92 (000 t)	239,931	204,298	123,294	567,522
	9. Growth rate of wheat area, 1951-92 (%)	1.1	0.6	-0.4	0.5
	10. Growth rate of wheat area, 1973-92 (%)	0.7	0.3	-1.6	0.0
	11. Growth rate of wheat area, 1983-92 (%)	0.3	-1.0	-1.1	-0.4
	12. Growth rate of wheat yield, 1951-92 (%)	3.0	1.9	2.3	2.4
	13. Growth rate of wheat yield, 1973-92 (%)	3.6	1.9	1.6	2.5
	14. Growth rate of wheat yield, 1983-92 (%)	2.0	1.5	2.3	1.9
	15. Growth rate of wheat production, 1951-92 (%)	4.1	2.5	1.9	2.9
	16. Growth rate of wheat production, 1973-92 (%)	4.3	2.2	0.0	2.4
	17. Growth rate of wheat production, 1983-92 (%)	2.4	0.5	1.3	1.4
	18. Wheat area as percent of total cereal area, 1990-92 (%)	24	46	43	32
	19. Average yield of all cereals, 1990-92 (t/ha)	2.5	4.1	2.2	2.8
	20. Growth rate of yields of all cereals, 1951-92 (%/yr)	2.3	2.2	2.2	2.2
Trade and utilization	21. Net imports of wheat, 1989-91 (000 t)	59,589	-75,173	14,794	..
	22. Net imports of wheat per capita, 1989-91 (kg/yr)	15	-90	36	..
	23. Per capita total wheat consumption, 1989-91 (kg/yr)	73	147	344	106
	24. Growth rate of per capita wheat consumption, 1983-91 (%/yr)	0.4	-0.7	0.2	-0.2
Measures of research efforts	25. Percent area under modern wheat varieties, 1990	69	..	..	..
	26. Number of wheat varieties released, 1966-90	1323	..	..	..
	27. Wheat varietal releases per million ha wheat area, 1966-90	0.9	..	..	..
	28. Number of full-time wheat improvement researchers, 1992	1,142	..	..	..
	29. Wheat improvement researchers per million t wheat production, 1992	5	..	..	..
Fertilizer use	30. Fertilizer applied per hectare of arable land, 1988-90 (kg nutrients/ha)	78	119	129	99
Prices	31. Farm price of wheat, 1991-92 (US$/t)	..	..	..	..
	32. Ratio of farm-level nitrogen price to wheat price, 1991-92	..	..	..	..
	33. Farm wage in kg of wheat per day, 1991-92	..	..	..	..

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