THE DEVELOPMENT OF WHEAT GROWING IN AMERICA

by

Charles Leach

THE NATIONAL COLONIAL FARM
RESEARCH REPORT NO. 8

The Accokeek Foundation, Inc.

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ACKNOWLEDGEMENT

Funding for this research and writing of this paper was provided by a grant from the Wallace Genetic Foundation.

Preface

The National Colonial Farm, a living history farm located in Southern Maryland, across the Potomac River from Mount Vernon, has for years been engaged in research on colonial American history. As a living history farm museum, The Farm is interested in providing the best examples and artifacts of farming of that area during that period, including the crops which were grown here by colonial farmers. Little work has been done in collecting and snythesizing the available data, both primary and secondary, on the kinds of crops grown at various points in this country's history; nor has much been done to develop an analysis of the genetic characteristics associated with changes in crop utilization. For this reason, research at the National Colonial Farm has a two-fold purpose: to provide information on the varieties of agricultural crops which may have been grown in the Chesapeake Bay Region on a farm such as the one ours is meant to emulate, and to improve the knowledge in the field of American history as to our agricultural heritage.

Wheat has an unusual history which is not well reflected simply by an examination of the American colonial period. The wheat used in colonial times was fairly limited in terms of varieties, and accords largely with what was being grown at the time in western Europe. Although diseases, particularly rust and the "Hessian" fly, affected the crops, prevention of loss was often attempted by means other than in searching for new varieties.

As wheat growing moved westward, varieties which had been brought from western Europe were found to be unsuitable for the drier and more extreme variations in temperature of our more western territories. New wheats were introduced from eastern Europe and western Asia which bore less of a relationship to the American colonial wheat. These new wheats have had a profound effect on our present-day wheats, including those grown in the eastern United States. The period of late nineteenth and early twentieth centuries was a particularly active and richly rewarding one for wheat development on the American continent.

The entire range of the development of wheat varieties has never been brought together, as far as is known by the Farm, although segments of it have received attention. Since colonial wheats did play a prominant part in the evolution of our present varieties, and since present varieties grown in the eastern United States are highly interrelated to the western wheat development process of the post Civil War era, the Farm believes that it is in the best interests of research to set out the entire record. By this means, the colonial period of wheat growing is placed in its proper context, and can be more easily understood and appreciated.

Forward

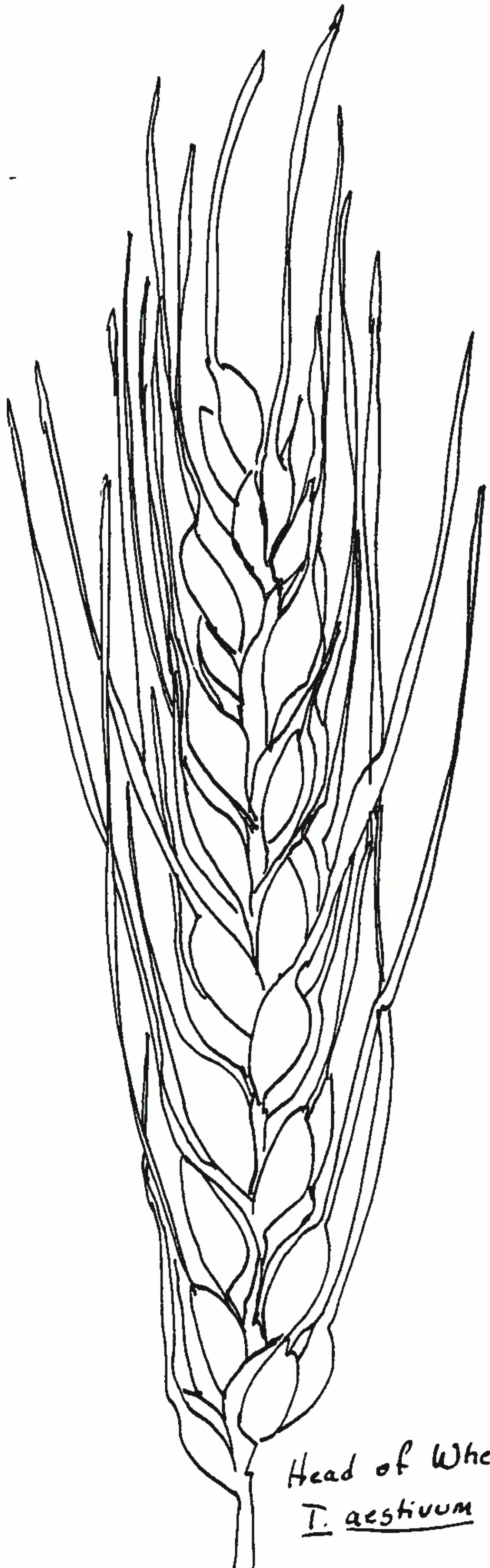
The National Colonial Farm is a living history museum which is interested in providing the best background setting it can for the display of colonial farming practices. The Farm and the Accokeek Foundation undertake research on various aspects of colonial agriculture in Southern Maryland in order to develop that understanding. One line of research is into the varieties of plants which were grown. This research naturally leads to an investigation of the development of plant varieties both prior to and also after the colonial period. The history of wheat varietal development in the United States naturally focuses on the region of the western states and on the time period of late nineteenth and the twentieth centuries. Although this research may seem far afield from colonial farming, it helps to set the context of the contribution of the colonial period to wheat development in America.

Introduction

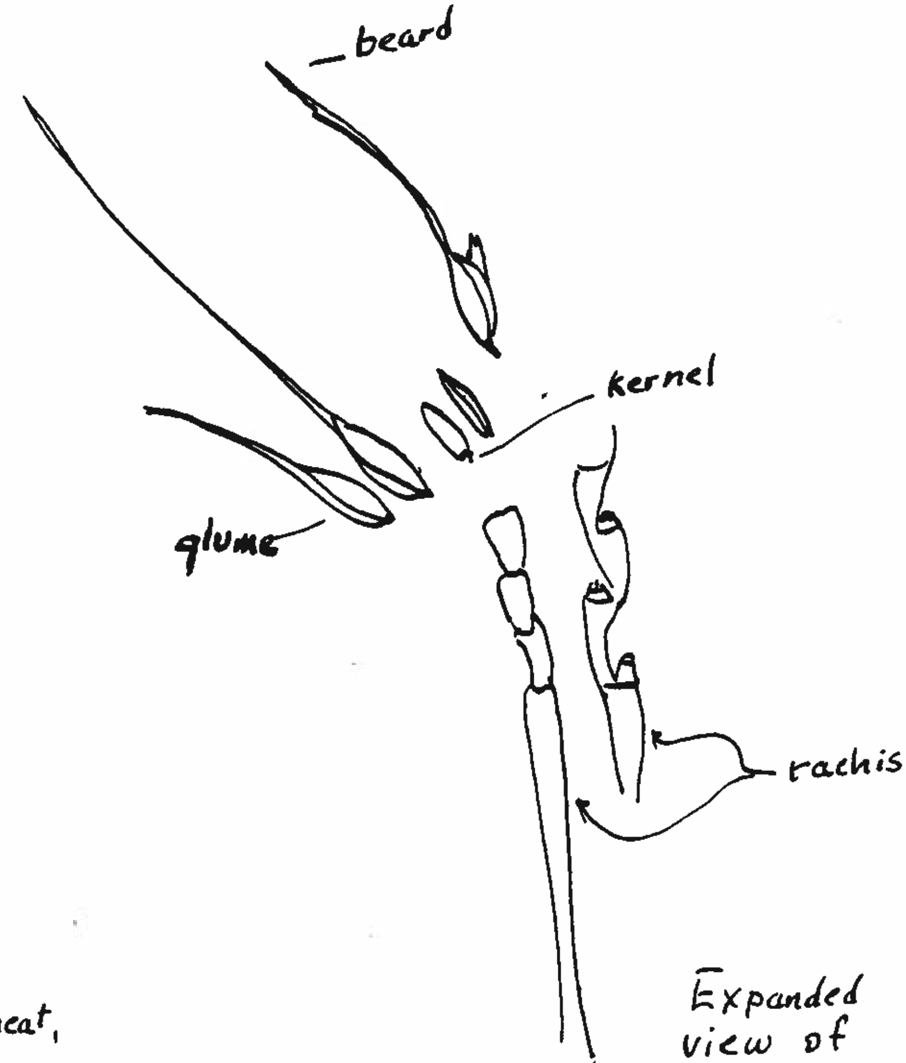
Wheat is grown in most parts of the world. It is grown in more diverse climatic and soil conditions than any other domestic plant on earth. It can be found in sub-tropic, desert, high mountain steepe, humid-temperature, and sub-artic regions. It is also thought to be the world's oldest domesticated plant, domesticated varieties having been found in archaeological sites from 8,000 B.C. (Helbaek, 1959). Wheat has been declared to be the basis upon which our civilization rests, and because of that, it is the most important of any of the domestic plants and animals. Wheat is an extremely important crop in the United States, particularly in the states between the Rocky Mountains and the Mississippi River, and a great deal of energy has been expended on the development of suitable varieties for cultivation here.

