Development and Spread of High-Yielding Wheat Varieties in Developing Countries

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Foreword

The most significant technological accomplishment of this century in international agriculture is the development of high-yielding cereal crop varieties. These fertilizer-responsive food crops, with a high degree of resistance to insect pests and diseases, have provided on-farm yields far in excess of those obtainable from traditional varieties. They have given rise to the green revolution, which has helped many nations increase their food production in the face of substantial increases in human population. Increased production means higher returns to many farmers and lower food costs to consumers.

The U.S. Agency for International Development (AID) has long been involved in crop improvement activities in developing countries. Since the early 1950s AID has supported the development and strengthening of national research programs in which considerable research has been done on varietal improvement. Since 1969 the Agency has also provided about 25% of the funding for international agricultural research centers sponsored by the Consultative Group on International Agricultural Research. Much of the research leading to the development of new crop varieties has been carried out at these centers. The national and international centers cooperate in the varietal development process, and the result is usually a joint product.

This publication documents the development and adoption of new wheat varieties. A comparable report on rice is being published simultaneously.

The research reported in this document represents, we think, a highly efficient and effective way to assist the needy in developing countries and to stimulate their economic development. AID is proud to have played a role in the process.

Nyle C. Brady
Senior Assistant Administrator for Science
and Technology
U.S. Agency for International Development

Preface

This report is, to borrow a biological term, somewhat of an induced mutant. It is the offspring of a series of earlier reports, the last of which was published in September 1978, but it differs from them in several ways. The most obvious change is that whereas wheat and rice were formerly covered in the same report, they are now the subject of separate, although nearly concurrent, publications. A less obvious change is that the reports are now published wholly by the Agency for International Development (AID) rather than in cooperation with the U.S. Department of Agriculture.

In addition to including a vast amount of new information, other changes have been made—

- The report has been almost entirely rewritten, with the principal exception of the first parts of chapters 1 and 2, which have been revised. Two new appendices have been added.
- There has been a change in style in the country chapter (chapter 3). Formerly many of the country entries consisted only of tables; these have now been cast in narrative form and contain a broader array of information. Tables are included when statistical information was available; they now indicate the proportion of total area covered by high-yielding wheat varieties.
- The footnotes have been moved to the ends of chapters and have been thinned out for the pre-1977 period. Also, some long-standing but now dated appendices have been dropped.
- The high-yielding wheat varieties are no longer listed, along with their genealogies, in a summary table. There are now simply too many to list. Considerable information of this type is, however, provided in chapter 2 and in the country sections in chapter 3.

While the varietal developments and releases can fairly readily be captured and reported, statistics on their use at the farm level generally remain somewhat elusive. Those that exist are, except for a few Asian countries, outside the main statistical stream; they are in the byways and must be tracked down. This detective process takes time and is not always successful. Coverage is often uneven.

Despite careful preparation and extensive review, this report undoubtedly contains some errors and inconsistencies. These are particularly likely to be found in the spelling, specification, or spacing of variety names and lines in individual nations. In some cases, what might seem like inconsistencies may be due to variation in transliteration and usage between countries. In other cases, particularly those involving genetics, scientific opinion occasionally varies. Nevertheless, I am responsible for any errors or inconsistencies and would be grateful to learn of them.

The updating of this report has been in part an AID contribution to a broader study of the impact of the international agricultural research centers that has been sponsored by the Consultative Group on International Agricultural Research. The area data from this report have been used as a basis for further statistical calculations presented in the reports of that study. In turn, some information provided in country studies prepared for the impact study has proved useful for this report.

Most of the research and writing of this report was done in 1984 and early 1985. Some information, however, was updated through late 1985.

This project provided a welcome, though demanding, addition to my usual activities. I am pleased to have had the opportunity to return to a subject that has the fortunate combination of being of great interest to me and of considerable importance for the developing world.

Dana G. Dalrymple

Acknowledgments

This edition was made possible only through the support of numerous individuals and organizations. Those who provided assistance on specific points are generally mentioned in the footnotes and references of the chapters that follow. Those who were of more general assistance are noted here.

First, it should be said that this report would not have been prepared had it not been for Dr. Nyle C. Brady, senior assistant administrator for science and technology, U.S. Agency for International Development (AID). Dr. Brady provided the stimulus to update the report, directed the allocation of resources to do so, and followed the project with keen interest.

Four other individuals also made vital contributions:

- Robert Bertram, my associate at AID, contributed directly through his knowledge of plant breeding and indirectly by carrying an increased workload while I was involved with this project.
- Daniel Timms of the International Economics Division, Economic Research Service (ERS), U.S. Department of Agriculture (USDA) diligently searched through USDA files and reports for statistical information.
- Walter Rockwood of AID served as editor. Suzanne M. Parent of METROTEC, INC., carefully guided the manuscript through the publication process.

Among the many scientists who provided valuable assistance and advice, I would particularly like to acknowledge the contributions of:

- Dr. Byrd C. Curtis, director, Wheat Program, International Maize and Wheat Improvement Center (CIMMYT);
- Dr. Arthur Klatt, associate director, Wheat Program, CIMMYT; and
- Dr. L.W. Briggle, research agronomist, Germplasm Resources Laboratory, Agricultural Research Service, USDA.

Several groups of individuals were of considerable help in obtaining data on specific nations:

- Country desk officers of the International Economics Division, ERS/USDA, Washington, D.C.; and
- AID food and agricultural officers and USDA agricultural attachés in developing countries.

Also of assistance were three fellow agricultural economists: Dr. Donald Winkelmann of CIMMYT and Drs. Jock Anderson and Carl Pray of the Consultative Group on International Agricultural Research Impact Study.

In addition, support came from other quarters. The International Agricultural Development Service (IADS) kindly provided a much-needed quiet haven for writing of the first draft. John Hyslop of the Office of International Cooperation and Development at the USDA arranged Chinese translations. Kim Harmon and Dolores SeGuine of AID typed much of the final draft.

I should not close without mentioning several other vital groups who will not be mentioned by name in this report. These are the many scientists and technicians who

carried out the varietal improvement work and who gathered the basic statistical data summarized here. The accomplishments reported in this bulletin are but the tip of a pyramid of activity by others. My role has been that of observer and reporter.

Acronyms

U.S. ORGANIZATIONS

AID, USAID	U.S. Agency for International Development
ARS	Agricultural Research Service, U.S. Department of Agriculture
ERS	Economic Research Service, U.S. Department of Agriculture
FAS	Foreign Agricultural Service, U.S. Department of Agriculture
USDA	U.S. Department of Agriculture

INTERNATIONAL ORGANIZATIONS AND CENTERS

CAAS	Chinese Academy of Agricultural Sciences
CGIAR	Consultative Group on International Agricultural Research (Washington, D.C.)
CIMMYT	International Maize and Wheat Improvement Center (Mexico)
FAO	Food and Agriculture Organization of the United Nations
ICARDA	International Center for Agricultural Research in the Dry Areas (Syria)
IRRI	International Rice Research Institute (Philippines)

1. WHEAT AND WHEAT BREEDING

I trust that the day will come when humanity will take as great an interest in the creation of superior forms of life as it has taken in past years in the perfection of superior forms of machinery. In the long run, superior life forms may prove to have a greater profit for mankind than machinery.

—Henry A. Wallace, 1936[1]

The planting of high-yielding wheat varieties (HYWVs) has expanded sharply in developing countries (DCs) since the mid-1960s. The new wheat varieties, along with critical inputs such as fertilizer and irrigation, provide the basis for what is popularly called the green revolution.

BACKGROUND AND FOCUS OF THE REPORT

Although the green revolution is a relatively new phenomenon in DCs, HYWVs are not new. Many wheat varieties have, over time, been classified as high yielding compared to their predecessors. The distinguishing characteristic of the modern HYWVs is their relatively short stem. They also are generally early maturing and have several other complementary plant features.[2]

Dwarf and semidwarf wheat varieties have been grown for more than a century. The dwarfing characteristic, however, became important with the advent and use of chemical fertilizer, which produced higher yields for plants that could respond to its application and not lodge (fall over). This was particularly true for intensively farmed areas where the water supply was not a limiting factor. Hence, it is not surprising to find that short varieties have been grown in Japan for a long time.[3]

The use of chemical fertilizer on domestic food crops in DCs, however, began largely in the 1950s and 1960s. The HYWVs began to make their appearance in DCs in the 1960s. The use of HYWVs and chemical fertilizer was stimulated by a food crisis in southern Asia in the mid-1960s.

The ancestry of most of the HYWVs can be traced to varieties developed in Mexico by Norman Borlaug and associates (subsequently grouped at the International Maize and Wheat Improvement Center [CIMMYT]). The origin and interrelationships of the current HYWVs are outlined in chapter 2. Chapter 3 provides estimates of the areas of HYWVs harvested in individual countries by crop years between 1965-66 and 1982-83. Preliminary estimates for 1983-84 also are included when available. While the main emphasis is on noncommunist nations, some information is included for the People's Republic of China.

No attempt is made to go beyond area data and to estimate increased overall wheat yields and production,[4] and no effort is made to discuss the economic and social effects of the HYWVs within the context of the green revolution. Rather, the purpose is to provide a historical and statistical base for policy analysis and other research.

DEFINITIONS AND SOURCES OF DATA

The identification of HYWVs and the determination of the area planted with them is a complex process. The general characteristics, problems, and sources of data are outlined here; more specific details are provided in the references and notes for chapter 3.

Varietal Definitions

This report emphasizes the wheat varieties developed by CIMMYT and the offspring of those or similar varieties developed in national research programs. Virtually all of these varieties are semidwarfs, although some might be considered intermediate in height and are potentially high yielding.[5] Their yield capacity, however, is seldom fully realized on farms because of a host of physical, biological, and management factors. Thus, "high yielding" refers to yield potential, not always to actual output.

This definition of HYWVs does not include all improved wheat varieties. Improved varieties of conventional height, produced as a result of breeding or selection, have been grown in many DCs for decades. (In India, for example, systematic research on wheat began in 1905.[6]) The early wheat varieties released in the Mexican program were of conventional height. Some traditional and improved varieties may be as high yielding as some semidwarfs under certain conditions.

In most countries, a progression of varieties in three stages might involve: I, traditional varieties: II, improved varieties of normal height; and III, HYWVs of shorter height—principally semidwarf and intermediate varieties (figure 1.1). A few of the early varieties introduced or distributed by CIMMYT might have fallen into stage II, but nearly all are now in stage III. Each stage may, in turn, be composed of successive waves of new varieties; few individual varieties have a very long life. Within stage III we would find a gradual replacement of imported CIMMYT varieties with crosses of genetic materials from agricultural centers with local varieties.

In most cases, the varietal sequence will follow the order indicated, but one stage will not com-

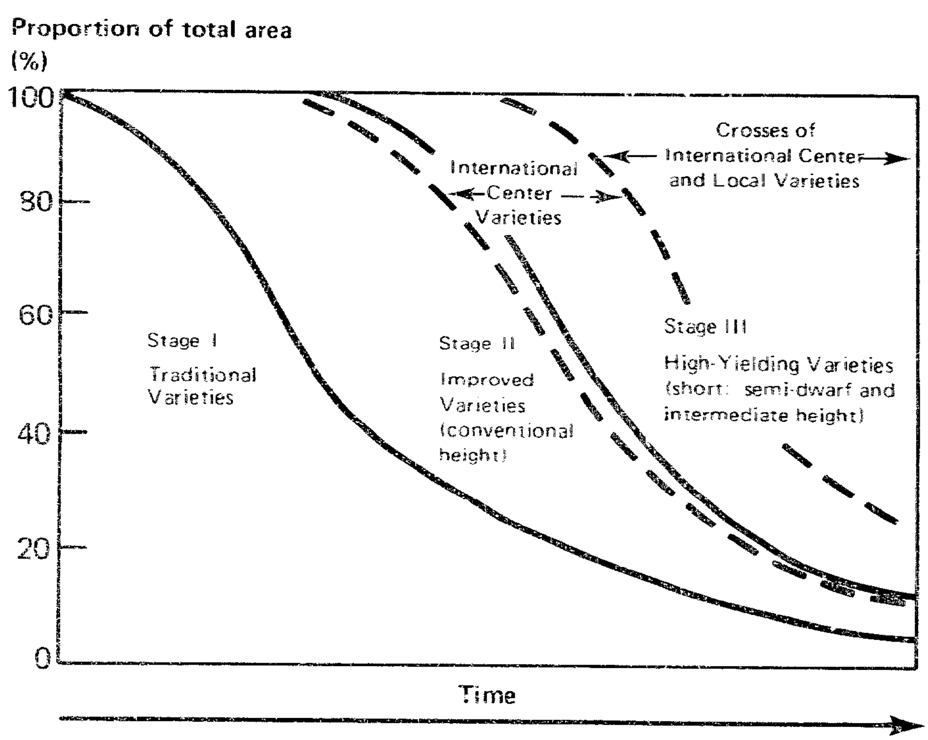


Figure 1.1. Generalized sequence for the adoption of modern wheat varieties in developing nations.

pletely replace the previous stage or stages. In some instances, however, farmers may have skipped stage II by moving directly from stage I to stage III. In other instances, bad experiences with newer varieties will cause farmers to temporarily move back a stage or two. The actual situation in an individual country may, of course, vary considerably.[7]

I have tried to limit the data reported here to the semidwarf and intermediate HYWVs of stage III, but that has not always been possible. National data are not always broken down by specific variety, so it is sometimes necessary to use whatever definition of HYWVs is used by the national reporting system. This process has undoubtedly included some improved (non-high-yielding) varieties, and the degree to which improved varieties are included may have changed over time.[8]

A more subtle definitional problem arises from the time span covered. Aside from the historical background in the next chapter, I concentrate on the adoption of varieties introduced by CIMMYT since the mid-1960s. HYWVs introduced and widely adopted before that time are not specifically covered in the statistics (but may have been included in some cases).

While most of the HYWVs reported here were developed by CIMMYT or are related in some way to such varieties, this is not always the case. The clearest examples are some short and semidwarf varieties of wheat that were developed in Italy early this century and are still planted in the Mediterranean region and used as parents there and elsewhere.

Some HYWVs have been developed by national programs from local varieties or mutants; they are not always semidwarfs, but they may be relatively short and high yielding compared to traditional varieties. Although CIMMYT is a major source of HYWVs, it is not the only one. Some countries other than those listed may be testing HYWVs and may even have moved into limited commercial production.

Data Sources

Data on area of HYWVs planted and on seed imports generally come from different sources. Most are unpublished. They usually apply to the July to June crop year.[9] In some cases, the sources do not indicate whether the area data are for planted or harvested area. Most, however, refer to area planted.

Area information is largely based on reports submitted by the Agency for International Development (AID) country missions or agricultural attachés at U.S. embassies. Such reports are usually obtained from official reports or estimates by the countries themselves. National systems for collecting this information are not, in many cases, highly advanced, and it is not possible to determine its accuracy. In some instances the HYWV area may be over- or underestimated.[10] For others it is simply not available. The area data, therefore, should be regarded as only approximate.

The HYWV seed figures are relatively accurate but incomplete except for unusually large shipments from Mexico and India.

SOME BASIC BIOLOGICAL CHARACTERISTICS

The basic biological characteristic of the HYWVs discussed in this report is their semidwarf growth habit. However, other biological characteristics also are important. Those features are related in part to their botanical classification; there are several different major species and types of wheat.

Classification of Wheat

In terms of botanical classification, wheat belongs to the genus *Triticum* and is composed of three species of commercial importance: common or bread wheats (*Triticum aestivum L.*); club wheats (*Triticum compactum Host*); and durum wheats (*Triticum durum Desf.*). Bread wheats were first extensively grown in northern Europe; club wheats in southern Europe; and durum wheats in the Mediterranean countries, in southern and eastern Russia, and in Asia Minor.

Each wheat species has distinct characteristics that make it suitable for special uses: the common wheats are used for bread; the club wheats, which are soft, are used for pastry; and the durum wheats, which are hard, are used for pasta products such as macaroni and spaghetti. Nearly all of the HYWVs reported here are bread wheats. The high-yielding durum varieties, however, are gaining importance in the Mediterranean countries. Club wheats are presently of minor international importance.

Growing Season

Wheat is basically a crop of the temperate and semitropical climatic zones. Its normal range can, however, be extended slightly by breeding and cultural practices.

Wheat is principally of two types, winter and spring. (A third type, facultative, falls between the two in cold tolerance but is of minor importance, except in China.) Botanically, the Mexican varieties are spring wheats (i.e., planted in the spring and harvested in late summer). Where winters are mild, spring wheats may, like winter wheats, be planted in the fall and harvested in the spring. This practice is enhanced by the photoperiod-insensitive nature of the Mexican wheats. The winter cultivation of spring wheats is generally practiced in the DCs in warm regions.[11] In some regions where there is a heavy summer monsoon, planting of Mexican varieties may be largely limited to the winter season. Virtually all of the data reported here are for spring wheats, though some data for winter wheats are included for a few Near East countries.

For several years CIMMYT has had a cooperative research program with Oregon State University aimed at transferal of some of the desirable characteristics of winter wheat to spring wheat and vice versa. The results to date are promising.[12] CIMMYT is also expanding its research on winter wheats in Mexico and Turkey.

HYWVs and Water Control

There is a close general relationship between the use of the HYWVs and water control. HYWVs do not require more water than local varieties in a physiological sense; in fact, because of higher yields and shorter growing periods, they may actually use less water per unit of product. However, because the high-yield potential of the varieties is achieved by applying inputs such as fertilizer and pesticides, an added cost is involved. When water control—both supply and drainage—is inadequate or unreliable, the added risk discourages the use of these and other inputs and reduces the advantage of the varieties. Thus, the attainment of the full potential of the HYWVs without undue risk requires an assured water supply.

Water requirements for wheat, however, differ sharply from these for rice. Wheat requires much less water per unit of land than rice—less than one-third under some Indian conditions. Thus, wheat is most often raised in drier climates and rice in monsoonal areas. Similarly, wheat is more often grown during the dry season and rice during the wet season. In some instances, where growing seasons permit, they are able to follow each other in multiple-cropping rotations. This is increasingly the case, for example, in Bangladesh.

Approximately two-thirds of the HYWVs were, as of the mid-1970s, grown in irrigated fields, principally in India and Pakistan.[13] Some important regions, however, such as North Africa and the barani (rainfed) area of Pakistan receive little, if any, irrigation.[14] Even without irrigation, yields of the HYWVs often are superior to local varieties. Consequently, increased attention is being given to developing drought-resistant wheat varieties, such as in the CIMMYT/Oregon State University wheat crossing program. Bread wheats are more apt to be raised under irrigation than are durum wheats.

THE NATURE OF HIGH YIELD

Because of the focus of this report on HYWVs, it is appropriate to cover the underlying nature of high yields.[15] The first step is to define yield. Traditionally, yield has been defined as quantity of plant output per unit of land per crop. This approach is satisfactory when only one crop is grown per year, as in developed nations with temperate climates. In the tropical developing nations, however, multiple cropping—the production of more than one crop per year—is often possible and usually practiced. In such a setting a temporal dimension of yield must be included: yield per unit of land per unit of time.[16]

As traditionally defined, yield increases can be achieved in three main ways:

Step 1—improvements in the genetic yield potential;

Step 2—better varietal adaption to environmental factors; and

Step 3—improved agronomy.

The first two steps primarily involve plant breeders and are complementary. The third step can be of equal or greater importance as far as yields are concerned but includes a somewhat different group of scientists.

Step 1 involves increasing the pure yield potential of the plant at the upper level of its production possibilities. This is the yield level reached when the normal factors of production—nutrients, water, insects, diseases, weeds, lodging, and other stresses—are effectively controlled. Yield increases of this nature have been obtained. They have generally resulted from the semidwarf or short stature of the plants because less of the plant's biomass is represented by stems and more is represented by harvested organs or grain. The reductions in straw weight are matched, more or less, on a one to one basis, by gains in grain yield, which increases the harvest index. Other physiological characteristics, such as rate of photosynthetic activities, may or may not be significantly different.

Step 2 includes a number of factors that lessen at least some of the normal constraints on productivity. Four particularly important factors are: resistance to lodging, suitable growth duration, greater resistance to insects and diseases, and greater tolerance of environmental stress. Happily, the shorter stem of the HYWV, which contributes to a higher harvest index, also contributes greater resistance to lodging. Growth duration suitable for the location is essential for high yield and double cropping. Most breeding programs have also given considerable attention to incorporating sturdier stems and natural resistance to insects and diseases. Increasing attention is being given to similarly incorporating greater tolerance for adverse environmental conditions—saline soil for example—but this research is not advanced in terms of its yield effects.

Step 3 includes a wide range of agronomic practices such as increased and more effective use of water, fertilizer, insecticides, and herbicides; closer spacing; and more effective and timely management. Once again, shorter plants are less likely to lodge at higher levels of nitrogen fertilization. On the other hand, they are less tolerant of competition from weeds. Generally a package of improved agronomic practices is recommended with use of the varieties.

If the definition of "yield" is broadened to take the time dimension into account, another factor becomes important. Typically, the HYWVs discussed in this report are photoperiod insensitive and tend to mature more rapidly than traditional varieties. The first (vegetative) stage of plant growth is shortened, a characteristic that can be of value in several ways. It may enable the crop to fit in a short growth season and avoid natural calamities (drought or storms) that occur at the end of a traditional growing season. Photoperiod insensitivity may have even more pronounced effects on cropping patterns. Reducing the time required for one crop increases the time available for others, which means that multiple cropping becomes possible. It also may mean that additional flexibility is introduced in terms of the type or scheduling of other crops. The influence of early maturity on increasing cropping intensity and overall production is generally not given the attention that it deserves in analysis of yield effects.

Semidwarf wheats are usually higher tillering than other wheats. (They produce additional stems.) Other qualities, such as increased resistance to insects and diseases, usually are incorporated and complement other yield factors. In some cases, production factors other than simple grain yield may be of significance. Straw yield is important in some DCs, and farmers may be interested in varieties of intermediate rather than semidwarf height. High yield is important, but it is not everything. Trade-offs may be involved.

METHODS OF VARIETAL IMPROVEMENT

HYWVs sometimes occur naturally but are most often the result of a carefully planned activity of a plant breeder. Natural crosses or mutations provided the genetic variation that laid the basis for much of the early and current improvement in varieties. These natural sources of variation can now be augmented by induced sources of variation.[17]

Varietal Introduction

Varietal introduction is usually the first phase in varietal improvement. Varieties that have proved themselves elsewhere, generally in other nations, are simply imported. Sometimes they can be used directly, but more often they have to be adopted through selection and breeding to meet local conditions. They may also be used as parents in developing new varieties.

Selection

Selection is an age-old technique for varietal improvement and consists, in its simplest form, of selecting the most promising plants, where there is natural variation, in a field. These variants may represent natural mutations, outcrossing, and mixtures. Farmers have improved their crops by selection for centuries. Plant breeders make selections from pure or single lines, but more often they select from the offspring of intended crosses.

Hybridization

Hybridization involves planned crosses and subsequent selection of desired plants from the offspring. Crossing of this type began for wheat in the United States in the late 1800s. The purpose is to combine the most desirable characteristics of two or more varieties. A cross of two different pure-line varieties will produce offspring with a great deal of variability in the early (F_2 or F_3) generations. Breeders carry the crossing through at least the sixth generation to stabilize the process and to produce true-breeding offspring. This process produces pure-line improved varieties rather than pure hybrids (which can only be the F_1 generation).

Hybrids

Hybrids are the first (F_1) generation of the cross and traditionally display hybrid vigor or heterosis. Two major challenges are involved in capturing this vigor for farm use. The first is to get a reasonably stable F_1 generation. This requires, among other things, genetically pure parents—which is not difficult with a self-pollinated

Figure 1.2. CIMMYT wheat-crossing nursery showing diversity of plant types (source: CIMMYT).

crop such as wheat. The second challenge is to develop an economical way of making the crosses in mass—which is difficult with a self-pollinated crop. Elimination of the internal source of pollen to prevent self-fertilization can be done manually at the laboratory level by removing the anthers (pollen sac), but this system is completely unsatisfactory if commercial quantities of seed are to be produced.

Thus, for a long time hybrid wheat seed seemed a practical impossibility. In the 1950s, however, the discovery of cytoplasmic male sterility (CMS) and a fertility restorer complex in wheat provided a new opportunity for wheat breeders. The CMS process, in its simplest form, involves a male-sterile (or female) flower that is crossed with (pollinated by) any line desirable as a male parent but that also possesses a gene or genes for restoration of fertility.

For every hybrid developed, three separate and distinct lines must be established:

- the male parent must be converted to restore fertility to all F_1 (hybrid) plants grown in farmer's fields;
- the female parent must have the proper cytoplasm and must be devoid of fertility restoring genes; and
- there must be a normal, fertile counterpart of the female parent (with normal cytoplasm) to use in production of additional seed of the male-sterile (female) parent—thus, the label "maintainer line."

This process is complicated and expensive. It is, nevertheless, the basis for emerging private hybrid seed wheat businesses in the United States and Argentina.[18]

An important new development in wheat breeding involves the use of chemically induced male sterility. Plants are sprayed with a chemical to induce male sterility at the proper growth stage ensuring cross-pollination. This is much simpler and less expensive than the CMS process. Wheat varieties developed in this way are marketed in the United States, and the process may become widely adopted.

Although semidwarf varieties are commonly used in breeding hybrids, the offspring are not always semidwarfs unless both parents are semidwarfs. The F_1 generation tends toward the height of the taller parent. Thus, some hybrids could face a lodging problem unless straw strength is incorporated in other ways.

There are a number of unsettled questions concerning the relative economic advantage of hybrids. A key one concerns yields. There is some difference of opinion among plant breeders as to whether heterosis (an increased growth capacity due to crossbreeding) is a particularly significant advantage in self-pollinated crops. Theoretically, the same yield characteristics can be obtained through genetic accumulation. Because hybrid seed costs more and must be purchased every year (seed of conventional varieties, if kept clear and viable, can be used year after year by the farmer), hybrid yields must be correspondingly higher. In the case of wheat it is not yet clear that hybrid yields are sufficiently greater than those of the best regular varieties to more than cover the additional costs. If chemically induced sterility makes it possible to reduce hybrid wheat seed costs, their economic potential will clearly be enhanced. Even so, the use of hybrids in many developing nations will be greatly hampered by the lack of well-developed seed production and distribution systems.

CIMMYT had a hybrid wheat research program through the 1960s but then dropped it.

Induced Mutations

Throughout history, virtually all of the basic genetic variability in plants has come about through natural processes. Beginning in the 1950s scientists induced mutations in wheat and rice varieties through the use of radiation or chemicals.[19] These mutations were fruitful in bringing about shorter plant height. Some short-statured mutants of wheat are grown in both developed and developing nations—though not yet over wide areas.[20]

Other Techniques

Related wheat breeding techniques currently under study include anther culture (particularly used for rice in China) and wide crosses involving wild relatives or distantly related species. Anther culture offers a way of speeding up and increasing the efficiency of the breeding process. Wide crosses are a means to broaden the genetic base. CIMMYT has made particular use of wide crosses in its experimental work.[21]

Clearly there are now a number of ways to develop higher yielding varieties. Further improvements in approach and technique will undoubtedly broaden the horizon further.

REFERENCES AND NOTES

[1]U.S. Department of Agriculture, *Yearbook of Agriculture, 1936* (Washington, D.C.: the Department, 1936), p. 120.

[2]*See* D.S. Athwal, "Semidwarf Rice and Wheat in Global Food Needs," *Quarterly Review of Biology* 46(1) (1971):24-26.

[3]In Japan increasing application of commercial fertilizer (fishmeal or soybean cakes) in the late 1800s and chemical fertilizer in the early 1900s led to an early interest in the development of varieties with shorter stems. Semidwarf wheat varieties, as will be noted in chapter 2, already existed in Japan at that time.

[4]Some of the factors involved in this process, however, are outlined in D.G. Dalrymple, "Evaluating the Impact of International Research on Wheat and Rice Production in the Developing Nations" in *Resource Allocation and Productivity in National and International Agricultural Research*, ed. T.M. Arndt, D.G. Dalrymple, and V.W. Ruttan, (Minneapolis: University of Minnesota Press, 1977), pp. 171-208; and "The Adoption of High-Yielding Grain Varieties in Developing Nations," *Agricultural History* 53(4) (1979):704-726.

[5]Full dwarf varieties are not grown commercially.

[6]A. Howard and G.L.C. Howard, *The Improvement of Indian Wheat*, Bulletin No. 171 (Pusa, India: Agricultural Research Institute, 1927), pp. 1-16; and C.E. Pray, "Underinvestment and the Demand for Agricultural Research: A Case Study of the Punjab," *Food Research Institute Studies* 19(1) (1983):59.

[7]A particularly well-documented case is provided by Y. Kislev and M. Hoffman, "Research and Productivity of Wheat in Israel," *Journal of Development Studies* 14(2) (1978):169.

[8]It has been reported, for example, that up to the 1968-69 season in India improved local varieties were included in the HYWV category. Thereafter, the definition was more strict. V.S. Vyas, *India's High-Yielding Varieties Programme in Wheat, 1966-67 to 1971-72* (Mexico City: International Maize and Wheat Improvement Center, 1975), pp. 5, 7.

[9]This designation is not as clear-cut as it may seem, especially when crop seasons cut across the July-to-June time period. The harvesting period follows the planting dates by several months, creating further difficulties.

[10]In the previous edition of this report, examples were given of over- and underreporting of rice in one district of India and in Bangladesh in the mid-1970s. (D.G. Dalrymple, *Development and Spread of High-Yielding Varieties of Wheat and Rice in the Less Developed Nations*, Foreign Agricultural Economics Report No. 95, [Washington, D.C.: U.S. Department of Agriculture, 1978], pp. 130-131.) No similar examples have been found for wheat.

[11]In Turkey it is possible to plant Mexican varieties during the winter in the southern coastal areas, but it is necessary to use winter wheat varieties in the cold, dry Anatolian Plateau.

[12]Background on this program is provided in K.R. Kern, "Probing the Gene Pools; Spring x Winter Crosses in Bread Wheat," *CIMMYT Today*, No. 12 (1980), 11 pp. More recent details are provided in CIMMYT annual reports. During the 1950s and 1960s many of the wheat varieties released in Argentina were from crosses of spring and winter wheats.

[13]Letter from D. Winkelmann, economist, CIMMYT, February 1974.

[14]*See*, for example, M.J. Purvis, "The New Varieties Under Dryland Conditions: Mexican Wheats in Tunisia," *American Journal of Agricultural Economics* 56(1) (1973):54-57; and R.I. Rochin, "A Micro-Economic Analysis of Smallholder Response to High-Yielding Varieties of Wheat in West Pakistan" (Ph.D. dissertation, Michigan State University, 1971).

[15]This section is largely based on recent writing by Lloyd Evans, individually and in coopera-

tion with others. His two most useful general articles are: "The Natural History of Crop Yield," *American Scientist* 68(4) (1980):388-397; and "Raising the Yield Potential: By Selection or Design?" in *Genetic Engineering of Plants*, ed. T. Kosuge, C.P. Meredith, and A. Hallaender (New York: Plenum Publishing, 1983), pp. 371-389. More specific research on wheat was reported in R.B. Austin, J. Bingham, R.D. Blackwell, L.T. Evans, M.A. Ford, C.L. Morgan, and M. Taylor, "Genetic Improvements in Winter Wheat Yields Since 1900 and Associated Physiological Changes," *Journal of Agricultural Science* 94 (1980):675-689. *Also see* H. Hanson, N.E. Borlaug, and R.G. Anderson, *Wheat in the Third World* (Boulder, Colo.: Westview Press, 1982), pp. 20-22; and B.C. Curtis, "Potential for a Yield Increase in Wheat," in National Association of Wheat Growers Foundation, *Proceedings of the National Wheat Research Conference* (Washington, D.C.: the Association, 1983), pp. 12-19.

[16]If two crops are grown in sequence each year, the yield of each individual crop may be less than the yield if only one crop were grown, but the combined yield of the crops is usually higher than the yield of a single crop. However, since the second crop may not be of the same type, weight or volume may be an inadequate measurement of output. Value of production may be a more relevant measure.

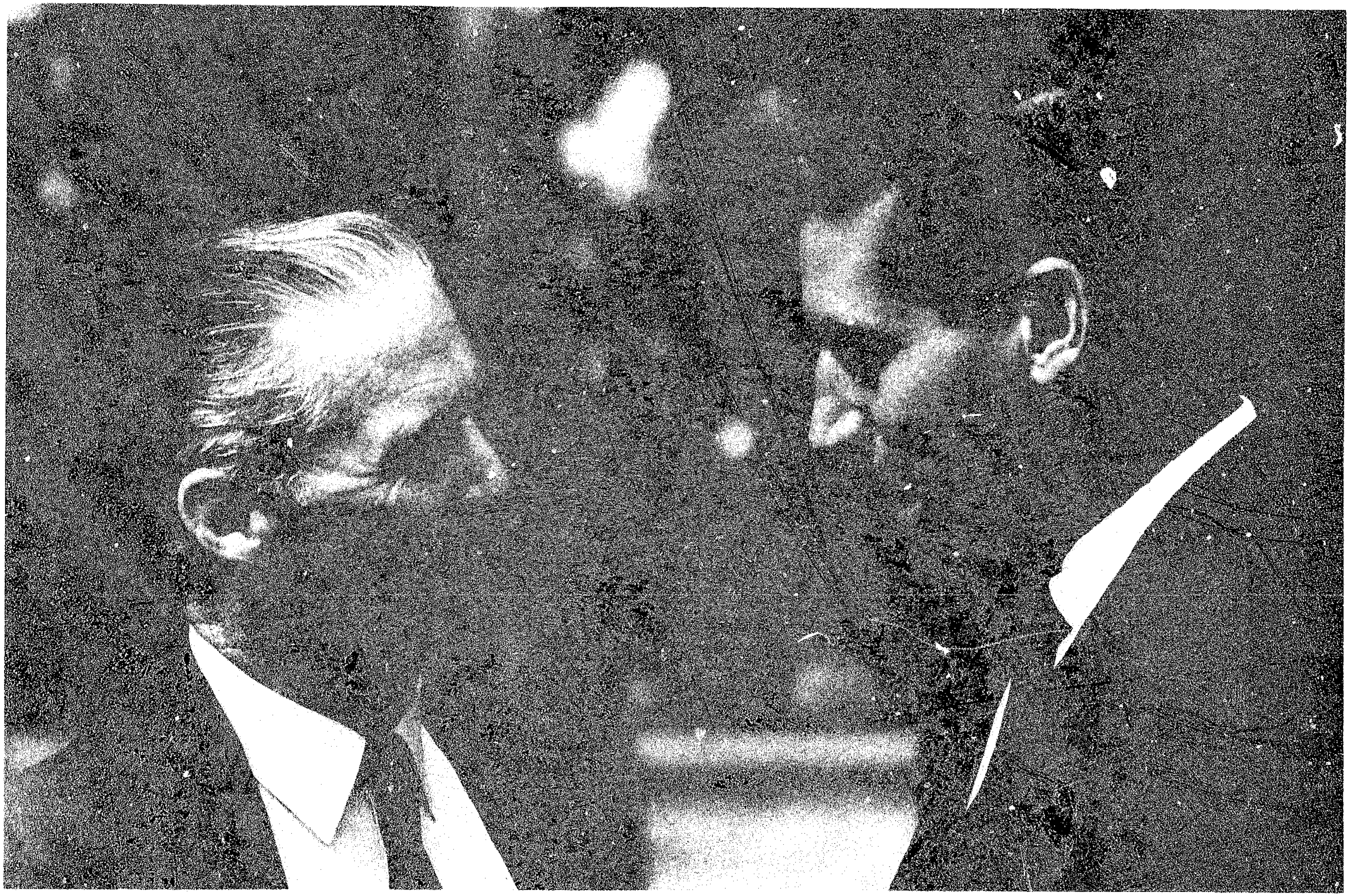
[17]This section draws heavily on conversations with L.W. Briggle of the Agricultural Research Service, USDA, Beltsville, Md. Particularly useful references are: L.W. Briggle, "Heterosis in Wheat–A Review," *Crop Science* 3(5) (1963):407-412; R. Rodriquez, M.A. Quinones, N.E. Borlaug, and I. Narvaes, *Hybrid Wheats: Their Development and Food Potential*, CIMMYT Research Bulletin No. 3 (Mexico City: International Maize and Wheat Improvement Center, 1967), 37 pp.; B.C. Curtis and D.R. Johnston, "Hybrid Wheat," *Scientific American* 220(5) (1969):21-29; and S.S. Virmani and I.B. Edwards, "Hybrid Rice and Wheat," *Advances in Agronomy* 36 (1983):145-214.

[18]For information on the latter program, see N. Machado, "Hybrid Wheat Program of Cargill in Argentina" in *Cereal Breeding and Production Symposium, Marcos Juarez, Argentina, November 7-12, 1983*, Special Report 718 (Corvallis: Oregon State University, 1984), pp. 331-333.

[19]Some work of this nature was done much earlier.

[20]For further details, see C.F. Konzak, *Mutations and Mutation Breeding*, Wheat Monograph (Madison, Wisc.: American Society of Agronomy, in press), table 1.

[21]Curtis notes "The focus of this kind of wide cross work is not the improvement of genetic yield potential per se, but rather increased yield through better resistance to diseases and greater tolerance to environmental extremes" (Curtis, *op. cit.* [*see* footnote 15], p. 16).



Historical Note: Dr. Norman Borlaug of CIMMYT talks to Dr. Dilbagh Athwal of Punjab Agricultural University at the first CIMMYT board meeting in September 1966. Dr. Borlaug won the Nobel Peace Prize in 1970 for his work on wheat improvement. Dr. Athwal was one of the first Indian wheat breeders to work with the Mexcian semidwarfs (source: The Rockefeller Foundation).

2. DEVELOPMENT OF HIGH-YIELDING WHEAT VARIETIES

. . . plant breeding, using germplasm from any source in the world, cuts across national boundaries and develops products useful in the end to all men and nations.

—Gove Hambidge and E.N. Bressman, 1936[1]

The origin and development of the wheat varieties reported here are considerably more complicated than their simple classification as HYWVs might suggest. Moreover, through history many HYWVs have been developed and used. The wheat varieties discussed here are the descendants of Japanese, American, and Italian breeding programs.

AN EARLY HYWV

The earliest known HYWV was reported on June 30, 1794, when the *American Mercury* of Hartford, Connecticut, published "An Account of a New Species of Wheat." The new variety was a hard winter wheat that, compared to the prevailing varieties, matured 15 to 20 days earlier, provided a heavier yield, and produced a third less straw due to its short stem. It also was resistant to disease (particularly with respect to rust), and because of its earlier maturity, it escaped the worst damage of the Hessian fly. The variety was known as "Forward Wheat" and came from Caroline County, Virginia, where it had been selected 7 years earlier. Seed was offered for sale in Connecticut in September 1795. By 1798-1800 it was generally grown in eastern Virginia and Maryland and was presumably adopted in the commercial wheat-growing areas of western New England.[2] Other such modern varieties may well have emerged unrecorded over time.

JAPANESE-AMERICAN ROOTS

Japan has a long history in the development of short wheat. In 1873 Horace Capron, the former U.S. Commissioner of Agriculture who headed an agricultural advisory group on a visit to Japan, wrote, "The Japanese farmers have brought the art of dwarfing to perfection." He noted that the wheat stalk seldom grew higher than 2 ft (60 cm) and often not more than 20 in (50 cm). The head was short but heavy. The Japanese claimed that the straw had been so shortened that no matter how much manure is used the stem will not grow longer. Capron noted that "on the richest soils and with the heaviest yields, the wheat stalks never fall down and lodge."[3]

Short Japanese wheat varieties were introduced in France in mid-1867 when La Société d'Acclimatation of Paris received seed of a productive early maturing wheat (Blé Précoce), listed as Haya Moughi, from a Dr. Mourier in Yokohama. The plant proved to have short straw.[4] In following years other seeds were imported and numerous reports of trials of Blé Précoce appeared in the bulletin of the Society. In 1880 it was listed in the book *Les Meilleurs Blés*. The straw was very short, erect, and stiff; and the plant flowered 2 to 3 weeks ahead of all the other spring wheats. The entry, however, noted that the variety was more of curiosity interest than of true agricultural merit.[5] *Blé Précoce du Japon* was sold commercially from 1882 to 1904 as a spring wheat. It was used for experimental breeding work from 1930 to 1955, but it does not appear that it was involved in the parentage of any significant commercial varieties.[6]

Two Japanese semidwarf varieties—Akakomugi and Daruma—did, however, turn out to be of immense consequence in subsequent international breeding programs.

- Akakomugi means "red wheat" in Japanese. It was often used as a parent in crops because of its dwarfness and early maturity. It was mainly raised in southern Japan but is no longer grown commercially. Akakomugi played an important role in the breeding of Italian semidwarf varieties early in the 20th century and is discussed in the section on Italian varieties.[7]

- Daruma, which may have come from Korea, became one of the recommended wheat varieties in the Tokyo and Kangawa Prefectures around 1900.[8] A white variant of Daruma was known as Shiro-Daruma and a red variant as Aka-Daruma.[9] In 1917 Shiro-Daruma (or perhaps Daruma) was crossed with an American variety called Glassy Fultz at the Central Agricultural Experiment Station (Nishigahara, Tokyo) to produce Fultz-Daruma.[10] The date and location of the cross of Aka-Daruma with Glassy Fultz are not clear. (Glassy Fultz was a selection of the American variety Fultz imported by the Japanese Government in 1887.[11])[12]

The Fultz-Daruma progeny were then used to make two other critical crosses with two related American varieties: (1) Fultz-Daruma with Turkey Red [13]; and (2) (Aka-Daruma x Glassy Fultz) with Kanred. (Kanred was selected from Crimean, which is a strain of Turkey.) This process is depicted in figure 2.1.

- The first cross was made at the Ehime Prefectural Agricultural Experiment Station in 1925. Seed from the initial cross was planted at the Konosu Experiment at the farm of the National Agricultural Station in 1926. Seed was subsequently sent to the Iwate Prefectural Agricultural Experiment Station. A semidwarf selection, Tohoku No. 34, developed from the seventh generation in 1932, was particularly promising. Following further testing, it was named Norin 10 and registered and released in October 1935. The stem of Norin 10 was particularly short—52-54 cm. Norin 10 was, in turn, used in breeding programs in Japan, the United States, and Mexico. Shiro-Daruma also was used at the Iwate station to breed Norin 1 in 1929 and Norin 6 in 1932.

