Appendix II-A
A Case Study of Wheat

Wheat is a major food staple in the diet of a large percentage of the world's population. Wheat grain in the United States is used almost exclusively for human consumption, although temporary localized oversupply may result in some wheat feeding to livestock.

Attempts to improve wheat plant populations by selection began several thousand years ago. The desirable attributes selected included the ability to withstand severe environmental stresses such as heat, cold, and drought and the stability of the seed head (which tends to disarticulate in wild forms).

Wheat seeds moved from country to country along with explorers and colonists. New varieties played major roles in the establishment of many productive wheat cultures—e.g., the Mennonite settlers introduced hard red winter (Turkey Red) wheat into the Kansas area from Russia in the late 19th century. And two private breeders—E. G. Clark of Sedgenick, Kans., and Danne of Elreno, Okla.–developed varieties that set new levels of productivity and straw strength in hard winter wheats which were sought by millers for their excellent flour recovery.

Breeding programs expanded during the first half of the 20th century. At first, the U.S. Department of Agriculture (USDA) played a lead role; hut the emergence of the Land Grant System and the establishment of the State experiment station concept prompted individual States to launch breeding programs designed to address the particular production problems faced by farmers within their respective boundaries.

As the State experiment stations began to assume more responsibility, USDA programs and personnel began to concentrate in central locations to assemble the optimal number of personnel for the greatest interaction and productive output. If the present trend continues, there will be virtually no USDA scientists engaged in actual wheat breeding. Instead they will have assumed the roles of basic researchers and regional coordinators supplying information to the public and private breeders.

Disease and insect resistance have been the primary breeding goals of many programs. The dramatic losses associated with severe pest problems have focused the attention of producers, researchers, and legislators on these areas of need. Other traditional breeding objectives have included improved use properties, tolerance to environmental stresses such as cold, wheat, wind dessication, and excessive moisture, and inherent yield capacity in the absence of significant production limitations.

The quality of wheat's end products has been improved significantly through breeding. Varieties have been tailored to meet the demands of various industries. The bread bakeries needed a higher protein and more gluten strength to make a lighter, larger loaf, while the cookie producer needed a low-protein flour with desirable dough-spreading properties.

Wheat productivity and management

The pattern of wheat productivity (yield per acre) in developed countries is remarkably similar. When yields are plotted over the centuries, there is a long period of barely perceptible increases in yield, from the time of first records of production to the end of the first third of this century (the period of 1925-35). Since around 1935, yield has increased sharply. Recent data suggest that yield increases may be leveling off. Why increases have been so substantial after generations of little success, is a complex question involving genetic resources, economic development, social interaction, and adoption of mechanical and biological innovations.

Until recently, the U.S. commercial seed companies, with one or two exceptions, have not been interested in wheat breeding programs as a profitmaking venture. Since wheat has a perfect flower and can fertilize itself, the farmer can purchase seed of a new variety and reproduce it from generation to generation. However, the discovery of cytoplasmic male sterility and nuclear restorer genes has stimulated industry interest in the possibility of developing hybrid wheat. The farmer would purchase the hybrid seed each year; the inbred lines used to make the hybrid would be the exclusive property of the originating company. Although progress has been good, problems exist with the sterility and restorer systems, the ability to produce adequate amounts of hybrid seed, and the identification of economic levels of hybrid vigor. The next 5 years should reveal the potential for success in hybrid wheat.

Several milestones of progress have been set in wheat. Yield has risen dramatically. Genetic protection against pests and other hazards has been a major contributor to increased yields. In addition, recent advances using semidwarf genes have been associated with significant yield improvement. The shorter, stiffer stems of the semidwarf plants allow maximization of resources without yield reductions. Improvement in the inherent yield components of stems per unit area, kernels per stem, and kernel weight has also contributed extensively to yield improvement.