Wheat is the common name for a genus in the grass family with the scientific name of *Triticum*. Like other grasses, the head (spike) of the wheat produces many seeds (or grains) in a tight inflorescence. The head has a central stem known as a rachis. Attached in zigzag pattern on alternative sides to the rachis are the spikelets or flowering mechanisms giving rise to one or more grains each. Encasing the grains on each spikelet are two bracts known as glumes. (see Figure 1)

The heads and grain of this wheat come in varied shapes and sizes. This diversity in appearance was taken by early investigators to differentiate the species of wheat. Other genetic factors have led authorities to alter this concept. The classification of wheat into species has now been a source of argument



Head of Wheat, *T. aestivum*



Expanded view of Wheat Spikelet

for almost a century. There are between 4 and 29 species of Triticum depending upon which authority is followed. Moreover, there are more than 200 cultivars (varieties) presently used in the United States (Reitz, 1976:4). Almost all of these are some form of bread wheat.

All species and varieties of Triticum can be assigned to one of three sub-genetic groups: einkorn (denoting the single korn or grain which develops per spikelet), macaroni, and bread wheats. The latter two names have been assigned to indicate wheat's most desirable uses.

Bread wheats possess an unusually large amount of gluten (an elastic like protein substance) when compared with the other two types, and it is this gluten which enables leavened dough made with flour of this wheat to hold together during the rising process. Both the macaroni and the bread wheats came about from a genetic accident, and this fact has led some authors to speculate on how different civilization in the western world might have been if this accident had not occurred, leaving us a breadless society.

The existence of the three groups of wheat has been known for several centuries, but the reason for their difference was not recognized until early in this century. The German botanist Max Schultz first explained the groups on the basis of anatomical, chemical and morphological properties. Then in 1918 the Japanese scientist T. Sakamura discovered the number of chromosomes in wheat. He found that all wheats had a basic haploid chromosome number of seven, but that some had 14 chromosomes and still others had 21 (doubled in the plant cells to become 14, 28, and 42, respectively). The finding was confirmed independantly by Karl Sax in the United States that same year (Peterson, 1965:63).

The bread wheats are those with 42 chromosomes and are called hexaploids (6 x the basic 7). The macaroni or emmer wheats are those with 28 chromosomes, called tetraploid, and the einkorn wheat with 14 chromosomes is known as diploid. Diploid is the standard term for a living organism. It has one set of chromosomes (haploid) from each of its parents. Although many wheats are either hexaploid or tetraploid, they all act as if they were diploid, as will be described below.

As with most domestic plants, there is disagreement about where wheat was first domesticated. A wild form of einkorn and emmer are both known to exist in the Near East, from Yugoslavia across Turkey to northwestern Iran (Harlow & Zahary, 1966). Helbaek (1969) believed strongly in an Iraqi Kurdistan origin at altitudes between 2,000 and 4,300 feet above sea level. Others have suggested Abyssinia or the Jordan Valley as the most logical area of origin (Issac, 1970). In any event, the area between Israel and southeastern Turkey has been accepted by most scholars as the logical seat of the original wild wheat plants. No wild form of hexaploid wheat has ever been identified. It has been assumed by many authorities that the genetic accident which created hexaploid wheat (presumably from a weed plant crossing with a tetraploid wheat) occurred in a field of domesticated wheat, and that, therefore, there never has been a wild hexaploid wheat (Helbaek, 1960:105).

Wheat can be placed into other categories which cut across species lines depending upon: whether it is sown in the spring (spring wheat) or the fall (winter wheat) whether the grain is red or white; hard or soft; whether or not the glume is bearded; and how tightly the spikelets hold together at harvest time. Moreover, because of these variations, plant breeders have been confronted by a number of conflicting demands from the several users--growers, millers, consumers--for the perfect wheat.

Wheat is an international crop, and much scientific data and new varieties have been exchanged among countries. In fact, today's wheat varieties in almost any country are truly international in their pedigrees. The focus of this report is on the development of wheat varieties in the United States. It is impossible to ignore the contribution from other countries, or for that matter, America's contributions to other nations around the world. None-theless, the central theme is American wheat growing, with examin-ations of other cultures as they are important to what is grown here.

Variation in Wheat

As noted previously, wheat has a basic set of seven chromosomes. The chromosomes are the bodies on which the genes are located, and are the fundamental part of reproduction. A living organism (diploid) normally has one set of chromosomes (haploid) from each of its parents. The fusion of two haploid reproductive cells is known as a zygote. Genes are located at particular points along the chromosome. For every chromosome arising from the female donor, there is a similar chromosome derived from the male parent which, for purposes of development in the offspring, needs to have similar genes found at corresponding loci. Such two chromosomes are described as homologs and the descendant is known as a homozygote. Homologosity is necessary for plant stability and reproductive ability (fertility).

For reproduction, a plant undergoes meiosis. This consists of two successive divisions, and a diploid cell will give rise to four haploid reproductive cells. A complete set of chromosomes with their representative genes as present in the reproductive cell constitute a complete set of the genes necessary for plant development. In fact, it has been shown that an egg cell, without fertilization, can engender a haploid plant, which will have the appearance of a diploid plant though with less vigor (Peterson, 1965:57).