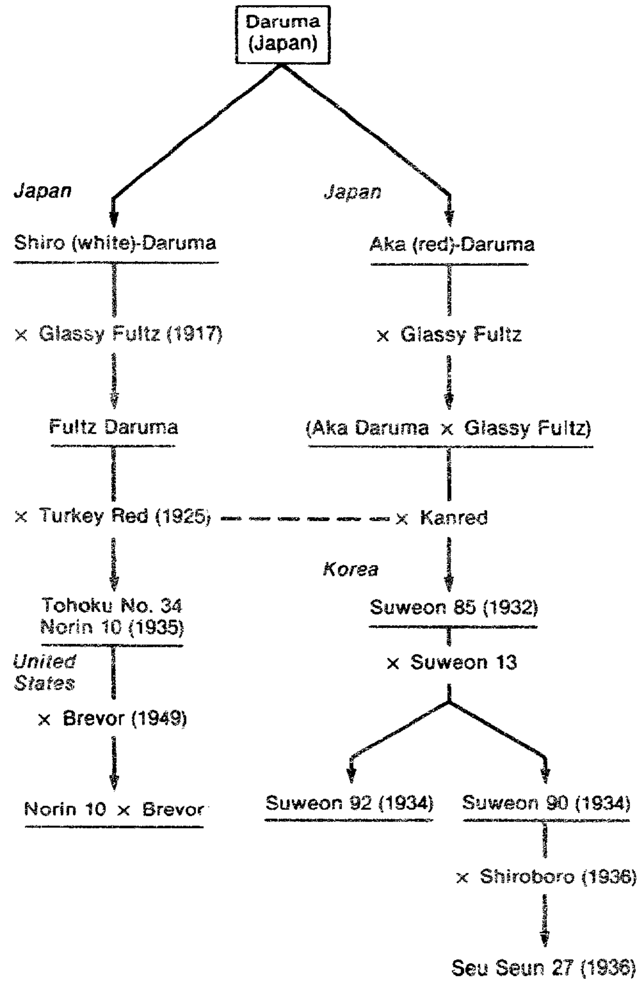


Figure 2.1. Genealogy of Norin 10, Suweon 92, and Seu Seun 27 semidwarf wheat varieties. Kanred was selected from Crimean, which is a strain of Turkey. Source: Information provided by T. Gotoh of Japan and Chang Hwan Cho of South Korea.

- The second cross was made at the Rikuu Branch Station (Omagari, Akita Prefecture) in Japan. The F_3 seeds were sent to Korea where Suweon 85 was developed; it was released in 1932. Suweon 85 was then crossed with Suweon 13 to produce Suweon 92 and Suweon 90, which were released to farmers in 1934. Suweon 90 was crossed with Shiroboro (from Japan) at the Seu Seun Branch Experimental Station in 1936 to produce Seu Seun 27, which was not released but was used for breeding.

Although Norin 10 was to become the major source of dwarfism in the world, Seu Seun 27 also has been extensively used in the United States. Suweon 92 had more limited use. In Japan Norin 10 was never grown widely. It was often used as a source of semidwarfism in crosses, but no superior varieties were obtained.

ITALIAN VARIETIES

In 1911 seed from some of the short-straw, early maturing Japanese wheat varieties was acquired by Ingegnoli, an Italian flower seed producer. He provided the wheat seed for Nazareno Strampelli at the Royal Wheat Growing Experimental Station at Rieti. Strampelli started using the Japanese varieties in his breeding programs in 1912.[14]

Strampelli was interested in developing wheat plants that would be both early maturing and resistant to lodging. Early maturity was desired for an increased resistance to blast—or stretta (wilting under hot wind stress)—and rusts. Resistance to lodging, obtained through shorter and thicker stems, was desired so fertilizer applications could be increased. These goals (aside from stretta resistance) were similar to those of later breeding programs and were largely accomplished.[15]

Of the several Japanese varieties used by Strampelli, Akakomugi appeared to be the most important. In 1913 it was crossed with Wilhelmina Tarwe × Rieti (a cross involving Dutch and Italian varieties originally made in 1906), producing two lines: *m.* 67 and 21 *ar.* The former was a parent of Villa Glori (1918) and other well-known varieties. The latter was a parent of, among others, Ardito (1916) and Mentana (1918).[16]

Ardito was the first variety to attain wide use. It had short straw (70-80 cm) and early maturity. By 1926 it accounted for nearly all of the 500,000 ha planted with early maturing varieties in Italy.[17] Ardito also was grown in other areas of the world and became one of the progenitors of improved Argentine varieties and of the Russian winter variety Bezostaya.[18]

Mentana, the second major variety, differed from Ardito in that it had earlier maturity and a longer stem (90-100 cm). Mentana attained international popularity due to its resistance to yellow rusts. Its genetic traits were bred into Frontana (Brazil) and Kentana (Mexico). Mentana also was one of the three varieties that had a key role in the Mexican wheat breeding program in the 1940s.[19]

As a result of a wheat campaign in Italy, an estimated 1,261,000 ha of early-maturing wheats were grown by 1932. This represented 25.4% of the total wheat area in Italy.[20] The typical varieties raised during the 1930s (such as Mentana) were taller than those used in the 1920s (such as Ardito). Subsequent breeding efforts placed increased emphasis on breeding a shorter stem, and the height of most varieties ranged from 65 to 85 cm. Some varieties had stems less than 40 cm.[21]

Italian varieties are grown in several DCs in the Mediterranean region, particularly Morocco, Algeria, and Turkey. Italian and Japanese varieties were used in early breeding work in Tunisia.[22] Italian varieties also are used widely in southeastern Europe and in China.

The Italian varieties are generally early maturing and have relatively short stems, but their plant type differs from the Mexican wheats. In some varieties the straw is stiff and brittle with a completely upright head, in contrast to the more flexible Mexican-type straw.

MEXICAN VARIETIES

In 1946 S. C. Salmon, a U.S. Department of Agriculture (USDA) scientist acting as agricultural advisor to the U.S. Army in Japan, noticed Norin 10 growing at the Morioka Branch Research Station in northern Honshu. Salmon brought 16 varieties of this plant type to the United States. They were grown in a detention nursery for a year and then made available to breeders.

Although Norin 10 was not satisfactory for direct use in the United States, it was useful for breeding.[23] Orville A. Vogel, a USDA scientist stationed at Washington State University, was the

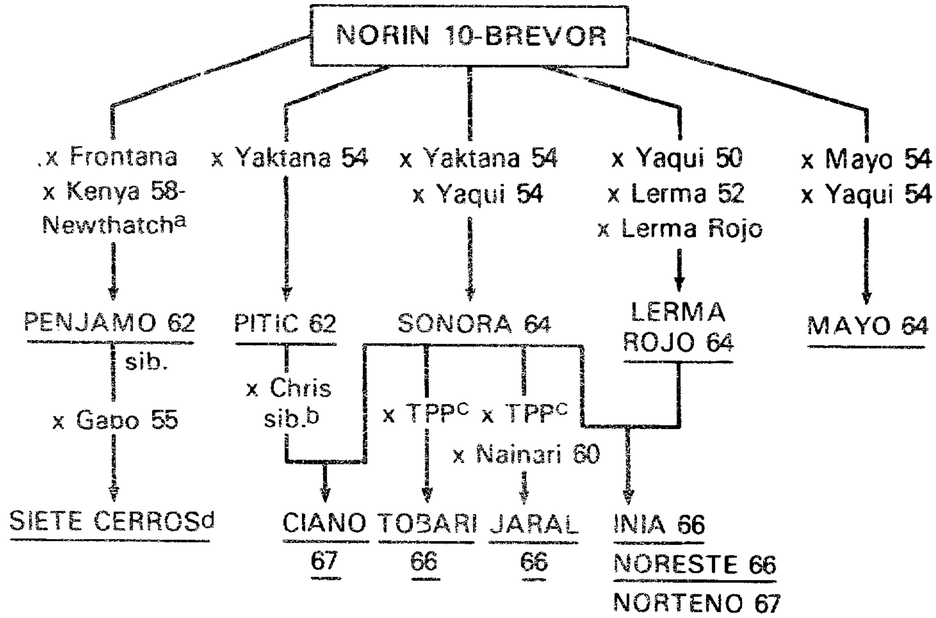


Figure 2.2. Genealogy of early semidwarf CIMMYT wheat varieties. Presentation of some of the more complex crosses is simplified for graphic purposes. [a]Frontana x Kenya-Newthatch was bred in Minnesota. [b]From Minnesota. [c]Tezanos Pintos Precos (TTP) is from Argentina. [d]Also known as cross 8156.

first to recognize its worth and to use it in a breeding program in 1949. Crossing Norin 10 with American varieties involved some problems, but a number of semidwarf lines eventually were developed. A cross of Norin and Brevor was to become particularly important.[24]

In the interim, word about the short-strawed germ plasm had reached Norman Borlaug in Mexico.[25] Wheats in his breeding program had reached a yield plateau because of lodging under high levels of nitrogen fertilization. In his words:

> We had recognized the barriers in our search for a usable form of dwarfness to overcome this problem until the discovery of the so-called Norin dwarfs. In 1953 we received a few seeds of several F_2 selections from the cross Norin 10 x Brevor from Dr. Orville Vogel. Our first attempts to incorporate the Norin 10 x Brevor dwarfness into Mexican wheats in 1954 were unsuccessful. . . . A second attempt in 1955 was successful and immediately it became evident that a new type of wheat was forthcoming with higher yield potential.[26]

The introduction of the Norin 10 genes led to the development of a number of improved Mexican semidwarf bread wheat varieties: Pitic 62, Penjamo 62, Sonora 63, Sonora 64, Mayo 64, Lerma Rojo 64, Inia 66, Tobari 66, Ciano 67, Norteno 67, and Siete Cerros.[27] In addition a semidwarf durum, Oviachic 64, was developed. (The number after each varietal name indicates the year of introduction.) The genetic origins of these early semidwarf varieties are depicted in figure 2.2.[28]

International diffusion of Mexican varieties was rapid at the experimental level. The first Mexican wheats arrived in India in 1962 via the international rust nursery system. They caught the eye of M. S. Swaminathan of the Indian Agricultural Research Institute (IARI). In March and April of 1963 and at the request of IARI, Borlaug toured wheat areas in India. Upon his return to Mexico he dispatched 100 kg of each of four varieties (Sonora 63, Sonora 64, Lerma Rojo, and Mayo) and small samples of 613 other selections. The material was grown and studied at seven locations during the 1963-64 season as part of the All-India Coordinated Wheat Trials.

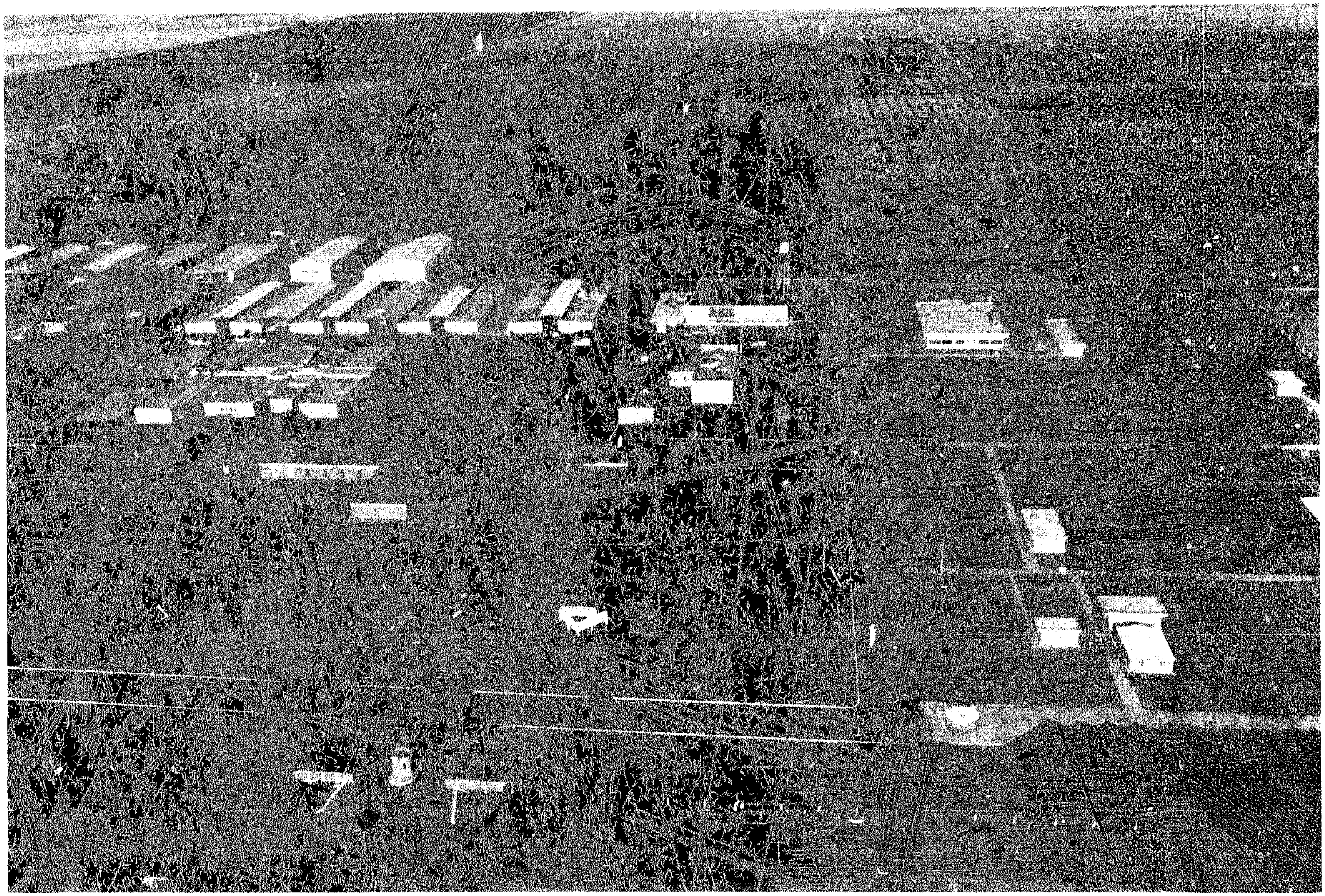


Figure 2.3. The CIANO experiment station of the National Institute of Agricultural Research in Ciudad Obregon, Sonora, Mexico. CIMMYT conducts its winter season research at this station where most of the Mexican semidwarfs were originally crossed. (Background on this station is provided in "Patronato of Sonora," *CIMMYT Today*, No. 16 [1985].)

In 1965 Lerma Rojo and Sonora 64 were released for general cultivation. Subsequently, the Government of India purchased 250 t of Mexican seed for planting during the 1965-66 season and 18,000 t for the 1966-67 season.[29]

In the spring of 1962 Borlaug gave some of the improved seeds to two trainees from Pakistan. The seeds subsequently were planted at the Agricultural Research Institute near Lyallpur. Borlaug visited Lyallpur in the spring of 1963 on the way back from India and upon his return to Mexico sent 205 kg of experimental seed. Borlaug visited Pakistan in the spring of 1964 and secured governmental support for the new varieties. Pakistan purchased 350 t of Mexican seed for planting during the 1965-66 season and 42,000 t for the 1967-68 season.[30]

The Mexican varieties proved remarkably well adapted to India and Pakistan. The reasons for this were explained by Rao:

- They had been bred in Mexico with alternate generations in different climatic and daylength regimens, primarily to produce two generations per year. A valuable additional effect of this system was to establish a good degree of insensitivity to photoperiod.
- Selection for disease resistance also had been practiced, and the stocks introduced showed a remarkable level of resistance to Indian diseases.
- A further important feature of the original stocks was their diversity. They had not been bred to pure-line standards, and there remained in them a reservoir of genetic potential that Indian wheat breeders were quick to exploit.[31]

The Mexican varieties and lines quickly spread to other developing nations. A full listing of the semidwarf bread wheat varieties named in various countries, together with the cross and pedigree of each, has recently been issued by CIMMYT in its publication by R. Villareal and S. Rajaram, *Semidwarf Bread Wheats: Names; Parentage; Pedigrees; Origin*, 1984. The report also includes a summary of cultivars with common origins and lists all the varieties that trace their origin to a common cross. Cross 8156 was the best-known early example (table 2.1), but there have been many others.

The development of new varieties in Mexico by CIMMYT is conducted in cooperation with

Table 2.1. Names used for cross 8156 in 1975

Name	Country
Red-seeded selection	
Super X	Mexico
Siete Cerros Rojo	Mexico
PV-18	India, Pakistan
PV-18A	India
V-18	India
Indus 66	Pakistan
Mexipak Red	Saudi Arabia, Lebanon
MR 548	India
NP 323	India
CB 90	India
PM 17	India
White-seeded selection	
8156 Blanco	Mexico
Siete Cerros 66	Mexico
Siete Cerros	Mexico
7 Cerros 66	Mexico
V-17	India
S-227	India
Sona 227	India
HD 1593	India
HD 1592	India
Kalyansona	India
Kalyansona 227	India
Kalyan 227	India
Mexipak	Pakistan, Iraq, Syria
Mexipak White	Lebanon
Mexipak-65	Egypt, Lebanon, Pakistan
Mexipak-69	Pakistan
Mexi-Pack	Iraq
Sidi Misri 1	Libya
Laketch	Ethiopia
Mivhor 1177	Israel
Hazera 1177	Israel
Bakhtar	Afghanistan

Sources: "Worldwide Use of CIMMYT Bread Wheat Germ Plasm," in International Maize and Wheat Improvement Center, *CIMMYT Review, 1975* (Mexico City: the Center, 1975), p. 98. For similar, but less extensive, information on other crosses, *see* R. Villareal, and S. Rajaram, *Semidwarf Bread Wheats: Names, Parentage, Pedigrees, Origin* (Mexico City: International Maize and Wheat Improvement Center, 1984), pp. 29-31.

the National Institute of Agricultural Research (INIA), and varieties are released by the Mexican government. The wheat varieties—both bread and durum—that have been released in Mexico in recent years are listed in tables 2.2 and 2.3 along with information on plant height and yield potential. Many of these varieties are mentioned again in chapter 3. Four more bread wheat varieties are under consideration for release in 1985.

Many of the varieties released by the Mexican government are, of course, used in other nations, but CIMMYT does not view the development of finished varieties as its main purpose: rather it provides improved lines to national programs, which in turn tailor them to the local environment.

Details of CIMMYT's wheat breeding program are reported in its annual publications *Research Highlights* and *Report on Wheat Improvement*, and no attempt is made to summarize them here. One development, however, should be noted—the development of spring x

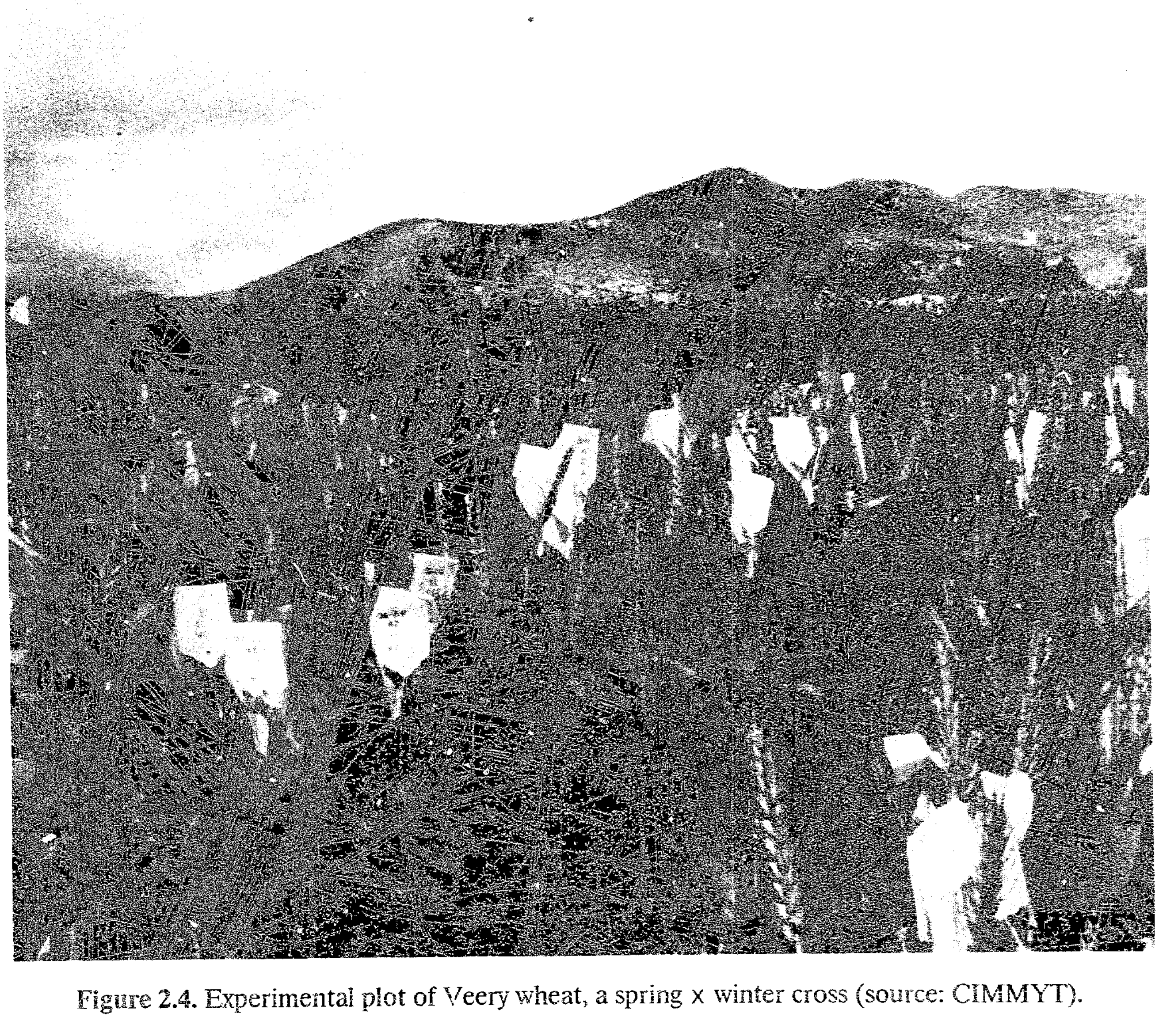


Figure 2.4. Experimental plot of Veery wheat, a spring x winter cross (source: CIMMYT).

Table 2.2. Selected bread wheat varieties released in Mexico from 1950 to 1985

Mexican release (yr)	Variety name[a]	Plant height (cm)	Yield potential[b] (kg/ha)	Grain color
1950	Yaqui 50	115	3500	Red
1960	Nainari 60	110	4000	Red
1962	Pitic 62	105	5870	Red
1962	Penjamo 62	100	5870	Red
1964	Sonora 64	85	5580	Red
1964	Lerma Rojo 64	100	6000	Red
1966	INIA 66	100	7000	Red
1966	Siete Cerros 66	100	7000	Amber
1970	Yecora 70	75	7000	Amber
1971	Cajeme 71	75	7000	Red
1971	Tanori 71	90	7000	Red
1973	Jupateco 73	95	7500	Red
1973	Torim 73	75	7000	Amber
1975	Cocoraque 75	90	7000	Red
1975	Salamanca 75	90	7000	Red
1975	Zaragoza 75	90	7500	Red
1976	Nacozari 76	90	7500	Amber
1976	Pavon 76	100	7000	Amber
1977	Pima 77	90	7000	Amber
1977	Hermosilio 77	85	7500	Red
1977	Jauhara 77	90	7500	Red
1979	CIANO 79	90	7500	Red
1979	Imuris 79	90	7500	Amber
1979	Tesia 79	90	7500	Red
1981	Glennson 81	90	8000[c]	Red
1981	Genaro 81	90	8000[c]	Red
1981	Ures 81	90	8000[c]	Red
1981	Tonichi 81	90	7500	White
1981	Sonoita 81	75	7500	White
1982	SERI 82	85	8000	White
1985	Opata 85	90	7500	Red

[a]Varieties were bred by CIMMYT and the National Institute of Agricultural Research in Mexico (INIA) or a predecessor organization.

[b]Measured at experiment stations in Mexico. Varieties were irrigated under conditions of high soil fertility and were essentially disease free.

[c]Yields of varieties released between 1976 and 1982 have had a range of 7500-8600 kg/ha in different seasons and trials.

Sources: International Maize and Wheat Improvement Center, *CIMMYT Review, 1982* (Mexico City: the Center, 1982), p. 65; and personal communication with B.C. Curtis and A. Klatt, Wheat Program, CIMMYT, September 1984 and December 1985.

winter bread wheat crosses. The purpose of this research is to transfer certain desirable characteristics of each type to the other. The research is in cooperation with Oregon State University. (Oregon's participation has been sponsored by the Agency for International Development.)

CIMMYT has focused on the transfer of certain winter wheat characteristics to spring wheats. Several outstanding lines have been developed: Veery "S," Bobwhite "S," and Alondra "S." Veery lines are being selected and used in a number of national wheat breeding programs, and they are generally considered to be outstanding; Alondra is showing excellent adaptation to acidic soils, and Bobwhite is showing excellent resistance to *Septoria tritici*.[32]

Most of the wheats discussed to this point have been bread wheats. However, considerable research by CIMMYT and cooperating agencies has incorporated the Norin 10 dwarfing characteristics (as well as other features) into improved durum varieties. This work began in Mexico in the 1950s, and in 1965 the first semidwarf durum (Oviachic) was released. Other releases are noted in table 2.3. Although the Mexican bread wheats were initially substituted for durum wheats in some regions in the Near East, this situation is being reversed with the introduction of improved durum varieties. There is thought to be substantial potential for further yield improvement in durums.[33]

SOURCES OF DWARFISM

The key physiological characteristic of HYWVs is their short stature. This has increased their harvest index and reduced lodging. Many other plant characteristics play a role in determining yield, but to date, height has clearly been a decisive one.[34]

Short stature can be caused by the influence of several genes (polygenes) or by a major gene or genes. It is not always possible to tell which influence is at work simply by observing a plant. In the case of semidwarf wheat, however, the shortness of essentially all of the varieties can be traced to one or more major recessive genes.

A number of semidwarfing genes have been identified or suggested for classification. The presently known list of reduced height (*Rht*) genes and their major characteristics is outlined in table 2.4. Of the 18 genes, 7 occur naturally and 11 were modified by induced mutation. Only four of the natural genes have provided the semidwarf source for virtually all of the semidwarf varieties in commercial use in the world: *Rht1*, *Rht2*, *Rht8*, and *Rht9*. Some of the remaining genes are of limited commercial use; others are more of scientific interest.

As noted in table 2.4, *Rht1* and *Rht2* come from Norin 10 and in turn are derived from Daruma. These genes have been known for some time and have been rather thoroughly studied.

Table 2.3. Selected durum wheat varieties released in Mexico from 1960 to 1979

Mexican release (yr)	Variety name[a]	Plant height (cm)	Yield potential[b] (kg/ha)
1960	Tehuacan 60	155	3,340
1965	Oviachic 65	80	4,350
1967	Chapala 67	90	5,680
1969	Jori C 69	85	6,330
1971	Cocorit 71	85	6,290
1975	Mexicali 75	90	7,160
1979	Yavaros	95	7,180
1984	Altar 84[c]	95	8,200

[a]Varieties were bred by CIMMYT and INIA or a predecessor organization.

[b]Measured at Ciano Experiment Station under good agronomic conditions and practices.

[c]Known as Gallareta S prior to release.

Sources: Letter from B.C. Curtis, CIMMYT, September 1984; and personal communication with A. Klatt, CIMMYT, May 1985.

Table 2.4. Reduced height (semidwarf) genes in wheat

Reduced height gene	Chromosome location[a]	Variety origin[b]	GA_3 response[c]	Dominance of gene[d]	Use in breeding[e]	Comments
		Numbered genes				
Rht1	4A[f]	Norin 10 (Daruma)	I	Partially dominant	Widest	A
Rht2	4D(s)	Norin 10 (Daruma)	I	Partially dominant	Widest	
Rht3	4A[f,g]	Tom Thumb	I	Semidominant	Doubtful	B
Rht4	Unknown	Burt (m)	S	Recessive	Doubtful	C
Rht5	Unknown	Marfed M1 (m)	S	Semidominant	Doubtful	
Rht6	Unknown	Burt (Brevor)	S	Recessive	Probably wide	D
Rht7	2A[h]	Bersee (m)	S	Recessive	Doubtful	E
Rht8	2D[h]	Sava (Akakomugi)	S	Recessive	Moderate	F
Rht9[i]	7B(s)	Mara (Akakomugi)	S	Recessive	Moderate	G
Rht10	4D(s)[j]	Ai-bian 1	I	Semidominant[k]	Uncertain	H
		Unnumbered genes[l]				
Karlik 1	Unknown	Bezostaya (m)	S	Recessive	Some	
Karcag 522M7K	Unknown	Karcag 522 (m)	S	Strongly dominant	Uncertain	
Magnif 41M1	Unknown	Magnif 41 (m)	S	Partially dominant	Uncertain	
Castelporziano[m]	Unknown	Cappelli (m)	S	Semidominant	Some	I
Durox[m]	Unknown	K6800707 (m)	S	Partially dominant	Promise/some	J
Edmore M1[m]	Unknown	Edmore (m)	S	Partially dominant	Promise	
Chris M1	Unknown	Chris (m)	S	Recessive	Uncertain	
Ankinga M1	Unknown	Ankinga (m)	S	Partially dominant	Promise	

Comments:

A. Also used as a source of dwarfism in durum and triticale varieties.

B. Source of extreme dwarfism. No commercial use, but may be useful in triticale, hybrid wheat, or as a means of controlling sprouting damage. (Gale)

C. Also carries *Rht6* derived from Brevor. No commercial use as yet. Coleoptile length not reduced.

D. A "minor" gene carried in all Burt materials; it has comparably smaller effect than *Rht1* or *Rht2*.

E. Has a negative effect on yields and probably little or no potential for breeding.

F. Produces greater height reduction than *Rht1* or *Rht2*. (Gale)

G. Probably transferred to Italian durum varieties Jucci, Montanari, and Ringo from bread wheat varieties Fortani or Acciaio.

H. Produces more severe dwarfism than *Rht3* according to Gale; Konzak rates dwarfing effect comparable to *Rht3*.

I. Most significant derivative is Grandur; was also used to develop Attila, Augusto, Miradur, and Tito.

J. Released as a variety in the United States (Idaho) in the early 1980s and in France in 1980 (as Cargi Durox).

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[a](s)=located on short arm of chromosome.

[b](m)=induced mutant; some sources of other varieties noted in parentheses.

[c]I=GA_3 (Gibberellic acid 3) insensitive; S=GA_3 sensitive.

[d]Terminology used by Konzak. Approximately equivalent terminology used by Gale is: Partially dominant (K)=incompletely recessive (G); semidominant (K)=partially dominant (G).

[e]As judged by Konzak. Doubtful=little use unless modified by additional genes; some=recent use for several varieties; promise=good potential; uncertain=promise, but still under investigation—modification seems possible. Rating for Durox suggested by Gale.

[f]Homoeologous to 4D(s). (Gale)

[g]Allelic with *Rht1*. (Gale)

[h]Unmapped.

[i]"*Rht9* has still not been demonstrated to be a single gene; its effect is seen only . . . on 7B(s) from Mara" (personal communication with Gale).

[j]A reduced height gene is also found on chromosome 2A (W. Yucheng, X. Xiuzhuang, T. Guoshun, and W. Qiuying, ["Monosomic analysis of plant height in wheat, Ai ban No. 1] [Chinese with English summary], *Acta Agronomica Sinica* 8[3] [1982]:198.

[k]Classified by Gale as dominant.

[l]Konzak has proposed that the genes listed below be called *Rht11* to *Rht16*, respectively, but no action has been taken.

[m]Durum.

Source: C.F. Konzak, *Mutations and Mutation Breeding*, Wheat Monograph (Madison, Wisc.: American Society of Agronomy, in press), table 3; letters from C.F. Konzak, May and June 1984; M.D. Gale and S. Youssefian, "Dwarfing Genes in Wheat" in *Progress in Plant Breeding*, ed. G.E. Russell, vol. I (London: Butterworths, 1985), pp. 1-35, especially pp. 7-17; and letters from M.D. Gale, March and November 1984.

They are found in virtually all of the semidwarfs grown in DCs (including some varieties in China) and in many of the developed nations (including the United States).

The other two major genes, *Rht8* and *Rht9*, are found, respectively, in the varieties Sava (Yugoslavia) and Mara (Italy), which are derived from Akakomugi, as noted earlier. Akakomugi is found in the ancestry of many Italian varieties and in the pedigree of numerous varieties grown elsewhere in the Mediterranean area, southern and eastern Europe, and China. Although Akakomugi and some of its offspring have long been recognized as dwarfing sources, it was not known until recently that its dwarfing genes are different from those in Norin 10.

Rht1 and *Rht2* appear, when found in bread wheat, individually and in combination. Norin 10 contains both genes, as do some other varieties:

- in Mexico (CIMMYT), Cajeme 71, Saric, Torim 73, Vicam, and Yecora;
- in India, HD 1949 and UP 301;
- in Africa, Gwebi, Limpope, and Ngezi; and
- elsewhere, D 6301 (USA), UC2 (Chile), Norin 2 (Japan), Courtot (France), and Barkaee (Israel).

Generally, however, only one or the other gene is found (and, in the case of durum, only *Rht1*[35]).

Varieties grown in Mexico that have both *Rht1* and *Rht2* seem to be shorter than other varieties that have just one or the other. The average height of three (Cajeme 71, Torim 73, and Yecora 70) was reported as 75 cm, compared to average heights of 85 to 105 cm for varieties with a single *Rht* gene. One rather peculiar variety is Oleson's Dwarf, which is thought to contain *Rht1* and *Rht2* plus a third as-yet unidentified gene (possibly *Rht8* or *Rht9*).[36]

The other naturally occurring genes are *Rht3*, *Rht6*, and *Rht10*. *Rht3*, known for some time, has traditionally been found in Tom Thumb (Tom Pouce);[37] it also occurs in Minister Dwarf. Because of its rather strong dwarfing effect, and apparent links to some undesirable traits, *Rht3* has not been widely used, but it is listed as a parent of the Mexican varieties Tordo and Topo and of the breeding line D 6899. *Rht10* is a relatively recent designation and is found in the Chinese variety Ai-bian I; its potential use in breeding programs is uncertain.[38] An extremely short variety was obtained by an American wheat scientist in central China in 1981; it was reported to have come from Tibet and is known as Tibetan Dwarf. Its genetic source of dwarfism is unknown.[39]

A number of induced mutations have been produced (see column 3 of table 2.4) that show varying degrees of promise. While the prospects of finding additional natural sources of semidwarfism are probably slim, induced mutations are a promising source. Some semidwarf wheat varieties have already been produced from induced mutations in developing nations, but it is not clear if they have different dwarfing genes.[40]

One point that should be kept in mind is that semidwarfism is not always an unmixed blessing. Individual genes may carry multiple effects (pleiotropy), some of which may be favorable with respect to yield and some of which may be unfavorable in terms of quantity or quality of overall yield. *Rht1* and *Rht2* seem to have a positive effect on yields even in the absence of lodging but may have a negative effect on protein. *Rht3*, *Rht4*, and *Rht7* are more apt to carry unfavorable effects.

It would be beneficial to broaden the genetic basis of semidwarfism. The present heavy reliance on just a few genes, while not critical, is not desirable. Other sources are known but not yet widely used. Additional sources need to be discovered or developed through induced mutations.

REFERENCES AND NOTES

[1]G. Hambidge and E.N. Bressman, "Better Plants and Animals–Foreword and Summary" in U.S. Department of Agriculture, *Yearbook of Agriculture, 1936* (Washington, D.C.: the Department, 1936), p. 132.

[2]Based on C.M. Destler, "Forward Wheat for New England: The Correspondence of John Taylor of Caroline with Jeremiah Wadsworth, in 1795," *Agricultural History* 42 (1968):201-205; and "The Gentleman Farmer and the New Agricul-

ture: Jeremiah Wadsworth," *Agricultural History* 46 (1972):145-147. Also noted in E.L. Jones, "Creative Disruptions in American Agriculture, 1620-1820," *Agricultural History* 48 (1974):523-524.

[3]H. Capron, "Agriculture in Japan" in *Report of the Commissioner of Agriculture for the Year 1873* (Washington, D.C.: U.S. Department of Agriculture, 1874), p. 369.

[4]"Séance du 5 Juillet 1867," *Bulletin de la Société d'Acclimatation* (Paris: the Society, 1867), pp. 453, 702-703, 784. Subsequently, a Mr. Ramel claimed that he first drew attention to early Japanese wheat in 1862 and attempted to introduce it, but apparently he was unable to obtain seed samples (*Bulletin de la Société d'Acclimatation* [1869], p. 168).

[5]H. Vilmorin, "Blé Précoce du Japon" in *Les Meilleurs Blés* (Paris: Vilmorin-Andrieux, 1880), pp. 120-121. Vilmorin-Andrieux was one of the leading seed firms of France. The varieties also were noted in another Vilmorin-Andrieux publication, *Catalogue Méthodique et Synonymique des Froments* (Paris: Vilmorin-Andrieux, 1889), pp. 18, 36, 39.

[6]Letter from P. Martin, Union des Cooperatives Agricoles des Céréales (UCOPAC), Verneuil l'Etang, France, March 1976. (UCOPAC acquired the cereals branch of the Vilmorin-Andrieux firm.) Martin noted that, while the variety was short by the standards of the late 1800s, it would no longer be considered so. He provided samples of the seed to the Agricultural Research Service (ARS), USDA, in 1976 (Plant Investigation [PI]-409010).

[7]This section is based on a letter from T. Gotoh, wheat breeder, Tohoku National Agricultural Experiment Station, Morioka, Japan, October 1975. *See* S. Takeda, *Mugisaku Shinsetsu* [New Technique of Wheat Cultivation] (1929).

[8]A Korean wheat researcher has suggested that Daruma was selected from a Korean variety known as Anzunbaengimil ("crippled wheat" in Korean) or Nanjangmil, which was distributed throughout Korea during the period from 1500 to 1941. Anzunbaengimil reportedly exhibited great variations in plant height; it was presumably a mixture of individuals carrying different combinations of semidwarf genes. It may have been disseminated to Japan during the period of the Japanese invasion about 1592. C.H. Cho, B.H. Hong, M.W. Park, J.W. Shim, and B.K. Kim, "Origin, Dissemination, and Utilization of Wheat Semidwarf Genes in Korea" (Korean, with English summary), *Korean Journal of Breeding* 12(1) (1980):1-12; and "Origin, Dissemination, and Utilization of Wheat Semidwarf Genes in Korea," *Annual Wheat Newsletter* 27 (1981):67. Also, Daruma was 1 of 1,000 wheats studied by the USDA from 1895 to 1897 and 1 of 245 briefly listed by Carleton; he noted, "The earliest ripening wheats are often dwarfed and come principally from India, Australia, and Japan" (M.A. Carleton, *The Basis for Improvement of American Wheats,* Bulletin No. 24 [Washington, D.C.: U.S. Department of Agriculture, Division of Vegetable Physiology and Pathology, 1900], pp. 46, 47, 62-63.)

[9]It is not certain whether white and red (brown) strains existed before 1910 but were not distinguished in the terminology or whether some sort of pure-line selection was made. Systemic pure-line selections of Shiro-Daruma and Aka-Daruma were made in the 1920s, and the varieties were in use through the 1930s (letter from T. Gotoh, February 1978).

[10]The official records simply list Daruma; the use of Shiro-Daruma is suggested by Inazuka (*see* footnote 12), p. 25; and Matsumoto (*see* footnote 12), p. 23.

[11]Fultz was first selected in Kansas in 1862. It was imported by the Japanese Government in 1887. For details, *see* J.A. Clark, J.H. Martin, and C.R. Ball, *Classification of American Wheat Varieties*, Bulletin No. 1074 (Washington, D.C.: U.S. Department of Agriculture, 1922), pp. 83-85.

[12]This section is largely based on letters from T. Gotoh, October 1975, November 1975, and February 1978; and C.H. Cho, Wheat and Barley Research Institute, Office of Rural Development, Suweon, Korea, March 1978, August 1979, and September 1979. Other references used were: T. Matsumoto, "Norin 10, a Dwarf Winter Wheat Variety," *Japan Agricultural Research Quarterly* 3(4) (1968):22-26; G. Inazuka, "Norin 10, A Japanese Semi-Dwarf Wheat Variety," Technical Report No. 82, Wheat Information Service, Kyoto University, Japan, 1971, pp. 25-30; and L.P. Reitz and S.C. Salmon, "Origin, History, and Use of Norin 10 Wheat," *Crop Science* 18(6) (1968):686.

[13]Turkey Red, better known as Turkey, was introduced in Kansas in 1874 by a group of Russian Mennonites; it later became the leading American variety. For details, *see* J.A. Clark et al., op. cit. (*see* footnote 11), pp. 144-147; and K.S. Quisenberry and L.P. Reitz, "Turkey Wheat: The Cornerstone of an Empire," *Agricultural History* 48 (1974):98-114.

[14]In 1922 Strampelli moved to the National Institute of Genetics as Related to the Cultivation of Cereals in Rome. Biographical material on Strampelli is provided in *Nazareno Strampelli* (Rome: Società Ploesana Produttori Sementi, Ramo Editcriale Degli Agricoltori, 1966), 44 pp.

[15]N. Strampelli, *Early Ripening Wheats and the Advance of Italian Wheat Production* (Rome: Tipografia Failli, 1933), pp. 5-7.

[16]*Origini, Sviluppi, Lavori e Risultati* (Rome: Istituto Nazionale di Genetica per la Ceralicoltura in Roma, 1932), pp. 91, 92, 99-101, appendix. (Actual release dates for farm use were 4 or 5 years later than noted here.)

[17]N. Strampelli, op. cit. (*see* footnote 15), p. 11, maps, and tables.

[18]The full pedigree of Bezostaya 1 is provided in United Nations, Food and Agriculture Organization, *Cereal Improvement and Production* (Near East Project Information Bulletin, Vol. VIII, No. 2-3), 1971.

[19]N.E. Borlaug, "Wheat Breeding and Its Impact on World Food Supply" in *Proceedings of the Third International Wheat Genetics Symposium, Canberra, 1968*, ed. K.W. Finlay and K.W. Shepherd (Canberra: Australian Academy of Sciences, 1968), p. 5. The other two varieties were Florence Aurore (Marroqui) and Gabo.

[20]Strampelli, op. cit. (*see* footnote 15).

[21]M. Bonvicini, "Indirizzi della Genetica Agraria per la Resistenza All'allettamento in *Triticum Vulgare*," *Caryologia* (Supplemento Atti del IX Congrèsso Internazionale di Genetica) (1954), pp. 738-743.

[22]F. Boeuf, "Le Blé en Tunisie," *Annales du Service Botanique et Agronomique* VIII (1932):96-110.