The use of applied genetics in wheat improvement occurs in close harmony with total wheat management systems. The farmer must integrate a huge assortment of alternatives in each decision—e.g., an individual producer may be deciding on a nitrogen program. If the farm is irrigated, the producer selects nitrogen amounts and application timing based on soil tests, intended crop and variety, the end use of that crop, and watering schedules. [f the farm is rainfed, the producer takes into account soil tests, crop considerations, and rainfall probabilities.

In both cases product prices at the time of sale must be predicted since they govern potential gross return, which in turn affects the costs of maintaining a profit margin. Genetic interaction in this system is intricate. The farmer must first select the variety most likely to produce at the maximum economic level. For irrigated land, it may be a short high-yielding semidwarf either for the cookie trade or the export market. The farmer knows that part of the value of his product is dependent on low protein. However, inappropriately high levels of nitrogen, which greatly improve yield, will also raise the protein of the crop beyond acceptable levels. If the export market is strong and the total U.S. supply reduced, the higher protein may be of little economic consequence.

In the case of the dryland farmer, the variety selected may be taller with lower yield potential but with much better levels of adaptation and tolerance to adverse environments. It may be designed for the bread industry or the export market. Part of the value is related to high-protein content. Since moisture conservation and use is critical, nitrogen applications and amounts must be selected so that the plants do not waste their moisture reserve. However, nitrogen applied too late may not receive enough rain to penetrate the soil and become available to the plants. If the plants "burn up" because of unwise water use early in the season, the seeds will be high in protein but low in yield. If inadequate nitrogen is available, the crop will generally be low in protein.

The abbreviated protein story is but one of many examples of farm management interaction with applied genetics in wheat production. Recent changes in energy price and availability, environmental restraints, marketing structures, and technology development are producing a new array of complex problems.

Genetic vulnerability in wheat

Genetic vulnerability is defined as a high degree of genetic uniformity in a crop grown over a wide acreage. Wheat, which is produced on about 62 million acres annually in the United States, has a relatively high level of uniformity and genetic vulnuerability. In 1974,102 hard red winter wheat varieties were grown on 36.6 million acres, with four varieties occupying 40 percent of the acreage. Hard red spring wheat varieties totaled 80 percent on 14.7 million acres, with three varieties occupying 52 percent of the acreage. Similar situations occurred with other classes of wheat. Plant pests, including diseases and insects, have periodically caused moderate to servere wheat crop losses in years favorable to the development of strains capable of attacking current forms of resistance.

Incorporating genetic resistance to pests has traditionally been the responsibility of public breeders. Wheat is a self-fertilized plant that can be faithfully reproduced from generation to generation. Private industry has been reluctant to invest R&D money in improvements since the farmer, following the initial seed purchase, can reproduce the crop without returning to the seed company. Thus, public breeders have been the main source of new varieties and have had the responsibility of delivering genetic improvements to the producer. Wheat breeding programs are generally designed to respond to State production needs. Goals and objectives are established by technical advisory groups that include breeders and scientists, growers, use industry representatives, and extension workers.

Genetic variability is available to the breeder from naturally occurring sources and artificially induced mutations. Naturally occurring variability has been collected from native plant populations throughout the world and is maintained in the World Wheat C ollection by the Science and Education Administration of USDA located in Beltsville, Md. Currently, about 37,000 accessions are contained in the collection. Breeders use the collection as a reservoir from which to draw exotic genes needed to improve the value of their breeding programs. In addition to variability within wheat varieties, the breeders can use special genetic techniques to draw valuable genes from related species such as rye and various forage grasses. This approach, while time-consuming and costly, has been used in a number of variety development programs. Mutations induced by artificial means have not been used extensively by the breeders, since desired mutations without detrimental effects are very difficult to obtain. Enough natural genetic variability seems to exist to satisfy needs in the foreseeable future.

The National Wheat Improvement Committee has stated that the World Wheat Collection is inadequately evaluated, characterized, and documented, forcing breeders to spend time and resources carrying out their own evaluation work. The committee has proposed a standard set of descriptors for all accessions in the collection, as well as an information management system to efficiently bring the information to the breeders.