The entire haploid set of chromosomes is known as a genome. In wheat, the genomes have been identified as to their genetic components, and have been so labeled. The diploid wheat einkorn has what are assumed to be the original seven chromosomes of wheat to which have been added other groups of seven chromosomes through cross fertilization. This original set of chromosomes is known as the A genome. Tetrapolid wheat, in addition to the A has a B genome. Finally, hexaploid wheat, on top of the A and B has a D genome. A zygote of hexaploid wheat, therefore can be described as AABBDD (one of each genome from each parent), while a reproductive cell would be described as ABD. Since the A genome is present in diploid wheat, the other two genomes must have come to wheat from other plants by natural hybridization and since the chromosomal composition of wheat has been identified, scientists have been attempting to find the other species which were the donors of the B and D genomes to wheat. To bring a new genome into a species, making it a fertile polyploid, requires either an unusual occurrance in nature or man's interference. If AA wheat were crossed with some plant having the genome composition BB, the resulting offspring would have the composition AB (one genome from each parent), and would also probably be infertile since it would be unlikely for the chromosomes of the two genes to be homologs. It is possible, however, for an AB type plant to be fertile, because there are degrees of homology, and fertility does not depend on "unambiguous exactness" (Riley, et. al., 1958:93).

The species with which wheat has been presumed to cross are all within the genus Triticum or closely related genera. These plants all have the basic seven chromosomes, and the genes on all such chromosomes are similar even if not the same. This fact presents the possibility of alien chromosomes taking the place of the original chromosomes resulting in a zygote called a homoeolog. Nonetheless, pairing between homoeologs is less frequent than in homologs.

When a monoploid plant (like AB, for example) is subjected to a shock, such as a rapid temperature change during its growing period, it occasionally doubles its chromosomes (Cannon, 1965:69). Such an occurrence would definitely result in a fertile plant, since each chromosome would now have a homolog (AABB in this case).

It is common practice in hybridization work to treat an F_1 individual (first generation cross) with the chemical colchicine to promote a shock and thus chromosome doubling (Suzuki, et. al., 1981:285). The assumption in most discussions of the origins of the polyploid wheats, as described by Ojvind Winge in 1917 in Denmark (Peterson, 1965:65), is that a cross occurred in plants growing near each other. This phenomenon may have happened frequently, and in fact is estimated to occur in one percent of all wheat plants (Peterson, 1965:183). Once a cross was effected, some external force acted on the resultant F_1 plant to make it double its chromosomes. This latter phenomenon was probably a rare occurrence. Nonetheless, polyploidy is very common throughout these related genera.

The origin of the D genome was first explained by Ernest Sears in 1949 when he and his associates successfully hybridized the wild grass Aegilops squarrosa, (now called Triticum taushii by Sears), which is a weed in wheat fields from the Balkans to Afghanistan. He made the cross with the tetraploid wheat, wild emmer, Triticum dicoccoides (Mangelsdorf, 1953:55). The resulting hybrid, artificially induced chromosome doubling, resembled spelt wheat (Triticum spelta), once the most important bread wheat in Europe.

The B genome, however, proved to be a much more difficult problem to detect. Many authorities had come to the conclusion that Aegilops speltoides (goat grass) was the donor of the B genome. Others had hypothesized that Agropyron, and especially A. triticum might be the diploid involved in the cross (Riley, et. al., 1958:91).

In fact, Sears and McFadden published in The Journal of Heredity in 1946 their conclusion as to the way in which bread wheat arose as follows:

> Triticum aegilopoides (wild einkorn) diploid
>
> gave rise to
>
> T. monococcum (domestic einkorn) diploid
>
> T. monococcum crossed with Agropyron triticum
>
> to produce T. vulgare (antiquorum)
>
> tetraploid then
>
> T. dicoccoides (wild emmer) tetraploid
>
> gave rise to
>
> T. dicoccum (domestic emmer) tetraploid
>
> T. dococcum crossed with Aegilops squarrosa
>
> to produce T. spelta hexaploid
>
> and that
>
> T. spelta crossed with T. vulgare (antiquorum)
>
> to produce the hexaploids
>
> T. compactum (club wheat)
>
> T. aestivum (common breadwheat)
>
> (Andrews, 1964:17)

Interestingly, the B genome has a gene P_h on chromosome number 5 which has been identified as a gene which restricts pairing (Suzuki, et. al., 1981:292). Under ordinary circumstances, when a polyploid individual divides at meiosis, it has an even number of chromosomes. The chromosomes may not divide as bivalents from genomes AB and AB) but may pair as trivalent and univalent (ABA and B, or some other combination, which would result in sterile gametes.

Morever, upon union of the bivalent gametes, the chromosomes might not pair as homologs but as homoeologs. Each chromosome potentially has a choice of three others with which to pair, and each combination could give rise to a morphologically different plant and the potential for sterile reproductive cells. The permutations become even more complex when the plant is a hexaploid or higher polyploid.

The gene P_h on the B_5 chromosome, however, prevents this type of random pairing in wheat. Because of the gene's existence, tetraploid and hexaploid wheat act like diploid plants at meiosis ensuring the stability of the wheat plant. This makes the B genome vital to the species and provokes even more interest in its origin. The P_h gene also makes hybridization more difficult, as will be discussed below. The origin of the B genome in wheat has remained a mystery until recently. During the late 1970's Mosha Feldman of Wiezmann Institute of Science in Israel, in a karyotype (chromosomes at the point of normal cell division) analysis of a newly discovered diploid wheat species, (now named Triticum searsii) identified that species as carrying the B genome. Since many researchers are not willing to commit themselves to this genome in T. searsii as in fact the B genome, it has generally been grouped together with the genome in several other species (including Aegilops) as having closely related S genomes (Feldman and Sears, 1981:106). T. searsii, named in honor of Ernest Sears, was first seen by Feldman in a vacant lot in Jerusalem near Hebrew University in the early 1960's. He thought little about the plant until he came across it again on a field trip in 1972. Collaboration with

Mordechai Kislev of Bar-Ilan University showed the discovery should be classified as a new species. Because of the difficulty of cross breeding wheat, Feldman is currently searching for individuals of the species which have a weakened or absent P_h gene, hoping that a lack of strong pairing might aid in the introduction of new genes to wheat.

With new information developed by Feldman and Sears, the way in which bread wheat arose is now outlined as follows:

> Triticum monococcum (wild einkorn) or Triticum monoccum boeticum (cultivated wild einkorn)
>
> crossed with a wild diploid wheat listed probably as Triticum searsii to give rise to a tetraploid wheat
>
> Triticum turgidum (wild emmer)
>
> Triticum turgidum was then cultivated for 10,000 years as T. turgidum dococcum before it crossed with the wild diploid T. tauschii
>
> to give rise to
>
> T. aestivum 8,000 years ago.
>
> (Suzuki, et. al. 1981:294).

As mentioned, the species of wheat are not firmly established. This is because the genetic and morphological characteristics of the species and varieties in the sub-tribe Triticinae, and even in the entire tribe Triticaea are so similar that it has been difficult to decide where to draw definite boundaries between species, and even genera.

During the latter half of the nineteenth century botanists had concluded that there were three great races of wheat with 10 existing and two ancient species (de Candolle, 1886). These can be expressed as follows:

1. Common wheat: Triticum vulgare

   T. hypernum

   T. aestivum

   Two ancient wheats discovered in archaeological finds among the Swiss lake region, T. vulgare antiquorum and T. vulgare compactum were presumed to be the forerunners of the above three cultivated species.

   Triticum turgidum--turgid wheat, and T. compositum--Egyptian wheat were believed to be modifications of the common wheat obtained through cultivation.