[23]Norin 10, when grown in the United States and Mexico, proved to be daylight sensitive and very susceptible to rusts and produced shriveled or shrunken grain.

[24]Reitz and Salmon, op. cit. (*see* footnote 12), pp. 686-687; L.P. Reitz, "Short Wheats Stand Tall" in U.S. Department of Agriculture, *1968 Yearbook of Agriculture* (Washington, D.C.: the Department, 1968), pp. 236-237; and L.P. Reitz, "New Wheats and Social Progress," *Science* 169 (1970):952-955. Brevor was developed from a cross between Brevon (Turkey/Florenc ,/Fortyfold/Federation) and an unnamed cross of Brevon's parents and Oro. It was developed cooperatively by the USDA and the Washington Agricultural Experiment Station, Pullman, Wash. The original cross was made in 1938, and the variety was released in the fall of 1949. *See* L.W. Briggle and L.P. Reitz, *Classification of Triticum Species and of Wheat Varieties Grown in the United States*, Technical Bulletin No. 1278 (Washington, D.C.: U.S. Department of Agriculture, 1963), p. 64.

[25]The Rockefeller Grain Program in Mexico began in 1943. It was conducted in cooperation with the Office of Special Studies of the Mexican Ministry of Agriculture. In 1959 Borlaug became director of the International Wheat Improvement Project supported by Rockefeller. The program was merged with a comparable corn program in October 1963 to form the International Center for Corn and Wheat Improvement. Work sponsored by the Mexican Government was shifted from the Office of Special Studies to the Mexican National Institute of Agriculture Research in January 1961. (E.C. Stakman, R. Bradfield, and P.C. Mangelsdorf, *Campaigns Against Hunger* [Cambridge, Mass.: Belknap/Harvard University Press, 1967], pp. 5, 12, 273.) For a more personal history of Borlaug's work, *see* L. Bickel, *Facing Starvation: Norman Borlaug and the Fight Against Hunger* (New York: Reader's Digest Press, 1974), 376 pp. *Also see* E.J. Kahn, Jr., "The Staffs of Life: II—Fiat Panis," *The New Yorker*, 17 December 1984, pp. 88-102.

[26]Borlaug, op. cit. (*see* footnote 19), p. 6. Although the Italian variety Mentana was, as noted in the previous section, used in early breeding efforts, it had a long stem and was not in the semidwarf category; it did, however, introduce daylength insensitivity. For further discussion of the use of Mentana, *see* footnote 28 and E.C. Stakman et al., op. cit. (*see* footnote 25), pp. 84-88. (Curiously, this book says very little about the Norin 10 types.) For background on Borlaug's introduction of the Norin 10 x Brevor crosses, *see* Bickel, op. cit. (*see* footnote 25), pp. 198, 208, 209.

[27]N.E. Borlaug, op. cit. (*see* footnote 19), pp. 6-7. Pitic was the first semidwarf variety to be released. Borlaug notes that these varieties did not have an effect on production until 1963.

[28]Mentana was one of the parents or grandparents of several of the varieties crossed with Norin 10/Brevor: Fontana (from Brazil), Lerma 52, Lerma Rojo, and Yaktana 54. It also was a parent of Gabo 60; Kentana 48, 51, and 52; Lerma 50 and 51; and Nainari 60. Florence Aurore, under the name Marroqui, was one of the parents of Yaqui 50, as well as of Mayo 48 and Yaqui 48.

[29]L. Bickel, op. cit. (*see* footnote 25), pp. 243-279; M.S. Swaminathan, Preface to *Five Years of Research on Dwarf Wheats* (New Delhi: Indian Agricultural Research Institute, 1968), pp. i, 3-5; and C.P. Streeter, *A Partnership to Improve Food Production in India* (New York: The Rockefeller Foundation, 1970), p. 12. *Also see* V.S. Vyas, *India's High-Yielding Varieties Programme in Wheat, 1966-67 to 1971-72* (Mexico City: International Maize and Wheat Improvement Center, 1975), pp. 1-9. According to Swaminathan India became interested in fertilizer-responsive varieties in 1957, and Tom Thumb and some Italian semidwarfs were introduced for experimental use; semidwarf winter wheats were introduced from Washington State University in 1959 (Swaminathan, personal communication, October 1985).

[30]L. Bickel, op. cit., (*see* footnote 25), pp. 243-279. Further statistics on seed purchases also are provided in chapter 3. *Also see* J.E. Eckert, "Farmer Response to High-Yielding Wheat in Pakistan's Punjab" in *Tradition and Dynamics in Small-Farm Agriculture*, ed R.B. Stevens (Ames, Iowa: Iowa State University Press, 1977), pp. 149-176.

[31]M.V. Rao, "Wheat" in *Evolutionary Studies in World Crops; Diversity and Change in the Indian Subcontinent*, ed. J. Hutchinson (Cambridge, England: Cambridge University Press, 1974), p. 40.

[32]*CIMMYT 1983 Research Highlights* (Mexico City: International Maize and Wheat Improvement Center, 1983), pp. 16-17.

[33]Background is provided in S.A. Breth, "Durum Wheat: New Age for an Old Crop," *CIMMYT Today*, No. 2 (1975):1-16.

[34]This complex genetic subject is covered only briefly here. The preparation of this section has benefited greatly from extensive correspondence with C.F. Konzak, Department of Agronomy and Soils, Washington State University, and M.D. Gale, Plant Breeding Institute, Cambridge, England. Both individuals kindly loaned me manuscripts that were of great help: C.F. Konzak, M.A. Davis, and P. Ruckerbauer, *Genetic Analysis*, "Genetic Improvement and Evaluation of Induced Semi-Dwarf Mutants–Bread Wheat" (Pullman: Washington State University, 1984); M.D. Gale and S. Youssefian, "Dwarfing Genes in Wheat" in *Progress in Plant Breeding*, ed. G.E. Russell, Vol. I (London: Butterworths, 1985), pp. 1-35. Several previous publications by Gale were also helpful: M.D. Gale and G.A. Marshall, "A Classification of the Norin 10 and Tom Thumb Dwarfing Gene in Hexaploid Wheat Varieties" in Indian Society of Genetics and Plant Breeding, *Proceedings of the Fifth International Wheat Genetics Symposium, New Delhi, February 1978*, ed S. Ramanajam (New Delhi: the Society, 1979), pp. 994-1001; M.D. Gale, C.N. Law, G.A. Marshall, J.W. Snape, and A.J. Worland, "Analysis and Evaluation of Semi-Dwarfing Genes in Wheat Including a Major Height Reducing Gene in the Variety 'Sava'" (Vienna, Austria: International Atomic Energy Agency, 1982), 23 pp.; and M.D. Gale, "Dwarfing Genes," *Annual Wheat Newsletter* 29 (1983):89. *Also see* H. Hanson, N.E. Borlaug, and R.G. Anderson, *Wheat in the Third World* (Boulder, Colo.: Westview Press, 1982), p. 32.

[35]The transfer of Norin 10 dwarfness to durums was made as early as 1956 (M.D. Gale, G.A. Marshall, R.S. Gregory, and J.S. Quick, "Norin 10 Semi-Dwarfism in Tetraploid Wheat and Associated Effects on Yield," *Euphytica* 30 (1981):347. Outside of the *Rht1* and *Rht2* group, we have noted in table 2.4 that several unnumbered genes have been found in durums.

[36]Background on Oleson's Dwarf is provided in D.G. Dalrymple, *Development and Spread of High-Yielding Varieties of Wheat and Rice in the Less Developed Nations,* Foreign Agricultural Economic Report No. 95 (Washington, D.C.: U.S. Department of Agriculture, 1978), p. 23. Oleson's Dwarf has been used as a parent for several varieties developed by private firms in the United States, including some recent hybrids. The germ plasm was obtained from CIMMYT.

[37]Considerable detail on the background of Tom Thumb is provided in D.G. Dalrymple, op. cit. (*see* footnote 36), p. 22.

[38]N. Izumi, S. Sawada, and T. Sasakuma, "Genetic Analysis of Dwarfness in *Triticum Aestirm* L. cv Ai-bian 1," *Seiken Ziho* 31 (1983):38-48. Ai-bian is variously reported to be a mutant of either Ai-Kantsau (which has both Suweon 86 and Villa Glori in its parentage) or Abbondanza (C.T. Liu, University of Idaho, to C.F. Konzak, Washington State University, March 1985; and Q-S. Zhuang, "Acreage of Semi-Dwarf Wheat Cultivars in China," forwarded by Haldore Hanson of CIMMYT, August 1984).

[39]Letters from W. Kronstad, Department of Crop Science, Oregon State University, November 1984; personal communication with W. Kronstad, July 1985.

[40]*See* C.F. Konzak, *Mutations and Mutation Breeding*, Wheat Monograph (Madison, Wisc.: American Society of Agronomy, in press). Durox has been released as a commercial variety in the United States (Idaho) and France (as Cargi Durox). For examples of varieties developed from induced mutations in DCs, *see*: *Mutation Breeding Newsletter* 18 (1981):14-15, 19 (1982):19, and 25 (1985):17-20; and *Mutation Breeding Review* 3 (1985):80-85 (a summary listing).

3. WHEAT VARIETIES AND AREA

The purpose of the wheat breeder is not to produce a single, in all respects ideal, variety, but a series of varieties, each of which is as nearly ideally adapted as possible to the economic conditions of the particular wheat-growing section for which it is designed. There will be work for the wheat breeder for years to come.

—Carl L. Alsberg, 1928[1]

This chapter summarizes information on the development and adoption of HYWVs in 42 DCs in four major regions: Asia, the Near East, Africa, and Latin America and the Caribbean. The importance of wheat production and HYWVs varies widely between nations. The amount of coverage provided here at the country level is not always proportional to the significance of the HYWVs, but it is in part a function of the availability of information.

A few basic facts on wheat production in DCs may help set the stage. While wheat is usually grown in temperate zones, it is also raised under semitropical conditions—usually in upland areas and/or during the cooler winter season. Most of the wheat area in the developing world is found in Asia. In 1983 about 63% of the total DC wheat area was in southern and eastern Asia (including China), 25% in the Near East, 11% in Latin America, and 1% in Africa.[2] For DCs as a whole, roughly 59% of the area is planted with spring habit bread wheat, 30% with winter habit bread wheat (including facultative), and 11% with durum wheat. About 34% of the total DC wheat is grown in irrigated areas, 28% is grown where there is adequate soil moisture, and 37% is grown in semiarid areas where soil moisture may be inadequate.[3]

A large number of HYWVs are grown in DCs. Pedigrees have not been included for most of the wheat varieties but are reported in some cases. Details are, however, provided in the CIMMYT publication by R. Villareal and S. Rajaram, *Semi-Dwarf Bread Wheats: Names; Parentage; Pedigrees; Origin* (1984). The parentage of many older varieties mentioned in this chapter is provided by A. C. Zeven and N. Ch. Zeven-Hissink in *Genealogies of 14,000 Wheat Varieties*, CIMMYT (1976). Information on more recent varieties and on the breeding programs in many of the countries is presented in CIMMYT's annual *CIMMYT Report on Wheat Improvement* (1973 to the present).

International nurseries (testing programs) operated by CIMMYT and the International Center for Agricultural Research in the Dry Areas (ICARDA) in cooperation with national wheat improvement programs provide a vital force in the distribution and testing of improved varieties. In 1982 CIMMYT's nursery program involved 280 cooperators in 100 countries. In 1982-1983 ICARDA's cereal program included 83 cooperators in 42 countries. Entries may come from national programs as well as from the centers.[4] Cooperators provide performance data to CIMMYT and ICARDA, but they are free to use nursery entries in any way that benefits their national programs.

There is increasing interest in expanding the production of HYWVs into (1) some of the warmer areas of DCs presently growing wheat and (2) the climatically favored areas and time periods of some of the tropical nations, particularly in Southeast Asia and Africa. Varieties with improved heat tolerance are especially needed.[5]

ASIA

Most of the Asian wheat area is concentrated in two nations: China and India. In 1983 China had about 30% of the total DC wheat area, and India had about 24%.[6]

The characteristics of production differ somewhat between southern and eastern Asia. This is shown in estimates reported by CIMMYT in 1981.[7] In terms of type of wheat, in southern Asia 95% of the area was planted with spring bread wheat and 5% was planted with durum; in eastern Asia 40% was planted with spring bread wheat, 60% with winter bread wheat, and less than 1% with durum wheat. Moisture environments also differ. In southern Asia 73% of the area was irrigated, 4% had adequate soil moisture (rainfed), and 23% had semiarid soils. In eastern Asia 25% was irrigated, 39% had adequate soil moisture, and 37% was semiarid.

HYWVs found early and intensive use in southern Asia, particularly in India, Pakistan, and Nepal. More recently HYWVs have been increasingly grown in Bangladesh. They are raised widely in China but have followed a somewhat different development path than in southern Asia. Some HYWVs have also been grown in South Korea, and seed has been shipped to Mongolia and Vietnam. (Japan, the home of the basic dwarfing material, is a developed nation and is not included here.)

Southeast Asia is an area of potential growth for HYWVs. Although it is a tropical region, there is an opportunity to raise wheat after rice during the dry, cool winter season, as in Bangladesh. Prospects for expanded wheat production are being examined in Thailand, Burma, the Philippines, Indonesia, and Sri Lanka. CIMMYT has research underway on wheat for more favored tropical areas; they initiated a south and southeast regional program in 1980 with headquarters in Bangkok. A number of technical and economic problems exist, but there are reasonable prospects for progress.[8]

Bangladesh

Wheat was a minor crop in Bangladesh until the mid-1970s when increased emphasis on food production stimulated interest in HYWVs. Research on HYWVs was initiated in 1965 after small quantities of the seed of two Mexican varieties, Sonora 64 and Penjamo 62, were received from Pakistan. Preliminary trials were planted during the 1965-66 and 1966-67 cropping seasons, and research intensified with the implementation of the Accelerated Wheat Research Project in 1970. The expanded Wheat Research Program was launched in 1975 with research taken up by the newly established Bangladesh Agricultural Research Institute. Close cooperation was maintained with CIMMYT.[9]

The expanded program was divided into two categories. A short-term program was aimed at meeting the immediate needs of the country and largely involved testing and selecting imported HYWVs. A long-term program involved identifying selections from advanced breeding lines from CIMMYT and elsewhere and then initiating a systematic crossing program (started in 1978). The emphasis of the long-term program was to develop varieties that are suitable for the various cropping systems of the country and that are resistant to leaf rust and *Helminthosporium* spot blotch.

Because most of the expansion in wheat area was expected to occur in essentially rainfed areas with short growing seasons, emphasis was put on selecting varieties suitable for those areas. Sonalika (from India) and Inia 66 were selected in 1973. For cultivation in irrigated areas with a longer growing season, Tanori 71 and Jupateco 73 were selected in 1975 and Norteno 67 was selected in 1977. Altogether, from 1968 to 1979, eight HYWVs were released for cultivation in different areas of Bangladesh.

Substantial quantities of HYWV seed have been imported. Yearly levels were as follows (in tons): 1972-73, 50; 1973-74, 1,000; 1974-75, 320; 1975-76, 4,075; 1976-77, 500; 1977-78, 2,971; 1978-79, 2,968; 1979-80, 11,475; 1980-81, 33,510; 1981-82, 7,006; 1982-83, 5,689; and 1983-84,

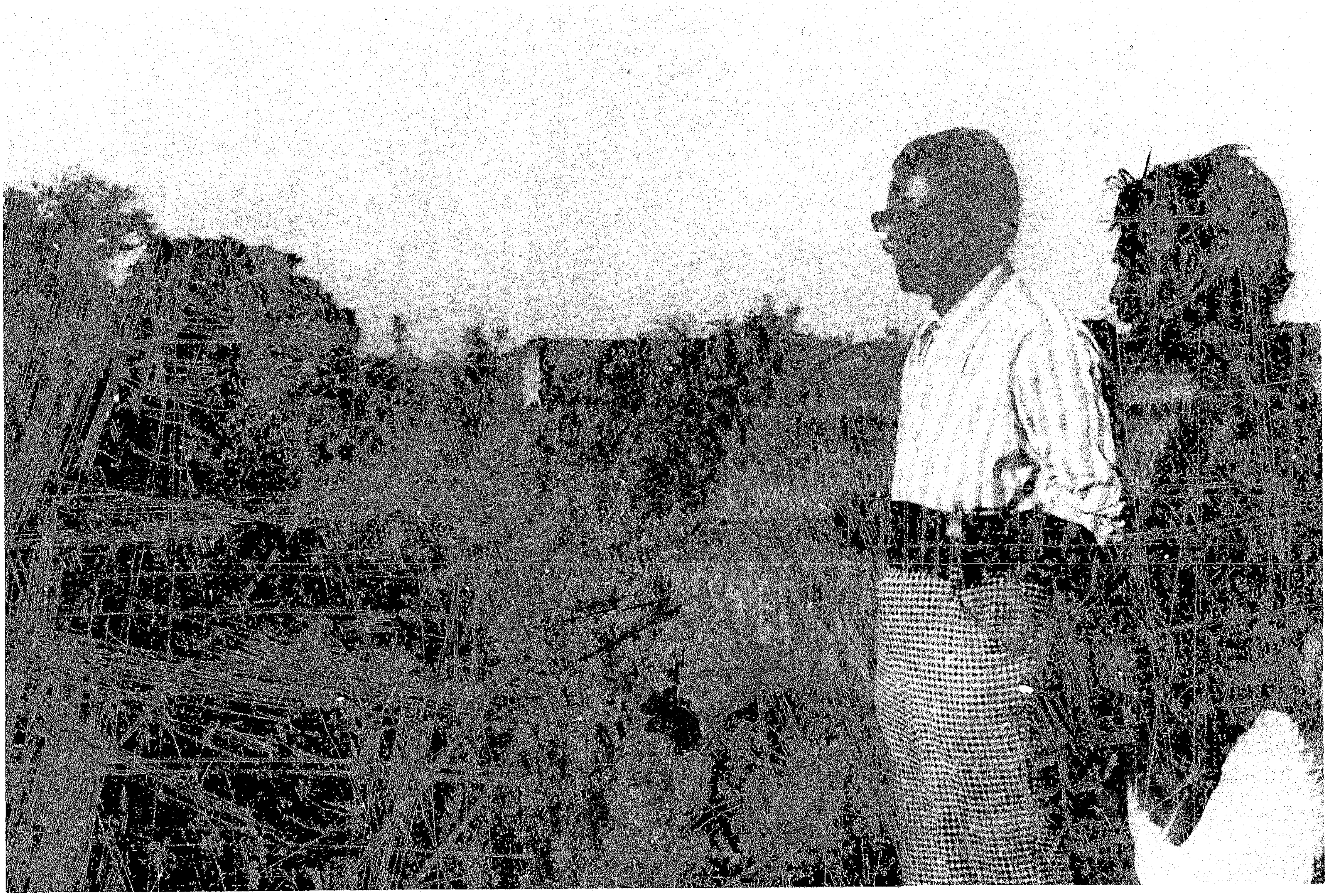

Figure 3.1. Dr. Sufi M. Ahmed, head of the wheat center at the Bangladesh Agricultural Research Institute, and a local farmer examine a field of Sonalika wheat growing next to rice (right) during the winter season.

2,449. The varieties were principally Sonalika and Kalyansona from India and Tanori 71 from Mexico.[10]

In the long-term research program, selection from advanced breeding lines identified the first variety (Balaka) for release in 1979. Four more HYWVs were released in 1983: Akbar, Anada, Barkat, and Kanchan. (The first three originated as CIMMYT lines; the fourth originated in India.) All are semidwarfs. Balaka lodges at higher levels of nitrogen fertilizer, but this is not true of the others. Akbar and Kanchan are considered particularly promising.

New wheat varieties are needed. Despite the various introductions, most of the wheat area is still planted with Sonalika. In 1984 it was estimated that Sonalika represented 70% of the total wheat area. The remaining 30% was divided as follows: India 66, 10%; Tanori 71, 8%; Jupateco 73, 5%; Pavon 76, 4%; Balaka, 2%; and other, 1%.[11] The basic problem with Sonalika is its susceptibility to leaf rust.

Table 3.1. Area of high-yielding wheat varieties in Bangladesh from 1967-68 to 1982-83

Crop year	HYWV area (ha)	Proportion of total area (%)
1967-68	1,200	1.6
1968-69	8,500	7.2
1969-70	9,300	7.7
1970-71	13,400	10.6
1971-72	15,000	12.5
1972-73	21,400	17.9
1973-74	17,400	14.5
1974-75	32,800	26.0
1975-76	87,800	58.6
1976-77	116,100	76.5
1977-78	157,400	83.5
1978-79	235,900	89.1
1979-80	410,400	94.8
1980-81	571,400	96.6
1981-82	516,400	96.7
1982-83	498,200	95.9

Sources: 1967-68 to 1971-72: D.G. Dalrymple, *Development and Spread of High-Yielding Varieties of Wheat and Rice in the Less Developed Nations*, FAER No. 95 (Washington, D.C.: U.S. Department of Agriculture, September 1978), p. 37; 1972-73 to 1981-82: Bangladesh Bureau of Statistics, *Monthly Statistical Bulletin of Bangladesh* (Dhaka: the Bureau, March 1983), p. 31; and 1982-83: Idem, *Monthly Statistical Bulletin of Bangladesh* (Dhaka: the Bureau, July 1984), p. 43.

The overall area planted with HYWVs in Bangladesh expanded sharply through the 1980-81 season and then declined slightly (table 3.1). Expansion of area was particularly rapid after 1974-75. The proportion of the total wheat area planted with HYWVs increased steadily to about 96% in 1980-81 and then leveled off. (Unofficial estimates, however, suggest that the area occupied by local varieties in 1984 did not exceed 1%.) The average yield of the HYWVs increased through 1977-78 and then dropped off slightly. The HYWV yields are about twice those of the local varieties.

While the HYWVs have largely replaced traditional varieties, they also were responsible for the substantial growth in the overall wheat area. With the expansion in both area and yield, production increased roughly 10-fold between 1973-74 and 1980-81. Wheat has become a significant crop in Bangladesh.

Burma

Burma had about 134,000 ha of wheat in both 1983 and 1984. Most of the area is planted with Monya White (IP-4) from India, which is not an HYWV. HYWVs have been introduced for testing, and those with promise include Ciano 79, Genaro 81, and SERI 82. A substantial potential is foreseen for HYWVs. Some may have moved into farm use.[12]

China

Although somewhat overshadowed by its rice production in the popular view, China is a major producer of wheat. It is, in fact, the largest wheat producer among the DCs. Since 1950 China has experienced both growth in the area planted with wheat and extraordinary gains in yields—four and a half times higher in 1984 than in 1950. As a result, wheat production in China has increased nearly sixfold since 1950.[13]

Wheat is produced over a wide range of environments in China, but production practices are

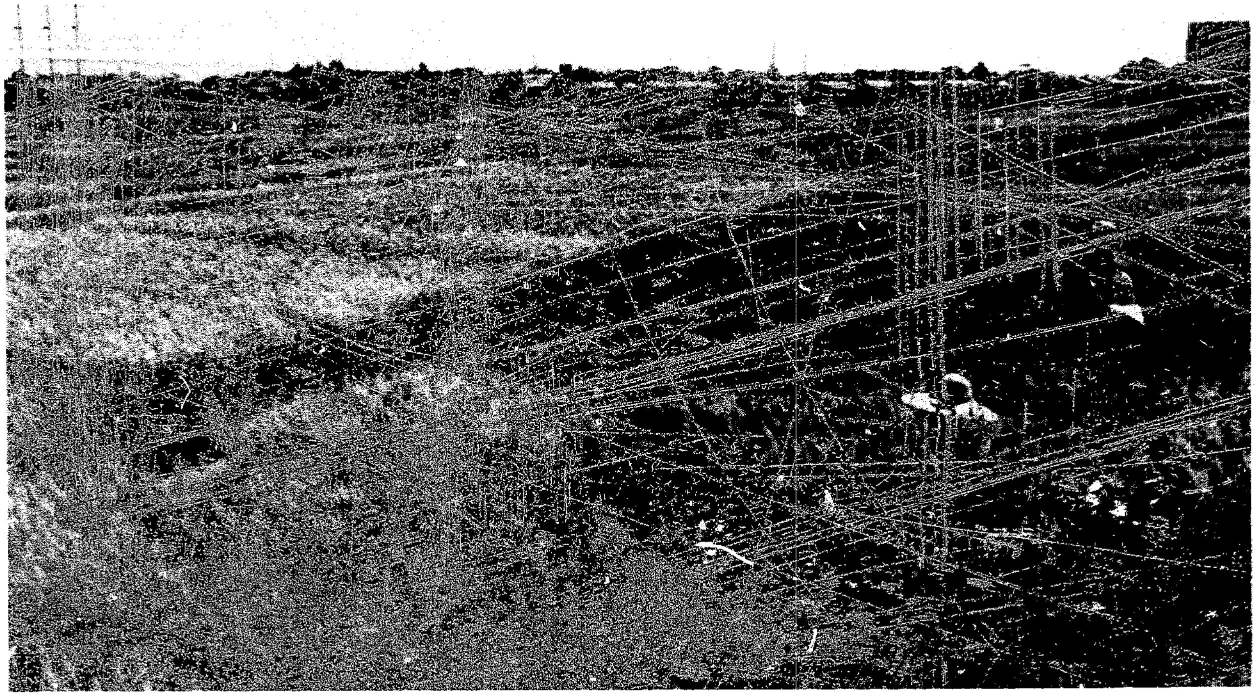

Figure 3.2. Wheat-breeding nurseries of the Institute of Crop Breeding and Cultivation, CAAS, Beijing (source: Q-S. Zhuang, CAAS).

generally intensive; 58% of the wheat is spring habit wheat, 18% is winter habit wheat, and 24% is facultative wheat. (Facultative types and, in milder areas, some spring wheats are fall sown.) About 80% of the area is double cropped, and as a result there is an emphasis on early maturing varieties. Perhaps 50% of the area is irrigated. The use of fertilizer is heavy by DC standards.[14]

Introduction of Mexican Varieties

The Mexican wheats were well known in China at an early date. The first experimental seeds were introduced from Pakistan sometime in 1968 or 1969. Several years of small-scale testing followed in the early 1970s, using seeds from Australia and Pakistan. In 1973 the Chinese Embassy in Mexico sent two staff members to CIMMYT to discuss research work and collect publications.

During the early 1970s, China imported large quantities of Mexican wheat seed: 1972, 2 t; 1973, 5,034 t; and 1974, 14,701 t. The shipments included the following types: Potam, 61.6%; Tanori, 24,7%; Saric, 7.0%; Inia, 3.5%; and Jori, 3.5%. The CIMMYT seeds were purchased mainly for direct planting in the southern provinces, where they were planted in the fall, and in the northeastern provinces, where they were planted in the spring. In the subtropical areas of southern China, wheat was increasingly sown after the late rice crop in the fall. Direct seeding of the Mexican varieties rose to a peak area of about 800,000 ha in the early 1970s, but then it declined sharply.[15]

The attempt to introduce Mexican varieties directly caused several difficulties. The most serious problem in the southern regions was sprouting of the grain in the field when rains occurred during high temperatures before harvest. The Chinese also found the varieties to be susceptible to several diseases—such as scab, *Helminthosporium*, and stripe rust—that are present in China but not prevalent in Mexico. They were also later

Figure 3.3. A short-statured wheat variety, Dongxie No. 3, being grown in a demonstration field near Beijing (source: Q-S. Zhuang, CAAS).

maturing than indigenous varieties and less tolerant of drought. As fall sown varieties they lacked tolerance for cold in the northern areas.

To remedy these defects the Chinese crossed their spring or winter wheats with Mexican spring wheats. The use of Mexican varieties in breeding programs fitted into a broader program of utilization of foreign varieties, about which little has been known until recently.[16]

Breeding Programs

China has used foreign varieties in wheat breeding for a long time.[17] In an article published in 1984, Yue Dahua, Chinese agricultural scientist, stated:

> In the past few decades, more than 11,000 foreign wheat cultivars were introduced from 80 countries. Some semidwarf to short-statured varieties from Australia, Chile, Italy, Mexico, USA and USSR possessing rust resistant characteristics were found suitable for use as breeding parents, and a few excellent introductions were recommended directly to the production units without further selection.[18]

A review of a recent Chinese book on wheat varieties[19] suggests that extensive use was made of Italian varieties descended from Mentana, particularly Funo and Abbondanza. Orofen, a descendent of Mentana developed in Chile (and released in 1958), was also commonly used. Although descended from Akakomugi, Mentana is not quite a semidwarf in terms of height and Abbondanza (introduced in 1956) is considered semitall in China. Other Italian varieties used included: Ardito, which is shorter; Mara, which is a semidwarf (*Rht9*); and a line identified as St 2422/462. Some early Chinese wheats, such as Fan 6, Mianyang 11, White Gao38, and Xiaoyan 6, are classified as semidwarfs.

The Chinese book indicates that the breeding of semidwarfs began in 1957 with the crossing of Suweon 86, a sister of Suweon 85 and a relative of Norin 10 (see figure 2.1),[20] with Xinong 6028 to produce Xiannong 39. Xiannong 39 was not released because of some plant deficiencies but was used extensively in breeding programs. Offspring include: Aiganzao; the relatively well-known Aifeng series 1, 2, 3, and 4 (80 cm);[21] and Jimai 7. Related varieties include Anxuan 5, Bainong 3217, Baiquan 40 and 41, Ping 39, Qixuan 2, and Zhengzhou 761.

The Chinese have made extensive use of one native source of dwarfism variously known as Huisian, Huixian Red, or Huixianhong. Huixian Red has been widely crossed with the Italian varieties noted above, particularly Abbondanza, to produce a number of semidwarfs including:

- Taishan 4 (85 cm), 5 (80 cm), and 6 (90 cm);
- Baiquan 5 (90 cm), 22 (92 cm), 25 (80 cm), 568 (92 cm), and 6502 (100 cm);
- Friendship 2 (87 cm); Luoyanj 3; Ning 7317 (80-90 cm); Youbao; Menxian 4; and Zixuan 2.

The origins of Huixian Red are a bit uncertain. It has recently been described as a "local variety originated from north Henan province, but it is different in many characteristics . . . and somewhat similar with Norin 14 from Japan."[22] An earlier report stated that it has been "cultivated for a long period as a local variety of winter wheat in Hui County, Sinxi (Sinxian) Prefecture, Henan Province. It . . . is probably introduced from Japan." The similarity with Norin 14 was also noted.[23] (The original cross for Norin 14 was made in Japan in 1924, and the variety was released in 1935; it has the same parentage as Norin 10 but is taller.[24]) CIMMYT obtained seed of Huixian Red in 1977, and tests showed it to contain one of the two Norin 10 semidwarf genes (*Rht1* or *Rht2*).[25]

Another more recent domestic source of dwarfism is Aibian-1 (Ai Bian No. 1). As noted in table 2.4, Aibian-1 has a different semidwarf gene (*Rht10*) than Norin 10. Aibian-1 has been reported to be a mutant of either Aiganzao (which has both Suweon 86 and Villa Glori in its parentage) or Abbondanza.[26]

As noted in chapter 2, an Oregon State University scientist obtained a promising source of dwarfism in central China in 1981. It was reported to have come from Tibet. The variety is extremely short, very early maturing, and tillers profusely. It is presently under study in Oregon and elsewhere.[27]

The Chinese have used Mexican (CIMMYT) varieties in their breeding programs. Reported progeny from the crosses of the Mexican varieties with Chinese varieties include:

- southwestern China region of winter wheat: Fan 13 (and sister line 2114); Yunmai wheat 32;
- southern China region of winter wheat: Longxi 35, Longxi 37, Fuhongke (Fu Red Chaff) 13, Fuhongke 19, and Guimai 1; and
- northern China region of winter wheat: Jinghong 8, Jinghong 9, Jinchun 3, Jinchun 4, Yanbei 8, and Yuanchun 7112 (spring varieties).

Mexipak, possibly a general name for cross 8156, was a parent of the varieties developed in China's southwestern winter wheat and northern spring wheat regions; Potam S70 was a parent of two of the varieties released in southern China. (An unidentified Mexican variety was a parent of Guimai.) In nearly every case the other parent was a Chinese variety. The principal exceptions were Yunmai 32 (in which the other parent was an Italian variety) and Jinghong 8 and 9 (in which the other parent was a cross of an Italian and an Indian variety).

The approximate dates of development and heights of the Chinese HYWVs, when reported, are: Fan 13 (1973), 85-100 cm; Yunmai 32 (1976), 80-100 cm; Longxi 35 and 37 (1977), 90 cm; Fuhongke 13 (1977), 85-90 cm; Fuhongke 19 (1977), 90-100 cm; Guimai 1 (1975), 90-100 cm; Jinghong 8 and 9 (1969) and Jinchun 3, 72 cm; and Yuanchun 7112 (1969), 70 cm.

In addition to these varieties, a short-statured variety released in southern China, Yuemai 1 (1975), 90 cm, had Santa Elena, an Australian variety, as a parent. Xuzhou 2962, derived from Yecora F70, was also released in eastern China (northern Jiangsu Province).

At least four semidwarf varieties were developed in China by induced mutations: Luten 1 (1968); Yuannong 61 (1971), 90 cm; Yuan Chun 7112 (1974), 70 cm; and Ningmai 3 (1976). Luten 1 was grown on more than 100,000 ha. Ningmai 3 was grown on about 140,000 ha in Jiangsu Province in 1981.[28]

Doubtlessly, there are other semidwarf varieties in use in China. Most of the varieties released since the 1970s have been semidwarfs. Some that gained commercial importance are Nonda 139, 93 cm; Beijing 10, 100 cm; Taishan 1, 95 cm; Fan 6, 80 cm; Mianyang 11, 78 cm; Ningmai 3, 100 cm; Yangmai 3, 100 cm; and Zhemai 2, 85 cm.

According to Q. Zhuang, the chief wheat breeder of the Chinese Academy of Agricultural Sciences (CAAS), the following semidwarf varieties were most widely grown in 1984: Bainong 3217, Mianyang 11, Jinan 13, Taishan 1 (100 cm), Xiaoyan 6, Kefeng 2 (spring sown), Zhengzhou 761, Jimai 7, Jingfeng 1, and Taishan 5. (The first three are the most widely grown.) Two hybrid varieties, Jimai 3 and Yangmai 3, are reported as extensively grown, but they may not be semidwarfs.[29]

Area Planted With HYWVs

The size of the area in China planted with HYWVs is uncertain. Official statistical estimates are scarce at the national level.

A key variable is the definition of "HYWV." One definition would limit HYWVs to those varieties with a height of less than 90-100 cm. Incomplete estimates of the total area of HYWVs by this definition are provided for 1980 to 1984 in table 3.2. Although the data for the periods 1980-82 and 1983-84 are not directly comparable, the area has clearly expanded significantly. By 1984 the HYWVs represented at least one-third of the total wheat area.

To circumvent the incomplete nature of the data, an alternative system was utilized for 1984. Q. Zhuang of CAAS estimated the proportion of the area planted with HYWVs of 100 cm or less in each of the wheat zones in the country. These estimates were then weighted using scattered estimates of the overall wheat area (figure 3.4) to produce a national total of 16.5 million ha, or 56% of China's total wheat area in 1984.

If a height limit of 105 cm is used and the same procedure involving the wheat zones is followed, an upper range figure of about 21.5 million ha, or 73% of the total area in 1984 would be obtained. These taller varieties generally have a yield potential of 5 t/ha.[30]

By any of these standards, the HYWVs are clearly of major significance in China.

India

Systematic research with wheat began in India in 1905 at the Indian Agricultural Research Institute at Pusa.[31] A long period of varietal improvement followed, but the number of person-years devoted to wheat research was small—1 in 1906, 2-3 in 1915-20, and 4-6 in 1935.

Table 3.2. Incomplete estimates of area planted with high-yielding wheat varieties in China from 1980 to 1984

Year	Area (ha)[a]			Proportion of total wheat area (%)[c]
	Fall sown[b]	Spring sown	Total	
		Under 90 cm		
1980	2,863,000	93,000	2,956,000	10.1
1981	3,111,000	141,000	3,252,000	11.4
1982	4,739,000	387,000	5,126,000	18.3
		Under 100 cm		
1983	8,364,000	556,000	8,920,000	30.7
1984	9,362,000	666,000	10,028,000	34.2

[a]Excludes varieties with less than 6,670 ha (less than 66,700 ha of winter wheat in 1980 and 1981 and 13,330 ha of spring wheat in 1981).

[b]Includes winter and facultative types and, in mild southern climates, some spring wheats.

[c]Based on USDA estimates of total wheat area.

Source: Letters from Q-S. Zhuang, Institute of Crop Breeding and Cultivation, CAAS, Beijing, and H. Hanson, CIMMYT, August 1984, October, November, and December 1985.

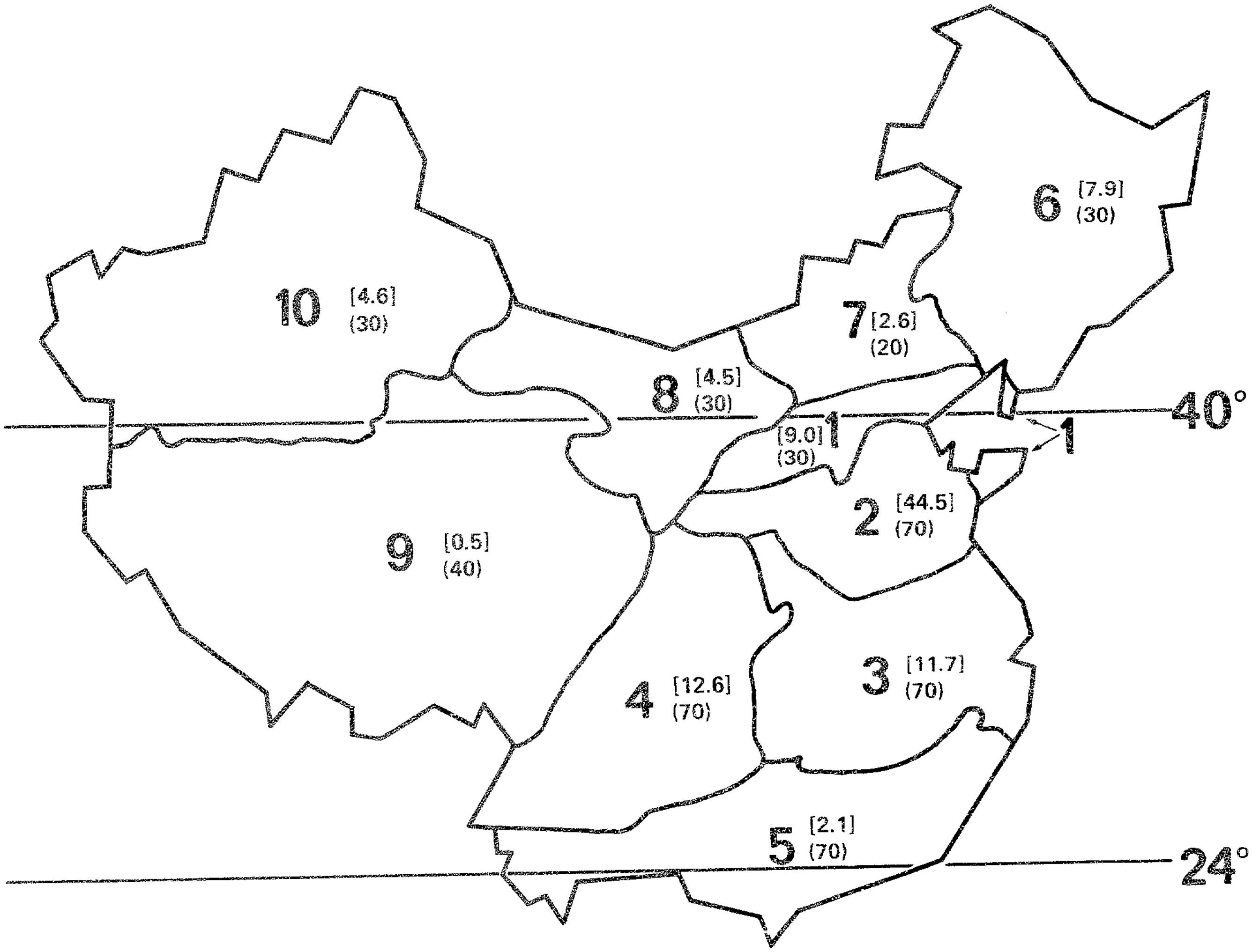

Figure 3.4. Wheat-producing zones in China: estimated proportion of national wheat area (in brackets) and proportion of wheat area in zone planted with HYWVs under 100 cm (in parentheses) in 1984. Source: Basic map from CIMMYT; zone 1 slightly modified by Bruce Stone of the International Food Policy Research Institute. HYWV percentage estimate from Q-S. Zhuang, CAAS, Beijing, October 1985.

Several new varieties were developed and released. The area growing improved wheat varieties expanded as follows: 1920-21, 820,500 ha (8.9% of total); 1928-1929, 1,724,700 ha (15.3% of total); and 1937-38, 3,105,900 ha (25.8% of total).[32]

The HYWVs were first introduced into India in 1962 through the international rust nursery system, sponsored by the USDA. When the nursery was grown at Delhi, Indian wheat scientists spotted the Mexican semidwarfs Pitic 62 and Penjamo 62 and concluded that their strong short stems and good rust resistance might enable them to break the yield ceiling then found in India.

The Mexican varieties were subsequently tested on three Indian research stations in 1962-63 and performed well. Norman Borlaug was invited to India in 1963 and arranged to supply 100 kg of each of four short-statured wheat varieties from Mexico and small samples of about 600 advanced lines. In trials harvested in the spring of 1964, two Mexican semidwarfs, Sonora 64 and Lerma Rojo 64, outyielded all Indian check (or control) varieties by 30%.

By 1964 the Indian government had committed itself to a dynamic national wheat production program built around the new semidwarfs. A large-scale demonstration of the semidwarfs was organized in 1965, which was made possible by seed multiplied in India and by a shipment of 250 t of Sonora 64 and Lerma Rojo 64 (200 t and 50 t, respectively). In 1966 India imported 18,000 t of seed from Mexico (mostly Lerma Rojo 64, the remainder Sonora 64), a record-breaking quantity at the time.

India did not long rely on imported varieties. Indian scientists identified two Mexican advanced breeding lines that performed better than the imported varieties, and by careful selection they developed the varieties Kalyansona and Sonalika. Kalyansona, a selection from line S. 227, was derived from the Mexican cross 8156 (as are Siete Cerros and Super X) but had better resistance to leaf rust. Sonalika was derived from line S. 308, which was not released to Mexican farmers because it was susceptible to Mexican races of leaf rust. Both varieties were released in 1967 and quickly gained wide popularity in India and elsewhere in southern Asia. Thereafter, as part of the All-India Coordinated Wheat Improvement Project, India developed a large-scale breeding program, and a large number of improved varieties were used throughout the country.[33]

Despite the availability of many HYWVs, first Kalyansona and then Sonalika have been dominant varieties. Various CIMMYT reports over the years have noted:

- Kalyansona represents about 48% of HYWV area and Sonalika represents 22% (1973);
- Sonalika and Kalyansona, in that order, are the leading varieties (1977 and 1978); and

Table 3.3. Leading semidwarf wheat varieties by zone in India in 1984

Zone	Irrigated land		Rainfed land
	Timely sown	Late sown	
Northern Hills	Sonalika (MP)	Sonalika (MP)	Sonalika (P)
Northern Plains	WL 711 (VP) HD 2009 (P)	Sonalika (MP)	IWP 72 (P)
North Western Plain	WH 147 (VP) HD 2009 (P)	Sonalika (MP)	Kalyansona (P)
North Eastern Plains and Far Eastern	Sonalika (MP) UP 262 (P) K 7410 HP 1102 (P)	Sonalika (MP) HP 1209 (P) UP 115 (P)	
Central and South Eastern	Sonalika (MP) Lok-1 (P) WH 147 (P)	Sonalika (MP) Lok-1 (P)	Mukta (P) Ag-30-1 (P) JU 12 (P)
Peninsular	NI 5439 (MP) HD 2189 (VP)	Sonalika (MP)	NI 5439 (MP) N 59
Southern Hills[a]		Neelgiri (MP) HW 517 (P)	

Key: MP=most popular; VP=very popular; P=popular

Note: All leading varieties in the irrigated areas were semidwarfs. In the rainfed zone, the MP and VP varieties were usually tall varieties. List does not include varieties classified as "getting popular" or "recently released."

[a]All land planted with wheat has restricted irrigation.

Source: Personal communication with J.P. Tandon, All-India Coordinated Wheat Improvement Project, Indian Agricultural Research Institute, New Delhi, December 1984.

- Sonalika is the most widely grown variety (1981).[34]

A review of wheat varieties at the 22nd All-India Wheat Research Workers Workshop in 1983 confirmed the dominance of Sonalika, followed by Kalyansona.[35] Sonalika was dominant in the important wheat states of Uttar Pradesh (60%-75%) and Bihar (75%-90%) and was widely grown elsewhere. A crude compilation of these data suggests that Sonalika might have occupied about 40% of India's total HYWV area. Data on seed production for 1980-81 suggest a higher figure, 53%, followed by Kalyansona with 17%. More recent information reveals the leading varieties by zones (table 3.3) in 1984. Sonalika was the "most important" variety in most of the irrigated zones, while Kalyansona was of relatively minor importance.

It is risky to have one variety dominate over wide areas. In the case of Sonalika, this problem is heightened by the fact that it is susceptible to a new race of leaf rust and must be replaced. Sonalika has remained popular because:

- it is the earliest maturing variety available;
- it is high yielding (yields in the range of 1.4-1.8 t/ha); and
- it has amber grain color.

The first factor is important in multiple-cropping rotations in which wheat is sown after rice is harvested in October and November. By the time land preparation has been completed, the sowing date for wheat is later than would be optimum for medium-term varieties.[36]

Other wheat varieties that were of some commercial importance in India in 1983 were: WH 147 (grown in Haryana and Madhya Pradesh), Arjun, WL 711 (popular in Punjab), WL 1562 (Punjab), HD 2009 (Haryana), HD 2189 and NI 5439 (Manharashtra), Lok-1, J24, UP 115, UP 262, and UP 368 (Uttar Pradesh).[37] Additional varieties listed in table 3.3 for the irrigated areas include: HP 1102, HP 1209, K 7410, Neelgiri, and WH 147. New varieties are released regularly.[38]

The overall area planted with HYWVs increased, on the whole, significantly and steadily from 1965-66 to 1983-84 (table 3.4). The percentage of wheat area planted with HYWVs declined only once (in 1979-80) and by 1981-82 had reached 75%. In 1982-83 India accounted for 43.2% of the total HYWV area in DCs (excluding communist Asia).

The geographic distribution of the overall HYWV area in 1983-84, according to preliminary data, was: Uttar Pradesh, 35.0%; Punjab, 16.4%; Bihar, 10.5%; Madhya Pradesh. 8.2%; Haryana, 8.1%; Rajasthan, 6.7%; Maharashtra, 4.7%; Gujarat, 2.9%; and other, 7.5%. The proportion

Table 3.4. Area of high-yielding wheat varieties in India from 1965-66 to 1983-84

Crop year	HYWV area (ha)	Proportion of total area (%)
1965-66	3,000	--
1966-67	541,000	4.2
1967-68	2,942,000	19.6
1968-69	4,793,000	30.0
1969-70	4,910,000	29.5
1970-71	6,480,000	35.5
1971-72	7,861,000	41.1
1972-73	10,177,000	52.3
1973-74	11,027,000	59.3
1974-75	11,194,000	62.2
1975-76	13,458,000	65.8
1976-77	14,522,000	69.4
1977-78	15,803,000	73.7
1978-79	15,899,000	70.2
1979-80	15,027,000	67.8
1980-81	16,100,000	72.3
1981-82	16,750,000	75.6
1982-83	18,070,000[a]	78.1
1983-84	18,550,000[b]	76.0

Key: --=negligible.

[a]Another source suggests a total of 17,847,000 ha (Fertilizer Association of India, *Fertilizer Statistics, 1983-84* [New Delhi: the Association, 1984], pp. II-100).

[b]Anticipated achievement.

Sources: 1964-65 to 1979-80: International Economics Division, Economic Research Service, USDA (from *Fertilizer Statistics*). 1980-81: *Economic Survey, 1983-84*, (New Delhi: Government of India, 1984), p. 92. 1982-83 and 1983-84: Ministry of Agriculture, *Annual Report, 1983-84* (New Delhi: the Ministry, 1984), p. 81.

of wheat area within each of the above states planted with HYWVs in 1983-84 varied substantially, ranging from highs of about 100% in Bihar and 97% in Punjab to lows of 42% in Madhya Pradesh and 58% in Rajasthan.[39]

Despite the extreme importance of the HYWVs in India, little general information about them is available. They seem to have blended into the agricultural landscape.

Republic of Korea

Korea has been a relatively small producer of wheat (roughly 26,000 ha in 1983), but it intends to increase production to reduce wheat imports. The Wheat and Barley Research Institute was established in 1977. The Mexican varieties have not proved to be well suited to the Korean climate and growing conditions.

Korea, however, has a good genetic base for wheat. A number of Korean semidwarf varieties trace their ancestry to the Daruma varieties of Japan. Two of the better-known varieties developed in the 1930s are Suweon 92 and Seu Seun 27 (see figure 2.1).

Several short-statured (semidwarf) varieties were released in the mid-1970s: Chokwang (previously known as Suweon 189), 1975; Suweon 215 and 216, 1977; and Milyang 5. Norin 72 is one of the parents of Chokwang and Milyang 5; Strampelli is one of the parents of Suweon 215 and 216. Seed of Chokwang and the Suweon varieties was multiplied for release in 1977.40 Chokwang and Strampelli/69D-3607 were in turn parents of Geurumil, which was released in 1979.[41]

Advanced lines with semidwarf stature in tests in the 1980s included the Suweon varieties 221, 222, 223, 224, 234, 235, and 236. Height ranged from 75 to 88 cm, compared to 90 cm for Chokwang. CIMMYT varieties are included in the ancestry of Suweon 221 (76 cm) and Suweon 224 (80 cm). Strampelli was one of the parents of Suweon 235 and 236.[42]

In total, it appears that essentially all of the limited wheat area in South Korea (26,000 ha in 1983) is sown with HYWVs.

Nepal

The wheat area in Nepal has expanded sharply since the mid-1960s. Most of the wheat growing area is rainfed, and the growing season in the Tarai (the southern plain where much of the area growth has occurred) is fairly short. As a result yields are not high.

The first Mexican variety to be grown in Nepal appears to have been Lerma 52, one of the parents of Lerma Rojo 64 but not a semidwarf. Lerma 52 represented all the limited HYWV area in 1965-66, 91.4% of the area in 1966-67, and 31.6% in 1967-68. Substantial quantities of

Table 3.5. Area of high-yielding wheat varieties in Nepal from 1965-66 to 1983-84

Crop year	HYWV area (ha)[a]	Proportion of total area (%)
1965-66	4,400	3.7
1966-67	11,300	9.0
1967-68	27,700	14.4
1968-69	54,300	26.1
1969-70	76,400	33.8
1970-71	98,300	43.1
1971-72	115,900	48.5
1972-73	170,200	65.7
1973-74	206,900	75.5
1974-75	246,800	84.8
1975-76	233,600	71.0
1976-77	254,000	73.0
1977-78	286,900	78.4
1978-79	304,000	85.4
1979-80	314,500	85.7
1980-81	327,300	83.5
1981-82	340,000[b]	85.0[b]
1982-83	405,700	84.0
1983-84[c]	435,600	92.1

[a]Improved varieties.

[b]Unofficial area based on estimate of proportion of total area planted with improved varieties provided by Nepalese official. The official figure was 100%, which seems likely to be in error.

[c]Preliminary estimate.

Source: Letters from C.T. Hash, Agricultural Development Office, USAID, Kathmandu, February and September 1984. Data from Department of Food and Agriculture Marketing Services, Nepal.

Table 3.6. High-yielding wheat variety seed imported by Pakistan

Year	Quantity (t)	Source	Comment
1965	350	Mexico	250 t Penjamo 62 and 100 t Lerma Rojo 64
1966	50	Mexico	Mostly Mexipak White (Siete Cerros); some Mexipak Red (Indus 66)
1967	42,000	Mexico	40,000 t Mexipak Red (Indus 66); 2,000 t Mexipak 65 (Siete Cerros)
1975	17,000	Mexico	9,600 t Yecora; 6,600 t Nuri; and 800 t other
1978	5,270	India	3,300 t Sonalika; 1,200 t WL-711; and 770 t HD-2009
	10,500	Mexico	Pavon-76

Sources: 1965-67; D.G. Dalrymple, *Development and Spread of High-Yielding Varieties of Wheat and Rice in the Less Developed Nations*, FAER No. 95 (Washington, D.C.: U.S. Department of Agriculture, September 1978), pp. 15, 40. 1975 and 1978: letter from P. Amir, research fellow, Pakistan Agricultural Research Council, Islamabad, January 1984.

Lerma Rojo 64 were imported for the 1966-67 season (38 t) and the 1967-68 season (450 t).

Thereafter, most wheat seed imports were from India: 160 t of S-331 (Choti Lerma) in 1968-69, 1971-72, and 1972-73; 1,776 t of S-227 (Kalyansona) from 1969-70 to 1972-73; 1,315 t of RR-21 (Sonalika) in 1971-72 and 1972-73; and 30 t of UP-301 in 1972-73. Slightly more than 0.5 t of Chenab 70 was imported from Pakistan (1970-71).[43]

Sonalika (RR-21), as in India, was popular. In 1976 CIMMYT reported that it occupied 95% of the HYWV area.[44] A 1981 CIMMYT report states that Sonalika predominated for the same reason as in India: its short growing season fitted the rice-wheat rotation.[45] In a tabulation prepared by the Nepalese Department of Agriculture in March 1983, it was the only variety listed as "very important." Lerma 52 (1960) was listed as "important," and Lerma Rojo 64 (1967), NL-30 (1975), and HD-1980 (1975) were in the third category, "less important." The fourth category, "grown only occasionally or not at all," contained Pitic 62 (1967), S-331 (1969), S-227 (1969), and NL 30 (1975). Lumbini (1981) and UP-262 (1981) were listed as "yet to be popularized." Recent releases include Tribeni (1982), Siddhartha (1982), Vinyak (or Binayak, 1983), and Vaskar (1983).[46]

The area planted with improved varieties grew fairly steadily through 1974-75, followed by a drop in 1975-76, and then a gradual increase in area through 1982-83 (table 3.5). The preliminary estimates for 1983-84 show further increases, although those may prove to be temporary due to a decline in wheat prices. Some of the improved wheat grown in Nepal (such as Lerma 52) may not qualify as a HYWV; hence, the actual HYWV area may be less than shown in table 3.6.

It is unclear how much the HYWVs are contributing to increased wheat production in Nepal because they are largely grown in rainfed fields with little or no fertilizer and in one large area (the Tarai) where the growing season is relatively short. The HYWVs, however, are evidently as good as any and do have other positive qualities bred into them.

As in India, a replacement will be needed for Sonalika because of the leaf rust problem. The National Wheat Development Program recommended NL-30 and HD 1982 for the Rarai in the mid-1970s, but neither variety has become popular.

Table 3.7. Wheat varieties released in Pakistan from 1966 to 1982-83

Variety	Date[a]	Variety	Date[a]
	Introduction[b]		
Mexipak	1966[c]	Arz	1976
Sonalika/Blue Silver[d]	1969	HD-2009	1978[c]
Yecora-70	1974[c]	WL-711	1978[c]
Nuri-70	1975	Pavon F76	1978[e]
	Pakistani/CIMMYT varieties		
Khushal-69	1969[c]	ZA-77	1979[e]
Barani-70	1970[c]	Bahawalpur-79	1979-80
Chenab 70	1970[c]	Indus-79	1979-80
Pak-70	1970	Khyberr 79	1979-80
SA-42	1972[c]	Zamindar 80	1979-80
Lyallpur 73	1973	Zarghoon-79	1979-80
Pari-73	1973	Pak-81 (Veery "S")	1981-82
Pothowar	1973[c]	Punjab-81	1981-82
Sandal	1973	Barani-83	1982-83
Tarnab-73	1973[c]	Faisalabad-83 (AARI-83)	1982-83
SA-75	1975[c]	Kohnoor-83 (Punjab-83)	1982-83
LU-26	1976[e]	Sarhad-82 (Bobwhite)	1982-83
Punjab-76	1976[c]		

[a]Year of release is approximate; different sources may vary by a year.

[b]Does not include all early introductions.

[c]Withdrawn; no longer recommended generally because of susceptability to leaf and/or stripe (yellow) rust.

[d]Sonalika is known in Pakistan as Blue Silver.

[e]Recommended only for zones free of stripe (yellow) rust.

Sources: J.G. Nagy, "The Pakistan Agricultural Development Model: An Economic Evaluation of Agricultural Research and Extension Expenditures" (Ph.D. dissertation, University of Minnesota, 1984), Table C-10; *CIMMYT Report on Wheat Improvement*, annual; *Annual Wheat Newsletter*, 27 (June 1981):70, 28 (June 1982):70, 30 (June 1984):86; and letters from P. Amir, Research Fellow, Pakistan Agricultural Research Council, Islamabad, March 1984 and P.R. Hobbs, wheat agronomist, CIMMYT, Islamabad, November 1984.

Pakistan

Wheat research in the region that is now Pakistan started at Punjab Agricultural College in Lyallpur in the early 1900s. The first selections released were 8-A and 9-D (both 1911). The first crosses were C-217, C-228, C-250, C-518, and C-591 (1930s). The area planted with improved varieties in the Punjab (which is now divided between Pakistan and India) increased gradually but significantly through the early 1940s when it represented 75% of the total wheat area. During the 1950s, varietal releases included C-271, C-273, H-68, and Dirk (from Australia).[47]

The CIMMYT/Mexican varieties were first introduced in 1962 by some Pakistani trainees returning from CIMMYT. The seeds they carried were subsequently planted at the Agricultural Research Institute near Lyallpur (now Fasialabad). Norman Borlaug visited Lyallpur in the spring of 1963 and upon his return to Mexico sent 205 kg of experimental seed to Pakistan. He visited Pakistan again in the spring of 1964 and secured governmental and Ford Foundation support for an All-Pakistan Wheat Research and Production Program.[48] Substantial quantities of HYWV seed were purchased from Mexico during the next 3 years (table 3.6).

A breeding program was initiated, and a large number of varieties have been released (table 3.7). Even so, massive imports of six varieties of seeds were necessary in 1975 and again in 1978 when rust disease was severe (table 3.7). Some of the varieties developed in Pakistan subsequently developed susceptibility to disease, particularly rust, and have been withdrawn from the officially recommended list. However, other rust-susceptible varieties--particularly Yecora, Pavon, and Mexipak--continue to be grown by farmers who are their own source of seed. This could create a serious problem if a rust epidemic should occur.

There are no published estimates of the relative importance of the various HYWVs at any given point in time. One source suggests that during the 1969-70 season, 81% of the HYWV area was planted with Mexipak, 12.5% with Indus 66, 4% with Norteno, and 1% with Inia 66.[49] A survey of wheat varieties by province during the late 1981-82 crop year revealed that Yecora occupied 53% of the total wheat area in Punjab, and Pavon represented 60%-65% of the total wheat area in Sind.[50] Both varieties were still heavily used in 1984.[51]

The proportion of total HYWV area represented by introduced varieties is estimated to have increased as follows: 1973-74, 0%; 1974-75, 3.1%; 1975-76, 12.1%; 1976-77, 16.7%; 1977-78, 20.3%; 1978-79, 39.5%; 1979-80, 56.8%; and 1980-81, 72.9%.[52] The original calculations did not place Mexipak in the introduction category, so the increase in this category is probably not nearly as great as it seems. However, it is surprising to find such a large proportion of the HYWV area still occupied by introductions. A large number of locally developed high-yielding varieties were released in the early 1980s, and these will probably bring the introduction figure down over time.

The overall area planted with HYWVs in Pakistan increased steadily from 1965-66 to 1982-83, aside from a slight pause in the early 1970s (table 3.8). The proportion of total area occupied by the HYWVs increased correspondingly and by 1982-83 reached 86.1%. The HYWV area figure is close to 100% in the irrigated and high rainfall areas. One HYWV, Lyallpur 73, is also extensively grown in areas where there is climatic stress and salinity.[53] As of 1982-83 the HYWV area was largely concentrated in Punjab, which had 74% of the total, followed by: Sind, 15.2%; NWFP, 8.8%; and Baluchinstan, 2.0%.[54]

Table 3.8. Area of high-yielding wheat varieties in Pakistan from 1965-66 to 1982-83

Crop year	HYWV area (ha)	Proportion of total area (%)
1965-66	4,900	--
1966-67	101,200	0.2
1967-68	957,100	16.0
1968-69	2,387,700	38.8
1969-70	2,681,500	43.0
1970-71	3,128,300	52.3
1971-72	3,286,200	56.7
1972-73	3,375,700	56.5
1973-74	3,475,200	56.9
1974-75	3,722,800	64.0
1975-76	4,015,600	65.7
1976-77	4,599,300	72.0
1977-78	4,684,500	73.7
1978-79	5,095,700	76.2
1979-80	5,587,100	80.7
1980-81	5,732,500	82.1
1981-82	6,172,000	85.5
1982-83	6,367,200	86.1

Key: --=negligible.

Sources: 1965-66 to 1971-72: D.G. Dalrymple, *Development and Spread of High-Yielding Varieties of Wheat and Rice in the Less Developed Nations*, FAER No. 95 (Washington, D.C.: U.S. Department of Agriculture, 1978), p. 40; and 1972-73 to 1982-83: Ministry of Food, Agriculture, and Cooperatives, *Agricultural Statistics of Pakistan, 1983* (Islamabad: the Ministry, Government of Pakistan, 1984), pp. 11-13.

NEAR EAST

The Near East, which for this report includes western Asia and North Africa, accounted for about 25.4% of the total DC wheat area in 1983. The most important countries (and their percentage proportion of DC area) in 1983 were: Turkey (8.9), Iran (5.6), Afghanistan (2.7), Morocco (2.0), Algeria (1.3), Syria (1.2), Iraq (1.2), and Tunisia (1.1). All these countries were among the top 12 DCs in terms of wheat-growing area. Yields, however, have been relatively low, especially in Algeria and Morocco.[55]

The region is geographically diverse. Of the total wheat area in the region, 14% is irrigated, 34% has adequate rainfed soil moisture, and 51% has semiarid soil conditions. In western Asia, HYWVs are mostly grown in irrigated fields (often partial or limited) or in areas with fairly high rainfall. HYWVs are irrigated in Egypt, but in the remainder of North Africa and Turkey they are usually grown under rainfed conditions. Spring bread wheat represents about 29% of the area, winter bread wheat about 40%, and durum wheat about 31%.[56] The latter two types are more important in this region than elsewhere in the developing world (except for China in the case of winter wheat).[57]

Semidwarf wheat was introduced to the Near East in 1963 when a former student of Borlaug grew the new Mexican varieties at an experiment station north of Cairo. Egyptian use of the varieties was limited until the early 1970s,[58] but the semidwarfs were adopted at an early date in a number of other countries in the region. The HYWVs were not limited to spring bread wheats but included winter bread wheats and durums. The high-yielding winter wheats are not of CIMMYT or Mexican origin and are often not semidwarfs. Therefore, it is sometimes difficult to draw a line between improved local varieties and HYWVs unless yield data are available.

Several regional wheat improvement programs have developed. The first was a project of the Food and Agriculture Organization of the United Nations and the United Nations Development Program on wheat and barley, established in 1962, which expanded into a program on field food crops. The second was the Arid Lands Agricultural Development Program (ALAD), sponsored by the Ford Foundation, which did some wheat research and testing in Lebanon. The ALAD work was absorbed by the International Center for Agricultural Research in the Dry Areas (ICARDA). Presently, wheat research at ICARDA is carried out in cooperation with CIMMYT.[59] The Arab Center for the Studies of the Arab Zones and Dry Lands in Syria also does wheat research.

There is a distinct lack of official statistics on HYWV use in much of the region. Reasonably complete data are available for a few countries, but major gaps in data exist for many others. Little information of any type is available for some countries.

Israel, a developed country and not a point of focus in this report, has had experience with HYWVs and is briefly covered in a footnote.[60]

Afghanistan

Afghanistan was making extensive use of HYWVs through the late 1970s, but nothing is known of developments since then. Both spring and winter wheats are grown, and seed imports have been of both types (table 3.9).

The estimated area planted with HYWVs increased gradually through 1976-77. Annual figures were as follows (in hectares): 1966-67, 1,800; 1967-68, 22,000; 1968-69, 122,000; 1969-70, 146,000; 1970-71, 232,000; 1971-72, 255,000; 1972-73, 450,000; 1973-74, 475,000; 1974-75, 522,000; 1975-76, 522,000; and 1976-77, 770,000.

These estimates probably were high because the definition of improved varieties may have included nonHYWVs. Also a 1977 CIMMYT report indicated that the area under improved varieties dropped during 1967-77, in contrast to the increase noted above. A 1978 CIMMYT report lists the area planted with improved varieties as 433,000 ha.

In 1975-76 the leading varieties included Mexipak, Bakhtar (Baktar), Bezostaya, and Kavkaz. From 1967 to 1976 Mexipak and Bakhtar were the leading spring varieties and Kavkaz was the leading winter variety followed by Bezostaya. The 1977 CIMMYT report indicates that Bezostaya and Kavkaz were largely replaced by local winter varieties because of problems of grain color, lack of awns, unpalatable straw, and susceptibility to stripe rust. In 1978 the varieties were reported to have become susceptible to diseases and poor in seed quality and purity. A number of promising new lines were identified.[61] Presumably, some HYWVs are still grown.

Table 3.9. High-yielding wheat variety seed imported by Afghanistan from 1965-66 to 1975-76

Year	Quantity (t)	Variety	Source	Comments
1965-66	50	Lerma Rojo 64A	Mexico	
1966-67	250	Lerma Rojo 64A	Mexico	
	170	Lerma Rojo 64A	Pakistan	
1971-72	6,000	Mexipak	Pakistan	2,000 t certified; 4,000 t uncertified
1972-73	2,000	Bezostaya		
1973-74	500	Kavkaz		An offspring of Bezostaya
1975-76	10	CY 1975	India	

Source: D.G. Dalrymple, *Development and Spread of High-Yielding Varieties of Wheat and Rice in the Less Developed Nations*, FAER No. 95 (Washington, D.C.: U.S. Department of Agriculture, 1978), p. 45.

Algeria

The current status of HYWVs in Algeria is somewhat uncertain. CIMMYT has been associated with an Algerian wheat improvement program for a long time but has not published reports on developments since 1980. Efforts to obtain recent information from Algeria and other sources failed, but CIMMYT provided one key set of estimates for 1983.

Algeria imported substantial quantities of HYWV seed, principally from Mexico, at intervals from 1969-70 to 1977-78. Recorded quantities are (in tons): 1969-70, 1,500; 1970-71, 17,200; 1972-73, 15,468; and 1977-78, 3,800 (Siete Cerros).[62] Estimates of area planted are available for a few years in the early 1970s and are summarized in table 3.10.

In 1978 five HYWVs with Mexican ancestry were released: Beni Slimane 76 (Arz), Cheliff 78 (Pavon "S"), Ghriss 75 (Anza), Setif 76

Table 3.10. Area of high-yielding wheat varieties in Algeria from 1969-70 to 1976-77

Crop year	Area (ha)	Varieties planted
1969-70	5,100	
1970-71	140,000	98.6% Mexican varieties (Inia 66, Siete Cerros, and Tobari); 1.4% Italian varieties
1971-72	320,000	Inia 66, Siete Cerros, Tobari, and Strampelli
1972-73	600,000	80% bread wheats: 56% Siete Cerros, 20% Inia, and 4% Tobari; 20% durum wheat: all Jori C69
1974-75	670,400[a]	Leading bread variety: Siete Cerros; leading durum variety: Cocorit
1976-77	300,000[a]	Bread wheats: 90% Siete Cerros, 8% Strampelli, and 2% other (Anza, Tobari, and Inia); durum wheats: Cocorit, Inrat 69, Capeti, and Montpellier[b]

[a]Indirect estimate.

[b]Jori did not prove to be adaptable. Breakdown data for durum varieties are not available.

Source: D.G. Dalrymple, *Development and Spread of High-Yielding Varieties of Wheat and Rice in the Less Developed Nations*, FAER No. 95 (Washington, D.C.: U.S. Department of Agriculture, 1978), p. 46.

(Syrimex), and Tessalah (Mexicano 1481).[63] As of 1980 the main bread wheat varieties included Anza, Siete Cerros, and Strampelli (along with Mahon Demais). The principal durum varieties did not include any HYWVs. (Capeiti, Inrat 69, and Cocorit 71 were grown only in a limited area.)[64]

Unpublished estimates provided by CIMMYT for 1983 suggest that Algeria had a HYWV area of 400,000 ha. Bread varieties accounted for about 275,000 ha, broken down as follows: Siete Cerros, 150,000 ha; Strampelli, 75,000 ha; and Anza, 50,000 ha. The durum varieties (Capeti, Inrat 69, and Cocori 71) accounted for the remaining 125,000 ha. The HYWVs have represented about 20% of Algeria's average total wheat area in recent years.[65] While the HYWV area has not increased much, if at all, since the early 1970s, increased research efforts are underway.

Cyprus

Cyprus, although a small country and a small wheat producer, has had a vigorous program of varietal improvement for bread and durum wheats. In the case of bread wheats, Mexican HYWVs have been extensively grown. As of 1973 about 14,000 ha were planted with Mexican-type varieties, principally Pitic 62. As of 1977, all of the bread wheat area was planted with varieties of Mexican origin. A 1978 varietal breakdown of a bread wheat area of 10,940 ha in Cyprus was: Hazera 2152, 40%; Hazera 18, 40%; and Pitic 62, 20%.[66]

Of the 16,350 ha planted with durum wheat in 1978, about 20% was devoted to Capeiti 8 (Capelli x Eiti), 15% to Aronas (a sister line of Cocorit 71), and the remaining 65% was planted with the traditional varieties Tripolitico and Kyperounda. Capeiti 8 is of Italian origin and was released in 1973. Aronas was selected from a large number of lines introduced from CIMMYT and was released in 1977; it was about 25 cm shorter than Kyperounda. Another durum variety, Mesaoria, which was also selected from a CIMMYT cross, was released in 1982; it was 7 cm shorter than Aronas. Recently, a further durum variety, Karpasia, was selected from a CIMMYT line and as of 1984 was being multiplied; it outyields Mesaoria and Aronas by 8%-10%.[67]

While these varieties were under development, other factors sharply influenced the setting for wheat production. First, the overall area planted with wheat was sharply reduced because of the Turkish invasion, the elimination of fallow, and a decision to favor the production of barley instead of wheat in rainfed areas. Second, it was decided to use the limited wheat area for the production of durums rather than bread wheats because bread wheats can be readily imported at lower prices than durum wheats. This shift was accomplished by 1980.

Thus, as of the 1983-84 season only 5,000 ha were sown with wheat, and all of this was planted with durum wheat. The variety distribution was Aronas, 60%; Mesaoria, 30%; and others, 10%.[68]

Egypt

Wheat is a major crop in Egypt and is the leading winter cereal. Wheat yields were steady from 1960 to 1970, increased in the early 1970s, and then leveled off through 1981. Giza 155 and 157, tall varieties, were released in 1968 and 1972, respectively. Giza 155 quickly became the dominant variety in the 1970s and between 1970 and 1979 accounted for about 81% of the total wheat area. It began to decline in importance in 1980.[69]

Two semidwarf HYWVs, Mexipak and Chenab, were released to farmers in the early 1970s—Mexipak in 1970, and Chenab in 1972 or 1973. The area sown with both expanded sharply to a peak in 1974 and then dropped through the rest of the decade. Annual area estimates were as follows (in hectares): 1970, 40; 1971, 160; 1972, 1,860; 1973, 2,820; 1974, 213,000; 1975, 78,600; 1976, 74,300; 1977, 125,620; 1978, 121,000; 1979, 45,800; and 1980, 1,250.

The reasons given for the drop in 1975 differ. They include (a) a change in the government policies, which required that a higher proportion of the Mexican varieties be sold to the government than of the traditional varieties, and (b) leaf rust, shattering, grain color, and baking and milling qualities. (The latter were considered particular problems of Mexipak and were expected to be rectified with the wider use of Chenab 70.)[70] Another account indicates that while the yields of Mexipak (and Chenab 70) were much higher (32%-40% higher) than the national average in 1971, 1972, and 1973, they dropped substantially in 1974 when they were only 12% above the national average. A recent analysis of the period stated: "This limited yield increase was much less than needed to compensate farmers for the increase in fertilizers and irrigation and the care in harvesting required for Mexican varieties."[71] Also the varieties produced less straw, which is highly valued as a forage in the summer.[72]

Other changes occurred in 1977 and 1978. Mexipak was dropped as a recommended variety in 1977 due to shattering and disease problems; Chenab was dropped in 1978 due to leaf rust difficulties. During this period about 500 t of the durum variety Mexicali 75 (Stork) were imported, renamed Sohag I, and recommended for middle and upper Egypt.[73]

Meanwhile, Egyptian wheat breeders were developing improved semidwarf varieties. In 1976 four new varieties were released. Two were selections from Mexican lines: Sakha 3 (= Potam "S") and Sakha 8 (= Bluebird "S"). Two were crosses between Egyptian and Mexican varieties:

- Giza 157: Giza 155 ($Pi62^4$ - $LR64^2$ x Tzpp - $Knott^2$), and
- Giza 158: Giza 156 x Siete Cerros.

These varieties showed good resistance to leaf rusts and shattering. They were also reportedly free of the disadvantages of the earlier Mexican varieties with respect to color of grain and flour and the quality of straw as animal feed. Giza 157 and Sakha 8 were recommended for the delta region (Giza 157 was also recommended for Middle Egypt); Giza 158 was recommended for Upper Egypt.[74]

Two further semidwarf varieties, Sakha 61 and Sakha 69 (both Inia - RL4220 x 7C/Yr"S"), were developed in 1979 and later released. They were followed by Giza 160 (Chenab 70 x Giza 155).

The area planted with each semidwarf (with the exception of Giza 158, which has not been commercially adopted) from 1978 to 1983 is shown in table 3.11. The proportion of the total wheat area planted with these varieties, including the area for Mexipak and Chenab, changed as follows: 1978, 21.1%; 1979, 11.6%; 1980, 35.7%; 1981, 43.9%; 1982, 52.7%; and 1983, 55.2%.

Less detailed estimates for more recent years show that the HYWV area has dropped back to about the 1981 level: 260,100 ha in 1984 and 257,900 ha in 1985. Giza 157 remained the leading variety in both years, followed by Sakha 61 in 1984 and Sakha 69 in 1985.[75]

A related point of a policy nature is that the Egyptian government support price for wheat has been set at a higher level for the semidwarf varieties than for the local varieties. During the 1980-82 period the HYWV prices averaged about 8.6% higher than for other wheat varieties.[76] Inputs are subsidized and extensive subsidies exist on bread.

AID has supported the Egyptian Major Cereal Improvement Project, which includes wheat research; an extensive varietal development program is underway for wheat.

Iran

In 1976 wheat was grown on about 2.1 million ha of irrigated land and on about 1.34 million ha of rainfed land. About 84% of the total area was

Table 3.11. Area of high-yielding wheat varieties in Egypt from 1978 to 1983

Year	Area (ha)					Total area (ha)
	Giza 157	Sakha 8	Sakha 61	Sakha 69	Stork	
1978	3,100	--	--	--	--	3,100
1979	18,900	3,400	--	--	--	22,300
1980	134,400	41,200	--	--	--	175,600
1981	193,600	60,100	1,700	--	2,500	257,900
1982	230,600	58,000	13,400	400	1,700	304,100
1983	200,800	53,800	47,100	3,300	1,200	306,200

Key: --=negligible.

Source: 1978-1981: A-M.M. Basheer, *Wheat Economics in Egypt*, Publication No. 40 (Cairo: Egyptian Major Cereals Improvement Project, May 1982), pp. 10-11, 41-42; 1982-1983: letter from S.A. Bowers, USAID, Cairo, July 1984.

used for winter wheat and 16% for spring wheat.[77]

Iran was an early adopter of the Mexican varieties. During the 1968-69 crop year it imported 1,500 t of Penjamo from Turkey; during the 1969-70 crop year 1,500 t was imported through a transshipment of Inia 66 from Denmark. Estimated areas planted with the Mexican varieties under the Wheat Impact Program were (in hectares): 1968-69, 10,000; 1969-70, 37,000; 1970-71, 63,000; 1971-72, 125,000; and 1972-73, 138,000. In 1975-76 the area was 140,000 ha.[78]

During the 1968-76 period Iran had a wheat breeding program involving crosses between Mexican varieties and local or other varieties. As of 1976 the principal varieties in use were (year of introduction if known in parentheses):

- spring wheats: Inia 66 (1968), Arvand (1973), Moghan I (1973), Moghan II (1976), Bayat (1976), Khazar I (1973);
- irrigated winter wheats: Omid, Roshan, Bezostaya (1969), Adl (1977), Karaj I (1973), and Karaj II (1973); and
- rainfed winter wheats: Azar and Rashed.[79]

With the exception of Inia and Bezostaya, the introductions represent reselections of CIMMYT material (e.g., Moghan 1 and 2 and Khazar I) or local crosses using some CIMMYT materials (e.g., Karaj 1 and Arvand).[80] They are considered HYWVs. Omid, Roshan, Azar, and Rashed are improved local varieties.

Little is known of the wheat developments since 1977, but a recent letter from Iran provided some insight.[81] Of the early introductions, Inia is still a successful variety in the Caspian Coast area and Bezostaya is still grown in northeastern Iran. The overall varietal breakdown for the irrigated area (circa 1983) is shown in table 3.12.

The varieties marked with question marks under the type classification in table 3.12 are of unknown origin. They may be releases made since 1977. Chenab, a Mexican variety not previously known in Iran, was included with 2% of the area. Bezostaya did not appear in this classification.

Altogether, the known HYWVs of Mexican origin accounted for about 829,000 ha or 35.9% of Iran's total irrigated area. Thus, HYWVs evidently continue to be widely used in Iran.

Iraq

Iraq was an early adopter of the Mexican varieties. Developments in wheat are well recorded through the late 1970s, but nothing is known of any changes in the 1980s.

Imports of HYWV seed started modestly and built to an astounding level in 1 year. Initially, 5 t of Mexipak were imported during the 1965-66 season. In September 1968, 800 t of Mexipak were imported from West Pakistan. In 1971 imports of Mexican seed jumped sharply to 70,000 t. This increase was in response to a drought-induced crop failure. Of the total, 60,000 t were shipped from Mexico and included about 25,000 t of Mexipak, 20,000 t of Inia 66, and 15,000 t of Jori 69. Algeria provided 10,000 t of Inia.

The area planted with HYWVs, which followed the quantity of seed imports, changed as follows (in hectares): 1967-68, 6,400; 1968-69, 41,700; 1969-70, 195,200; 1970-71, 125,000; 1971-72, 950,000; 1972-73, 595,000; 1973-74, 700,000; and 1974-75, 750,000. The enormous increase in HYWV area in 1971-72 was possible given the quantity of seed available.[82]

From 1967-68 to 1970-71, the HYWV area was entirely planted with Mexipak. In 1970-71 and 1971-72, the HYWV area was composed of Mexipak, Jori 69 (in irrigated areas), and Inia 66 (in rainfed areas). A similar pattern was found in 1974-75. In 1977 Cocorit 71 was mentioned along with Abu-Ghraib 1 (a bread wheat developed in Iran but about which nothing else is known). Abu-Ghraib 3, a bread wheat variety of Mexican extraction (and a sister of Marcos Juarez INTA and Soltane), was released in 1978. As of the late 1970s the HYWVs occupied most of the irrigated (92%) and high-rainfall (75%) wheat areas in Iraq.[83]

Table 3.12. Area of principal wheat varieties in irrigated zone of Iran, circa 1983.

Variety (type)	Area (ha)	Proportion of total area (%)
Omid (W)	807,000	34.9
Roshan (W)	357,000	15.4
Inia (S), Khazer (S), and Naz (S?)[a]	270,000	11.7
Arvand (S)[a]	234,000	10.1
Bayat (S), Darab (S?)[a]	148,000	6.4
Azadi (?)	98,000	4.2
Adl (W)[a]	50,000	2.2
Chenab (S)[a]	50,000	2.2
Moghan 1, 2 (S)[a]	45,000	1.9
Tabasi (?)	33,000	1.4
Alborz, Kaveh (?)	31,000	1.3
Karaj 2 (W)[a]	20,000	0.9
Karaj 1 (W)[a]	12,000	0.5
Other	158,000	6.8
Total	2,313,000[b]	100.0

Key: W = winter; S = spring; ? = unknown.

[a]HYWVs of CIMMYT or Mexican extraction.

[b]Estimated by the USDA to be 5.5 million ha.

Source: Letter from M.A. Vahabian, Seed and Plant Improvement Institute, Ministry of Agriculture and Rural Development, Karadj, Iran, April 1984.

Nothing is known of HYWV developments in the 1980s. If the HYWVs continued to represent the same proportion of the total area (about 50%) as they did in the mid-1970s, they would now cover nearly 600,000 ha.

Jordan

The wheat area in Jordan is relatively small, and the HYWVs have played a modest role. As of the late 1970s Cocorit 71, Jori 69, and Stork were considered promising wheat varieties and were being multiplied. Wheat statistics did not differentiate between improved Jordanian and Mexican varieties, but the total area of improved varieties was small—about 7,000 ha in 1974-75, 10,000 ha in 1975-76, and 12,000 ha in 1976-77. As of the 1983-84 season the principal wheat varieties being multiplied were Der Alla No. 2, Hurani, and F.8. It is estimated that these varieties were planted on 20,000 ha.[84]

Lebanon

The HYWV area in Lebanon in the 1970s was modest. It rose gradually from 50 ha in 1967-68 to a total of about 20,000 ha in 1972-73, which held as an average through 1976-77. (It was slightly lower in 1974-75 and slightly higher in 1976-77.)

The HYWV area in 1968-69 and 1969-70 was entirely planted with Mexipak. In 1976-77 Mexipak remained the principal variety; Jori was planted on 3,000 to 4,000 ha. A 1979 report stated that Mexipak represented 60%-80% of the bread wheat area and that Jori occupied 40% of the durum wheat area. No more recent information has been found.[85]

Libya

Most of the wheat area in Libya, estimated by the USDA to be 325,000 ha in 1983 and 1984, is rainfed and is in a coastal strip along the Mediterranean Sea and in two nearby regions—the Jefara Plains and the Jebels (low mountains). Desert irrigation projects constitute a fourth region. HYWVs and improved varieties are grown to a variable extent in each of the four regions.

- *Coastal strip.*—Some of the coastal wheat area is irrigated. Experimental yields of up to 5-6 t/ha have been achieved with new varieties such as Mekhtar (Nainari x 8156[2]). The area actually planted with such varieties is not known.

- *Jefara Plains.*—The most widely grown variety is Gamenya from Australia (Kenya 117A/2* Gabo//Mentana/6* Gabo). Gamenya is clearly an improved variety, but it is not certain whether it should be classified an HYWV.

- *Jebels.*—Mexicali, a durum HYWV, is estimated to cover about 90% of the cereal area of about 100,000 ha. However, Mexicali seed has been intermingled with other varieties, and in 1983 it was estimated to be at least a 50% mixture. The average yield of Mexicali was about 1.2 t/ha on farms and 4 t/ha on experiment stations. Some advanced lines have outyielded Mexicali by 20% in experimental plots.

- *Desert irrigation projects.*—Between 40,000 and 50,000 ha of wheat are raised in three desert projects. Presumably, all of the area is planted with HYWVs. The average yield in one project (Sebha) rose from 1 t/ha in 1977 to 5 t/ha in 1980. The highest durum wheat and bread wheat producing lines in experiments in 1980 produced yields of 8.34 t/ha (Snipe "S") and 7.43 t/ha, respectively.

It is not possible to develop a precise overall HYWV estimate for Libya on the basis of available data. The HYWV area is probably between 125,000 and 150,000 ha. A CIMMYT team, which visited Libya in March and April 1983 and provided the information above, concluded that the further introduction of new varieties with increased yield potential would undoubtedly have a substantial effect on national yields. Fertilizer use at present, however, is limited.[86]

Morocco

Morocco has had a long involvement with HYWVs, which started in 1967-68 with an import of 1 t of Siete Cerros. In 1968-69 Morocco imported 500 t of Mexican varieties composed of 250 t of Siete Cerros, 100 t of Inia 66, 100 t of Tobari 66, 25 t of Penjamo, and 25 t of Norteno. Trials of CIMMYT varieties and lines were planted at the National Agricultural Research Station in Rabat and at provincial research stations.