2. Hard wheat: Triticum durum

   T. polonicum--Polish wheat

   These two species were believed to have been derived from common wheat grown in Spain or northern Africa.

3. Spelt wheat: Triticum spelta

   T. dococcum--starch wheat

   T. monococcum--one-grained or einkorn wheat

   It was believed that T. dococcum was an ancient cultivated variety of T. spelta, but since neither had been found in a wild state, it was decided that they must both be derivatives of common wheat of some ancient period. T. monococcum, on the other hand, because it grew with only one grain per ear, *because it appeared to grow wild in the Crimea and Caucasus, and because it did not cross with other species under experiments of the last quarter of the nineteenth century, was believed to be a unique species.*

One of the most extensive research efforts on the specition of wheat was initiated by Nikolai Vavilov in the 1920's supported by the Russian government. Vavilov travelled to all parts of the world collected extensively and brought together more than 31,000 samples (Socolofsky, 1969:428: Mangelsdorf, 1953:51). Working with the knowledge of its chromosome composition, Vavilov divided the wheat species into three major groups with ten species and nine subspecies (Vavilov, 1951:175).

These species, together with an indication of what Vavilov believed to be their geographic distribution, are as follows:

Twenty-one Chromosomes

<u>Triticum vulgare</u>--soft wheat--S. W. Asia
<u>T. vulgare compositum</u> Turkish Armenia
<u>T. compactum</u>--club wheat S. W. Asia
<u>T. sphaerococcum</u>--shot wheat--N. W. India
<u>T. spelta</u> Southern Germany
<u>T. macha</u> Western Georgia, SSR

Fourteen Chromosomes

<u>T. durum</u>
subsp. <u>abyssinicum</u>--hard wheat--Abyssinia & Yemen
subsp. <u>expansum</u> Mediterranean region
subsp. <u>orientale</u> Iran and Central Asia
<u>T. turgidum</u>--English wheats
subsp. <u>abyssinicum</u> Abyssinia & Erithrea
subsp. <u>mediterraneum</u>--English wheat--Southern Europe
<u>T. polonicum</u>--Polish wheat
subsp. <u>abyssinicum</u> Abyssinia
subsp. <u>mediterraneum</u> Southern Europe

T. dicoccum--emmer (two grained wheat)

subsp. abyssinicum	Abyssinia, Yemen, India
subsp. euroneum	Western Europe
subsp. asiaticum	Georgia, Armenia, Iran
T. percicum--Persian wheat	N. E. Turkey, Georgia, Dagestan
T. dicoccodies--wild emmer	Southern Armenia, N. E. Turkey, Western Iran, Syria, Northern Palestine

T. timopreevi--genetically distinct wheat--Western Georgia

Seven Chromosomes

T. monococcum--cultivated einkorn--Western Georgia, N.E. Turkey
T. aegilopoides--wild einkorn--Armenia, Turkey, Georgia

For an extended period of time, T. dicoccoides and T. aegilopoides were the only known wild wheats. Each was believed to be the immediate progenitor of its respective cultivated species (T. dicoccum and T. monococcum), and although there was discussion about which came first, it had been generally agreed that T. boeoticum (T. aegilopoides) was the original wheat from which all others had arisen. Even though experts disagreed on the number of distinct species, Vavilov's fourteen species (substituting T. aestivum for T. vulgare and T. vulgare compositum) were in vogue up to and during the 1950's (Mangelsdorf, 1953:54).

In 1954, MacKey began to advance a revision of the classification of wheat by assigning all hexaploid wheats to a single species, T. aestivum. Moreover, T. aegilopoides, which is now known as T. boeoticum (it was found that boeoticum has been published prior to aegilopoides, is regarded by many as being so similar to the cultivated T. monococcum that the two are essentially one species still others argue that all tetraploid wheats except T. timopreevii should be subsumed under the species T. Turgidum or T. durum (Heiser, 1973:76).

Then again in the late 1960's and early 1970's, a new drive was started to incorporate more of the related species into the genus Triticum. This move would suggest that the entire genus of goat grass Aegilops, which has been shown to be responsible for the D genome, and was at the time thought to be responsible for the B genome in common wheat, is in reality the same genus as wheat. The new grouping of species is based on genome analysis and includes the genomes A, B (recognized only in cultivated wheat, but closely related to S), C, D, G (found only in T. timopreevii), M, S, and U. Only those species sharing the A genome are recognized as being cultivated. These species include T. aestivum (AABBDD), T. turgidum (AABB), and T, timoprevvi (AAGG), and T. monococcum (AA). The other 25, including 11 which are diploid and 10 which are tetraploid, are considered to be wild (Feldman and Sears, 1981:106). Although the A genome is shared by only the cultivated species under this classification, the D genome and the U genome are shared rather widely, which apparently helps to hold the group together as a genus.

It is interesting to note that the United States official grain standards still recognize six species: T. aestivum, T. compactum, T. spelta, T. turgidum, T. durum, and T. dococcum. All of these are currently grown in the United States, though T. aestivum is by far the most important commercially, as it is throughout most parts of the world. In 1969, T. aestivum occupied more than 92 percent of the total wheat acreage in the United States (Reitz, 1976:3-4).

Under the new system of classification, what are believed to be the original wild species of wheat are now characterized as merely varieties of cultivated species, namely T. monococcum boeoticum and T. turgidum dicoccoides. This leads to the question of where and how the recognized cultivated species developed from the wild.

Wheat is the product of the Old World. Although today wheat is grown in all parts of the world, this phenomenon is one that occurred only during the last century. Prior to that wheat was grown in a broad belt from Europe through southern Russia, northern India, and into China. It was brought to the United States and Mexico in the 17th and 18th centuries. Until this century the length of time wheat has been grown was not known, nor even suspected. Early researchers believed that they could trace wheat back to 2,700 B.C. in China and 3,300 B.C. in Egypt. They knew it had been established before those times, but felt they had no real idea of how long. Local legends and written data provided no help in this endeavor (deCandolle, 1886).

Vavilov began his research into the derivation of our domestic wheats during the 1920's, but even in 1930 Carleton Ball could write "The origins and early history of wheat are unknown" (Ball, 1930:48). Today, however, through the work of Hans Helbaek and other archaeologists, we have a much better picture, and can believe that wheat has been cultivated for some 10,000 years.

Vavilov postulated that the original area of domestication was the one which today shows the greatest variation in wheat forms, both cultivated and wild. Based on this theory of the "hearth", he theorized that diploid wheats were first domesticated in Abyssinia and spread from there to Yemen and via Egypt to Mesopotamia, Turkey and finally Europe (Vavilov, 1951:188).

Other researchers have disputed this theory, however. Issac remarked that what appeared to Vavilov as hearths were in fact frontiers--that the wheat seeds were brought to those areas from their original areas of cultivation, and that because of the change in environmental conditions from the original areas, new wheat forms developed, hence the greater variety (Issac, 1970:52). Helbaek disagrees with Vavilov on archaeological evidence. Nearly all authorities agree that the tetraploid wheat known as T. dicoccoides was the direct progenitor of the cultivated emmer, T. dicoccum. Likewise, that the diploid wheat known as T. boeoticum was the direct progenitor of the cultivated einkorn, T. monococcum. Also, that the hexaploid wheats never had a wild ancestor, and that both T. boeoticum and T. dicoccoides were growing long before cultivation (Issac, 1970:50). Because of findings at Jarmo, a prehistoric site in the Sulaimaniya province of northern Iraq, from the 7th millenium B.C., Helbaek has speculated that both einkorn and emmer were first cultivated in northeastern Iraq at altitudes between 2,000 and 4,300 feet and brought lower and west in what has been called the "great neolithic migration" (Helbaek, 1960:103). By moving the wheat away from its natural habitat, Helbaek maintains, mutants, hybrids and other freaks in the wheat began to emerge as survivors while they had no chance in the original locale. He notes that emmer adjusted well to the "artificial ecology" of the irrigated alluvial plain of lower Iraq, while einkorn did not. Thus, it was emmer that was marked for a continued spread throughout western Asia and Europe and not einkorn (Helbaek, 1959:366-67).