The area planted with HYWVs for the 6 years for which estimates are available was (in hectares): 1967-68, 200; 1968-69, 4,900; 1969-70, 46,500; 1970-71, 90,000; 1971-72, 206,000; and 1972-73, 294,000. The varietal composition of this area underwent some changes over time. While Siete Cerros and Tobari were each fairly important in 1969-70, BT 908 from Mexico (Newthatch/Marroqui//Kenya C9906/Mentana) was even more important. The area of Siete Cerros and Tobari dropped sharply in 1970-71 as a result of their susceptibility to a *Septoria* leaf blotch epidemic during the 1968-69 season. BT 908 became the dominant variety in 1970-71 (95% of the area) and held this position for the next 2 years.[87]

Only fragments of information are available for the subsequent period. In 1974-75 the varietal breakdown of certified seed production was: Nasma, 40%; BT 908, 33%; Siete Cerros, 20%; and 2306, 7%. In 1976 a CIMMYT report mentioned that Cocorit 71 and Jori 69 were among the durums grown. In 1980 the main bread wheats reported were Nasma, Siete Cerros, Potam, Tegyey 32, and Pynite. All but Pynite are HYWVs. Tegyey 9 and 11 were approved for release in 1981. Among the durums the only HYWVs appeared to be Cocorit 71 and Jori 69. In 1981 a sizable quantity of Inrat 69 was imported from Tunisia because of a drought in Morocco. Two recent releases are ASCAD 65 (Stork "S"), a durum wheat, and Jouda (Kal x Bb), a bread wheat.[88]

A team from ICARDA, visiting Morocco in May 1982 reported that durum wheat was grown on about 75% of the wheat area and bread wheat on about 25% of the area. The durum varieties and their area were as reported for 1980. In the case of bread wheat, the team noted that Nasma was grown on or about 70% of the area and that Potam, Siete Cerros, and Pynite occupied the remaining 30%. Another report indicates that the importance of Cocorit 71 has increased in recent years.[89]

The origin of several of the Moroccan varieties may be of interest. Tegyey 9, 11, and 32 are all derived from a cross between Siete Cerros and an advanced line of Mara Zerameck. Nasma (149) was developed by the Direction de la Recherche Agronomique in Rabat from a cross of Dwarf Breadwheat 69 (from Montpellier) and Florence Aurore.[90]

In total, virtually all of the bread wheat area and a small but probably expanding portion of the durum wheat area appears to be planted with HYWVs. If it is assumed that in 1983 about 95% of the bread wheat area and 10% of the durum wheat area was planted with HYWVs and that bread wheat represented 25% of the total area and durum wheat 75%, it can be calculated that about 30% of the overall area was planted with HYWVs. Thus, the HYWV area might have been nearly 600,000 ha.

Oman

Semidwarf wheat varieties were first imported from Pakistan and India in 1970. Mexipak was found to be suitable for some areas, and in 1973 seed was distributed to farmers on a limited scale. During 1977-78, 40 t of Kalyansona was imported from India and distributed. Two other Indian varieties were "awaiting release" in early 1978: Safed Lerma and HD 1999. As of 1985 essentially all of the limited wheat area (placed at about 1,000 ha in 1980 by FAO) was reportedly planted with HYWVs.[91]

Saudi Arabia

Work on variety testing in Saudi Arabia started in 1965, and a wheat improvement program was initiated in 1971-72. Seed imports have long played an important role. The first import was a gift of 2 t, principally Mexipak 65, from Pakistan in 1969-70. In 1970 the Ford Foundation donated 0.8 t of Super X, which provided the initial basis for the wheat improvement program. In 1974-75, 680 t of Super X was imported from Egypt (500 t for the 1974-75 crop and 180 t for the 1975-76 crop). Further imports were 500 t in 1975-76 and 1,150 t in 1976-77.

The area planted with HYWVs during the 1970s was (in hectares): 1972-73, 140; 1973-74, 2,000; 1974-75, 10,000; 1975-76, 12,000; and 1976-77, 13,500. The HYWVs increased from about 19% of the total wheat area in 1974-75 to 23% in 1976-77.[92]

In the early 1980s the overall wheat area began to expand rapidly, rising from 67,000 ha in 1980 to 288,000 ha in 1983 and 495,000 ha in 1984. Seed imports also increased, climbing from an estimate of 9,000 t in 1981-82 to 40,000 t in 1982-83 and 100,000 t in 1983-84. As of early 1984 only four varieties were approved for import: Yecora Rojo, Van Ern, Westbred, and Probred. About 95% of those seeds imported were Yecora Rojo, which in turn is estimated to represent more than 98% of the total wheat area. Westbred and Probred are semidwarfs sold by American seed firms. All recent wheat seed imports have been from the United States.[93]

Syria

Syria has made extensive use of HYWVs since the early 1970s, and HYWVs are now a significant portion of the total wheat area.[94] An initial import of 5,160 t of seed was made in 1970-71 (origin not indicated). The varietal composition was: Siete Cerros, 1,870 t; Inia, 1,150 t; Pitic, 770 t; Lerma Rojo 64, 740 t; Mexipak 65, 540 t; and Penjamo 62, 90 t. During 1972-73, 50 t of Jori 69 were imported.

Those imports do not, however, seem to have been Syria's first exposure to Mexican varieties. In 1969 Syria released Syrimex, a selection from a CIMMYT line. Gezira 17, a high-yielding durum variety that was a natural mutant selected from a field of an Italian variety called Alexi, was approved as a new variety in 1972 (although seed was not distributed until 1977).

A CIMMYT report for 1977 indicated that 70%-80% of Syria's wheat area was planted with durums and 20%-30% with bread wheats. (By the early 1980s the respective proportions seemed to be closer to 70% and 30%.) In the case of durums, Jori 69, Gezira 17, and Cocorit 71 were listed only as among the "other varieties." In the case of bread wheat, however, Mexipak was the dominant variety, followed by Syrimex (Syrmex).

Data on HYWV seed production in Syria from 1982 to 1984 indicate the following varietal composition: Mexipak, 56.8%; Jori 69c, 16.7%; Siete Cerros, 14.1%; and Gezira 17, 12.4%. The two bread wheats accounted for nearly 71% and the two durums for 29%. The continuing importance of the original introductions is surprising. Seed production of Syrimex ceased in 1969.

Some new varieties were recently introduced. In October 1983, the Syrian Variety Release Committee approved Sham 1, a durum wheat, and Sham 2, a bread wheat. Both were selected from CIMMYT advanced breeding lines grown at ICARDA and were tested by the Agricultural Research Center of the Ministry of Agriculture.

Figure 3.5. Syrian farmers examine on-farm tests of wheat varieties conducted in cooperation with ICARDA (source: ICARDA).

Sham 1 yields up to 18% more than Mexipak. Both have high levels of resistance to disease, mature 1 week earlier than other Syrian varieties, and have other advantages. Other varieties coming into use include the durum varieties Crane-sib and Waha (both with Mexican origins) and the bread wheat variety Golan (S311 x Norteno; identified by ICARDA from a cross made in India). The use of Gezira 17 has declined because of a susceptibility to disease.

The area planted with HYWVs has increased fairly quickly through 1978 and then more gradually (table 3.13). A drop in area in 1981 was probably related to a decline in overall wheat area that year. By 1983 HYWVs occupied about 50% of the total area.

Syria's increase in HYWV production is tied in with a change in cropping patterns from cotton-fallow to cotton-wheat in irrigated areas near the Euphrates and Khabour Rivers. In 1981 only 22.1% of the HYWV area was irrigated. Of the total wheat area on irrigated land, 75% grew HYWVs (down from 81% and 83% in the previous 2 years) and 25% grew local varieties. The yields of the HYWVs were nearly twice those of the local varieties (down slightly from an 8-year average yield of 2.32 times that of the local varieties). Of the total HYWV area 80.3% was in the private sector and 19.7% was in the cooperative sector. (The proportion grown in the private sector represented an increase from 58.4% in 1976.)

Tunisia

Wheat production in Tunisia is divided into two principal zones: the North, where rainfall is generally above 400 mm, and the central and southern regions, where sporadic rainfall ranges between 150 and 350 mm. During the period 1980-82 about 90% of Tunisia's wheat area was planted with durum wheat and 10% with bread wheat. The bread wheats are principally found in

Table 3.13. Area of high-yielding wheat varieties in Syria from 1971 to 1983

Year	HYWV area (ha)	Proportion of total area (%)
1971	38,000	3.0
1972	75,000	5.5
1973	121,000	8.2
1974	225,000	14.6
1975	269,700	15.9
1976	340,800	21.4
1977	362,800	23.7
1978	518,500	33.3
1979	559,900	38.7
1980	641,600	44.3
1981	574,100	45.7
1982	601,600	49.2
1983	601,500	50.1

Sources: 1971-1973: D.G. Dalrymple, *Development and Spread of High-Yielding Varieties of Wheat and Rice in the Less Developed Nations*, FAER No. 95 (Washington, D.C.: U.S. Department of Agriculture, September 1978), p. 53; 1974-1981: I. Naji, "Introduction of High Yielding Wheat Varieties in Syria" (Damascus: International Center for Agricultural Research in the Dry Areas, March 1984); 1982-83: I. Naji, ICARDA (forwarded by J.P. Srivastava, August 1984).

the North.[95]

Tunisia has long been active in wheat varietal improvement, and numerous improved varieties have been grown for some time. Both AID and CIMMYT have supported Tunisian breeding programs.[96] The first substantial area of Mexican varieties was grown in 1968. Varieties released from 1969 to 1981 are listed in table 3.14. INRAT 69, the first variety to be released, was developed from a cross of Kyperounda (an introduction from Greece) and Mahmoudi (local). Newer varieties have Mexican germ plasm in their pedigree. The yield potentials of the newer varieties are high compared to that of good traditional varieties. Although it may be difficult to realize full yield potential in rainfed fields, the yields of the HYWVs during the 1980-82 period averaged nearly 2.5 times higher than the ordinary varieties in the case of durum wheat and 2.0 times higher in the case of bread wheat. (The HYWVs may have, of course, been grown under more favorable conditions.)[97]

The area planted with HYWVs (as classified in government statistical reporting) grew modestly and somewhat unevenly from 1968 to 1979, expanded sharply in 1980 and 1981, and leveled off in 1982 and 1983 (table 3.15). The expansion in percentage terms was aided by a decline in the overall wheat area in the early 1980s. The HYWVs are planted entirely in the northern zone.

Initially, much of the HYWV area was planted

Table 3.14. High-yielding wheat varieties developed and released in Tunisia from 1969 to 1981

Variety	Year of release	Maximum yield potential (t/ha)[a]
	Durum wheat	
INRAT 69	1969	3.5
Amal 72	1972	3.5
Badri	1972	4.0
Maghrebi	1974	5.5
Ben Bachir 78[b]	1980[c]	6.0
Karim 79[d]	1981[c]	6.5
	Bread wheat	
Soltane	1972	4.5
Carthage 74	1974	6.0
Dougga 74	1974	6.0
Fath	1974	5.5
Salambo 80	1980	6.5
Tanit 80	1980	6.5

[a]Compared to 2.0 t/ha for D-117 (a durum wheat) or 3.5 t/ha for Florence Aurore (a bread wheat).

[b]Sister of Stork.

[c]Date of release varies slightly in other reports.

[d]Sister of Bittern.

Source: W.F. Johnson, C.E. Ferguson, and M. Fikry, *Tunisia: The Wheat Development Program*, Project Evaluation Report No. 48, (Washington, D.C.: U.S. Agency for International Development, October 1983), table D-9.

Table 3.15. Area of high-yielding wheat varieties in Tunisia from 1968 to 1983

Year	HYWV area (ha)	Proportion of total area (%)
1968	800	--
1969	12,000	1.6
1970	53,000	5.1
1971	102,000	10.7
1972	60,000	5.8
1973	149,200	13.1
1974	155,000	14.5
1975	225,700	21.2
1976	205,700	17.4
1977	228,400	21.9
1978	252,000	22.2
1979	249,000	22.0
1980	311,000	34.6
1981	352,000	38.5
1982	327,000	42.0
1983	344,000	36.0[a]

Key: --=negligible.

[a]There was a decline in the HYWV percentage due to a sharp increase in the area planted with ordinary varieties in the central and southern regions.

Sources: 1968-1977: D.G. Dalrymple, *Development and Spread of High-Yielding Varieties of Wheat and Rice in the Less Developed Nations*, FAER No. 95 (Washington, D.C.: U.S. Department of Agriculture, September 1978), p. 54; 1978-1979: W.F. Johnson, C.E. Ferguson, and M. Fikery, *Tunisia: The Wheat Development Program*, Project Evaluation Report No. 48, (Washington, D.C.: U.S. Agency for International Development, October 1983), table D-11; 1980-1982: U.S. Agricultural Attaché Reports from Tunis: TS-3010, May 25, 1983; JS-4010, April 20, 1984.

with bread wheat, but the balance swung in the mid-1970s, and high-yielding durum varieties became much more important. As of 1983 about 79% of the HYWV area was occupied by durum wheat and 21% by bread wheat. Still, according to official statistics, from 1980 to 1982 HYWVs were planted on a higher proportion of the bread wheat area (66.3%) than the durum wheat area (35.7%).

The HYWV proportion for durums actually may be more than 36%. In a set of varietal estimates reported in 1979, varieties considered as HYWVs in table 3.14 represented 97% of the total durum wheat area.[98] Estimates made by CIMMYT staff members for 1983 suggested that HYWVs represented about 82% of the total durum wheat area.[99] Perhaps one or more of the varieties included in table 3.14 was not considered a semidwarf in the preparation of the official estimates.

On the other hand, the HYWV proportion for bread wheats could be lower than 66%. As of 1983 the leading high-yielding bread wheat varieties were (in decreasing order of importance): Dougga, Tanit, Carthage, and Salambo. All are semidwarfs. The varieties are estimated by CIMMYT staff to have represented only about 40% of the bread wheat area. In this case, additional varieties are evidently included in the official variety list or there has been a change in the list over time.[100]

In any case, the HYWVs have come to assume an important role in wheat production in Tunisia.

Turkey

Wheat may be more important to the economy of Turkey than to the economy of any other DC. There are three main wheat environments: winter, transitional, and spring. The winter zone accounts for about 75% of Turkey's wheat growing area and is located on the Anatolian Plateau in the eastern part of the country. The transitional zone rings the plateau and does not require varieties with quite as much winter hardiness. The spring wheat zone is largely in the coastal regions. Despite the importance of wheat in Turkey, relatively few official statistical data are available.[101]

Varietal Introductions and Improvement

Four institutes for agricultural research were established in the 1920s, just after Turkey received its independence. From then until the 1960s, about 30 improved wheat varieties were released.

A new period of varietal improvement was initiated in the 1960s with the arrival of the semidwarf wheats. In 1965 a farmer in the coastal spring wheat area obtained 40 kg of Sonora 64 and Lerma Rojo 64 seed from an AID technician who had brought them from Mexico. The results were so good that 100 farmers got together and obtained government approval to import 60 t of Sonora 64 seed from Mexico. The seed was planted during the 1966-67 season.

Several other critical events also happened in the 1960s. In 1966 a group of American agricultural consultants, visiting Turkey at government invitation, suggested both a study of the experience of the 100 farmers and large-scale imports of seed. The government decided to import 22,000 t of Mexican seed in 12 varieties for the 1967-68 season. In preparation two Oregon State University scientists were asked to visit Turkey in early 1967 to evaluate the fields planted with Sonora 64 and to develop a package of cultural practices for farmers who would grow the imported wheats. As a result 12 county agricultural extension agents and farmers from Oregon and Washington went to Turkey in the fall of 1967 to assist in a large-scale educational campaign.

Thereafter, the HYWV area expanded sharply. During the 1967-68 season some 60,000 farmers planted the Mexican wheats on 170,000 ha. Within 3 years the wheats were reportedly planted on 1.1 million ha, well over half the spring wheat area.

The Mexican varieties, however, were not strongly resistant to the Turkish strains of two fungal diseases (stripe rust and *Septoria* leaf blotch) and were not suitable for the large winter wheat area. Turkey, therefore, asked the Rockefeller Foundation to help design a program for wheat improvement and training of scientists. An agreement was signed in 1969; CIMMYT and Oregon State University (which already had an AID-sponsored team within the Anatolian Plateau) also were involved. A wheat research and training center was established, and 16 students were sent to the United States for graduate studies. The project continued through 1976 and then began to shrink as Turkish capabilities increased.

In the case of spring wheats, the project involved selecting and testing crosses introduced from CIMMYT and elsewhere as well as expanding the domestic breeding program. The first step led to the release of four improved varieties in the mid-1970s: the bread wheats Cumhuriyet 75 (Ciguena S) and Sakarya (Chanate), and the durums Dicle 74 (Cocorit 71) and Gediz 75 (LD375-TC2/Jori "S"). Improved varieties released since then include:

- Bread wheats.—Lachich (from Israel) and Argelato (Mara/Orlandi), Libellula (Tevere/Giuliani/San Pastore), and Oros all from Italy). Ata 81 (Kavkaz/Cumhuriyet 75) and Gonen (8156/Mara//Bb) were developed from crosses and selections made in Turkey.
- Durum wheat.—Gokgol 79 (which came as an advance line from CIMMYT).

Most of the spring wheats incorporate semidwarf germ plasm from CIMMYT or Italy.

In the case of winter wheats, much more than breeding was involved. Agronomic practices needed to be changed, and those received most of the research attention. Two satisfactory varieties were already available: Bezostaya, a well-known Russian variety (200 t of which had been received in the late 1960s), and Bolal 2973, a selection of a cross (Cheyenne//Kenya/Montana) originally made at the University of Nebraska. Bezostaya was quickly adopted in Eastern Thrace and represented 75% of the wheat area in that region in 1972, but it expanded more slowly in the Anatolian Plateau. Bolal 2973 was released in 1974. Other winter wheats released through 1984 include:

- Bread wheats.—Kirac 66, Tosum 21, Tosum 22, Tosum 144, Etoile de Choisy, Porsuk 2800, Lancer (from the United States), Hayama 79 (Scout 5/Agent), Gerek 79 (Men. sib x My 48-4/14/Yayla 305), Kirkpinar 79 (63-112-66-2 x 7c), Sadova 1, Vratza, and Dobrudja. (The last three are from Bulgaria.)
- Durum wheats.—Kunduru 1149 (local selection, 1967), Cakmak 79 (Uveyik 162-61-130), and Tunca 79 (Fata sel. 185-1 x 61-130 Leeds).

Three of the winter wheat varieties were developed from crosses made in Turkey: Gerek 79, Cakmak 79, and Tunca 79. Some of the varieties released have not become commercially important, and some might be considered improved rather than HYWVs.

Early Estimates of HYWV Adoption

Data on the adoption of HYWVs in Turkey are scarce and not entirely consistent. Some figures on the adoption of Mexican varieties were noted in earlier editions of this book. A 1967-68 figure of 170,000 ha seems satisfactory, but figures for later years differ. Estimates provided by the U.S. agricultural attaché suggest the following increase in area of Mexican varieties (in hectares): 1968-69, 579,000; 1969-70, 623,000; 1970-71, 640,000; and 1971-72, 650,000. However, a survey sponsored by CIMMYT of 1,250 wheat farms in six regions of Turkey in the spring of 1973 resulted in an estimate of the Mexican HYWV area in 1971-72 of 1.09 million ha, which is 60% larger than the figure suggested by the attaché. In 1976-77 a rough estimate that about 26% of the total wheat area was planted with a wide range of HYWVs (Mexican, Italian, Russian, and others) suggested a total area of 2.2 million ha.

The CIMMYT survey cited earlier showed that in 1971-72 farmers planted high-yielding spring wheat varieties on about 65% of the area (ranging from a high of 95% in the Mediterranean region to 40% in South Mamara and 35% in the Aegean region). In the case of winter wheats, Bezostaya was planted on 79% of the area in Eastern Thrace but on only 11% of the area in the Anatolian region (where Bolal remained as the dominant variety).

One other piece of variety information pertains to HYWV seed production and distribution in 1979 (table 3.16). Rankings of individual varieties varied by category. Still, Penjamo (a CIMMYT variety) ranked fourth in seed production, which is surprising considering its disease susceptibility. (It evidently ranked higher than the other spring varieties in this respect.)

Recent Developments

No official data have been found for the 1980s. However, information provided by Turkish and CIMMYT wheat specialists provide some useful insight on wheat varieties in Turkey.[102] New improved varieties currently recommended are listed in table 3.17. All of the varieties have already been noted.

A key question is whether these improved varieties should be considered HYWVs. While most, if not all, of the spring varieties probably fall into the HYWV category, opinions may differ with respect to the winter varieties. A wheat specialist with some experience in Turkey thought the winter HYWVs might be limited to Bezostaya, Porsuk, Gerek 79, Kirkpinar 79, Cakmak 79, and Tunca 79, with Bolal and Haymana 79 considered borderline cases. Wheat scientists currently in Turkey indicate that Bolal, Gerek, Kirat 66, and Haymana 79 can outyield Bezostaya. Not mentioned in either HYWV list are Lancer, Ankara 093/44, Sadova, Vratza, and Dobrudja. Ankara 093/44 is being withdrawn as a recommended variety in 1985. The last three are, however, considered HYWVs. Thus, most of the improved varieties seem to be in the HYWV category.

Overall, wheat scientists in Turkey estimate that about 50% of the country's total wheat area in 1984 was planted with improved varieties. The estimated regional distribution was: Eastern Thrace, 100%; Marmara, 85%; Aegean, 85%; Mediterranean, 70%; Black Sea, 30%; Transi-

Table 3.16. HYWV seed production and distribution in Turkey in 1979

Variety	Type	Production (t)	Distribution (t)
Dicle 74	S/D	21,155	9,231
Bezostaya	W/B	16,208	10,835
Bolal 2973	W/B	16,150	5,297
Penjamo	S/B	12,000	5,533
Kirac 66	W/B	7,271	4,209
Kunduru 1149	W/D	6,000	4,974
Orso	S/B	4,272	3,221
Cumhuriyet 75	S/B	1,568	1,361
Others		3,270	2,479
Total		87,894	47,140

Key: S=spring, W=winter, B=bread wheat, D=durum wheat.

Source: Letter from A.R. Persi, agricultural attache, American Embassy, Ankara, March 1981. Data provided by the Ministry of Agriculture, Government of Turkey.

Table 3.17. Improved wheat varieties recommended in Turkey in 1984

Wheat type	Date released or introduced	Habit	
		Spring	Winter
Bread	Before 1978	Cumhuriyet 75[a] Penjamo 62[b] Libellula[c] Orso[c] Argelato[c]	Bezostaya[a] Bolal 2973[a] Lancer[d] Kirak 66 Ankara 093/44[a,b] Prosuk 2800
	After 1978	Gonen[d] Ata 81[d] Lachich[d] Malabad[d]	Gerek 79[d] Kirkpinar 79[d] Haymana 79[d] Sadova 1 Vratza Dobrudja
Durum	After 1974	Dicle 74[a] Gediz 75 Gokgol 79	Kunduru 1149[a] Cakmak 79[d] Tunca 79[d]

[a]Most widely grown.

[b]Will likely be removed from list of recommended varieties in 1985.

[c]Facultative variety.

[d]Expanding in use.

Sources: Personal communication with B.C. Curtis and A. Klatt, CIMMYT, February 1985 and letter from B. Skovmand, CIMMYT, Ankara, April 1985.

tional, 30%; Central Plateau, 50%; Southeast, 30%; and East, 10%.

Moving from these percentages into actual area presents several difficulties. One, which may not be expected, is that estimates of the overall wheat area differ. Turkish wheat scientists cite a figure of 9.1 million ha for 1983-84; yet the USDA estimate for 1984, and indeed the average for the last 5 years, is 8.6 million ha. There is also a question of whether the improved variety area proportion of 50% should be discounted to some degree to allow for non-HYWVs—and if so, how much? If the USDA area estimate is used and it is assumed that 80% of the improved variety area (or 40% of the total) was planted with HYWVs, the HYWV figure would be 3.44 million ha.

One way to check this calculation is to estimate the HYWV area as a proportion of the spring and winter wheat areas and then compute the total area. The wheat specialists in Turkey estimated that the spring wheat area occupied 25% of the total area and the winter wheats 75%. Hence, with the USDA estimate of area and assuming that 80% of the spring wheat area and 25% of the winter wheat area was planted with HYWVs, the total area for HYWVs is 3.43 million ha, nearly 40% of the total area.

The fact that the two HYWV figures are nearly identical does not prove that they are right. Different assumptions and definitions of HYWVs would produce different results. For example, one wheat scientist thinks that the HYWVs represent 90% or more of the spring wheat area. Such a figure would produce a total HYWV area of 3.66 million ha or 42.6% of the total. In any case, the HYWVs represent a substantial increase over the HYWV estimates cited earlier for 1976-77.

To date the level of resources devoted to wheat improvement in Turkey has been thought to be modest, considering the importance of the crop. A considerable yield potential remains to be tapped, particularly in the winter wheat area in the Anatolian Plateau. However, agronomic and management practices may still be as much or more of a limiting factor on the plateau as the varieties grown.

Yemen Arab Republic

Yemen Arab Republic is a small wheat producer with about 50,000 ha of wheat as of 1977. Virtually all of the wheat was durum wheat. The history of wheat improvement in Yemen Arab Republic has been brief. It started in 1973 when an FAO plant breeder was stationed in the country. In 1976 Sonalika was released for rainfed area in the Yarim region, and it was later introduced in other areas; it was expected to occupy 200 ha in 1978. Kalyansona was also introduced but withdrawn because of disease problems. The American variety Red River (a sister of Tobari 66) was recommended for one region under irrigation. As of late 1983 it was planned to extend the research program to other areas of the country. The following varieties looked particularly promising: Pavon "S", Sakha 78 (Egypt), Tanori, and Blue Silver (Pakistan; another name for Sonalika).[103]

People's Democratic Republic of Yemen

Kalyansona and Sonalika were introduced and released in 1973. As of 1978 about 40% of the relatively small wheat area was planted with the two HYWVs. Meanwhile, a search was underway for varieties better suited to local growing conditions. Following performance tests one line (S 311 x Norteno) was released as Ahgaf. Ahgaf is a sister of Golan, was released in Syria, and is partly of Indian origin. It is taller than its two predecessors; this characteristic was desired in order to increase straw yield. Ahgaf was grown on 500 ha during the 1983-84 season and is expected to replace Kalyansona and Sonalika.[104]

AFRICA

Wheat is an important crop in some of the more temperate-climate nations of Africa. The HYWVs have found a modest foothold in several countries, principally in East Africa. Coverage in this section is limited to seven countries: Ethiopia, Kenya, Nigeria, Sudan, Tanzania, Zambia, and Zimbabwe. The North African countries are included in the section on the Near East. The Republic of South Africa is discussed briefly in a footnote.[105] In addition, HYWVs are being grown in several other African nations:

- West Africa.—In Senegal HYWVs were planted for the first time in 1973-74 on an experimental basis. Small areas of HYWVs were reported in Cameroon, Chad, Ghana, Mali, and Upper Volta in 1975. Wheat is also grown in Mauritania, Mozambique, and Niger.[106]
- East and southern Africa.—HYWVs of various types have been grown in Madagascar. CIMMYT has been involved in research in Burundi, Malawi, Rwanda, and Somalia. Wheat is also grown in Botswana and Lesotho.[107]

African wheat environments are diverse. In West Africa the growing season is short, and in the dry season (mid-November to early March) irrigation is usually needed. In East Africa wheat is generally produced in rainfed fields at high elevations; some exceptions are the lowlands of Somalia, Zambia, Zimbabwe, and Botswana, where irrigation is used. In West Africa and some nations in East Africa heat-tolerant varieties are needed.[108]

There is considerable interest in expanding wheat production in many African nations, but relatively few technical and scientific resources are generally available for the needed research. As noted in the introduction to this chapter, CIMMYT is doing some research on wheat for more favorable tropical areas.[109]

Ethiopia

Wheat production is of major importance in Ethiopia, where all wheat is grown as a rainfed crop. As of 1977-78 about 70% of the area was planted with durum wheat and 30% with bread wheat Most of the bread wheat area grew impro ed varieties, but the durum wheat area grew almost entirely traditional varieties.[110]

Ethiopia began to use improved varieties of bread wheat on a commercial level in 1968. Most of the early improved bread varieties released were developed in Kenya. The first varieties of Mexican origin were released in 1974.[111] The first improved durums were released in 1976, and the first bread wheats developed in Ethiopia were released in 1980. Details are provided in table 3.18. Data are not available on the relative

Table 3.18. Improved wheat varieties released in Ethiopia from 1973 to 1983

Variety	Year	Origin	Comments[a]
		Bread wheat	
Mamba	1973	Kenya	Withdrawn; susceptible to stripe rust
Enkoy	1974	Kenya/Ethiopia	Major variety[b]
Romany BC	1974	Kenya/Mexico	Widely grown; susceptible to stripe rust
Dereselgan	1974	Mexico	Little grown; susceptible to stripe rust
Sonora	1975	Mexico	Not in demand
CI14393	1977	Mexico	Not in demand
K6290 Bulk	1977	Kenya	Major variety[c]
Genet 71	1977	Mexico	Not in demand
K6295-4A	1980	Kenya	Important variety
ET 13 A2	1980	Ethiopia	Important variety
ET 12 D4	1980	Ethiopia	Small demand
KKBB	1982	CIMMYT	Not multiplied
		Durum wheat	
Gerardo Vz	1976	CIMMYT/Ethiopia	Withdrawn; susceptible to leaf and stem rust
Cocorit	1976	CIMMYT	Not in demand
LD357/C8155	1979	United States	Not in demand
Boohi	1982	CIMMYT	Fair demand

[a]As of 1983.

[b]Cross K4500 in Kenya; not released because it did not meet bread-making standards. Released in Tanzania as W3697 and in Zambia as Tai.

[c]Also known as cross K6290; released as K. Nyati in Kenya (not recommended in 1984) and as Malawi elsewhere. Other selections are used in Tanzania, North Zambia, and possibly Mozambique.

Sources: F. Pinto, "Wheat Situation in Ethiopia (1978-1984)" (Addis Ababa: Ethiopian Seed Corporation, April 1984), Table 3; and International Maize and Wheat Improvement Center, *CIMMYT Report on Wheat Improvement, 1981* (Mexico City: the Center, 1984), p. 121.

heights of the varieties in Ethiopia or their semidwarf status. Three new CIMMYT varieties were to be released in 1984-85: Bobwhite 7, Sunbird 4, and Veery 17.

Following the revolution in 1974, wheat production was organized in four main ways: peasant associations (PAs), producer cooperatives, relief and rehabilitation commissions, and state farms. The PAs represented about 86.7% of the total wheat area in 1982-83, while the other three accounted for the remaining 13.3%. The PAs grow mostly traditional varieties. The other three groups use improved varieties only. Seed multiplication and distribution is handled by the Arsi Rural Development Program, which has been in operation since 1966, and the Ethiopian Seed Corporation, which was established in July 1978 under the Ministry of State Farms.

The four major bread wheat regions and the proportion of area reportedly sown with improved varieties in 1983-84 were: Arsi, 98%; Bale, 95%; Gondar, 50%; and Shoa, 23%. The figures for the first three regions, however, are thought to be high by some observers. (In the case of Bale, they place the actual proportion at 30%).[112] Regardless, the proportion of improved varieties in other regions is virtually nil.

As of 1982-83 it was estimated that of the total 706,000 ha of wheat grown in Ethiopia about 250,000 ha (35.5%) were planted with improved varieties released since 1974. Including improved varieties released before that time would raise the total to 384,000 ha or 54.4% of the total. Nearly all of the area with improved varieties in either case is presumed to be bread wheat.

Kenya

In 1906 a prominent Kenyan wheat grower, Lord Delamere, employed an English plant breeder, G.W. Evans, to develop varieties resistant to stem rust. Evans initially used varieties from Italy (Rieti), Australia, Canada (Red Fife), and Egypt. In 1920 a full-time plant breeder, G.I.L. Burton, was employed by Kenya's colonial government. Originally, Burton was stationed near Nairobi, but he moved in 1927 to the main research station at Njoro.[113] Some of the varieties developed by Burton at Njoro, such as Kenya, Kenya Blanco, and Kenya Rojo, were used in early Mexican work. Unfortunately Burton's records were lost in a fire, and the parentage of most of his varieties is unknown.[114]

Wheat is grown as a commercial crop in the highlands of the Rift Valley Province and near Mt. Kenya. Bread wheats are much preferred, but some durum wheats are grown. Production is entirely on rainfed land and over a wide range of elevation. Some varieties are recommended for all altitudes; others are recommended for a specific altitudinal range.

The wheat program at Njoro has produced a vast number of improved varieties. In 1978 CIMMYT noted that 132 varieties had been released since 1908, of which 25 were still being commercially grown.[115] In 1975 CIMMYT listed seven varieties of Mexican extraction being grown in Kenya; by late 1977 the number had increased to 17.[116] Others have followed.

The list of recommended Kenyan wheat varieties for 1984 is provided in table 3.19. Of the 16 varieties, 13 appear to have Mexican parentage (particularly Tobari 66), and they accounted for 83% of the 1983 wheat-growing area or nearly 96,000 ha. Three varieties with no Mexican parentage accounted for the balance of 1983 area or nearly 23,500 ha. The nine leading varieties in terms of area show a wide range in height—from 77 to 102 cm—but all have good lodging resistance. Yield does not seem to be correlated with height.

Nigeria

Nigeria, a tropical nation, is not normally thought of as a wheat-producing country. Yet irrigated wheat has been grown for centuries along the shores of Lake Chad during the cool, dry season. Most of the area is, however, only marginally suitable for wheat because the cool period is too short. High temperatures during periods of vegetative growth limit tillering and, during heading (harvesting), cause a reduction in yields.[117]

With the development of four irrigated areas in northern Nigeria in 1959, interest in wheat production and wheat research increased. Variety screening was initiated, and trials of Mexican varieties began during the 1966-67 season. In early 1971 two Mexican varieties were recommended: Sonora 63 and (Lee x N10-B) GB-55) GB-56. Siete Cerros was recommended for Kano State in 1975. Inia 66 and Indus 66 were released for the Chad Basin area. Super X and Anza were also grown. As of 1984 the Institute for Agricultural Research (Ahmadu Bello University, Zaria) recommended five varieties for production: two tall non-Mexican wheats, Tousson and Florence Aurore,[118] and three Mexican semidwarfs, Sonora 53, Siete Cerros, and (Lee x N10-B) GB-55) GB-56. Siete Cerros was the most popular of the group and was grown in all of the wheat-growing areas, especially in the Kano River project.

The actual area planted with all varieties and with the semidwarfs is uncertain. Estimates suggest that the overall wheat area expanded from a few hundred hectares in 1959-60 to 2,000 ha in 1967-68; an average of 3,700 ha from 1973-74 to 1975-76; 6,000 ha in the late 1970s; and 15,000 ha in 1984. As of 1976 CIMMYT estimated that 80%-90% of the irrigated area was planted with semidwarfs. A CIMMYT scientist places the HYWV area in 1983 at about 10,000 ha. The largest area was in the Lake Chad area, followed by Kano.

The Nigerian HYWV area could increase. Nigeria has embarked on a program to significantly increase wheat production with plans to put wheat into 50% of the irrigable land in the northern Guinea and Sudan savanna areas of the country (estimated to be 345,000 ha when fully developed). There is, however, a wide range of constraints on wheat production. Germ plasm is needed with increased heat and drought tolerance.[119]

Table 3.19. Wheat varieties recommended for planting in Kenya in 1984

Variety[a]	1983 area (ha)	Year of release	Height (cm)	Lodging resistance	Yield[b] (% of K. Tembo)	Notes/ pedigree
K. Fahari	21,610	1977	100	Good	117	A
K. Tembo	19,380	1975	84	Good	100	A
K. Nungu	17,860	1975	84	Good	96	B
K. Nyangumi	17,240	1979	79	Good	117	C
K. Paka	15,710	1975	77	Good	96	A
K. Paa	11,130	1980	100	Good	138	D
K. Kongoni	5,980	1981	87	Good	125	D
Bounty	1,800	Unknown	102	Good	96	E
K. Ngiri	1,100	1979	80	Good	92	A
K. Bongo	1,080	Unknown	98	Fair	79	C
K. Kulungu	890	1982	92	Good	104	B
K. Popo	530	1982	105	Good	104	A
K. Leopard	170	1966	102	Poor	100	C
K. Mamba	--	Unknown	Unknown	Fair	96	C
K. Nyumbu	--	1982	115	Good	103	B
K. Zabadi	--	1979	99	Good	104	A
Total	114,480[c]					

Key: --=negligible.

A. Contains Tobari 66 in parentage.

B. Contains Sonora 64 in parentage.

C. No evident CIMMYT germ plasm in pedigree (K. Nyangumi and K. Mamba contain African Mayo).

D. CIMMYT/Mexican origin.

E. Introduction. Bounty 208 and 309, selections of Mexican extraction, were released in the United States in 1971 and 1974, respectively, by Cargill; they are not related.

[a]Varieties previously released but not recommended for 1984 because of leaf and stem rust and lodging include: African Mayo (fair lodging resistance), K. Kibo, K. Koforu (1976; good lodging resistance), K. Mbogo, K. Nyaka, and K. Nyati.

[b]Yield determined at the wheat program at Njoro.

[c]Does not represent the total area of all varieties.

Sources: Cols. 1-4; letters from F.T. Kanungi, USAID Mission, Nairobi, Kenya, April, May 1984. Cols. 5-6; *Planting Guide*, Kenya Seed Company (provided by Harold Norton, Agricultural Attache, American Embassy, May 1984).

Sudan

Improved wheat varieties, principally from Egypt (such as Giza 155), have been grown extensively in Sudan's irrigated wheat areas for a number of years. In 1971 a semidwarf variety known as Mexicani, a selection from a Mexican cross, was released.[120] The estimated area planted with Mexicani increased significantly during the 1970s: 2,400 ha in 1972-73; 50,000 ha in 1974-75; and about 150,000 ha in 1976-77.

As of 1975-76 the area growing Mexicani represented about 36% of Sudan's total wheat-growing area; the rest was planted with Giza 155, a non-HYWV. During the 1976-77 season the HYWV area represented about 50% of the total wheat area and increased to about 60% in 1977-78.[121] Subsequently, Giza 155 continued to decline in importance and was not grown in Gezira (the principal wheat producing region) after 1981-82.

New varieties with Mexican ancestry include Condor, from Australia, which is similar to Mexicani but with more attractive white grains, and Antizana, from Ecuador. HD 2172 from India has been released as Debeira.

As of 1983, Mexicani was grown on more than 90% of the total wheat area in Gezira. However, the overall wheat area in Gezira dropped sharply from 1978-79 (177,730 ha) to 1983-84 (106,480 ha). Thus, Mexicani represented a larger proportion of a smaller total. An HYWV area of approximately 100,000 ha has been assumed for 1982-83.

There are two principal reasons for the drop in Sudan's wheat growing area: low government-controlled prices for wheat and the low productivity of wheat compared to other crops. The government recently took steps to raise the price of wheat and to announce those prices prior to the planting season. High temperatures during the winter are a problem—and were particularly so in 1983-84. Varieties with greater tolerance to heat are needed.[122]

Tanzania

In 1971 Tanzania began a wheat improvement program with Canadian assistance. The first varieties were produced from selections obtained from the Plant Breeding Institute in Njoro, Kenya. In 1973 the Lyamungu Research Station made 270 t of seed with Mexican parentage available to farmers: 180 t of W3503, later known as Trophy, a tall variety, and 90 t of 3654, later known as Kwecha.[123]

The recommended variety list in 1978 included, in addition to Trophy and Kwecho: Tanzania (T.) Holi (K-6793-6), T. Kororo (4140), T. Kosi (K6648-6), T. Kwecha (3654), T. Mamba (3679), T. Mbuni (26-73), T. Nyati (3742), and T. Tai (W-3697). The leading varieties that year were Kororo, Mbuni, Nyata, and Trophy . Kwecha, Kororo, and Kosi have semidwarfs in their ancestry, but it is not clear if they are semidwarfs.

Some of the Tanzanian varieties are also grown elsewhere in Africa. Tai (W-3697) is known as cross K4500 in Kenya (not released), as Enkoy in Ethiopia, and as Tai in Zambia. Kosi is known as K. Fahari in Kenya, where it was the leading variety in 1983. Nyati is known as K6290 or K. Nyati in Kenya and Malawi.

On balance, it appears that nearly all of the wheat area in Tanzania is planted with improved varieties and HYWVs, but the proportion of the area planted with the latter is not clear. The total wheat area has recently averaged about 50,000 ha.

Zambia

Zambia has a small wheat area but a high proportion of HYWVs. Semidwarfs used for breeding or released in the mid-1970s include: Mexipak (not released, 1975); Jupateco (1975); Emu, a CIMMYT line selected in Zambia; and Limpopo, Sonora, and Tanori (all 1977). Two lines originating in Kenya were released in 1979: 6920-17 (Nyati) and W-3697 (Tai).[124]

As of 1984 most of these varieties were known as older lines and had largely been withdrawn because of disease problems and low yields. Two new varieties, Loerie and Canary, were released in late 1983. Both are selections from a screening nursery from CIMMYT and are semidwarfs (96 cm and 97 cm, respectively) with good resistance to lodging. They have yield potentials of 8 t/ha. Loerie is a sister of Veery. A prospective Zambian release, D1, is a reselection of Loerie.

With these improved varieties, Zambia has the potential to rapidly expand its wheat area beyond the current figure of only 3,000 ha. Availability of irrigation water seems to be a principal constraint. However, a new variety, Whydah, was recently released for the northern rainfed acid soil region. (It is a Brazilian line with probable CIMMYT parentage.) This area is thought to have considerable potential for wheat production if suitable varieties can be found.

Zimbabwe

Essentially all of the wheat area in Zimbabwe is planted with HYWVs. Moreover, all of the HYWVs are semidwarfs. Average wheat yields (5.15 t/ha from 1980 to 1983) in Zimbabwe are among the highest in the world, and in 1983, according to USDA estimates, were exceeded only by a few western European nations.[125]

A number of HYWVs have been developed and released in Zimbabwe over time, but the semidwarf era seems to have started with the release of Tokwe in 1967. A few of the others that followed were later withdrawn because of

Table 3.20. Semidwarf varieties in commercial production in Zimbabwe

Variety	Date of release	Height (cm)	Pedigree/ origin
Tokwe	1967	75	Mex [6 x Mezoe-ND74]
Limpopo	1974	75	Son 64/T2 PR/NA160/3/Tokwe
Gwebi	1975	81	Sister of Yecora 70
Torim 73	1978	82	Introduction from CIMMYT
Angwa	1980	78	Cajeme 71/Corre Caminos//Inia
Chiwore	1981	82	TOB/CNO//CC/SK/3/A267/4/YR"S"
Rusape	1982	65	Veery 10

susceptibility to disease or other problems. Those currently in commercial production are reported in table 3.20.