More recent evidence has led Issac to the conclusion that modern tetraploid wheats stem from the Jordan Valley emmers. Moreover, emmer has always been of a highly specialized type, requiring many generations to produce a plant that "cannot have derived from the first generations of cultivated plants". Einkorn, alternately, has always been of minor importance, found only in and near Turkey. Researchers have therefore concluded that emmer may have been cultivated before einkorn, and that the original area of cultivation may have been southern Asia, around the Jordan (Issac, 1970:61). This theory is bolstered by the finding of T. searsii. T. searsii is the species believed to have contributed the B genome to emmer. It is generally agreed that emmer spread from western Asia along the Danube and from there throughout neolithic Europe.

Because emmer and einkorn are almost universally believed to have originated somewhere in the area where the wild species or varieties are now found, a triangular region bounded by Turkey, Iraq and Israel, it has often been assumed that hexaploid wheats were derived in this area as well. Helbaek disputes this assumption with the evidence from archaeological digs in Europe. He notes that large amounts of club wheat, T. compactum are found in the Swiss lake dwellings of 3,000 B.C. and earlier, whereas club wheat is not important in any of the near eastern villages until at least 1,000 years later. T. compactum needs an area of heavy summer rain to flourish, and Helbaek suggests that either club wheat originated as a weed of emmer in the Near East, but did poorly until it was taken west or else it may have originated in Central Europe and then was returned to the settlements in Asia (Helbaek, 1959:367). Authorities noted, in addition, that spelt, T. spelta, appears in the subalpine area of Europe, and that it has never been found in prehistoric deposits outside of Europe, while today cultivation of this crop is restricted to Cental European mountain districts. Because of the work of Sears and McFadden in producing a hybrid which closely resembles spelt using T. dicoccum and Aegilops squarrosa (now T. tauschii according to Sears and Feldman), Helbaek has stated that it is believable that a reshuffling of genes could have taken place under the extreme environmental conditions of the mountainous regions. The outcome could have been a local retrogression with the structural habit of emmer. Both emmer and spelt are heavily glumed, with kernels jammed into sturdy spikelets. However, spelt has an unusual joint between the rachis and spikelet, which may have been inherited from Aegilops. Lastly, spelt's cell formation resembles the hexaploid wheats making the entire plant an oddity (Helbaek, 1959:369).

Evidence would suggest that changes were slow in the development and use of wheat. Emmer and einkorn are not particularly good breadmaking wheats, although recent experimentation with durum wheat would indicate that there has been more prejudice than hard information involved in declarations that leavened bread cannot be made from the tetraploid wheats. Because the primitive wheats of einkorn and emmer had their grains firmly encased in the glumes of the spikelet, the wheat was probably heated to remove the grain and then either eaten, or chewed or ground into meal. Soaking coarse meal in water makes a gruel. If the gruel were left standing several days in a warm house, it would become infested with airborne yeasts, fermentation would ensue and a mild alcoholic beverage could be the result (Baker, 1969:64).

In all probability,early fields of wheat had a large variation in the genetic characteristics of the crop as well as numerous weeds which could hybridize with the wheat. The farmer could select from this diversity individual plants which appeared particularly desirable as seed crop for the following year. Since wheat is self-pollinated, if the plants are relatively isolated from weeds, seed from a particular individual will grow into a plant morphologically similar to its parent. Farmers could begin a process of genetic screening merely through selection of individuals. Although it may have been largely unconscious, it is almost certain that it was in this way that we came to have the particular varieties we did up to the seventeenth and eighteenth centuries.

Whether one considers spelt and club wheats separate species with separate origins, the fact is that club wheat, spelt wheat, and shot wheat (T. sphaerococcum) differ only slightly in a few genes from common wheat. Because of this, many authorities have believed that it was from these wheats that the common bread wheat T. aestivum nee vulgare arose in a European locale. (Mangelsdorf, 1953:55). However, others have supposed that this latter species originated somewhere in northeastern Turkey and adjacent areas of the USSR and Iran. The tetraploid wheat T. persicum is morphologically the closest to T. aestivum of any of the tetraploid wheats (Baker, 1965:68). Since Persian wheat is known only in a limited area of northeastern Turkey, the conclusion drawn from these facts is that Persian crossed with a diploid species in an event unrelated to the formation of club spelt or shot wheats. Today's common wheat arose in Turkey if one follows this logic.

It is known that the cooler climate of Southern Europe favored spelt over emmer there, and that spelt wheat became very important in Italy after 2,000 B.C., and appears to have become a principal wheat in central Europe by 1,000 B.C. (Issac, 1970:63). As noted previously, club wheat was important to the Swiss lake dwellers apparently before it was known elsewhere. To this day, it has been successful only in those areas outside of the range of early grain cultivation, i.e. in those locales where summer rains are pronounced. Club wheat was grown in Iraq in 2,000 B.C. and in other parts of the Near East in 1,000 B.C., but never became an important crop there (Issac 1970:62). Shot wheat kernels have been found at the site of Mohenjo-Daro in India, dating from 2,500 B.C. (Mangelsdorf, 1953:55). Whether of Turkish or European origin, it is interesting to speculate that if the genetic accident had never occurred adding the D genome to wheat and if bread wheat had never been selected from the general crop of the day by the early Swiss and Central Europeans, we might not have known leavened bread today.

The 16th century A.D. common wheat T. aestivum was cultivated throughout Europe. It was this wheat (including T. spelta) which was brought by various routes to America during the next centuries and established our wheat culture here.

Curiously, since wheat cultivation was initiated in the dry climate of the Near East, the grains grown in England, by reason of the climate there prevalent, were ones that had become adapted to a good deal of moisture. To survive west of the Mississippi River, wheat needed to be more drought resistant, more consistent with its original environmental adaptation. Finding this new wheat marked the real beginning in American wheat development. Although wheat disease, especially smut, Ustilago tritici, and rust, Puccinia sp., which are encouraged by humidity, as well as the so-called "Hessian Fly", Mayetiola destructor, had prompted some selectivity in the early agricultural period of the United States, it was this trans-Mississippi settlement which established the importance of the wheat breeders. At first, new wheats were brought into use merely by a form of selection. The "pure line" selection process (wheat variations) was "invented" by the Danish botanist Wilhelm Johannsen. A mix of lines was separated into its component parts, and improvement instigated by continued propagation of "superior breeds" (Mangelsdorf, 1953:56). At the close of the 19th century some cross breeding was practiced, but the principles of the practice were not understood. Then in 1900, there was a discovery (or rediscovery) of Gregor Mendel's work on the inheritance in plants. This work had earlier been brushed aside when presented in the 19th century. Following the rediscovery, with realization of its import, a rapid advance of hybridization, genetic identification, and experimental plant formations was undertaken.