Five of the seven varieties evidently represent crosses made in Zimbabwe utilizing Mexican germ plasm. A sixth was selected from a CIMMYT line, and the seventh (Torim 73) was an introduction. Rusape, the shortest statured variety released to date, is highly resistant to lodging and has the greatest yield potential.

The relative popularity of the individual HYWVs has varied over time. Shortly after Tokwe and Limpopo were introduced, they were widely planted; it is estimated that Limpopo accounted for 80% of the total wheat-growing area in 1976 and 70% in 1977. In 1978, however, Gwebi accounted for 55% of the area and Limpopo dropped back to 35%. The varietal situation in recent years is estimated in table 3.21. The relative importance of Rusape (released in 1982) is expected to increase sharply.

The total area planted with wheat in Zimbabwe has varied. Wheat is irrigated and grown only in the winter. Drought seriously reduced the irrigated area in 1983 and 1984. From 1971 to 1981 USDA estimates placed the average area at 33,600 ha. Local estimates have placed the area at 44,000 ha in 1982, 22,000 ha in 1983, and 20,000 ha in 1984.

Table 3.21. Breakdown of semidwarf wheat varieties in Zimbabwe from 1982 to 1984

	Proportion of total area (%)		
Variety	1982	1983	1984
Angwa	40.9	40.9	42.5
Gwebi	29.5	29.5	30.0
Tokwe	10.2	9.1	7.5
Limpopo	10.2	9.1	5.0
Torim 73	9.1	9.1	5.0
Chiwore	--	2.3	5.0
Rusape	--	--	2.5

Key: --=negligible.

LATIN AMERICA

Within the developing world, Latin America is the third most important region in terms of area planted with wheat. Most of the wheat area, however, is in two countries: Argentina and Brazil. In 1983, 7.0% of the total DC wheat area was in Argentina and 1.9% was in Brazil; among all the DCs Argentina ranked fifth and Brazil ranked ninth. Other important wheat growing countries are Mexico, Chile, and Uruguay.[126]

Virtually all of the Latin American wheat area (95%) is planted with spring bread wheats. Winter bread wheats occupy only about 1% of the area and durum wheats occupy 4%. Only 9% of the area is irrigated (less than any other major area), and 43% is semiarid (greater than average for DCs). Thus, nearly all of Latin American wheat is spring bread wheat grown in rainfed fields, many of which are in semiarid areas.[127]

Although HYWVs were developed in Mexico, their principal use—aside from Mexico itself—was initially in Asia and the Near East. This was because the HYWVs most nearly achieve their yield potential when there are assured water supplies and fertilizers are applied. Wheat is seldom grown under these conditions in Latin America outside Mexico.

Not all of the Mexican varieties have been semidwarfs. Research programs, using tall varieties, were initiated in several Latin American countries in the 1950s by the Rockefeller Foundation.[128] A number of improved varieties of traditional height were developed, many of which are still of significant economic importance.

The introduction of semidwarf varieties in national breeding programs in Latin America started in the mid-1960s. Several semidwarf varieties were introduced during the 1970s, and the pace of introduction seems to be accelerating. A list of semidwarf varieties introduced in the Southern Cone countries from 1978 to 1984 is provided in table 3.22 [129] CIMMYT has regional wheat programs in both the Andean and Southern Cone regions.

Despite the widespread use of HYWVs statistics on area planted are relatively scarce. Available information on 11 countries (Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador, Guatemala, Mexico, Paraguay, Peru, and Uruguay) is summarized in this section. Based on developments to date, it appears that the area planted with HYWVs, and their yields, will increase further—particularly when irrigation and the use of fertilizer expand.

Argentina

Improved varieties of wheat have been available to Argentine farmers since early in this century. Initially, the varieties were largely from the United States. By the mid-1930s the Argentine Department of Agriculture had developed three varieties suited to local conditions. During the 1950s and 1960s many of the varieties were from spring x winter crosses. As of the late 1960s almost the entire wheat area was planted with improved varieties.[130]

Semidwarf Varieties

In 1963 CIMMYT's predecessor organization (Office of Special Studies) began an informal cooperation with Argentina's Coordinated National Wheat Breeding Program of the Instituto Nacional de Technologia Agropecuaria (INTA). In 1972 the first two semidwarf varieties (reselections), Marcos Juarez and Precoz Parana, were named and approved for release. INTA released five other new varieties in the next few years including Balcarceno (1976), Diamante (1974), Calden (1974), Insurgentes (1975), and Leones (1974). Three semidwarf varieties also were developed by Dekalb Argentina S.A. during this period: Lapacho (1973), Tala (1973), and Urunday (1975). Other semidwarf varieties released by commercial firms included Buck Nandu (1976) and Cargill Trigal 700 and 705 (both 1976).[131]

Since 1978, 26 additional semidwarf varieties have been released, most developed with CIMMYT germ plasm (table 3.22) Of the 41 releases since 1972 (table 3.23), 20 were issued by the public sector and 21 by private firms.[132] Argentina is the only DC in which the private sector is a major source of semidwarf wheat seed. With these varieties and those released previously, Argentina is well supplied with promising semidwarfs.

Area Planted

It is easier to specify the varieties released in Argentina than it is to indicate the total area planted with wheat. Annual variety surveys are not available, so it is necessary to make estimates in other ways. The process produces differing results.

One Argentine agency has utilized data on seed sales to estimate the area planted with major varieties in each of the principal wheat-growing areas of the country for the 1974-75 to 1980-81 period.[133] When the semidwarf varieties were broken out of this list (only 5 were listed separately—Marcos Juarez, Leones, Lapacho, Tala, and Nandu) and aggregated for the years in which the data were available for each zone, they produced the following estimates (when available, proportion of total wheat area in parentheses): 1974-75, 216,000 ha; 1975-76, 458,900 ha; 1976-77, 1,052,500 ha (18.1%); 1977-78, 996,200 ha (28.6%); 1978-79, 1,175,000 (27.2%); 1979-80, 1,489,600 ha (36.7%); and 1980-81, 2,211,100 ha (47.9%). Other semidwarfs may have been included in a "resto" category, which represented nearly 10% of the total from 1976-77 to 1980-81.

Over the 6-year period the importance of Lapacho and Tala declined sharply while that of Marcos Juarez, Leones, and Nandu increased correspondingly. As of 1980-81 the relative importance of the varieties was (as a proportion of the semidwarf area): Marcos Juarez, 66.0%; Nandu, 19.2%; Leones, 13.3%; Tala, 1.1%; and Lapacho, 0.5%. Because of their higher yields the semidwarfs represent a higher proportion of pro-

Table 3.22. Semidwarf wheat varieties released in Southern Cone countries from 1978 to 1984

Country	1978-1979	1980	1981	1982	1983	1984
Argentina	Chaqueno INTA (L) Labrador INTA (R)* Saira INTA (R)* Victoria INTA (L) Buck Mechonge (R)* Buck Pangare (L) Klein Chamaco (L) Dekalb Chanar (R)* Dekalb Quebracho (R)*	Chasico INTA (R)* Buck Pucara (L) Trigal 707 (R)* Trigal 708 (R)* Trigal 800 (L) Bonaerense Valvderde (R)[a]	La Paz INTA (L) Klein Atalaya (R)* Trigal 806 (R)*	Buck Candisur (R)[a] Klein Cartucho (R)*	Las Rosas INTA (R)* Buck Patacon (L) Norkin T82 (R)* Tuc Norteno INTA (R)*	Pampa NTA (L) Retacon INTA (L)
Brazil	Herval (L) Moncho "S" (D)* Nambu (D)* Pampa (L)	Alondra 4546 (R)* Candiota (L)* El Pato (D)* Mitacore (L) Tifton (D)[b] Tucano (D)*	Anahuac (D)* Aracatu (L) Cocoraque (D)* Jandaia (L)	Candeias (R)* Pavao (D)* Tapejara (L) Tucurui (L)	BR10 (Formosa) (R)* Butui (R)* CEP 7672 (L) CEP 7780 (L) Flamingo (L)	OCEPAR 7 (Batuira) (D)* OCEPAR 8 (Macucu) (R)* OCEPAR 9 (Perdiz) (R) OCEPAR 10 (Garco) (R) OCEPAR 11 (Juriti) (R)* CEP 7778 (L)
Chile	Sonka INIA (D)* Lucero INIA (L) Trisa INTA (D)* Andalien (L) Andifen (L) Exito Baer (L) Manquefen (L) SNA 3 (R)*[a] Yecora 70 (D)*		Anoca INIA (L) Carolina (L) Labriego INIA (L) SNA 7 (R) SNA 8 (R) Victoria (D)*	Chasqui INIA (D)* Lancero INIA (L) Maiten INIA (D)* Millaleu INIA (D)* Onda INIA (D)* Sipa INIA (D)* Talafen (L)	SNA12-Graneros (D)* SNA24-Porvenir (D)*	Aromo INIA (L)[a] Chagual INIA (D)*[a] Cisne INIA (D)*[a] Ovacion INIA (D)* Sauce INIA (D)*
Paraguay	Itapua 25 (D)* Timgalen (D)[c]	7605 (R)	C 7659 (R)	Alondra-1 (D)* Cordilleras-3 (D)*		Cordillera 4 (D)[b]
Uruguay			E. Hornero (L) Trigal 909 (R)			

Key: *=Received as advanced line from CIMMYT; D=Direct release of variety/line developed outside country; R=Local reselection of cross made outside country; L=Local cross.

[a]Durum wheat.

[b]Introduced from United States.

[c]Introduced from Australia.

Source: Personal communication with M.M. Kohli, CIMMYT Southern Cone Wheat Program, Santiago, Chile.

Table 3.23. Semidwarf wheat varieties released in Argentina from 1972 to 1984

Public sector	Private sector
INTA[a]	José Buck S.A.
Balcareno	Candisur
Calden	Nandu
Chaqueno	Mechongue
Chasico	Pangare
Cochico	Patacon
Diamente	Pucara
Insurgentes	
Labrador	Cargill S.A.[b]
La Paz	700
La Rosas	705
Leones	707
Marcos Juarez	708
Precoz Parana	800
Pampa	806
Retacon	
Saira	Dekalb Argentina S.A.
San Augustin	Chanar
Tuc Norteno	Lapacho
Victoria	Quebracho
	Tala
Other	Urunday
B. Valverde[c]	
	Klein
	Atalaya
	Cartucho
	Chamaco
	Northrup King Semillas S.A.
	Norkin T82

[a]Instituto Nacional de Technologia Agropecuaria.

[b]Varieties sold under the brand name of Trigal.

[c]Released by the Chacra Experimental Agricola located in Barrow, which is under the management of the State of Buenos Aires but has a close relationship to INTA.

Source: Personal communication with M.M. Kohli, CIMMYT Southern Cone Wheat Program, Santiago, Chile.

duction than they do of area.[134]

The semidwarf proportions and area reported here are below the minimal figures suggested in the previous edition of this report for 1975-76 (about 1.05 million ha or 20% of total area) and 1976-77 (about 2.6 million ha or 30%).[135] They are also below an estimate, presumably for the early 1980s, by Hanson, Borlaug, and Anderson[136] that 80% of Argentina's 5 million ha were planted with semidwarfs in 1982. A CIMMYT regional wheat breeder estimated that 90% of the area was planted with semidwarf varieties in 1982 and 95% in 1983.[137] Subsequent discussions with the national wheat coordinator suggested a level of about 90% in 1984, but others think that it may have been 95%.[138]

The overall wheat area in Argentina was estimated by the USDA as 7.32 million ha (a record high) in 1982 and 6.88 million ha in 1983. An HYWV proportion of 90% in 1983 would have produced an HYWV area of 6.19 million ha; a 95% proportion would have meant an HYWV area of 6.54 million ha.

In any case, the trend in HYWV use has risen. There is no doubt about the importance of semidwarfs; the problem is to indicate precisely how important they are.

Associated Developments

With the increase in the use of semidwarf varieties, there has been an increased use of fertilizer on wheat. The use of three major fertilizer types—urea, diammonium phosphate, and anhydrous ammonia—increased in terms of both total amount used and area covered from 1977-78 to 1983-84.[139] Even so, the amount used in the latter year was not great. Beginning in 1984 the new Argentine government took a series of steps to encourage fertilizer use: the tariff on nitrogen fertilizer was abolished; the price of nitrogen and wheat was maintained at a 5:1 ratio; and fertilizer was bought in exchange for grain at harvest. About 100,000 t of urea was used. The government expanded the program in 1985.[140]

Another development is that the earlier maturity of the semidwarfs has facilitated their extensive use in double cropping rotations with soybeans. In the regions involved more than 90% of the wheat stubble is sown to soybeans; this area comprises up to 80% of the total soybean area. The rotation has been found to be too intensive in areas where water is limited and other rotations involving three crops every two years (the third crop may be corn or soybeans) are being introduced.[141]

Given the changes in fertilizer policy, Argentina would seem to have the base for increased production.

Bolivia

Bolivia has released several semidwarf wheat varieties with CIMMYT ancestry: Jaral 66, Saguayo 79 (1979), Quimore 79 (1979), Pilancho 80 (1980), Tarata 80 (1980), Totora 80 (1980), and Sacaba 80 (1981, a durum wheat). Tarata 80 is Pavon S; Totora 80 is Pavon F76. Sacaba 80 is Anhinga "S". Three local reselections are PAI-4, PAI-593, and PAI-711.

A local institute, the Centro de Investigacion de Agricultura Tropical, in cooperation with CIMMYT, has attempted to increase wheat production in the Department of Santa Cruz. In 1982 more than 6,000 ha were planted with Jaral 66, Saguayo 79, and Quimori 79. An emergency seed project in the highlands contemplated bringing in some 2,000 t of Pavon F76 (Totora 80).

An estimate of the HYWV area by a CIMMYT scientist in 1985 was in the 30%-35% range. This figure differed sharply by region—ranging from 100% of the area in the eastern lowlands to a much lower proportion in the highlands.[142]

Brazil

Brazil has a long history of improved wheat use but imports large quantities of wheat and has a strong interest in expanding domestic production. One of the earliest and best-known improved varieties was Frontana, which was developed from a cross of Fronteria (Alfredo Chaves 6 x Polyssu) and Mentana (an Italian variety discussed in chapter 2). Frontana was released in 1940, was used in breeding a number of the Mexican varieties, and still may be grown. Frontana is not, however, a semidwarf. Brazil's area of semidwarf varieties was limited until the 1970s.

Developments Up to the Mid-1970s

The principal wheat development activity in the 1970s was in Paraná State. In 1975 Paraguay 214, an introduction from Paraguay and a sister

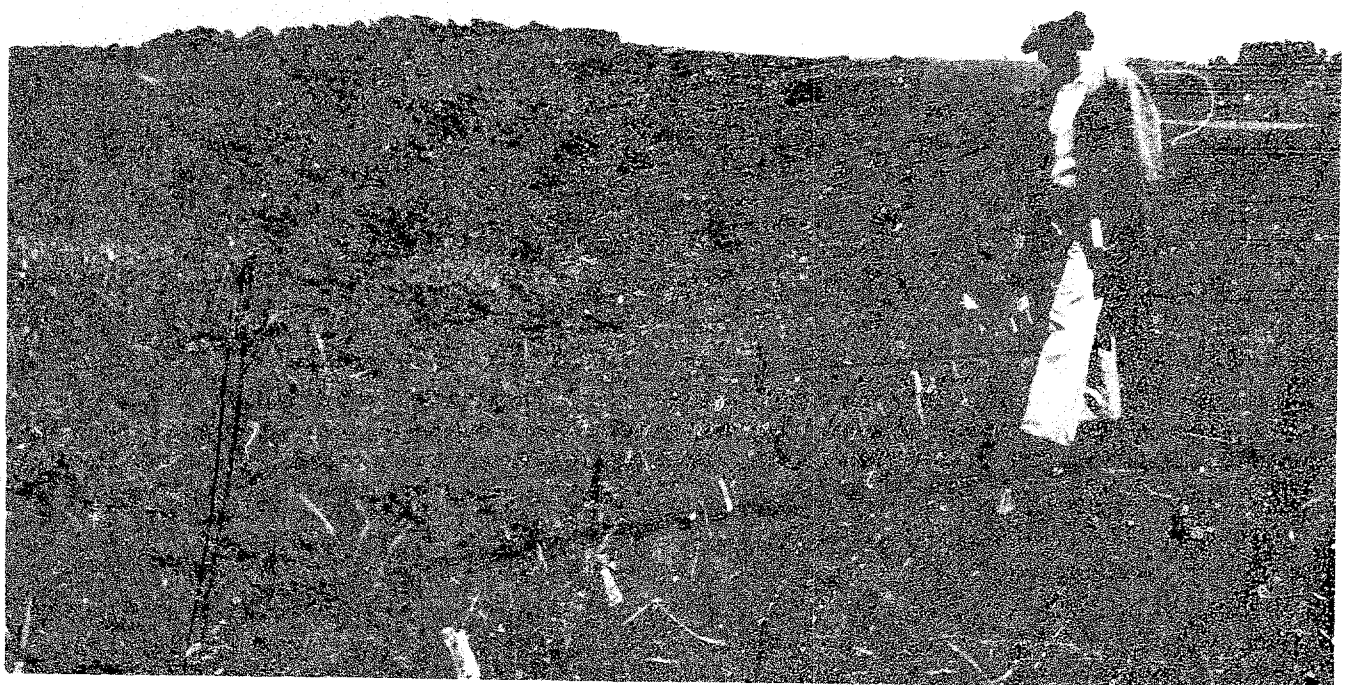

Figure 3.6. Aluminum-tolerant and non-tolerant plants, Empresa Brasilerira de Pesquisa Agropecuaria, Passo Furdo, Brazil (source: CIMMYT).

line of the Mexican semidwarf variety Jaral, was planted on more than 200,000 ha and represented 19.3% of the total wheat production in Paraná. Sonora 63 and 64 accounted for about 7.1% of the total wheat production in Paraná in 1975.[143] A commission from Paraná purchased 14,000 t of semidwarf Mexican wheats (9,000 t of Tanori F71 and 1,000 t of Jupateco F73 from Mexico and 4,000 t of Inia F66 from California) in 1976. About 650,000 ha of Mexican-type semidwarf varieties were planted in Paraná State in 1977. The principal varieties were (in decreasing order of seed sales): Tanori, Inia, Paraguay 214, Jupateco, and Paraguay 281.[144]

The other major wheat-producing Brazilian state is Rio Grande do Sul. Four varieties with short straw and Norin 10 x Brevor in their ancestry were grown during the early 1970s: IAS-52, IAS-53, IAS-54, and IAS-55.[145] They accounted for the following proportions of the wheat area in the state: 1970-71, 5.2%; 1971-72, 28.0%; 1972-73, 31.4%, 1973-74, 54.7%; and 1974-75, 43.4%. Of the four varieties, IAS-54 was by far the most important—representing 34.5% of the total area by 1974-75 (by which time IAS-52 and IAS-53 were no longer used). During 1970-75 the total wheat area in the state averaged about 1.5 million ha. Thus, the area of short-strawed varieties in 1974-75 may have been about 650,000 ha.

Wheat is considerably less important in other states in Brazil. Paraguay 214 was planted on about 2,000 ha in Mato Grosso in 1975. Semidwarfs were included in the varieties recommended for Sao Paulo and Mato Grosso in 1978, and substantial areas of HYWVs (including some semidwarfs) were grown in Sao Paulo and to a lesser extent Mato Grosso in 1977. The seed purchasing commission from Paraná, noted earlier, also purchased 4 t of 15 semidwarf Mexican varieties for testing in Bahia State. Siete Cerros performed well.

A major factor limiting expansion of semidwarfs in certain areas of Brazil was aluminum toxicity induced by high aluminum levels in acid soils. A cooperative program was established with CIMMYT in 1972 to select varieties resistant to aluminum toxicity.[146]

Developments Since the Mid-1970s

Semidwarf varieties released in Brazil from 1978 to 1984 are noted in table 3.22. Of those listed Alondra 4546 (also known as Alondra "S"), released in Paraná in 1980, is of special note. Alondra 4546 grows well in Brazil, and it was first presumed that this was because of its tolerance for acid soils and aluminum toxicity. Later testing showed that the variety was only mildly tolerant of aluminum, and its outstanding performance results from an ability to extract phosphorus from acid soils. This characteristic is genetically controlled and has been passed on to many offspring of Alondra.[147] One offspring is the selection BR10-Formosa, which was released for irrigated wheat cultivation in the central region of Brazil.[148]

In terms of use the only accessible data concern the availability of seed. In 1978, IAS-54 represented 5.14% and IAS-55 represented 2.1% of the seed available in Rio Grande do Sul. In Parana in 1979 the breakdown was: Inia 66, 17.7%; Jupateco, 13.7%; Tanori, 12.1%; and Tobari, 0.2%.[149] The comparable breakdown for Brazil as a whole in 1983 was: Anahuac, 16.5%; Cocoraque, 7.0%; and Inia F-66, 4.8%. These varieties were particularly concentrated in Paraná where they accounted for 42.3% of the seed available. Small quantities were also found (in decreasing order) in Mato Grosso, São Paulo, and Minas Gerais.[150] It is possible that small quantities of some of the varieties used in previous years were included in the "other" category (6.1% in Paraná). Because farmers normally do not plant new seed each year and, hence, buy only a portion of their needs, it cannot be said that the above figures represent a comparable proportion of the total area planted, but they do give an approximate idea of the trend in use of HYWVs.

A CIMMYT regional wheat breeder estimates that for Brazil as a whole, roughly 30% of the total wheat area was planted with semidwarfs in 1982 and that the figure rose to 43% in 1983.[151] The total wheat area in both years was 2.8 million ha. Thus, the semidwarf area may have been about 840,000 ha in 1982 and 817,000 ha in 1983.

Cooperative research between CIMMYT and several Brazilian institutions on the development of semidwarf varieties that will resist aluminum toxicity continues, and advanced lines are undergoing yield tests and multiplication. A first set of four varieties from those lines was released in Paraná in 1984.[152]

Chile

Chile made use of American club wheats as early as 1866. By the mid-1930s some Australian varieties were also grown.[153] A wheat improvement program was initiated in Chile in 1955 in cooperation with the Rockefeller Foundation. Joseph A. Rupert, who had worked in Mexico, started testing lines from Chile and Mexico, and several varieties were released, including Orofen and Rulofen in 1958 and Orofen 50 and Chifen in 1961.[154]

Wheat research by Chile's Instituto de Investigaciónes Agropecuarias (IIA) resulted in release of 21 varieties from 1964 to 1975. Of these, 11 semidwarfs were raised commercially. As of 1976-77 they were expected to be grown on about 193,000 ha. The leading semidwarf varieties, their year of release, and approximate proportion of total HYWV area in 1976-77 were: toquifen (1968), 31.1%; Quilafen (a durum wheat, 1970), 31.1%; Melifen (1974), 10.4%; Aurifen 1973), 7.8%; Mexifen (1973), 7.8%; Antufen (1974), 5.2%; Loncofen (1973), 2.6%; Noafen (1974), 1.6%; and other varieties 2.4%.[155]

HYWVs were introduced by two other groups. The Sociedad Nacional de Agricultura sponsors an experiment station that introduced several varieties, including SNA-1. SNA-1 is a semidwarf selected from germ plasm provided by CIMMYT. The Catholic University of Chile released Marianella, a new semidwarf variety of Mexican origin, in 1977. It was planted on about 15,000 ha in 1978.[156]

A large number of semidwarf varieties have been released since 1978 and are summarized in table 3.22. Most were released by IIA, but some were in the SNA series. A regional CIMMYT plant breeder estimates that about 70% of the total wheat area in both 1982 and 1983 was planted with semidwarfs.[157] This would have produced semidwarf areas of 250,000 ha in 1982 and 330,000 ha in 1983.

Colombia

A wheat improvement program began in Colombia in 1926. Mexican varieties were introduced by Juan Orguela in 1949 and Joseph A. Rupert of the Rockefeller Foundation in 1950. The first variety of Mexican ancestry released was Menkemen 52 (Mentana 48 x Kenya), a sister of Lerma 50. This was followed by Bonza 55 (Yaqui 48 x Kentana) in 1955 and Narino 59 in 1959. In addition to being higher yielding than native varieties, the new varieties were resistant to yellow rust.[158]

Semidwarf varieties from Mexico were introduced in 1958, but the effort to incorporate the short plant type was not immediately successful. Major varieties subsequently introduced through the cooperative efforts of the Rockefeller Foundation and the Instituto Colombiano Agropecuario, were:

- in 1963: Bonza 63 and Crespo 63, tall varieties (120-125 cm); Miramar 63 and Napo 63, normal varieties (105-110 cm); Tiba 63 and Tota 63, semidwarfs (95-105 cm); and
- in 1964: Miramar 64, a normal variety.

ICA assumed direction of the Wheat Improvement Program at the end of 1964. Three tall varieties, Samaca 68, Sugamuxi 68, and Zipa 68, were named in 1968. Because of resistance to yellow rust—as well as other good qualities—the Colombia varieties found a wide distribution in other nations.

The area planted with improved and semidwarf varieties during this early period followed a peculiar pattern. It increased through 1968 to a peak area of about 54,600 ha and then declined through 1973 to a low of 9,200 ha. The decline reflected a general drop in overall wheat area, which some observers believe was at least partly the result of imports of American wheat under the PL-480 program and unfavorable wheat prices.[159]

ICA released two new HYWVs in 1976: Icata and Engativa. Icata is not a semidwarf variety. Engativa is a semidwarf (its parentage is Sonora 64-A-Andes 64-A x Tiba 63), and it resists lodging. About 50 t of seed were distributed to farmers in 1977.[160]

Only two HYWVs have been released since 1977: ICA-Yuriya in 1980 and ICA-Susata in 1983 (formerly known as Alondra "S"). ICA-Susata is intended for the Cundinamarca and Boyaca regions with altitudes of 1,950 to 2,760 m and 350 to 500 mm of annual rainfall. Regional trials had yields of 4 t/ha. Pavon "S" was to be released in the early 1980s, but as of June 1984 it was still being multiplied.[161]

The HYWV area in Colombia in 1983 is estimated to have been as high as 45,000 ha, which would have represented nearly all of the wheat area.[162]

Ecuador

A wheat improvement program for Ecuador was established by the Ministry of Agriculture in 1956, and the Rockefeller Foundation agreed to provide the advisory services of John Gibler, leader of the wheat work in Colombia. Thus, early use was made of Colombian and Mexican varieties. While many of the improved varieties in use in the early 1970s had some Mexican ancestry, they were not semidwarfs; 81% of the total wheat-growing area was planted with such varieties in 1975-76.[163]

Semidwarfs were introduced in the 1970s. Atacazo 69 was one of the first. In 1978 Antizana 77 and Chimborazo 77 were released. INIAP-Altar was released in 1982. (Tobari "S" is one of its parents.) In tests it significantly outyielded Atacazo 69 and Chimborazo 77.[164]

In 1982 official statistics indicated that Antizana 77 was planted on 2,472 ha and that Chimborazo 77 occupied 5,817 ha. Thus, the two semidwarfs occupied nearly 8,300 ha, about 25.3% of the total planted area.[165]

Guatemala

The wheat area of Guatemala has long been planted with Mexican varieties. They were first introduced in 1949 and 1950 in the highlands, to which they were evidently well adapted. A book published in 1967 stated that "for more than a decade the entire acreage of wheat in Guatemala has been sown to Mexican bred varieties."[166] The Mexican varieties were joined by the Colombian variety Narino (of Mexican extraction), which was widely grown in the 1960s. Guatemala also imported significant quantities of Mexican wheat seed: 506 t in 1967, 22 t in 1970, and 100 t in 1971.[167]

As of 1978 the leading varieties of Mexican extraction were: Narino 59 (1961), Xelaju 66 (1967), Tobari 66 (1967), Azteca 67 (1970), Pato

(1971), Altense 73 (1974), Maya 74 (1975), Gloria 74 (1975), Quetazal 75 (1976), Reina 76 (or Reyna 76) (1977), and Chivito 77 (1978). Subsequent releases include Tecupan, Patzun, Patzicia, Via Laura, and ICTA Sara.[168]

In 1978 it was estimated that about 80% of the total wheat area was planted with varieties of Mexican extraction. In the early 1980s the proportion was placed at nearly 100%.[169] The total wheat area was about 40,000 ha in the early 1980s.

Mexico

Although the HYWVs originated in Mexico and numerous HYWVs were released through 1985 (a complete list was provided in tables 2.2 and 2.3), little statistical information has been found on their use. The area planted with improved varieties in Mexico was more than 90% of the total wheat area in 1960. The semidwarfs were first introduced in 1961 and began to replace the improved varieties, but the replacement process was not recorded in statistical terms after 1964.[170] By the end of the decade, however, it was thought that 90%-95% of the total wheat area was planted with HYWVs.

Estimates of the area planted with HYWVs from 1971 to 1976, provided by the Instituto Nacional de Investigaciónes Agricolas (INIA), were (in hectares): 683,000 in 1971; 687,000 in 1972; 647,000 in 1973; 655,000 in 1974; 700,000 in 1975; and 785,000 in 1976.[171] CIMMYT suggested that the total area planted with eight varieties in 1973 was 609,000 ha—about 6% less than the INIA estimate; inclusion of additional varieties may have raised the total.[172]

Attempts to secure more recent official estimates of the HYWV area were unsuccessful. CIMMYT, however, supplied some estimates of the area planted with individual varieties in 1983.[173] Of the total HYWV area about 84% was bread wheat and 16% was durum wheat. Within the bread category 70.7% was irrigated and 13.3% was rainfed. The principal varieties within each category and their relative importance were:

- irrigated bread wheats—Genaro 81, 28.0%; Glennson 81, 13.3%; Giano 79, 13.3%; and others (Ures 81, Seri 82, Tonichi 81, Sonoita 81), 16.1%;
- rainfed bread wheats—Pavon 76, 6.7% and others (Tesia 79, Cleopatra 74, Zacatecas 74, and Nacozari 76), 6.7%; and
- durum wheat—Yavaros 81, 13.3% and other (Mexicali 75 and others) 2.7%.

The CIMMYT figures were developed on the basis of a total HYWV area of 750,000 ha in 1983. It was assumed that all the wheat area was planted with HYWVs, which may not have been the case. The proportion was estimated by one CIMMYT wheat specialist to be at least 95% and probably close to 99%. All wheat varieties are released by INIA, and all the varieties released for the past 20 years have been HYWVs.[174]

The USDA estimates that the total wheat area in Mexico was 950,000 ha in 1982 and 840,000 ha in 1983. If, to be conservative, the HYWV proportion is placed at 95%, the HYWV area would have been 902,500 ha in 1982 and 798,000 ha in 1983. If the percentage is placed at 98%, the HYWV areas would have been 931,000 ha in 1982 and 823,200 ha in 1983, respectively. Wheat yields in Mexico are among the highest in the developing world.

Paraguay

A national wheat improvement program was initiated in Paraguay in 1966. Initially, it developed tall varieties (Mexican and others). However, in 1970 those varieties were replaced rapidly by a semidwarf variety known as 214/60 or Paraguay 214, a sister of Jaral. It was reportedly planted on over 30,000 ha or more than 60% of the total wheat area in 1972. Paraguay 214, however, was susceptible to diseases and was replaced. Other Mexican semidwarfs planted from 1972 to 1975 included Sonora 64 and Penjamo 62. They were phased out because of rust susceptibility.[175]

In 1976 the overall varietal breakdown was: 281/60, 60%; Itapua 1, 20%; Itapua 5, 15%; and others, 5%. Itapua 5 is a semidwarf (Sonora 64 x Klein Rendidor) and a sister of Marcos Juarez from Argentina. Promising lines identified in 1976 were 281/71 (Timgalen, from Australia), 128/69, 98/68-E, and 7605. (All had some Mexican ancestry.)[176]

Subsequent semidwarf releases included Itapua 25 (1978), Timgalen (1978-79), C 7605 (1980, Brazilian origin), C 7659 (1981, Brazilian ancestry), and Alondra-1 and Cordilleras 3 (1982, Mexican ancestry, Veery 3 or Genaro 81). As of early 1984, Paraguay planned to release four new varieties within the next 2 years.[177]

A regional CIMMYT representative estimates that the semidwarf proportions of the wheat-growing area were 10% in 1983 and 20% in 1984. Total wheat area estimates were 75,000 ha for 1982 and 80,000 ha for 1984, suggesting semidwarf areas of 7,500 ha in 1983 and 20,000 ha in 1984.[178]

Peru

Peru made early use of Mexican and Colombian varieties. Sierra 1 and 2 were sister lines of the Mexican variety Yaktana 54. The Colombian varieties Bonza and Narino also were used. In 1974 the area planted with improved varieties totaled about 16,300 ha. None of the varieties in use through the mid-1970s, however, were semidwarfs.[179]

The first Peruvian semidwarf of Mexican extraction was Participation, bred at the Agricultural Experiment Station in La Molina in 1966 and released for use in the coastal region in 1975.[180] Other semidwarfs released were: Costa 78 (1978), Majes 2 (Bluebird #2), El Gavilian (1981, Pavon F76), INIA C102 (1981), Cristina (1982, Tesia 79), and La Molina 82 (1982, Veery "S").[181]

It is not known what proportion of the wheat area in Peru is planted with HYWV semidwarfs, but it is evidently not very high. One estimate is 10%, or possibly a bit more.[182] An improved local variety, Ollanta, accounts for about 80% of Peru's wheat production.[183]

Uruguay

From the start of a wheat improvement program in 1912 to 1981, 31 varieties of wheat were released. Two were semidwarfs: Estanzuela (E.) Dolores (Sonora 64/Selkirk-E//Lerma Rojo 64A), 1974; and E. Hornaro (Novafen/Klein Impacto), 1981. E. Dolores proved susceptible to rust and was withdrawn from certification in December 1976. E. Zorzal, which was introduced from Chile in 1976 in nurseries, had Norin 10 ancestry but was not considered a semidwarf; it was withdrawn in 1975. Novafen, one of the parents of E. Hornaro, came from Chile and was an offspring of Norin 10.[184] Semidwarfs from Argentina have also been introduced.

The proportion of the wheat area occupied by semidwarf varieties from 1981-84 is shown in table 3.24. Clearly, the overall semidwarf proportion is high and increasing. Most of the semidwarf area was occupied by semidwarfs from Argentina, but E. Hornero has rapidly gained popularity. The total wheat area in Uruguay was about 270,000 ha in 1983; 74.5% of this would produce a semidwarf area of about 200,000 ha.

Table 3.24. Proportion of wheat area occupied by semidwarf varieties in Uruguay from 1981-82 to 1983-84

	Proportion of wheat area (%)		
Variety	1981-82	1982-83	1983-84
Marcos Juarez INTA	43.0	45.0	25.0
Estanzuela Hornero	--	3.0	24.0
Buck Pangare	7.0	14.0	23.0
Dekalb Tala	0.6	2.0	5.0
Diamente INTA	9.0	8.0	3.0
Cargill Trigal 800	--	1.0	1.0
Precoz Parana INTA	1.0	1.0	0.7
Victoria INTA	--	--	0.2
Leones INTA	0.6	0.3	0.1
Pampa INTA	--	0.2	--
Total	61.2	74.5	82.0

Key: --=negligible.

Source: "Asesoria Technica Agronomica," paper provided by T. Abadie, Estación Experimental Agropecuaria la Estanzuela, Colonia, May 1984.

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[2]U.S. Department of Agriculture, "Grain Data Base," Washington, D.C.: the Department, International Economics Division, Economic Research Service (ERS), January 1985 (computer printout).

[3]International Maize and Wheat Improvement Center, *World Wheat Facts and Trends, Report One* (Mexico City: the Center, 1981), p. 3. Subsequent analyses at CIMMYT (unpublished) suggest that about 75 percent of the spring bread wheat is grown in adequately watered conditions and 25 percent is grown in harsh conditions; two-thirds of the spring durum wheat is grown in

harsh environments (trip report from C.O. Qualset, University of California, Davis, to CIMMYT, March-April 1985). CIMMYT has compiled data and outline maps on the major wheat-producing areas in 22 DCs; *see* "Wheat Producing Regions in Developing Countries," Mexico City: International Maize and Wheat Improvement Center, May 1985 (mimeographed).

[4]International Maize and Wheat Improvement Center, *CIMMYT Report on Wheat Improvement, 1981* (Mexico City: the Center, 1984), p. 93; and International Center for Agricultural Research in the Dry Areas, *ICARDA Annual Report, 1983* (Damascus: the Center, 1984), p. 120. *Also see* "International Testing Program in Wheat, Triticale, and Barley," *CIMMYT Today*, No. 10 (July 1979), 15 pp.; and D.L. Plucknett and N.J.H. Smith, "Networking in International Agricultural Research," *Science*, 225 (1984):991.

[5]For details, *see* R.L. Villareal and A.R. Klatt, eds., *Wheats for More Tropical Environments: A Proceedings of the International Symposium* (Mexico City: International Maize and Wheat Improvement Center, 1985), 354 pp.

[6]U.S. Department of Agriculture, op. cit. (*see* footnote 2), p. 3.

[7]International Maize and Wheat Improvement Center, op. cit (*see* footnote 3), p. 3.

[8]*See*, for example, International Maize and Wheat Improvement Center, *CIMMYT Report on Wheat Improvement, 1981* (Mexico City: the Center, 1984), pp. 124-129, and *CIMMYT Report on Wheat Improvement, 1982* (1984), pp. 162-164; and R. Villareal and A.R. Klatt, op. cit. (*see* footnote 5). Two wheat varieties have been released in the Philippines but have not yet been widely used. Results of a study on the economics of wheat production in northern Thailand are in International Maize and Wheat Improvement Center, *CIMMYT Research Highlights, 1984* (Mexico City: the Center, 1985), pp. 103-106.

[9]This section is largely based on two reports: S.M. Ahmed, "Wheat" in Bangladesh Agricultural Research Council, *Agricultural Research in Bangladesh* (Dhaka: the Council, 1983), pp. 37-41; and S.M. Ahmed, "Wheat in Bangladesh," *CIMMYT Today*, No. 15 (November 1982), 15 pp. Additional information was provided in H. Hanson, N.E. Borlaug, and R.G. Anderson, *Wheat in the Third World* (Boulder, Colo.: Westview Press, 1982), pp. 69-73; annual issues of International Maize and Wheat Improvement Center, *CIMMYT Report on Wheat Improvement* (Mexico City: the Center); and a letter from L. Butler, CIMMYT/Canadian International Development Agency Wheat Programme, Dhaka, Bangladesh, November 1984. Sources of statistical data are cited in the tables.

[10]D.G. Dalrymple, *Development and Spread of High-Yielding Varieties of Wheat and Rice in Less Developed Nations*, Foreign Agricultural Economic Report No. 95 (Washington, D.C.: U.S. Department of Agriculture, 1978), pp. 3-7; and attachment to letter from W.J. Jadwin, USAID, Dhaka, Bangladesh, March 1984.

[11]Bangladesh Agricultural Research Institute, "Status of Wheat Research," Dhaka, Bangladesh, 1984, p. 2.

[12]Personal communication with A. Klatt, CIMMYT, May 1985.

[13]The average wheat yield was 636 kg/ha in 1950 and had risen to 2,682 kg/ha by 1984. Virtually all of the increase has occurred since 1964, and the growth in the early 1980s was particularly pronounced. By comparison, the average yield in the United States in 1984 was 2,611 kg/ha (U.S. Department of Agriculture, op. cit. [*see* footnote 2]).

[14]Letters from Q-S. Zhuang, research professor and wheat breeder, Institute of Crop Breeding and Cultivation, Chinese Academy of Agricultural Science, Beijing, October and November 1985. The data on habit were calculated by Dr. Zhuang from data reported in International Maize and Wheat Improvement Center, "Wheat Producing Regions in Developing Countries," Mexico City, July 1985; they are quite different from estimates reported earlier by H. Hanson et al., op. cit. (*see* footnote 9), p. 74, and they may vary to a much smaller extent from estimates made by others. The irrigated figure excludes the Yangtze Valley and southern and southwestern China where drainage is a problem.

[15]H. Hanson, "China's Progress with Wheat and Maize," paper prepared for the Workshop on Agricultural and Rural Development in China, Cornell University, Ithaca, N.Y., April 6-8, 1981, p. 13.

[16]The previous section is based, except as noted, on material previously reported in D.G. Dalrymple, op. cit. (*see* footnote 10), pp. 41-42.

[17]This section is, except as noted, based on the following references: J. Shanboa, ed., *[Wheat*

Varieties and Their Pedigrees in China] (Chinese), (Beijing: Chinese Agricultural Publishing House, 1983), 417 pp. (especially pp. 92-93, 156-159, 171-173, 230-232, and 326-327); Q-S. Zhuang, op. cit. (*see* footnote 14); letter from Q-S. Zhuang to H. Hanson, CIMMYT, August 1984; and letters from D. Liu, President Nanjing Agricultural College, Jiangsu Province, April and May 1984.

[18]Y. Dahua, "Wheat Genetic Resources Programmes in China," *Plant Genetic Resources Newsletter* (Rome: United Nations, Food and Agriculture Organization) March 1984, p. 2. Varieties were also obtained from Yugoslavia and Romania.

[19]J. Shanboa, op. cit. (*see* footnote 17).

[20]Suweon 86 was crossed in Japan around 1923, and F_3 seeds were sent to Korea where further breeding work was done (letter from T. Gotoh, Director, Okinawa Branch of Tropical Agriculture Research Center, May 1984).

[21]Aifeng 3 carries the *Rht2* dwarfing gene (M.D. Gale and G.A. Marshall, "A Classification of the Norin 10 and Tom Thumb Dwarfing Genes in Hexaploid Bread Wheat" in Indian Society of Genetics and Plant Breeding, *Proceedings of the Fifth International Wheat Genetics Symposium, New Delhi, February 1978,* ed. S. Ramanajam (New Delhi: the Society, 1979), p. 997.

[22]D. Liu, op. cit. (*see* footnote 17).

[23]J. Shanboa and L. Dina, eds., *Reports on Chinese Wheat Varieties* (1964), pp. 163-164 (cited in letter from D. Liu, see footnote 17).

[24]T. Gotoh, op. cit. (*see* footnote 20).

[25]Letter from S. Rajaram, wheat breeder, CIMMYT, April 1984.

[26]Letter from C.T. Liu, University of Idaho, to C.F. Konzak, Washington State University, March 1985; Q-S. Zhuang, op. cit. (*see* footnote 17).

[27]Letter from W.E. Kronstad, Department of Crop Science, Oregon State University, November 1984 and July 1985. The variety is called Tibetian Dwarf in Oregon. The genetic source of dwarfism has not yet been determined.

[28]*Mutation Breeding Newsletter*, no. 18 (1981), p. 14; no. 19 (1982), p. 19; and no. 25 (1985), pp. 17-20. The last issue provides a detailed list of varieties released from 1966 to 1981; two are reported to have either a short culm or short straw and, at one point, to have been planted on more than 100,000 ha: Jingfen No. 1 (1977) and Yuangfen No. 4 (1978).