As noted previously, crossing plants with different genomes requires chromosome doubling in order to assure homozygosity. Beyond that, however, hybridization required some knowledge of dominant and recessive genes, and of probability.

Genes can be either dominant or recessive. Dominance in a gene (usually expressed with a capital letter as A or B, etc.) means that the physical characteristic controlled on that gene will show up in the individual, whether the gene is paired with another dominant gene in the zygote, or with a recessive gene (usually expressed with a lower case letter as a or b, etc.). To achieve a characteristic which is associated with a recessive gene, both of the paired genes need to be recessive. Thus, for example, an individual with a gene AA, crossed with an individual aa, will give rise to F_1 offspring Aa which will appear to be exactly like the AA individual in that characteristic. However, in the F_2 generation, mating one Aa with another Aa, the possibility of 4 kinds of offspring arise: AA, Aa, aA and aa. The probability is that each one of such possibilities will occur in 1/4 of the progency. Three quarters of the F_2 generation will express the dominant genetic characteristic arising from A. Only one quarter of these individuals will express the recessive characteristic arising from a. If the recessive characteristic is the one which is desired, the aa individuals become the desired hybrids. When only one gene is to be transferred in a cross, the task is relatively simple. However, if several genes are desired, the work becomes infinitely more complex.

The most traditional method of hybridization is the "pedigree". The seed of each plant resulting from a cross (F_1) are grown in separate F_2 plots. F_2 plants are then selected based on their genetic or morphological desirability and grown in separate F_3 plots. This process is repeated as long as necessary to insure the genotypes are those which carry only the desirable characteristics and not a potential mixture. The length of time needed is based on the number of genes to be transferred and on mathematical probability. "Backcrossing" is a method used when only one or two genes are to be transferred. The F_1 plants are recrossed with the original desirable parent, until through selection, only the preferred genotypes are apparent. In addition, transfer of whole chromosomes and genomes can be accomplished through the above methods. It requires from 5 to 12 years to develop a new hybrid of wheat (Peterson, 1965:185-91).

Problems Associated with Wheat Production

As a natural grain, wheat did not lend itself well to cultivation. Three attributes of wheats identified today as "wild" (T. boeoticum and T. dicoccoides), which make their use problematical in a traditional reaping and gathering situation are their

1) fragile rachis central stem, 2) tough glume (husk) and 3) variable ripening characteristics (Flannery, 1965). All of these attributes help the plant to survive as a wild plant. When the grain is ripe, the rachis breaks apart scattering the seed, while the glume protects the seed from undesirable elements. The grain ripens at varying times, thus foiling environmental disasters which might devastate a crop at one point in time. If a person were to attempt to harvest the wheat at maturity the rachis would break and the fruit would be scattered, making the task difficult. Apparently it was common to harvest wheat in ancient periods by grasping the stem high and cutting beneath the hand. Thus, the heads would be shaken slightly (Baker, 1965:66). In addition, however, because grains on the head ripened at different points in time, the entire wheat plant could not be reaped at one time (Peterson, 1965:178). Finally, the glumes of wild wheat hold the kernels in an unrelenting grip that do not release the grains even if soundly threshed after reaping. It was discovered early-on that by heating the spikelets, the glumes would unclasp their hold, and this process resulted in the early parched or roasted grain culture. In addition to releasing the kernels, this process also killed the germ so it would not sprout and thus the grain could be stored for a season as food (Flannery, 1965:1252).

Despite man's assumed accommodation to primative wheat's growing characteristics, it is also presumed that he selected wheats, as he collected them, for a tougher rachis, uniform maturation and loose glumes. The genes which produced these favorable (from a human standpoint) characteristics would thus become more numerous in the farmer's seed crop and would eventually displace all unfavorable wheat individuals from his cultivated field (Helbaek, 1959:365). In fact, the main distinguishing characteristics between T. boeoticum and T. monococcum and T. dicoccoides and T. dicoccum is that two cultivated species (or varieties) have tougher rachis and looser glumes than do their wild ancestors (Peterson, 1964:10-12). Throughout the centuries beginning with conscious wheat selection through recent sophisticated hybridization programs, the wheat breeder has continued to strive for a tough rachis and a "naked" glumes plant.

In addition to being easily harvested because of a stem that would hold together and a chaff that would fall away, the number and size of the grain has been important to wheat gatherers. The more and larger grains per head, the easier the task of collecting sufficient wheat to meet whatever demands were to be made on it. In this regard, einkorn, because it develops only one grain per spikelet, has always been considered an inferior variety. Although a dark bread can be made from it, because of the small amount of fruit and the difficulty in removing the glumes, einkorn is nearly always restricted to animal feeds (Baker, 1965:65).

Beyond einkorn, large and many-grained wheats have been an important objective of wheat breeders. The difficulty with wheat having large and numerous grains is that there is a propensity for the wheat to lodge (fall down at harvest time, making harvesting difficult or impossible). Thus a search for a strong, stiff straw has been a concomitant need for using better developed wheat heads. Today's wheat straw is sufficiently strong to be used in bedding and in the manufacture of paper board (Heiser 1973:84).

There are additional considerations in wheat breeding. Merely finding a wheat that is good for harvesting is only a small part of the battle. Wheats naturally thrive differently in different environments, and selection for optimal growth given the condition of moisture, daylight, temperature and soil is important. Moreover, wheat is subject to a number of diseases and pests. Discovering resistant varieties has been one of the chief aims of wheat breeders for at least two and a half centuries.

Figuring prominently in the selection of wheats are those factors which cut across species lines. As noted above, wheat grains can be either hard or soft, white or reddish colored, and wheat plants can be either winter (fall) or spring sown. At one point in the nineteenth century, it was believed that the difference between wheat sown in the fall or wheat sown in the spring was merely a matter of acclimatization, and that a gradual reintroduction of the variety to the other mode would result in a perfectly viable plant (de Candole, 1886:354). In fact the Russian scientist Trofin Lysenko, who ousted Vavilov, (the latter was eventually exiled to a Siberian labor camp where he died during World War II), built his reputation on the premise that genetics was a farce, and that organisms could be altered merely by introducing them to new environments. Needless to say, such a theory set the Russians' wheat breeding program back several decades (Socolofsky, 1969:428-9).

In fact, most winter wheats have a growth habit which is different than most spring wheats, and this growth is genetically controlled. Winter wheats exhibit pseudo stems (leaf sheaths) which grow prostrate during the winter months, and before the true stems appear. The spring habit is erect, and exhibits true stems at germination. Winter wheat is vulnerable to cold weather and cannot be grown, in general, beyond the January isotherm of -12^{o}. Thus, most of the northern Great Plains in the United States must utilize spring wheats. Winter wheats have the advantage of early maturation, thus avoiding much susceptibility to insects and fungi which have their peak of development during the summer months. Wheat varieties may be predominantly winter, predominantly spring or intermediate. No species has only one growth habit (Peterson, 1965:9).