[29]Q-S. Zhuang, op. cit. (*see* footnote 14); and *Agricultural Yearbook of China, 1983* (Beijing: Chinese Agricultural Publishing House, 1984), p. 452. Ji-mai was planted on 266,800 ha in Hebei Province, and Yang-mai 3 was planted in 448,224 ha in Anhui, Jiangsu, and Shanghai Provinces.

[30]This section has been developed from estimates provided by Q-S. Zhuang, op. cit. (*see* footnote 14) and personal communication with A. Klatt, associate director, Wheat Program, CIMMYT, September 1985.

[31]A. Howard and G.L.C. Howard, *The Improvement of Indian Wheat*, Bulletin No. 171, Vol. 44, no. 2 (Pusa, India: Agricultural Research Institute, 1927):1-16.

[32]C.E. Pray, "The Impact of Agricultural Research in British India," *Journal of Economic History* XLIV (1984):430-437. *Also see* C.E. Pray, "Underinvestment and the Demand for Agricultural Research: A Case Study of the Punjab," *Food Research Institute Studies* XII(1) (1983):56, 76-77.

[33]H. Hanson, et al., op. cit. (*see* footnote 9), pp. 43-49; Indian Agricultural Research Institute, *Five Years of Research on Dwarf Wheats* (New Delhi: the Institute, 1968), preface and pp. 1-8. Details on composition of seed shipments based on D.G. Dalrymple, op. cit. (*see* footnote 10), pp. 15-16, 38. One of the S.227 selections made at Punjab Agricultural University was released as Kaylan 227.

[34]International Maize and Wheat Improvement Center, *CIMMYT Review, 1975* (Mexico City: the Center, 1975), p. 94; Idem, *CIMMYT Report on Wheat Improvement, 1977* (Mexico City: the Center, 1979), p. 211; Idem, *CIMMYT Report on Wheat Improvement, 1978* (Mexico City: the Center, 1980), p. 245; and Idem, *CIMMYT Report on Wheat Improvement, 1981* (Mexico City: the Center, 1984), p. 126. A leaf rust epidemic in 1972 and 1973 on Kalyansona caused a switch to Sonalika (letter from E. Saari, CIMMYT, January 1985).

[35]"Project Director's Note," 22nd All-India Wheat Research Workers' Workshop, Coimbatore, India, 1983, pp. iii-v.

[36]International Maize and Wheat Improvement Center, *CIMMYT Report on Wheat Improvement, 1981* (Mexico City: the Center, 1984), p. 126.

[37]"Project Director's Note," op. cit. (*see* footnote 35), p. iii-v.

[38]Varieties released by the Central Varietal Release Committee during 1982-83 included: CPAN 1676 (Rohini), DWL 5023(d), HD 2281, HI 617 (Sujata), HI 784 (Swati), HUW 37, HUW 55, Lok-1, and Raj 1555(d) ("Project Director's Note," op. cit. [*see* footnote 35], p. x). In addition, state varietal release committees also released varieties, some of which were not tested under the coordinated program.

[39]Calculated from Indian data provided by M. Landes, International Economics Division, ERS, USDA. (HYWV data was reported by the Fertilizer Association of India, New Delhi.)

[40]D.G. Dalrymple, op. cit. (*see* footnote 10), p. 36.

[41]"Item from Korea," *Annual Wheat Newsletter* 29 (1983):73-74.

[42]"Items from Korea," *Annual Wheat Newsletter* 27 (1981):65; and "Items from Korea," *Annual Wheat Newsletter* 30 (1984):73-74.

[43]D.G. Dalrymple, op. cit. (*see* footnote 10), p. 39.

[44]International Maize and Wheat Improvement Center, *CIMMYT Report on Wheat Improvement, 1976* (Mexico City: the Center, 1978), p. 224.

[45]International Maize and Wheat Improvement Center, op. cit. (*see* footnote 36), p. 127.

[46]Listing of recent varieties released provided by C.T. Hash, USAID, Kathmandu, Nepal, September 1984.

[47]C.E. Pray, op. cit. (1983) (*see* footnote 32), pp. 59, 76.

[48]D.G. Dalrymple, op. cit. (*see* footnote 10), pp. 15, 40; H. Hanson, et al., op. cit. (*see* footnote 9), p. 49.

[49]International Maize and Wheat Improvement Center, *1969-70 CIMMYT Report* (Mexico City: the Center, 1971), p. 90.

[50]Attachments to letter from P. Amir, research fellow, Pakistan Agricultural Research Council, Islamabad, April 1984. (The survey data was provided by D. Byerlee of CIMMYT.)

[51]Letter from P.R. Hobbs, wheat agronomist, CIMMYT, Islamabad, Pakistan, November 1984.

[52]J.G. Nagy, "The Pakistan Agricultural Development Model: An Economic Evaluation of Agricultural Research and Extension Expenditures" (Ph.D. dissertation, University of Minnesota, 1984), tables C-6, C-10.

[53]Personal communication with A. Klatt, CIMMYT, May 1985.

[54]Pakistan Agricultural Research Council, *Agricultural Statistics of Pakistan, 1983* (Islamabad: the Council, 1984), p. 13. For more general background information through 1981-82, *see* Pakistan Agricultural Research Council, *Statistical Bulletin on Wheat in Pakistan* (Islamabad: the Council, 1983), 159 pp.

[55]U.S. Department of Agriculture, op. cit. (*see* footnote 2).

[56]International Maize and Wheat Improvement Center, op. cit. (1981) (*see* footnote 3).

[57]The early history of durum wheat in the region is summarized by A.M. Watson in *Agricultural Innovation in the Early Islamic World: The Diffusion of Crops and Farming Techniques, 700-1100* (Cambridge, England: Cambridge University Press, 1983), pp. 20-23.

[58]L. Bickel, *Facing Starvation; Norman Borlaug and the Fight Against Hunger* (New York: Reader's Digest Press, 1974), pp. 246, 247, 249.

[59]A list of varieties released in the region as an outgrowth of cooperative efforts between ICARDA and national programs is provided in International Center for Agricultural Research in the Dry Areas, *ICARDA—A partner in Cereal Improvement* (Damascus, Syria: the Center, 1985) pp. 34-35. In 1984, 700 nursery sets were requested by 46 countries (Ibid., p. 5).

[60]Israel has made use of improved varieties at every stage of its development. Local strains were replaced by Florence x Aurore after World War II, and this variety was widely grown until the late 1950s. It was replaced partly by the original Mexican varieties and the semidwarf varieties in the middle to late 1960s. Next, varieties were selected out of CIMMYT material. Finally, the CIMMYT material was crossed with local varieties. The latter two categories, which have accounted for about 90% of the area, were Ceeon (Sion/Hazera 2152), Lakhish, and Miriam. During the 1983-84 season, the varietal composition was: Shafir (Hazera 895), 32.7%; Barkai (Barkaee), 26.7%; Lakhish, 17.1%; Miriam, 15.8%; Bet-Lehem, 5.2%; Daganit (Deganith), 1.5%; and others (including 2230), 0.8%. All contain CIMMYT germ plasm. The last three (including 2230) are new varieties. In the future, Barkai, Lakhish, and Miriam are expected to be replaced by newer varieties. (Y. Kislev and M. Hoffman, "Research and Productivity in Wheat in Israel," *The Journal of Development Studies* 14[2]

[1978]:166-181; letters from M.J. Pinthus, Department of Field and Vegetable Crops, Hebrew University, Rehovot, Israel, June 1975, November 1977, and May and June 1984; and letter from Z. Eyal, Department of Botany, Tel Aviv University, to B.C. Curtis, CIMMYT, February 1984.)

[61]D.G. Dalrymple, op. cit. (*see* footnote 10), p. 45; and International Maize and Wheat Improvement Center, *CIMMYT Report on Wheat Improvement, 1977* (Mexico City: the Center, 1979), pp. 206-208; and Idem, *CIMMYT Report on Wheat Improvement, 1978* (Mexico City: the Center, 1980), pp. 239-241.

[62]This paragraph is taken from D.G. Dalrymple, op. cit. (*see* footnote 10), p. 46.

[63]International Maize and Wheat Improvement Center, *CIMMYT Report on Wheat Improvement, 1978* (Mexico City: the Center, 1980), p. 9.

[64]International Maize and Wheat Improvement Center, *CIMMYT Report on Wheat Improvement, 1980* (Mexico City: the Center, 1982), p. 139.

[65]Letter from D. Winkelmann, economist, CIMMYT, August 1984.

[66]D.G. Dalrymple, op. cit. (*see* footnote 10), p. 43; T. Samios, "Constraints to Cereal Production and Possible Solutions in Cyprus" in International Maize and Wheat Improvement Center, *The Gap Between: Present Farm Yield and the Potential, 5th Cereals Workshop, May 5-9, 1979, Algiers, Algeria*, Vol. 1 (Mexico City: the Center, 1980), p. 21.

[67]T. Samios, op. cit. (*see* footnote 66), p. 21; A. Hadjichristodoulou, *Capeiti, a New Durum Wheat Variety for Cyprus*, Technical Bulletin 10 (Nicosia: Agricultural Research Institute, 1973), 11 pp.; A. Hadjichristodoulou, A. Della, and C. Josephides, *A New Durum Wheat Variety, Aronas*, Technical Bulletin 22 (Nicosia: Agricultural Research Institute, 1977), 14 pp.; A. Hadjichristodoulou, C. Josephides, and A. Karis, *Performance of the New Durum Wheat Variety "Mesaoria" Under Rainfed Conditions*, Technical Bulletin 41 (Nicosia: Agricultural Research Institute, 1982), 11 pp.; and letter from A. Hadjichristodoulou, Agricultural Research Institute, Nicosia, Cyprus, February 1984.

[68]Letter from A. Hadjichristodoulou, op. cit. (*see* footnote 67).

[69]Most of the area figures cited in this section came from A-M.M. Basheer, *Wheat Economics in Egypt*, Publication No. 40 (Cairo: Egyptian Major Cereals Improvement Project, 1982), pp. 10-11, 41-42. Data for 1982 and 1983 were provided in attachments to a letter from S.A. Bowers, Project Officer, USAID, Cairo, July 1984. Technical information was taken from A.S.A. Gomaa, "Winter Cereal Crops in Egypt" in *Farm Yield*, op. cit. (*see* footnote 66), pp. 99-101.

[70]D.G. Dalrymple, op. cit. (*see* footnote 10), p. 47. The change in government policy does not seem to have been mentioned by others as a factor and may bear further examination. Growers are required to sell a portion of their wheat and rice crops to the government at a fixed price.

[71]A-M.M. Basheer, op. cit. (*see* footnote 69), p. 10.

[72]U.S. Agricultural Attaché Report EG-0002 from Cairo, 25 January 1980, p. 10. For further comments on the high value of straw, *see* International Maize and Wheat Improvement Center, *CIMMYT Report on Wheat Improvement, 1978* (Mexico City: the Center, 1980), p. 199.

[73]Letter from E.E. Saari, CIMMYT, January 1985.

[74]U.S. Agricultural Attaché Report EG-2048 from Cairo, 9 September 1982, p. 4.

[75]Department of State telegram 32310 from Cairo, 24 December 1985. The use of HYWVs may be limited in part because they are recommended for early planting, which is not possible in multiple cropping with cotton. (Barley may be grown instead of wheat in some places.)

[76]Attaché Report EG-2048, op. cit. (*see* footnote 74), plus various other attaché reports.

[77]International Maize and Wheat Improvement Center, op. cit. (*see* footnote 3), p. 15.

[78]D.G. Dalrymple, op. cit. (*see* footnote 10), p. 48.

[79]International Maize and Wheat Improvement Center, *CIMMYT Report on Wheat Improvement, 1976* (Mexico City: the Center, 1978), p. 217; and Idem, *CIMMYT Report on Wheat Improvement, 1977* (Mexico City: the Center, 1979), p. 235; and D.G. Dalrymple, op. cit. (*see* footnote 10), p. 48.

[80]Parental crosses are noted in D.G. Dalrymple, op. cit. (*see* footnote 10), p. 19. Moghan 1 is a sister of Mexicani in Sudan, SNA-1 in Chile, and Anza in California.

[81]Letter from M.A. Vahabian, Seed and Plant Improvement Institute, Ministry of Agriculture and Rural Development, Karadj, Iran, April 1984.

[82]D.G. Dalrymple, op. cit. (*see* footnote 10), p. 49.

[83]International Maize and Wheat Improvement Center, *CIMMYT Report on Wheat Improvement, 1977* (Mexico City: the Center, 1979), p. 236; Idem, *CIMMYT Report on Wheat Improvement, 1978* (Mexico City: the Center, 1980), pp. 9, 295-296; Y.A. Hermis and S.A.A. Hussain, "Constraints to Cereal Production and Possible Solutions in Iraq" in *Farm Yield*, op. cit. (*see* footnote 66), pp. 70-71; and R. Villareal and S. Rajaram, *Semi-Dwarf Bread Wheats: Names: Parentage; Pedigree; Origin* (Mexico City: International Maize and Wheat Improvement Center, 1984), pp. 6, 18.

[84]D.G. Dalrymple, op. cit. (*see* footnote 10), p. 43-44; letter from K. Laurent, USAID, Amman, Jordan, March 1984.

[85]D.G. Dalrymple, op. cit. (*see* footnote 10), p. 50; A. Alameddine, "Constraints to Cereal Production and Possible Solutions in Lebanon" in *Farm Yield*, op. cit. (*see* footnote 66), p. 34.

[86]D.A. Sanders, and W.L. Wilson, "Report: Libya, 25 March-1 April, 1983," Mexico City: International Maize and Wheat Improvement Center, 1983, 27 pp.

[87]D.G. Dalrymple, op. cit. (*see* footnote 10), p. 51. The parentage of BT 908 is Newthatch/Marroqui//Kenya C9906/Mentana. The septoria epidemic was noted in International Maize and Wheat Improvement Center, *CIMMYT 1983 Research Highlights* (Mexico City: the Center, 1984), p. 23; and Idem, *CIMMYT Report, 1968-69* (Mexico City: the Center, 1970), p. 97.

[88]International Maize and Wheat Improvement Center, *CIMMYT Report on Wheat Improvement, 1976* (Mexico City: the Center, 1978), p. 176; Idem, *CIMMYT Report on Wheat Improvement, 1980* (Mexico City: the Center, 1982), pp. 139, 140; and Idem, *CIMMYT Report on Wheat Improvement, 1981* (Mexico City: the Center, 1984), p. 120. Also, D.G. Dalrymple, op. cit. (*see* footnote 10), p. 51; and International Center for Agricultural Research in the Dry Areas, *ICARDA Annual Report, 1984* (Damascus, Syria: the Center, 1984), p. 71.

[89]C. Schaller, D. Rasmussan, and J. Srivastara, "The Review and Recommendations on the Cereal Improvement Program of Morocco, May 8-15, 1982," Damascus, Syria: International Center for Agricultural Research in the Dry Areas, 10 pp.

[90]International Maize and Wheat Improvement Center, *CIMMYT Report on Wheat Improvement, 1980* (Mexico City: the Center, 1982), p. 140; and D.G. Dalrymple, op. cit. (*see* footnote 10), p. 51.

[91]M. Akhtar, "Varietal Position of Wheat in Oman," Directorate of Agriculture, Muscat, Oman, 1978; and personal communication with A. Klatt, CIMMYT, May 1985.

[92]D.G. Dalrymple, op. cit. (*see* footnote 10), p. 52; and International Maize and Wheat Improvement Center, *CIMMYT Report on Wheat Improvement, 1978* (Mexico City: the Center, 1980), pp. 302-303.

[93]Letters from J.M. Kuhl, American Embassy, Jidda, Saudi Arabia, May and September 1984. More general information is provided in D.B. Ottaway, "Saudis Create 'Wheat Belt' in the Desert," *The Washington Post*, 25 November 1984, p. A25.

[94]This section is based on D.G. Dalrymple, op. cit. (*see* footnote 10), pp. 19, 53; International Maize and Wheat Improvement Center, *CIMMYT Report on Wheat Improvement, 1977* (Mexico City: the Center, 1979), p. 241; I. Naji, "Introduction of High-Yielding Wheat Varieties in Syria," Damascus, Syria: International Center for Agricultural Research in the Dry Areas, Cereal Improvement Program, March 1974; International Center for Agricultural Research in the Dry Areas, *Two New Wheat Varieties for Syria* [news release], 11 December 1984; letter from D. Winkelmann, CIMMYT, May 1984; "CIMMYT/ICARDA Bread Wheat Cooperative Program," *Wheat Newsletter* 30 (June 1984):78; letter from J.P. Srivastava, ICARDA, August 1984; and H. El-Akhrass, "A Study of Collaboration Between International Agricultural Research and Syria," Consultative Group on International Agricultural Research Impact Study, January 1985, pp. 35-37.

[95]International Maize and Wheat Improvement Center, *CIMMYT Report on Wheat Improvement, 1980* (Mexico City: the Center, 1982), pp. 140-141; U.S. Agricultural Attaché Report No. TS-3010 from Tunis, November 1984, p. 9; personal communication with D. Sechler, USAID, Tunis, February 1985. The proportions reported for 1980-82 are higher for durum wheat and lower for bread wheat than reported in the past. (Over the 10-year period from 1970 to 1979, the proportion of bread wheat averaged

23% and the proportion of durum wheat, 77%: W.F. Johnson, C.E. Johnson, C.E. Ferguson, and M. Fikery, *Tunisia: The Wheat Development Program*, Project Evaluation Report No. 48 [Washington, D.C.: Agency for International Development, October 1983], table D-3.)

[96]Details on AID support and details on the wheat improvement program are provided in W.F. Johnson, et al., op. cit. (*see* footnote 95), 33 pp.

[97]W.F. Johnson et al., op. cit. (*see* footnote 95), table D-9; U.S. Department of Agriculture, Attaché Report TS-3010, op. cit. (*see* footnote 95), p. 9; D.G. Dalrymple, op. cit. (*see* footnote 10), p. 54; and U.S. Department of Agriculture, op. cit. (*see* footnote 2).

[98]H. Ketata, H. Halila, M. Deghaies, A. Maamouri, and M. Harrabi, "La Production Cerealier en Tunisia" in *Farm Yield*, op. cit. (*see* footnote 66), p. 55. The varieties listed and their proportion of the durum wheat total were INRAT 69, 71%; Badri, 15%; Amal, 6%; and Maghrebi, 5%. The same varieties are also mentioned in International Maize and Wheat Improvement Center, *CIMMYT Report on Wheat Improvement, 1980* (Mexico City: the Center, 1982), p. 141.

[99]Letter from D. Winkelmann, CIMMYT, August 1984. The HYWVs listed included all those in the durum wheat category in table 3.14. In decreasing order of importance they were INRAT 69, Karim, Badri, Maghrebi, Ben Bachir, and Amal. In 1984 more than 50,000 ha were planted with certified seed of Karim and Ben Bachir (International Center for Agricultural Research in the Dry Areas, *ICARDA Annual Report, 1984* [Damascus, Syria: the Center, 1984], p. 134).

[100]The two leading improved bread wheat varieties are Florence Aurore and Arianna 66 (Kenya 338 x Etoile de Choisy). The latter variety may be considered an HYWV in the official tabulation. In 1984 Salambo, Tanit, and Dougga reportedly covered nearly 40,000 ha of 140,000 ha planted with bread wheat (International Center for Agricultural Research in the Dry Areas, *ICARDA Annual Report, 1984* [Damascus, Syria: the Center, 1984], p. 134).

[101]This section is largely based on D.G. Dalrymple, op. cit. (*see* footnote 10), pp. 55-56; "Turkey's Wheat Research and Training Project," *CIMMYT Today*, No. 6 (1977):18; H. Hanson, et al., op cit (*see* footnote 9), pp. 59-68; and G. Tansey, *The Turkish Wheat Research and Training Project, 1969-82* (New York: The Rockefeller Foundation, 1984), 83 pp., especially pp. 7-11, 28-33. Also, International Maize and Wheat Improvement Center, *CIMMYT Report on Wheat Improvement, 1976* (Mexico City: the Center, 1978), pp. 219-220; and N. Demir, *The Adoption of New Bread Wheat Technology in Selected Regions of Turkey* (Mexico City: International Maize and Wheat Improvement Center, 1976), 27 pp.; and personal communication with A. Klatt, CIMMYT, and W. Kronstad, Oregon State University.

[102]Telex from Kamil Yakar and B. Skovmand, Ankara, to B.C. Curtis and A. Klatt, CIMMYT, February 1985 (forwarded by Curtis, February 1985). Yakar is with the Agricultural Research Institute; Skovmand is CIMMYT's wheat representative in Turkey. Additional information provided by Arthur Klatt, CIMMYT, on several dates.

[103]D.G. Dalrymple, op. cit. (*see* footnote 10), p. 44; International Maize and Wheat Improvement Center, *CIMMYT Report on Wheat Improvement, 1977* (Mexico City: the Center, 1979), p 238-239; Idem, *CIMMYT Report on Wheat Improvement, 1978* (Mexico City: the Center, 1980), pp. 304-305; N.M. Chaudhri, "A Note on Promising Wheat Varieties for the Y.A.R.," ARDA, November 1983, 3 pp.

[104]Letter from J.S. Bashki, Agronomy Expert, UNDP/FAO Project on Improvement of Crop Production, Aden, Yemen, May 1978, and J.P. Srivastava, ICARDA, November 1984.

[105]The Republic of South Africa has made extensive use of Mexican varieties. During 1976-77 about 865,700 ha were planted with varieties of Mexican extraction. This represented nearly 46% of the total wheat area. The leading Mexican varieties were Inia 66, T4, Zambese, SST3, Bella, and Tobari 66. During the 1983 crop year about 737,200 ha were planted with varieties of Mexican extraction representing about 40.8% of the total area and 50.1% of total production. The leading varieties were (as a percent of total production): SST 66, 16.7; SST 44, 15.5; SST 33, 10.3; Inia, 6.0; and others, 3.5. (Letters from A. Ventner, counselor, Embassy of South Africa, Washington, D.C., January 1978, and W.P. Grabbelazar, director, Grain Crops Research Institute, Potchenfstroom, South Africa, March 1984.)

[106]International Maize and Wheat Improvement Center, *CIMMYT Report on Wheat Improvement, 1978* (Mexico City: the Center, 1980), pp. 205, 209, 211, 214-216; Idem, *CIMMYT*

Report on Wheat Improvement, 1980 (Mexico City: the Center, 1982), p. 145; and Idem, *CIMMYT Report on Wheat Improvement, 1981* (Mexico City: the Center, 1984), p. 120.

[107]International Maize and Wheat Improvement Center, *CIMMYT Report on Wheat Improvement, 1978* (Mexico City: the Center, 1980), pp. 208-209; and Idem, *CIMMYT Report on Wheat Improvement, 1979* (Mexico City: the Center, 1981), p. 151.

[108]L.W. Briggle and B.C. Curtis, *Wheat Worldwide*, Wheat Monograph (Madison, Wisc.: American Society of Agronomy, in press).

[109]R. Villareal and A. Klatt, op. cit. (*see* footnote 5).

[110]This section is based almost entirely on F. Pinto "Wheat Situation in Ethiopia (1978-1984)," Addis Ababa: Ethiopian Seed Corporation, April 1984, 3 pp. plus 3 tables; and personal communication with F. Pinto in Addis Ababa, Ethiopia, June 1984. Further background can be found in D.G. Dalrymple, op. cit. (*see* footnote 10), pp. 57-58.

[111]Ethiopia imported some wheat seed from India in the early 1970s: 0.87 t in 1970-71 and 11.0 t in 1971-72 (Kalyansona and Sonalika). These varieties grew well in irrigated soils in the Auas Valley, but production was discontinued after 1974 (D.G. Dalrymple, op. cit. [*see* footnote 10], p. 57).

[112]Letter from H. Shawel, former Ethiopian agricultural official, to J.R. Anderson, December 1984.

[113]*Growing Wheat in Kenya* (Njoro: Plant Breeding Station, 1974), p. 1; and U.S. Agricultural Attache Report No. 46 from Nairobi, October 16, 1959.

[114] L. Bickel, op. cit. (*see* footnote 58), p. 132.

[115]International Maize and Wheat Improvement Center, *CIMMYT Report on Wheat Improvement, 1978* (Mexico City: the Center, 1980), p. 206.

[116]International Maize and Wheat Improvement Center, *CIMMYT Review, 1975* (Mexico City: the Center, 1975), pp. 95-96; and D.G. Dalrymple, op. cit. (*see* footnote 10), p. 58.

[117]This section is based on the following sources: D.J. Andrew, "Wheat Cultivation and Research in Nigeria," *Nigerian Agricultural Journal* 5(2) (n.d.):67-72; Ahmadu Bello University, *History and Status of Wheat Research in Nigeria*, Miscellaneous Paper 85 (Zaria, Nigeria: the University, 1979), 50 pp., especially pp. 1-10, 17; International Maize and Wheat Improvement Center, *CIMMYT Report on Wheat Improvement, 1976* (Mexico City: the Center, 1978), p. 177; Idem, *CIMMYT Report on Wheat Improvement, 1978* (Mexico City: the Center, 1980), p. 212; Idem, *CIMMYT Report on Wheat Improvement, 1980* (Mexico City: the Center, 1982), p. 145; A.M. Falaki, "Wheat Production Status, Constraints, and Research Priorities in Nigeria" and F.C. Orakwe, "Wheat Germplasm Development for Heat and Drought Tolerance for Nigeria" both in R. Villareal and A. Klatt, op. cit. (*see* footnote 5); letter from G. Varughese, CIMMYT, January 1985; and B.B. Wudiri, "The Development and Use of Semi-Dwarf Wheat Varieties in Nigeria," Maiduguri, Nigeria: Lake Chad Research Institute, June 1985, 2 pp.

[118]These varieties were first recommended in 1965; they are susceptible to lodging.

[119]A.M. Falaki and F.C. Orakwe, op. cit. (*see* footnote 117).

[120]Selections from the same cross have been released as Moghan 1 in Iran, Anza in California, and WW15 in Australia (C.O. Qualset, et al., "Anza, New High-Yielding, Short-Statured Wheat Variety," *California Agriculture* 27[2] [1973]:14-15.)

[121]D.G. Dalrymple, op. cit. (*see* footnote 10), p. 60

[122]Letters from E. Witt, USAID, Khartoum, Sudan, May and August 1984; International Center for Agricultural Research in the Dry Areas, *ICARDA Annual Report, 1984* (Damascus, Syria: the Center, 1984), p. 71.

[123]D.G. Dalrymple, op. cit. (*see* footnote 10), p. 61; and International Maize and Wheat Improvement Center, *CIMMYT Report on Wheat Improvement, 1976* (Mexico City: the Center, 1978), pp. 191-192; Idem, *CIMMYT Report on Wheat Improvement, 1978* (Mexico City: the Center, 1980), pp. 219-222; and Idem, *CIMMYT Report on Wheat Improvement, 1981* (Mexico City: the Center, 1984), p. 121.

[124]International Maize and Wheat Improvement Center, *CIMMYT Report on Wheat Improvement, 1977* (Mexico City: the Center, 1979), pp. 200-204; Idem, *CIMMYT Report on Wheat Improvement, 1978* (Mexico City: the Center, 1980), p. 221; and G.L.C. Musa, "Irrigated Wheat Varieties and Their Prospects," *Productive Farming* No. 126 (1984):15-18.

[125]This section is based on D.G. Dalrymple,

op. cit. (*see* footnote 10), pp. 19, 59, 60; International Maize and Wheat Improvement Center, *CIMMYT Report on Wheat Improvement, 1976* (Mexico City: the Center, 1976), pp. 179-180; Idem, *CIMMY Report on Wheat Improvement, 1978* (Mexico City: the Center, 1980), p. 213; letter from M.L. Winter, USAID, Harare, Zimbabwe, January 1983; letter from N.A. Mashiringwani, wheat breeder, Crop Breeding Institute, Department of Research and Specialist Services, Harare, Zimbabwe, March 1984; and personal communication with A. Klatt, CIMMYT, May 1985. *Also see* K.J. Billing, *Zimbabwe and the CGIAR Centers; a Study of Their Collaboration in Agricultural Research*, Study Paper 6 (Washington, D.C.: Consultative Group on International Agricultural Research, 1985), pp. 81-85.

[126]U.S. Department of Agriculture, op. cit. (*see* footnote 2).

[127]International Maize and Wheat Improvement Center, op. cit. (*see* footnote 3), pp. 1, 23.

[128]Details on early programs are provided in E.C. Stakman, R. Bradfield, and P.C. Mangelsdorf, *Campaigns Against Hunger* (Cambridge, Mass.: Belknap/Harvard University Press, 1967), pp. 216-234.

[129]The table does not include all wheat varieties with CIMMYT origins in their pedigree–particularly local crosses and reselections.

[130]J.A. Clark, "Improvement in Wheat" in *Yearbook of Agriculture, 1936* (Washington, D.C.: U.S. Department of Agriculture, 1936), p. 229; D.H. Fienup, R.H. Brannon, and F.A. Fender, *The Agricultural Development of Argentina* (New York: Praeger, 1969), p. 106; and letter from M.M. Kohli, CIMMYT, Santiago, Chile, January 1985.

[131]International Maize and Wheat Improvement Center, *CIMMYT Annual Report, 1972* (Mexico City: the Center, 1972), p. 84; Idem, *CIMMYT Report on Wheat Improvement, 1977* (Mexico City: the Center, 1979), p. 228; Idem, *CIMMYT Report on Wheat Improvement, 1978* (Mexico City: the Center, 1980), p. 224; D.G. Dalrymple, op. cit. (*see* footnote 10), pp. 62-63. The parentage of Lapacho and Urunday is the same as Ciano 67, but the selections have more resistance to stem rust races in Argentina. Tala is slightly taller than Lapacho and Urunday and does not resemble other Mexican varieties as closely.

[132]I am indebted to M.M. Kohli of CIMMYT (Lima) and W.L. McCuistion of Oregon State University for their considerable help with the identification of these varieties. Further information is provided in several papers in Oregon State University, *Cereal Breeding and Production Symposium: Marcos Juarez, Argentina, November 7-12, 1983*, Special Report 718 (Corvallis: the University, 1984), pp. 317-330. Cargill has a hybrid wheat program in Argentina (ibid., pp. 331-333).

[133]J.A. Penna, L.F. Macagno, and G. Merchante, "Estimación del Area Cosechada de Trigo por Variedad y pro Región Triguera Entre 1973 y 1980: Una Primera Aproximación," Buenos Aires: Instituto Nacional de Technologia Agropecuaria, 1983, 9 pp. Also, letters from J.A. Penna, January, March, and May 1984. Excludes zone VN, which is of minor importance.

[134]In 1980-81 the five semidwarfs accounted for about 57% of total wheat production (J.A. Penna et al., op. cit. [*see* footnote 133], p. 9). The proportion by major zone varied as follows: IIN, 86%; I, 57%; III, 20%; and VS, 0% (J.A. Penna, L.F. Macagno, and G.M. Navarro, *Difusión de las Variedades de Trigo con Germoplasma Mexicana y su Impacto en la Producción Nacional: Un Analisis Economico*, Documento de Trabajo No. 3 [Buenos Aires: Instituto Nacional de Technologia Agropecuaria, 1983], pp. 14-19, 47).

[135]D.G. Dalrymple, op. cit. (*see* footnote 10), p. 63.

[136]H. Hanson et al., op. cit. (*see* footnote 9), p. 82.

[137]Letter from M.M. Kohli, CIMMYT, Santiago, Chile, March 1984.

[138]Letter from M.M. Kohli, August 1984, and personal communication from A. Klatt, CIMMYT, May 1985.

[139]Attachment to letter from M. Pineiro, Centro de Investigaciónes Sociales Sobre el Estado y la Administration, Buenos Aires, April 1984.

[140]J. Diehl, "Argentina Rests Hope on Its Farms," *The Washington Post* 19 June 1984, p. 1.; and D. Avery, "U.S. Farm Dilemma: The Global Bad News is Wrong," *Science* 230 (1985):409; International Maize and Wheat Improvement Center, *CIMMYT Research Highlights 1984* (Mexico City: the Center, 1985), p. 79. Results of recent fertilizer trials are provided in the latter reference, pp. 73-79.

[141]Oregon State University, op. cit. (*see* footnote 132), pp. 440-443.

[142]International Maize and Wheat Improve-

ment Center, *CIMMYT Report on Wheat Improvement, 1980* (Mexico City: the Center, 1982), p. 118; Idem, *CIMMYT Report on Wheat Improvement, 1981* (Mexico City: the Center, 1984), p. 103; Iowa State University, "Analysis of Cooperation and Coordination Between the International Research Centers (CIMMYT, CIAT, CIP) and the National Centers of Latin America," Ames, Iowa: the University, 1981, p. 101; letters from H.J. Dubin, CIMMYT, Quito, Ecuador, January and October 1984; and personal communication from A. Klatt, CIMMYT, May 1985.

[143]Paraguay 214 accounted for 11.0% of wheat production in Parana in 1974 and 1.5% in 1973. Sonora 63 and 64 represented 2.1% of production in 1974 and none in 1973.

[144]Paraguay 281 (Paraguai 281) is not a semidwarf but an old variety originally developed in Colombia. It came from Paraguay, where it was selected from the 1960 International Rust Nursery. Its parentage is 1879/Mayo 54.

[145]The genealogies of three of the varieties are IAS-52: IAS 15/3/Mayo 54/Norin 10/Brevor 28-LC; IAS-53: IAS 16/3/Yaktana 54/Norin 10/Brevor 21-LC; and IAS-54: IAS 16/5/Norin 10/Brevor 17/Yaqui 53/3/Yaqui 50/4/Kentana 54 B. The pedigree of IAS-55 is unknown. The average height of IAS-54 and IAS-55 is reported to be 90 cm. The varieties were developed by the Federal Research Program at Pelotas, Brazil.

[146]The information provided in this section was previously reported in D.G. Dalrymple, op. cit. (*see* footnote 10), pp. 64-65.

[147]H. Hanson et al., op. cit. (*see* footnote 9), pp. 80-81.

[148]"Items from Brazil," *Annual Wheat Newsletter* 30 (1984):48.

[149]International Maize and Wheat Improvement Center, *CIMMYT Report on Wheat Improvement, 1978* (Mexico City: the Center, 1980), p. 226. Excludes both LA 1549 and Paraguai 281 (*see* footnote 144). LA 1549 sometimes produces semidwarf plants.

[150]Attachments to letter from J.M. Pompeu Memoria, Advisory Office for International Cooperation, Empresa Brasileira de Pesquisa Agropecuaria, Brasilia, February 1984. Data exclude LA 1549 and Paraguai 281.

[151]Letter from M.M. Kohli, CIMMYT, Santiago, Chile, March 1984.

[152]International Maize and Wheat Improvement Center, *CIMMYT Report on Wheat Improvement, 1980* (Mexico City: the Center, 1982), pp. 124, 126, 127; Idem, *CIMMYT Report on Wheat Improvement, 1981* (Mexico City: the Center, 1984), p. 106; and personal communication with M.M. Kohli, op. cit., November 1984.

[153]J.A. Clark, op. cit. (*see* footnote 130), p. 230.

[154]E.C. Stakman, op. cit. (*see* footnote 128), pp. 232, 233, 271.

[155]D.G. Dalrymple, op. cit. (*see* footnote 10), p. 65.

[156]Selections from the same cross as SNA-1 have been released as Mexicani in Sudan, Moghan 1 in Iran, and Anza in California.

[157]M.M. Kohli, op. cit. (*see* footnote 151).

[158]The first three paragraphs of this section are based on E.C. Stakman et al., op. cit. (*see* footnote 128), pp. 222-223, 269-271; and R. Hertford, J. Ardila, A. Rocha, and C. Trujillo, "Productivity of Agricultural Research in Colombia" in *Resource Allocation and Productivity in National and International Agricultural Research*, ed. T.M. Arndt, D.G. Dalrymple, and V.W. Ruttan (Minneapolis: University of Minnesota Press, 1977), pp. 101-113.

[159]*See* L. Dudley and R. Sandilands, "The Side Effects of Foreign Aid: The Case of Public Law 480 Wheat in Colombia," *Economic Development and Cultural Change* 23 (1975):325-336.

[160]D.G. Dalrymple, op. cit. (*see* footnote 10), p. 66.

[161]Letters from H.J. Dubin, CIMMYT, Quito, Ecuador, January and October 1984; H.J. Dubin and P.C. Wall, "Andean Region Program," *Wheat Newsletter* 30 (1984):77; and U.S. Agricultural Attaché Report No. CO-4016 from Bogotá, March 6, 1984, p. 2. Details on the two varieties are provided in "ICA-Yuriya," Estación Experimental Obonuco, September 1979, 13 pp.; and Instituto Colombian Agropecuario, *ICA-Susata, Trigo de Alto Rednimiento*, Plegable Divugative No. 177 (Bogotá: the Institute, August 1983) (both provided by L.I. Holmes, agricultural counselor, American Embassy, Bogotá, July 1984).

[162]H.J. Dubin, op. cit. (*see* footnote 161), October 1984.

[163]E.C. Stakman et al., op. cit. (*see* footnote 128), p. 270; and International Maize and Wheat Improvement Center, *CIMMYT Report on Wheat Improvement, 1976* (Mexico City: the Center, 1978), p. 136.

164International Maize and Wheat Improvement Center, *CIMMYT Report on Wheat Improvement, 1978* (Mexico City: the Center, 1980), pp. 9, 230-231; Idem, *CIMMYT Report on Wheat Improvement, 1980* (Mexico City: the Center, 1982), p. 118; Idem, *CIMMYT Report on Wheat Improvement, 1981* (Mexico City: the Center, 1984), p. 103; and letters from H.J. Dubin, CIMMYT, Quito, Ecuador, January and June 1984. Imbabura was released in 1978; it is a semidwarf derived from a Mexican selection but never multiplied.

165International Maize and Wheat Improvement Center, *CIMMYT Research Highlights, 1984* (Mexico City: the Center, 1985), pp. 99-102. Other details are provided in D. Byerlee, "Comparative Advantage and Policy Incentives for Wheat Production in Ecuador," International Maize and Wheat Improvement Center, Economics Program, Working Paper No. 01/85, 1985, 99 pp.

166E.C. Stakman et al., op. cit. (*see* footnote 128), p. 268.

167D.G. Dalrymple, op. cit. (*see* footnote 10), p. 67.

168International Maize and Wheat Improvement Center, *CIMMYT Report on Wheat Improvement, 1978* (Mexico City: the Center, 1980), p. 232; Iowa State University, op. cit. (*see* footnote 142), p. 62; H.J. Dubin, op. cit. (*see* footnote 164), January 1984; and letter from C. McFarland, USAID, Guatemala City, February 1984.

169D.G. Dalrymple, op. cit. (*see* footnote 10), p. 67; and Iowa State University, op. cit. (*see* footnote 142), p. 62.

170Compiled from information provided in N.A. Barletta, "Costs and Social Benefits of Agricultural Research in Mexico" (Ph.D. dissertation, University of Chicago, 1970), pp. 136, 138. Barletta provides estimates of the use of six variety groups for six regions from 1948 to 1964; data for the semidwarf group were reported for 1963 and 1964 only (p. 140).

171Letter from E.A. Luna, Instituto Nacional de Investigaciónes Agricolas, Mexico City, January 1978.

172International Maize and Wheat Improvement Center, *CIMMYT Review, 1975* (Mexico City: the Center, 1975), p. 97. The varietal breakdown was (a) Yecora 70, Cajeme 71, and Tanori 71, 73.9%; (b) Siete Cerros 66, 12.2%; (c) Lerma Rojo 64 and Delicias, 10.3%; and (d) Jori 69 and Corocit 71 (durum), 3.6%.

173Letter from D. Winkelmann, economist, CIMMYT, August 1984 (enclosing an estimate from S. Rajaram, wheat breeder, CIMMYT).

174Personal communication with A. Klatt, CIMMYT, May 1985.

175D.G. Dalrymple, op. cit. (*see* footnote 10), p. 68.

176International Maize and Wheat Improvement Center, *CIMMYT Report on Wheat Improvement, 1976* (Mexico City: the Center, 1978), p. 139.

177U.S. Department of State telegram 02909 from Asunción, Paraguay, May 25, 1984.

178Letters from M.M. Kohli, CIMMYT, Santiago, Chile, March and December 1984.

179E.C. Stakman et al., op. cit. (*see* footnote 128), pp. 270, 271; and D.G. Dalrymple, op. cit. (*see* footnote 10), p. 69.

180Background on Participation is provided in R.V. Novoa, "Inheritance of Height and Other Characters Under Conditions of the Coast of Peru" in *Proceedings of the 4th International Wheat Genetics Symposium*, ed. E.R. Sears and L.M. Sears (Columbia: University of Missouri, 1973), p. 612.

181International Maize and Wheat Improvement Center, *CIMMYT Report on Wheat Improvement, 1978* (Mexico City: the Center, 1980), pp. i, 235; and letters from H.J. Dubin, CIMMYT, Quito, Ecuador, January and June 1984.

182Personal communication with A. Klatt, CIMMYT, May 1985.

183Letter from D.D. Bathrick, USAID, Lima, May 1984. The estimate was provided by the National Wheat Producers Association, Lima. Seed multiplication and distribution is currently a big problem.

184*70 Años de Mejoramiento Genetico de Trigo*, Miscelanea 51 (Estación Experimental Agropecuaria la Estanzuela, Centro de Investigaciónes Agricolas, 1982), 28 pp.; "Items from Uruguay," *Annual Wheat Newsletter* 29 (1983):159; and letters from T. Abadie, wheat breeder, Estación Experimental Agropecuaria la Estanzuela, February and May 1984.

4. SUMMARY OF AREA ESTIMATES

There is scarcely time to congratulate ourselves on the achievements of today because we have to hustle to produce something better for tomorrow. The task of the breeder and geneticist has become never-ending.

—Gove Hambidge and E. N. Bressman, 1936[1]

This chapter summarizes, by region, the HYWV data presented for individual DCs in the previous chapter. It also indicates the approximate proportions of total wheat area represented by HYWVs in these regions. Comparative data are included for rice.

SOME NOTES OF CAUTION

Because summarization of national data on HYWVs is an imprecise task, such data should be viewed with considerable caution. Data limitations and problems in evaluating center contributions particularly need to be kept in mind.

Data Limitations

The data summarized here should be viewed only as estimates. They cannot be considered exact because of problems in both definition and reporting that have already been noted. Even though HYWVs can be easily defined in general terms, they are difficult to differentiate from some improved local varieties—and may not be differentiated in national statistics.

Some nations do a surprisingly complete job of collecting varietal data, but in most cases data are scarce. Many crop reporting systems are either not able or are not highly motivated to gather information on varieties.[2] When data are gathered the procedures followed may not be very advanced. When estimates are not available it is necessary to turn to inexact sources: estimates by breeders, information on seed sales, or both. The result is a substantial variation in the quality and accuracy of national estimates.

The weaknesses of various national estimates are compounded when one attempts to add them up to produce regional totals. Definitions of HYWVs, moreover, may vary by country. In some cases varieties that appear to be in the HYWV category on the basis of national yield levels may be left out. Gaps in reporting and differences in reporting periods become additional difficulties. The situation varies among areas, with the Asian data being generally reliable and the accuracy of the Near East and African data being somewhat more variable.

One set of figures that does not appear here is that of area planted with leading individual varieties. Data of this nature are even less often reported at the country level than HYWV data as a whole. It is clear that one HYWV, Sonalika, has been planted on an exceptionally wide area in India, Nepal, and Bangladesh—perhaps 7-8 million ha in 1982-83.[3] It would be desirable to have such area data for all the leading HYWVs.

In analyzing the data, it should be recognized that we are dealing with a joint product—the result of collaboration by national and international agricultural research programs. Varieties used by IARC plant breeders usually have many linkages to earlier national breeding programs, and IARC varieties are usually tested, further selected, and developed in national programs. The interaction between IARC and national centers is synergistic. Hence, it is difficult and probably not useful—possibly even divisive—to try to evaluate which party contributed what proportion of the final joint product.

HYWV AREA

In this section the HYWV areas for each country are summarized for each of the four DC regions and then totaled. Complete time series data for the 1965-66 to 1982-83 crop years are available only for Asia. The primary focus, therefore, is on the 1982-83 crop year. Even in the case of 1982-83, complete crop year data are not available for every country, and it has been necessary to use data for the last available year, or even guesses. In some cases official data may be subject to revision. Moreover, some data have been reported for calendar years and have had to be aligned with a crop year, a process that entailed some difficulties.[4]

Southern and Eastern Asia

Wheat is principally grown in four nations in southern Asia (Bangladesh, India, Nepal, and Pakistan) and in China. The HYWV statistics for southern Asia are good with time series data available for HYWVs since the mid-1960s. However, only limited and uncertain data are available for China.

Time series data for HYWVs for the four southern Asian nations for the 18-year period from 1965-66 to 1982-83 are summarized in table 4.1 and figure 4.1. Comparative data for high-

Table 4.1. Estimated area planted with high-yielding varieties of wheat and rice in southern and Southeast Asian nations from 1965-66 to 1982-83

Crop year	Area (ha)		
	Wheat[a]	Rice[b]	Total
1965-66	12,300	13,800	26,100
1966-67	653,500	984,500	1,638,000
1967-68	3,928,000	2,584,000	6,512,000
1968-69	7,243,500	5,198,400	12,441,900
1969-70	7,677,200	7,487,300	15,164,500
1970-71	9,720,000	9,631,300	19,351,300
1971-72	11,278,100	12,953,300	24,231,400
1972-73	13,744,300	14,753,300	28,497,600
1973-74	14,726,500	18,895,600	33,622,100
1974-75	15,196,400	20,290,400	35,486,800
1975-76	17,795,000	22,374,100	40,169,100
1976-77	19,491,400	24,031,600	43,523,000
1977-78	20,931,800	28,124,400	49,056,200
1978-79	21,534,600	30,216,100	51,750,700
1979-80	21,339,000	30,261,400	51,600,400
1980-81	22,781,200	33,909,500	56,690,700
1981-82	23,778,400	36,025,300	59,803,700
1982-83	25,341,200	35,725,400	61,066,600

[a]Bangladesh, India, Nepal, and Pakistan.

[b]Bangladesh, Burma, India, Indonesia, Nepal, Pakistan, Philippines, Sri Lanka, and Thailand.

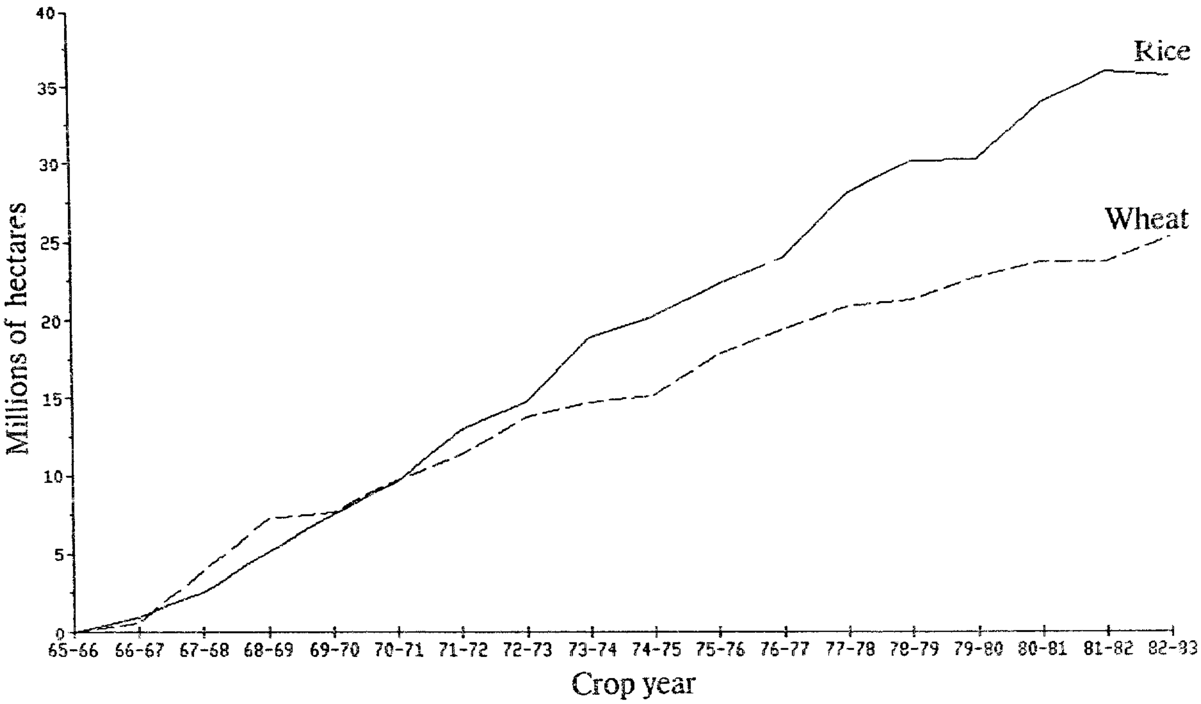

Figure 4.1. Estimated area planted with high-yielding varieties of wheat and rice in southern and Southeast Asian nations from 1965-66 to 1982-83. Source: Table 4.1.

yielding rice varieties (HYRVs) are included for nine nations. The area of both crops expanded at a steady rate throughout the period; wheat, however, expanded less rapidly than rice, and its rate of growth lessened somewhat in the mid-1970s. India accounted for the largest share, by far, of the area for both crops in the regions. In the case of wheat, India was followed by Pakistan.

Outside the nine nations, the HYWV picture is mixed. For example, only a small area of wheat (26,000 ha) is grown in South Korea. Wheat is, however, a significant crop in China, and incomplete estimates indicate that at least 8.9 million ha were planted with HYWVs of less than 100 cm in 1983. HYWVs are not known to be grown in other communist Asian nations except for North Korèa, for which no data are available.

The Asian data are summarized for 1982-83 in table 4.2. The HYWV area in the noncommunist nations greatly exceeded that in the communist nations (China); the HYRV areas, however, were much closer. (The estimates for the communist nations are rough and should be considered accordingly.)

Near East (Western Asia and North Africa)

HYWVs are grown in at least 18 countries in the Near East. In several, particularly Oman and Yemen, the overall area is so small that it is not considered. Israel makes extensive use of HYWVs, but it is considered a developed country. Good statistics are available for Cyprus, Egypt, Saudi Arabia, Syria, and Tunisia, and it is possible to make reasoned estimates for Turkey. However, in the case of Algeria, Afghanistan, Iran, Iraq, Jordan, Lebanon, Libya, and Morocco, statistics are limited and "guesstimates" or earlier figures have been used.

In assembling country estimates for the regional total, low estimates were selected when available and numbers were rounded downward. Country estimates of HYWV area used for 1982-83 are as follows (in hectares): Algeria, 400,000; Afghanistan, 400,000; Cyprus, 5,000; Egypt, 300,000; Iran, 800,000; Iraq, 600,000; Jordan, 20,000; Lebanon, 20,000; Libya, 100,000; Morocco, 600,000; Saudi Arabia, 300,000; Syria, 600,000; Tunisia, 350,000; and Turkey, 3,400,000.

Table 4.2. Total area of high-yielding varieties of wheat and rice for Asia in 1982-83 crop year

Region	Area (ha)		
	Wheat	Rice	Total
Selected Asian nations	25,341,200[a]	35,725,400[b]	61,066,600
Other Asian nations	26,000[c]	648,300[d]	674,300
Subtotal[e]	25,367,200	36,373,700	61,740,900
Communist nations	8,920,000[f]	33,380,000	42,300,000
Total	34,287,200	69,753,700	104,040,900

[a]Bangladesh, India, Nepal, and Pakistan.
[b]Bangladesh, Burma, India, Indonesia, Nepal, Pakistan, Philippines, Sri Lanka, and Thailand.
[c]South Korea.
[d]South Korea and West Malaysia.
[e]Excludes North Korea.
[f]Incomplete estimate of area planted with semidwarfs of less than 100 cm in China.

The total on this basis would be 7,895,000 ha. In view of the uncertainty of some of the data, the total is conservatively rounded to 7.6 million ha.

While the overall HYWV area trend probably has been upward in the region, the individual country pattern varies more than in other regions. This is because a large proportion of the wheat in some countries is grown in rainfed conditions; variations in rainfall can cause significant variations in the wheat area from year to year. Also seed supplies have been inadequate in some countries. Government price policies and market conditions have limited the HYWV area in other regions.

Africa (Except North Africa)

The wheat area in Africa is concentrated in a few countries, principally in East Africa, but small areas exist in numerous other countries. Data are included on HYWV production in only seven countries—six in East Africa and one in West Africa. Definitions of HYWVs vary among countries, as does the quality and extent of area data. Both mirror the wide range in production conditions and yields.

Estimates for HYWV area in individual countries in 1982-83 are (in hectares): Ethopia, 250,000;[5] Kenya, 96,000; Nigeria, 10,000; Sudan, 100,000; Tanzania, 10,000; Zambia, 3,000; and Zimbabwe, 22,000. The total area for the seven countries is 491,000 ha. HYWVs are probably found in a few other African nations and may represent a high proportion of the total area in some, but their aggregate area is probably small. A figure of 500,000 ha is used for the region.

Latin America

The HYWVs reported here for Latin America are essentially all semidwarfs. Much of the HYWV area is concentrated in Argentina. Unfortunately, detailed varietal surveys are not conducted in that country, and it is necessary to rely on other techniques to assess the total HYWV area. It is assumed that roughly 90% of the wheat-growing area in Argentina was planted with HYWVs in 1982 and 1983, although some estimates run as high as 95%. A different problem is that the Latin American data are often reported on a calendar- rather than crop-year basis; the 1983 data are assumed to reflect the 1982-83 crop year.

A review of the data reported earlier produces roughly the following HYWV estimates for 1982-83 (in hectares): Argentina, 6,190,000; Bolivia, 6,000; Brazil, 800,000; Chile, 300,000; Colombia, 40,000; Ecuador, 8,000; Guatemala, 40,000; Mexico, 800,000; Paraguay, 6,000; Peru, 8,000; and Uruguay, 200,000. The total is 8,398,000 ha. Rounding down slightly, again to be conservative,

Table 4.3. Estimated area planted with high-yielding varieties of wheat and rice in developing nations in 1982-83

Region	Area (ha)		
	Wheat	Rice	Total
Asia	25,400,000	36,400,000[a]	61,800,000
Near East	7,600,000	100,000	7,700,000
Africa	500,000	200,000	700,000
Latin America	8,300,000	2,500,000	10,800,000
Subtotal	41,800,000	39,200,000	81,000,000
Communist Asia	8,900,000[b]	33,400,000[c]	42,300,000
Total	50,700,000	72,600,000	123,300,000

[a]Excludes Taiwan.

[b]Incomplete estimate of area of varieties of less than 100 cm in China.

[c]Excludes North Vietnam.

produces a figure of 8,300,000 ha. Argentina represents nearly 74% of this total, and if the HYWV estimate for Argentina is substantially in error, the total figure for the region is similarly influenced.

Total HYWV Area

Estimates for the four regions in 1982-83 are totaled in table 4.3. A separate entry is provided for communist Asia. Rice is included for comparison. In view of the uncertainty of some of the data, the regional totals have been selected from the lower variants cited in the previous country sections, and two regional totals were further ounded down. (The latter step reduced the total by about 400,000 ha.) This process may have been overdone.

The total estimated HYWV and HYRV areas for the four regions (excluding communist Asia) were roughly 81 million ha in 1982-83, with the HYWV area slightly larger (51.6% of the total) than that for HYRVs (48.4%). In each case the largest area was in Asia. For wheat Asia was followed at some distance by Latin America and the Near East; Africa, not a substantial wheat-growing area, was last by a wide margin. China had a substantial area of HYWVs.

The distribution of the HYWV and HYRV areas throughout regions, excluding communist Asia, is shown in table 4.4 (columns 1, 3, and 5). Clearly, the HYWV area is heavily concentrated in Asia, and the HYRV area is almost exclusively located there. Overall, Asia accounted for 76.3% of the total HYWV and HYRV area. Within Asia much of the HYWV and HYRV area was in India (43.2% of the total HYWV area in the four regions and 47.6% of the total HYRV area—or 45.4% of both crops). The area proportions by region mirrored to some extent the overall distribution of the area of the two crops (columns 2, 4, and 6), except in the case of wheat in Asia and the Near East; the HYWV proportions were significantly higher in Asia and lower in the Near East than the distribution of the area of the two crops

Perspective on changes in total HYWV area over time may be obtained from two sources. First, comparison of the data for noncommunist nations for 1982-83 with roughly comparable data for 1976-1977, reported in the previous edition of this report, reveals that the HYWV area increased from 29.4 to 41.8 million ha, a growth of 42.2%. Secondly, calculations made for the Consultative Group on International Agricultural Research (CGIAR) impact study suggested the following growth in the area of modern varieties, including China (in millions of hectares): 1970, 12.0; 1975, 24.8; 1980, 37.8; and 1983, 48.6. The figures are largely derived from, but are not fully comparable to, data reported in this study. The

Table 4.4. Distribution of high-yielding varieties of wheat and rice throughout developing regions of the world in 1982-83

Region	Area (%) HYWVs	All wheat	HYRVs	All rice	HYWVs and HYRVs	All wheat and rice
Asia[a]	60.8	46.5	92.9	86.2	76.3	69.9
Near East	18.2	36.6	0.3	1.2	9.5	15.7
Africa	1.2	1.4	0.5	4.4	0.9	3.2
Latin America	19.9	15.5	6.3	8.2	13.3	11.2
Total	100.1[b]	100.0	100.0	100.0	100.0	100.0

[a]Excludes communist Asia.

[b]Total is greater than 100 due to rounding.

rate of growth is similar to that reported for selected Asian nations in figure 4.1.[6]

HYWV AND HYRV PROPORTIONS

Interpretation of the regional HYWV and HYRV area statistics can be facilitated by comparing them with the total wheat and rice areas. This section examines cross-sectional data for 1982-83 for the four regions and time series data for wheat and rice in Asia. Due to problems in matching reporting periods for HYWVs and HYRVs with those for total area at the regional level, the results should not be taken as exact.[7]

Regional Totals

The HYWV and HYRV proportions in 1982-83 are summarized for each of the four developing regions and for the developing world as a whole in table 4.5. The total HYWV and HYRV area represented about 50% of the total wheat and rice area in the four regions. The proportion for HYWVs (60.9%), however, was considerably higher than that for HYRVs (41.6%). When communist Asia, for which the data are particularly uncertain, is added, the situation is reversed, with the HYWV area (51.9%) becoming slightly smaller than that for HYRVs (53.6%).

Table 4.5. Estimated area of high-yielding varieties of wheat and rice as a proportion of total area in developing nations in 1982-83

Region	% of area planted with high-yielding varieties: Wheat	Rice	Wheat and rice
Asia[a]	79.2	44.9	54.6
Near East	30.6	8.4	29.6
Africa	50.6	4.7	13.3
Latin America	77.6	32.9	59.0
Subtotal	60.9	41.6	49.8
Communist Asia[b]	30.6[c]	81.0	58.0
Total	51.9	53.6	52.9

Note: See text footnote 7 for discussion of basic data used in making the calculations reported here.

[a]Excludes Taiwan.

[b]Excludes North Korea.

[c]Incomplete estimate of proportion of varieties of less than 100 cm in China.

When the total figures for HYWVs and HYRVs are considered by region, Latin America surprisingly has the highest percentage (due to heavy use of HYWVs in Argentina). Asia is close behind, followed by the Near East and Africa. The regional HYWV proportion was particularly high in Latin America and Asia, followed by Africa and the Near East. The regional HYRV proportion was highest in Asia, followed by Latin America and at some distance by the Near East and Africa.

By way of comparison, the CGIAR impact study, noted earlier, calculated that the proportion of modern wheat varieties (HYWVs) in the developing nations, including China, increased as follows over time: 1965, 0.1%; 1970, 14.0%; 1975, 27.0%; 1980, 39.9%; and 1983, 49.8%. The data are not fully comparable to those reported here, but they do underline the expanding significance of the new varieties.[8]

Time Series Data

In the case of the southern and Southeast Asian nations, as shown in table 4.6 and figure 4.2, the adoption of HYWVs (in four nations) got off to a fast start but then increased at a slower rate during the 1970s and the 1980s. As of the early 1980s, adoption approached the 80% range, and there is some question as to how much higher it might go. In contrast the adoption rate for HYRVs (in 9 nations) was slower and steadier, with perhaps a slight slowing in 1981-82 and 1982-83. (The percentage figure for HYRVs rose in 1982-83, in contrast to the area figure reported in table 4.1 and figure 4.1, because of an overall decline in total rice area in 1983-84.)

FUTURE RATES OF ADOPTION

Countries currently with high levels of HYWV and HYRV adoption are likely to face slower rates of increase in area in the future. Some nations are probably well along the adoption curve or approaching the top. For most major countries, moreover, the top of the curve for HYWVs and HYRVs may be considerably below 100%.

Several supply-and-demand factors constrain adoption. On the supply side:

- the present HYWVs are not suitable for all soil and climate conditions, and
- if they are to attain their potential, they require fertilizer and other inputs that are either not available or not fully used by every farmer. (Supply is still a problem in many areas.)

On the demand side:

- consumers may not prefer HYWVs over traditional varieties, and
- government price policies may not encourage the production of HYWVs; in some countries there is a strong demand for the longer straw of taller varieties.

Table 4.6. Estimated proportion of total area of high-yielding varieties of wheat and rice in southern and Southeast Asian nations from 1965-66 to 1982-83

Crop year	% of area planted with high-yielding varieties	
	Wheat[a]	Rice[b]
1965-66	--	--
1966-67	3.6	1.4
1967-68	18.4	3.6
1968-69	32.3	7.1
1969-70	33.1	10.1
1970-71	39.6	13.0
1971-72	44.6	17.5
1972-73	53.3	20.3
1973-74	58.6	24.8
1974-75	62.7	26.8
1975-76	65.8	28.4
1976-77	70.1	31.0
1977-78	73.8	35.1
1978-79	71.9	37.3
1979-80	71.4	38.3
1980-81	75.3	42.0
1981-82	78.5	43.8
1982-83	79.5	45.1[c]

Note: See text footnote 7 for discussion of basic data used in making the calculations reported here.

Key: --=negligible.

[a]Bangladesh, India, Nepal, and Pakistan.

[b]Bangladesh, Burma, India, Indonesia, Nepal, Pakistan, Philippines, Sri Lanka, and Thailand.

[c]The 1981-82 estimate for Thailand was used in calculating the estimated total for 1982-83.

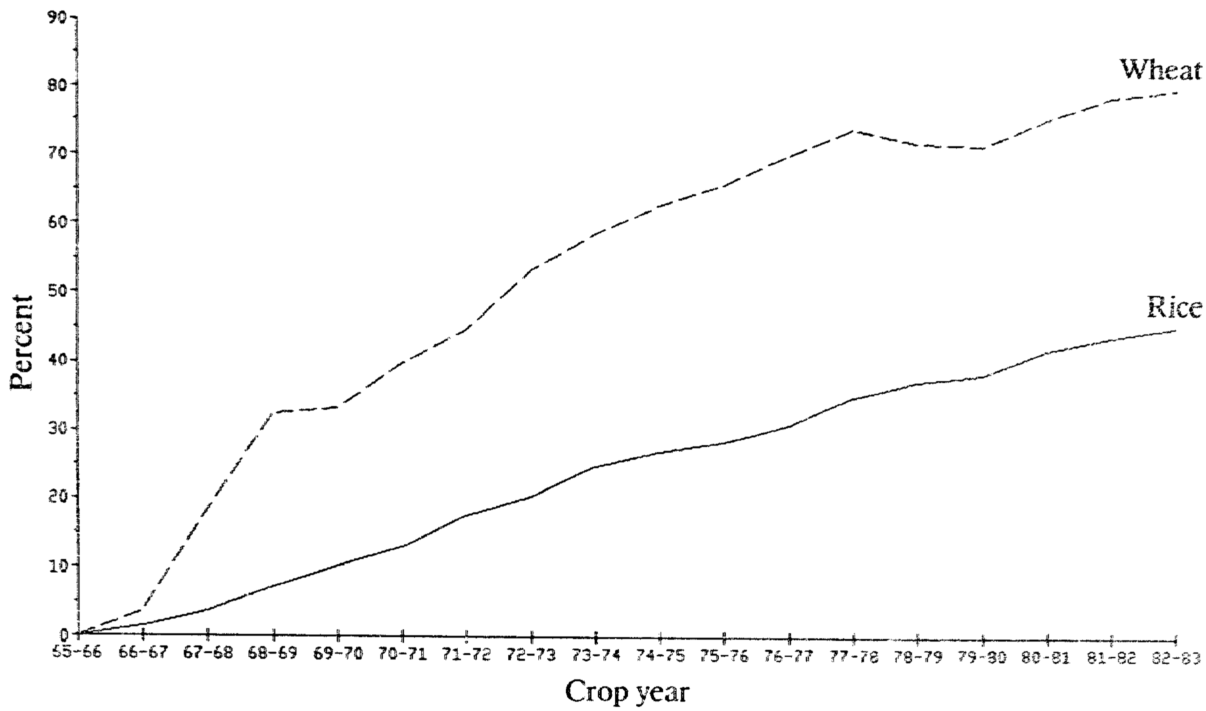

Figure 4.2. Estimated proportion of area of high-yielding varieties of wheat and rice in southern and Southeast Asian nations from 1965-66 to 1982-83. Source: Table 4.6.

Although increased attention has been given to developing HYWVs that meet local tastes and preferences, they still may not meet all consumer requirements.

When vast areas are planted with the same or similar varieties and intensively cultivated, there is an increased possibility of insect and disease problems. Thus, a high adoption rate of an individual HYWV is not necessarily desirable. While there have not been any massive problems with wheat to date, difficulties could arise—perhaps with Sonalika (because of susceptibility to leaf rust) in India, Nepal, and Bangladesh. In the case of rice, there have been ominous incidents in several Asian nations.[9]

Because of these and other factors, the HYWVs are unlikely to completely replace traditional varieties in most major areas in the near future. Even if HYWV adoption levels began to taper off, however, yield levels would not necessarily stagnate. New HYWVs with greater yield potential, yield stability, or both, are constantly being developed. The use of other production inputs, such as fertilizer, is generally low, and considerable potential for yield increases remains even after the initial HYWV adoption curve levels off.

REFERENCES AND NOTES

[1]G. Hambidge and E.N. Bressman, "Better Plants and Animals—Foreword and Summary" in U.S. Department of Agriculture, *Yearbook of Agriculture, 1936* (Washington, D.C.: the Department, 1936), p. 121.

[2]In the United States, for example, the USDA has conducted a national wheat variety survey only once every 5 years. A few states, principally in the Midwest, conduct annual varietal surveys. The future of the national wheat variety survey is presently in doubt; the 1984 survey, summarized in appendix B, may well have been the last.

[3]This is a very rough estimate derived on the assumption that—following data presented in the country section—the following proportions of the HYWV area were planted with Sonalika in 1982-

83: Bangladesh, 70%; India, 40%; and Nepal, 30%. In addition, Sonalika is grown in Pakistan under the name Blue Silver; the current area, however, is evidently small. While the area reported here for Sonalika is clearly very large, it is not a record–that probably falls to the Russian wheat variety Bezostaya, which is estimated to have been planted on at least 16 million ha (National Academy of Sciences, *Genetic Vulnerability of Major Crops* [Washington, D.C.: the Academy, 1972], pp. 135-136.)

[4]Briefly, wheat data reported on a calendar-year basis were aligned with the preceding crop year (i.e., 1983 with 1982-83). The problems associated with this process are discussed in footnote 7.

[5]The area represents varieties released since 1974. Inclusion of improved varieties released before this date would have raised the total to 384,000 ha.

[6]Consultative Group on International Agricultural Research, *Summary of International Agricultural Research Centers: A Study of Achievements and Potential* (Washington, D.C.: the Group, 1985), p. 7; and discussion with R. Herdt, 1985.

[7]These calculations, with one exception for Latin America, utilize unpublished estimates of total wheat and rice area that were prepared by the World Analysis Branch, International Economics Division, ERS, USDA, and obtained from a computer printout informally known as the "Grain Data Base" (January 3, 1985, printout containing information as of November 1984). This source was used because the data-gathering process for the HYWVs provided only a partial set of information on total area. The USDA/ERS information was needed to get a complete and consistent DC picture over time.

Use of the data, however, led to a perplexing situation. The USDA/ERS data are reported for calendar years, while the HYWV data cited in this report are almost always for crop years. Thus, the calendar-year and crop-year data needed to be matched up. This process produced an unexpected result when official statistics were examined for India and Pakistan; in the case of wheat the crop-year data matched the following calendar year (i.e., 1982-83 was aligned with 1983), while in the case of rice the crop-year data matched the previous calendar year (i.e., 1982-83 was aligned with 1982). The timing of the main harvest of the two crops varies, and this may have led to the split. In any case, it provides a dilemma in trying to compute percentages. When examining southern and Southeast Asia (as in table 4.1), it would seem appropriate to follow the split pattern. However, this may not be appropriate for the entire developing world (as in table 4.3). Because of the importance of India and Pakistan (which grew about 54% of the total HYWVs, in 1982-83), the split pattern was followed when matching was necessary, but this could involve errors in some cases. The matter needs to be considered more closely. Other USDA and FAO data series merit examination.

[8]Consultative Group on International Agricultural Research, op. cit (*see* footnote 6), p. 10. Also, similar estimates by major countries and regions are provided.

[9]T.T. Chang, "Conservation of Rice Genetic Resources: Luxury or Necessity?," *Science* 244 (1984):254-255.

Appendix A

EARLY CHINESE WHEAT VARIETIES IN AMERICAN COLLECTIONS

In the course of updating this report, it was discovered that there is a large collection of Chinese wheat varieties, which were gathered between World Wars I and II, in the National Small Grains Collection of the USDA at Beltsville, Maryland. Most of the Chinese accessions fall into two groups. The first is a set of varieties collected in the 1920s by H.H. Love, a Cornell University plant breeder who had worked at the University of Nanking for several years;[1] P. Howard Dorsett, a USDA plant breeder;[2] and the University of Nanking. The second group, dating from the 1930s, was composed of varieties developed by the University of Nanking.

The first group totals about 1,140 accessions, with the Cereal Investigation (CI) numbers principally in a range from 8,000 to 12,500; a few had lower CI numbers, indicating that they had been obtained earlier.[3] Fortunately, plant height estimates were available, presumably from the time they were first propagated by the USDA. A special tabulation revealed that there were 13 accessions in the 100- to 105-cm height range, 15 from 106 to 110 cm, 19 from 111 to 115 cm, and 45 from 116 to 120 cm. The remainder ranged from 121 to 170 cm in height.

Information on those in the shortest category (100-105 cm) is given in table A.1.

The sources of the next shorter height category (106-110 cm) were much the same, except that two varieties measuring 106 cm (5083 and 5088) were obtained from the Panama-Pacific International Exposition in California in 1915.

It is not known whether any of these varieties contain semidwarf genes. Height figures are highly influenced by the environment and are not an infallible guide. Mark Sorrells of Cornell University and W.L. McCuistion of Oregon State University planted samples of 92 of these varieties in 1984 and 1985. Preliminary results from both universities indicate that some of the varieties are in the semidwarf height range.[4] Further plantings are planned. Tests will be conducted to determine whether dwarfing genes are present in the shortest varieties.

The second group consists of 80 varieties from the University of Nanking (within the PI range from 124266 to 124371) obtained in 1937. These varieties were grown, along with a number of other more recent Chinese varieties, in the Winter Wheat Introduction Nursery at Corvallis, Oregon during the 1983-84 season by W. McCuistion.[5] The Nanking series produced some varieties that were short.[6] Whether they actually have a gene or genes for semidwarfism will have to await further testing.[7]

If it is determined that either group has varieties with dwarfing genes, it will be of some interest. It can be recalled from chapter 3 that only one naturally occurring Chinese semidwarf (Huixian Red) has been identified so far. (Aibian-1 is reportedly a mutant of Ai-Kantsau or

Table A.1. Some early short Chinese wheat varieties in the National Small Grains Collection

CI number	Plant height (cm)	Source[a]	Date collected
8453[b]	100	Dorsett (4777)	1/8/26
8622	100	Love (129)	1926
8452[b]	102	Dorsett	1/8/26
8902[c]	103	Dorsett (7384)	9/11/26
10198[d]	103	Love (A1)	1929
8595	104	Love (22)	1926
9373	104	University of Nanking	9/12/27[e]
9369	105	University of Nanking	9/12/27[e]
9372	105	University of Nanking	9/12/27[e]
9374	105	University of Nanking	9/12/27[e]
9377	105	University of Nanking	9/12/27[e]
9379	105	University of Nanking	9/12/27[e]
9384	105	University of Nanking	9/12/27[e]

[a]Includes numbers given by collector.
[b]Collected in Harbin, Manchuria.
[c]Collected in Mishatau, Kirin Province.
[d]Named Tsingkiang; collected in Kiangsu.
[e]Date received.

Abbondanza.) The other Chinese semidwarfs are probably the result of crosses with foreign varieties, which were reportedly not initiated until 1957.

Several related historical items should be noted. First, there is an extensive collection of material at Cornell University on H. H. Love's work on wheat, including a list of Chinese wheat varieties sent to N. Vavilov in February 1932.[8] Dorsett met Vavilov in October 1929 in Seoul.[9] Later Vavilov wrote of the "strong short straw" and "dwarfism" of the Chinese and Japanese varieties.[10] Another point is that the USDA National Small Grain Collection might contain more older varieties than the Chinese collections, which suffered heavy losses during the period of the cultural revolution.[11]

REFERENCES AND NOTES

[1]*See* H.H. Love and J.H. Reisner, *The Cornell-Nanking Story*, Cornell International Agricultural Development Bulletin 4 (Ithaca, N.Y.: Cornell University, 1964), 52 pp.

[2]For biographical information on P.H. Dorsett, *see* T. Hymowitz, "Dorsett-Morse Soybean Collection Trip to East Asia: 50 Year Retrospective," *Economic Botany* 38(4) (1984):378-388.

[3]I am indebted to Jeanmarie Burton, formerly a staff member of the National Small Grain Collection, Plant Genetics and Germplasm Institute, Agricultural Research Service, USDA, for providing the information reported here on the USDA Chinese accessions. She also arranged the computer sort on the basis of height.

[4]The first Oregon State University trials on the winter crop produced height data on 70 of the older Chinese varieties: 7 had heights of 75 cm and 5 had heights of 80 cm. The cut-off point for semidwarf height under existing growing conditions was roughly set at 80 cm. Of 13 varieties, 4

are listed in table A.1 (CI 8453, CI 8622, CI 8452, and CI 9373). By comparison, of 43 newer Chinese varieties for which height data were provided, 39 had heights in the 50-70 cm range.

The trials at Cornell University covered winter and spring crops. Height data was obtained on 47 varieties in both seasons; of these, 13 had heights of 80 cm or less (including 3 listed in table A.1: CI 9372, CI 9373, and CI 9384). Five of the varieties for which height data was recorded only in the spring had heights of 75 cm or less (including four in table A.1: CI 8452, CI 8453, CI 8622, and CI 8902).

[5]Of the 80 Nanking varieties, 15 were winter killed. Of the remaining 64, 2 had heights of 90 cm (Nanking 112, PI 124281, and Nanking 395, PI 124354) and 3 had heights of 95 cm (Nanking 81, PI 123281; Nanking 471, PI 124353; and Nanking 486, PI 124358). By comparison, of the 108 other newer Chinese varieties that were not winter killed, 9 had heights of less than 90 cm and 17 had heights of 95 cm.

[6]Letter and enclosure from W.L. McCuistion, Department of Crop Science, Oregon State University, September 1984.

[7]Earlier, in 1974, C.F. Konzak and M.L. Hu of Washington State University screened over 1,000 older wheat accessions from China and found a few varieties, mostly spring wheat, that were either semidwarfs or mixed for the semidwarf character. Unfortunately, the detailed records of this work have been misplaced, and it is not certain whether the same varieties are involved (personal communication with C.F. Konzak, April and May 1984).

[8]Items at Cornell University include (a) a list entitled "Chinese Wheat Varieties Collected by Dr. Love, 1929," which provides H.H. Love's accession numbers, variety names, and province; (b) the "Wheat Plan of Planting Chinese Varieties, 1940-41, 1942-43"; and (c) a list of the varieties collected by Love written in Chinese, including 880 numbered varieties not included in the first list. The list sent to Vavilov includes both Love's accession numbers and the USDA CI numbers (starting at 10198). All of these materials were found by M.E. Sorrells of the Department of Plant Breeding and Biometry at Cornell. Other Love materials exist in the Cornell Archives.

[9]T. Hymowitz, op. cit. (*see* footnote 2), p. 381.

[10]N.I. Vavilov, *World Resources of Cereals, Leguminous Seed Crops and Flax, and Their Utilization in Plant Breeding* (Moscow: Academy of Sciences of the USSR, 1957), pp. 236-237. Translated and published by the Israel Program for Scientific Translations, 1960. (Also noted in N.I. Vavilov, "Selected Writings of N.I. Vavilov: The Origin, Variation, Immunity, and Breeding of Cultivated Plants," *Chronica Botanica* 13(1/6) (1949/50):297.

[11]*See* Y. Dahua, "Wheat Genetic Resources Programmes in China," *Plant Genetic Resources Newsletter* (Rome: United Nations, Food and Agricultural Organization), March 1984, p. 2.

Appendix B

SEMIDWARF WHEAT VARIETIES IN THE UNITED STATES

The HYWVs discussed in the body of this report are principally semidwarfs. Semidwarf wheat varieties are also grown extensively in the United States and other developed nations. Genetic linkages exist between virtually all of the semidwarfs raised in DCs and those grown in the United States. These interrelationships and the area planted with semidwarfs as of the end of 1979 were reported in an earlier publication.[1]

BACKGROUND

Virtually all of the semidwarf wheat grown in DCs contains, as noted in the text, dwarfing genes that originated in Asia. The principal carrier of these genes was Norin 10 x Brevor. This cross was the source of dwarfism used by CIMMYT and, hence, is included in the pedigrees of nearly all of the semidwarf varieties grown in DCs. Another relative of Norin 10, Suweon 85, provided dwarfing genes for several lines developed in Korea and widely used in the United States: Suweon 90, Suweon 92, and Seu Seun 27. The genetic interrelationships between these varieties were depicted in figure 2.1.

Early efforts to develop semidwarf varieties of wheat in the United States made use of these dwarfing sources as well as offspring of Norin 10 x Brevor, which had been developed by O.A. Vogel of USDA at Washington State University. Some CIMMYT-Mexican varieties were introduced and grown directly, some were selected from crosses made in Mexico, and some were used as parents in crosses made in the United States. A few other natural sources of dwarfism have also been used on a limited scale.[2] A few short varieties of wheat have been developed through induced mutations, but none as yet have been widely planted.[3] Thus, virtually all of the semidwarfs used in the United States to date result from foreign sources of dwarfism.

The definition of "semidwarf," however, provides some difficulties. The presence of a semidwarf gene does not mean that the offspring are necessarily semidwarfs. Several recent American winter wheat varieties with semidwarf ancestry are taller than is usual for this category.[4] On the other hand, it is possible to develop short varieties—varieties comparable in height to the taller semidwarfs—that do not contain a dwarfing gene. This has also happened in the United States.[5] Actual heights may, moreover, vary according to growing conditions. Hence, the classification of semidwarf varieties is imprecise.

National surveys of the area planted with individual wheat varieties have been conducted in the United States every 5 years since 1919. The most recent survey, which unfortunately may be the last, was conducted in 1984. When the semidwarf varieties are identified, which as noted entails some complications, it is a comparatively easy task to calculate their total area.

VARIETIES RELEASED

In my earlier study, examination of the genealogies and height characteristics of American wheat varieties resulted in the identification of 151 semidwarf varieties as of late 1979.[6] Varieties developed in both the public and private sector were included. Not all of these varieties were grown commercially to any extent. Of the 151 varieties, 66 had CIMMYT-Mexican varieties in their pedigrees.

In the 5 years since that list was compiled, a number of semidwarfs have been developed and released. It has not been possible to be as thorough as before in tracking these varieties, particularly for the private sector, but a preliminary attempt identified at least 72 additional semidwarfs. Of these, 32 were developed by the public sector and have usually been recorded and described (or will be) in *Crop Science*. The 40 private sector varieties have not usually been recorded in this way, but information on semidwarf status has been obtained from the firms involved. There were a few winter wheat varieties with semidwarf ancestry whose classification was debatable.[7] Of the total of 72 varieties, 25 contained CIMMYT-Mexican lines or varieties in their pedigree.

AREA PLANTED

Results of the 1984 wheat variety survey have recently been published.[8] The basic tabulations included area data on 156 semidwarfs. The total area of the 156 semidwarfs was 18,815,000 ha—58.7% of the total wheat area (table B.1). This represented a sharp increase from 1979. About 36% of the semidwarf area in 1984 (21% of the total area) was composed of varieties with some CIMMYT-Mexican ancestry.

The 25 leading semidwarf varieties in 1984, along with the proportion they represented of the national area, were as follows: Newton, 6.05%; TAM W105, 6.04%; Vona, 4.65%; TAM W101, 4.25%; Marshall, 3.23%; Stephens, 2.47%; Len, 2.31%; Hawk, 2.05%; Caldwell, 1.97%; Pro Brand 812, 1.77%; Coker 747, 1.75%; Hart, 1.58%; Wings, 1.24%; Daws, 1.14%; Olaf, 1.05%; Brule, 0.96%; McNair 1003, 0.89%; Pike, 0.81%; Coker 762, 0.77%; Pioneer 2550, 0.72%; Pioneer S76, 0.68%; Coker 797, 0.63%; Oslo, 0.62%; Coker 916, 0.62%; and Newana, 0.6%.

Of the 10 leading wheat varieties in area, 9 were semidwarfs. Of the nine semidwarfs, four (including the varieties with the first and third largest areas) had some CIMMYT-Mexican ancestry. Of the nine, only one (TAM W101) did not show a sharp increase in area over 1979.

Clearly the semidwarfs have assumed a major role in wheat production in the United States in recent years. Some further expansion is possible, but the pace will undoubtedly slow.

Table B.1. Semidwarf area as a proportion of total wheat area in the United States

Year	Semidwarf area (ha)	Proportion of total wheat area (%)
1964	651,100	2.9
1969	1,540,300	7.0
1974	6,376,600	22.1
1979	9,052,000	31.3
1984	18,815,000	58.7

REFERENCES AND NOTES

[1]D.G. Dalrymple, *Development and Spread of Semidwarf Varieties of Wheat and Rice in the United States: An International Perspective*, Agricultural Economic Report No. 455 (Washington, D.C.: U.S. Department of Agriculture, 1980), 150 pp.

[2]A natural mutant is believed to be the source of short height in Hart, Pioneer S-76, Pioneer S-

77, and Pioneer S-78 (Ibid., p. 68, footnote 44). Sava, which as noted in table 2.4 carries the *Rht8* dwarfing gene, is included along with Suweon 92 in the ancestry of Pike (*see* "Registration of Pike Wheat," *Crop Science* 21 [1981]:799). Oleson's Dwarf, noted in footnote 36, chapter 2, has been utilized in some varieties developed by private firms.

[3]Two induced mutants with reduced height were released in 1964 in Missouri (Lewis and Stadler), but the area subsequently planted with each was very small. In 1984 Durox, a semidwarf durum wheat developed in the State of Washington, was released in Idaho.

[4]Examples, some of which may be called tall semidwarfs, include Fillmore, Manning, Redwin, and Rose (see the registrations for each, respectively, in *Crop Science* 25 [1985]:368; 21 [1981]:636; 23 [1983]:1222-1223; and 22 [1982]: 1265).

[5]Arkan, which has no semidwarf ancestry (its parents are Sage and Arthur), is shorter than Newton, the leading semidwarf (*see* "Registration of Arkan Wheat," *Crop Science* 23 [1983]:1221-1222).

[6]Identifications included Hart and Pioneer S-76, S-77, and S-78 (*see* footnote 2).

[7]These varieties have been mentioned in previous footnotes. Varieties include Arkan (60,200 ha) and Pike (259,400 ha) and exclude Fillmore (13,400 ha), Manning (46,700 ha), Redwin (388,600 ha), and Rose (101,400 ha).

[8]V.L. Siegenthaler, J.E. Stepanich, and L.W. Briggle, *Distribution of the Varieties and Classes of Wheat in the United States, 1984*, Statistical Bulletin 739 (Washington, D.C.: U.S. Department of Agriculture, 1986), 106 pp. Also the final report contains much other varietal data relating to geographic location and market classes, which are not analyzed here.

Appendix C

NOTATION AND CONVERSION FACTORS

PLANT BREEDING NOTATION

x	Single cross (old terminology)
/	Single cross (new terminology)
//	Second cross (in an extended pedigree)

CONVERSION FACTORS

Hectare (1 ha = 2.471 acres)
Centimeter (1 cm = 0.3937 inch)
Kilogram (1 kg = 2.2046 pounds)
Metric Ton (1 t = 2,204.6 pounds)