Hard wheats are generally less susceptible to disease, or more drought resistant, and are usually more winter hardy. Redder wheats have tended to be stronger and to yield more than the white ones. Wheat growers have traditionally opted to grow a harder, redder wheat because of those facts. The difficulty occurs when the grower is confronted by the miller and/or the consumer. The miller has traditionally found that softer wheats grind more easily, and that it is easier to remove the bran. Millers and growers have routinely worked at cross purposes in America (Colwell, 1969:23). Moreover, the American consumer has been acclimated to white flour. Because the milling process mixed some of the bran into the wheat, red wheats have tended to produce an off-colored flour. The harder the bran, the worse the problem.

Millers have overcome this difficulty in the twentieth century by bleaching the flour, a practice they have undertaken since 1904. At first there was a great deal of controversy about the safety of the practice of bleaching and some government officials employed the Pure Food Act passed in June, 1905 to halt the custom for a time. The controversy raged for more than two decades among millers, growers, experimenters, and officials before the usage was finally permitted and the issue laid to rest (Hargreaves, 1968).

Some wheats have long awns or "beards" extending from the glumes. These awns enable the wild wheat spikelets to dig their way into the ground. The awns however, making threshing and milling a clean wheat more difficult and all other things being equal, millers also prefer beardless varieties. Many early American farmers however, believed the bearded varieties to be hardier and so elected to grow them (Bausman and Munroe 1946:150).

Aside from rainfall and winter temperatures, wheats are also dependent upon the amount of daylight and the soil fertility. Wheats have been adapted to germinating and maturing at particular longitudes. It has been found that it is sometimes difficult to transfer varieties to regions where the length of the day differs significantly (Borlaug, 1965:1093).

On the other hand, information about soil fertility is readily transferable but has often received little attention. When the transplanted European began cultivating wheat on American soil during the eighteenth century, it was not uncommon to get yields or 20 to 30 bushels per acre on raw land. This yield quickly declined however to 8 to 10 bushels per acre, as the natural fertility of the soil was depleated. Upon advice coming from

from the old countries, crop rotation, utilizing a legume as one crop to restore nitrogen, as well as liming and manuring the fields began to be practiced. These practices alleviated the problem to a large extent. The early eighteenth century represented a period of agricultural awakening to the husbandry necessary to maintain productivity (Fletcher, 1950:124-42).

Today (1973) the average yield in the United States is 31.7 bushels per acre (Reitz, 1976:1). The wheat acreage in the Great Plains, where the greatest amount of American wheat is grown, is fertilized at a low rate, if at all. It has been shown in Mexico as well as in western European countries that heavy applications of fertilizer as well as intense irrigation can produce 100 or more bushels per acre (Borlaug, 1965:1091). This problem has increased the necessity to produce stronger strawed varieties (Reitz, 1968:237). There is also a related problem of the amount of energy necessary to produce the fertilizer and to irrigate the fields which is disproportionately high relative to the yields obtained. This is a situation which will need to be examined carefully during the next years to assure continued high yields of grain under conditions of diminishing supplies of traditional energy sources.

Insects and fungi have commonly played havoc with wheat varieties. As new varieties have been developed to be resistant to pests, the problem has been exacerbated. European wheats of the sixteenth and seventeenth centuries, which were the stock from which American wheats were produced, were large "land races" with a great deal of genetic variation. However, during the selection process carried on by the farmers, genetic variation was gradually diminished. As noted previously, since wheat is self pollinated, it is possible to grow large amounts of genetically similar plants. The races of fungi, bacteria and insects which attack the plants are genetically diverse. However, under the circumstances it is only a matter of a few years before new strains can become dominant and virtually wipe out a homogenic crop. Therefore, the fight to develop resistant varieties continues unabated. Breeders try to keep about five years in front of disease development.

The common parasites are the rusts - stem, leaf and stripe (Puccinia graminis, P. tubigo-vera and P. glumurum, respectively), smut (Ustilagotritici), scab (Usarium graminearum) and powdery mildew (Erysiphe graminis). Most diseases flourish in the humid, warm eastern United States, but some find the drier climate of the central portion of the country more favorable to development. Stem rust causes badly shriveled kernels, while leaf rust attacks the green parts of the plant causing a lack of vigor. Stripe rust occurs on all above ground plant parts. The smut varieties replace both grain and chaff with black spores which are blown away before the harvest, leaving a bare rachis. Scab attacks seedlings and either kills or greatly weakens them. Powdery mildew, as the name suggests, produces gray, powdery spores. Severely infected plants will fail to mature or be stunted (Reitz, 1976:47).

Three major insect problems are the "Hessian" fly (Mayefolia destructor) called Hessian because it was believed to have been brought to America by the Hessians during the Revolution (Fletcher, 1950:146), grasshopper (Melanoplus femur-rubrum) and cinch bug (Blissus levcopterus). The Hessian fly is prominant in the eastern United States. Its maggots feed between the leaf sheaths and stems, causing the stem to be weakened and to break shortly before harvest. Grasshoppers tend to be a western phenomenon. By eating leaves and stems, grasshoppers cause the heads to fail. The cinch bug feeds on and deposits eggs on the growing plant. The larvae suck on the plants for fluids. Spring wheat is most susceptible to this latter insect (Reitz, 1976:42).

American Wheat Development Milestones

It is unclear which specific types of European wheat arrived in colonial America. Nearly all new wheat strains grown in the United States until the late nineteenth century were first discovered elsewhere. It is known that in northern Europe, including England, common bread wheat (T. aestivum) was the one most frequently cultivated. From several accounts, the varieties known as Red Lammas and White Lammas are presumed to have been the English wheat which were brought to the colonies. Red Lammas was grown in Virginia, its name later being changed to Red May. It is still grown in parts of the United States. A variety known as Red Chaff (a white wheat) emerged in 1798 and was still grown in this century as Goldcoin (Ball 1930:53). Spelt wheat was also reported as an early colonial variety (Percy, 1978:2).

It seems highly likely that because of the weedy conditions of the American fields as well as the potential for cross pollination by several European varieties being brought to the colonies from diverse countries, wheat fields rapidly developed mixed races (Colwell, 1979:68). For sharp eyed growers, mixed races in turn probably gave rise to the possibility of selection from crosses, mutants or hybrids and might promote discovery of new and better varieties.

One such discovery is known to have happened in Virginia. In about 1787, a Mr. Isbill of Caroline county had noticed a single ripe ear in a field of "mixed wheat supplied by a local merchant". The following year Isbill sowed the grain from the ear, resulting in another field of early ripening, short stemmed wheat. By 1794, several thousands of bushels were being grown on Caroline County farms (Destler, 1968:202).

The new wheat, a white, hard, winter variety, was named Forward Wheat. It was found to resist the "pestilence" prevelent in Virginia and ripened sufficiently early to avoid being attacked by the "cockle". It ripened 15 to 20 days earlier than the standard varieties. Because it was short, it could be sown in denser stands, producing a higher yield per acre. A wheat that matured this early would enable the farmer to cut the wheat during the first days of June, thresh it during the early summer, and market the wheat in early autumn (Destler, 1968:201-2). Preparing wheat for market was a time consuming task requiring scything into small bundles, binding the bundles, drying the wheat, threshing it on the barn floor and finally winnowing it on a good breezy day (Singleton, 1972:75). It was normal practice to thresh in the fall and then wait for thaws in the winter or spring to operate water wheels for grinding (Destler, 1968:203).

John Taylor of Caroline County Virginia succeeded in persuading Jerimiah Wadsworth of Hartford, Connecticut to try the variety. Wadsworth in turn was so impressed that he induced many in New England to grow the wheat. It would appear that the commercial wheat growing area of western New England generally adopted the new variety for a time (Destler, 1968:204).

Though not much is known of Forward wheat, it can be assumed that it must have been nearly as susceptible to the rusts and insects as Red May or that new strains of these pests developed to attack the wheat, else we should have heard more about this particular variety today. New England did have very destructive epidemics of rust and mildew in the seventeenth century, and has been a wheat importer since that time (Ball, 1930:52). The Red May did fall victim to the Hessian fly and the black stem rust, *Puccinia graminis* var. *tritici*, (called the "blast" by colonial farmers) which apparently grew worse as the nineteenth century began. There is disagreement by current scholars about the merits of this early wheat and its probable value to early wheat growers. Evaluations have ranged from praise to declarations of its lack of dependability (Ball, 1930:53; Fletcher, 1950:145; Colwell, 1979:68).

In 1800 Pennsylvania could claim to be the leading producer of wheat in the newly formed union. Pennsylvania shared some of the glory of wheat production with New York, but it was the former colony and state that became the richest in the North, and that distinction was due to wheat (Fletcher, 1950:143). Speculation has it that Pennsylvania achieved the status of major wheat exporter in part because the climate was so favorable to the varieties then known and because the colony developed later than most of the colonies to the south and east of it (Fletcher, 1950:148). Corn was the first principal grain to be grown in the colonies because it was easy to plant and tend, while wheat required more sophisticated equipment (Schlebecker, 1975:190). Wheat was more difficult to harvest (Singleton, 1972:75), and mills for grinding wheat required refined technology and machinery (Colwell, 1969:23). However, in addition to the development of the techniques to grow, harvest and mill wheat, this grain had a competitive advantage in the market by the last quarter of the eighteenth century, selling for as much as 3-1/2 times the price of corn (Fletcher, 1950:148). The wars in Europe after 1790 pushed the price of wheat on the foreign market even higher (Destler, 1968:203). It is no wonder that farmers who were just starting out would plant wheat rather than corn at that time.

Farms on the frontier in Pennsylvania, or even a quarter of a century after the frontier had passed, tended to be subsistence farms, with little more than a quarter of the acreage put into production. Grain was the chief surplus product of a Pennsylvania farm, and this was sold to buy the necessities by which the farm family would live (Lord, 1975:35). Wheat quickly wore the land out, however. Originally, impoverished land would be allowed to lie fallow for several years but even this policy did not rejuvenate the fertility the land had when it was first used (Fletcher, 1950:144). American farmers fell behind European agriculturists in their knowledge and use of fertilizers, and it was not until between 1825 and 1840 that widespread use of crop rotation, lime, and manure came into vogue. In the meantime, Ohio had taken over as the leading wheat producer in the nation, producing nearly 20 percent of the crop in 1839 (Fletcher, 1950).

Westward expansion of wheat growing followed quickly. By the end of the 1840's the crop was well established in Illinois, southeastern Wisconsin and Iowa. Following the Panic of 1857 wheat growing spread to the newly opened lands of western Wisconsin and Minnesota. It was said that wheat growing required no special skills and crude tools, and even though it quickly exhausted the soil, the price of a farm could be paid with the proceeds of a single season's harvest (Ernst, 1964:125). It was thus that the importance of wheat growing left the Eastern United States very quickly after coming to the fore there. Unfortunately for the large numbers of farmers who from 1870 to 1920 were attracted westward by dreams of fabulous profits from raising wheat, many of them fell victim to overwhelming economic burdens and were forced to give up their farms (Saloutus, 1946:173).

New wheat varieties were introduced in the East during the first half of the nineteenth century to combat the fly and rust problems and also to improve yields. Steeps were commonly used by colonial farmers to avert diseases and to improve yields (Percy, 1978:7). Steeping and liming was started in England between 1625 and 1650 to prevent smut (Ball, 1930:51). Seed was dumped into a brine which contained common salt as well as other chemicals like ferrous sulphate. Lighter seeds would float to the top. These lighter seeds were thought to be diseased seeds in the eighteenth century. Salt, however, has been shown to have no positive effect against fungi, even though many early experimenters made great claims for various consistencies and lengths of time for steeping. Urine and lime, which were added sometimes to the steep may have improved vigor. The practice of steeping was discontinued with the rise of chemical knowledge. The chemical industry proved to have more specific remedies (Smith and Secoy, 1976).

Bayberry bushes, Morella, sp. were once thought to be a harbinger of wheat rust, and many states ordered the bushes destroyed. Rust does spend part of its existence on bayberry, but it has since been found that widespread epidemics are caused by windblown spores that can last for years (Reitz, 1976:47).

American envoys were requested to search aboard for useful plants on their travels. The Navy played a large role in this context (Ryerson, 1976:250). The variety known as Mediterranean apparently first grown in a country bordering on the Mediterranean Sea, was sent to the United States in 1819 (Ball, 1930:55).

Fletcher reports that it was not grown in Pennsylvania until after 1840. It was discovered growing on the New Jersey farm of a retired Navy lieutenant by a Pennsylvania traveler. The Navy man in turn claimed to have obtained seed in Leghorn, Italy (Fletcher, 1950:145).

Because Mediterranean, a soft, red, winter wheat, could be sown late and yet would ripen early, it escaped damage from both ends of the life cycle of the Hessian fly. It also matured sufficiently early to be harvested before rusts could do much destruction. Mediterranean did not completely replace the earlier known Red May, since farmers, a traditionally conservative lot, would not totally part with a proven product even though a new variety was reputedly better (Colwell, 1979:69). Mediterranean did, however, become widely grown shortly after it was introduced (Ball, 1930:55).

Mediterranean wheat was apparently improved by selection, although these selected varieties were named without regard to keeping records or to establishing a process of registration. Therefore, the descendants of Mediterranean have proven hard to determine conclusively. Lancaster, Quaker and German are three of the better known ones. Their names are associated with the prolific use of the progenitor (Mediterranean) in south central Pennsylvania. A Pennsylvania Dutch farmer from this area, one Abraham Fultz of Mifflin, discovered in 1862 what must have been a genetic mutant in a stand of Lancaster wheat. This new wheat became known as Fultz. It was beardless, and also apparently gave a bigger yield on a stronger stalk than did Mediterranean or Lancaster. Beardless varieties are in general more useful than bearded ones at threshing and milling time. For this reason, the new wheat became a sought after variety, and for the next half century became the most widely grown soft winter wheat in America (Colwell, 1979:20).

Fultz was used in turn to develop other varieties of soft red winter wheat. Fulcaster, a later variety, was produced in 1886 by S. M. Schindel of Hagerstown, Maryland when he crossed Fultz with Lancaster. Still later, higher yields were obtained at the Ohio Agricultural Station in Wooster from two new varieties developed by staff agronomist, C. C. Williams. Trumbull (named for a county in eastern Ohio) was released in 1908, while Fulhio became widely grown in the 1920's. These two varieties promised to increase yields by as much as four bushels per acre, and higher yields became increasingly important in this century as wheat began to be pushed to more marginal land by the higher yielding corn plant. In time, the Ohio experiment station developed two new varieties from Fultz and Fultz offspring, Thorne and Vigo, both produced only sparsely today (Colwell, 1979:70).

It has been reported that wheat came to the New World with Columbus in 1493 or 1494. A Spanish wheat is known to have been grown in Sonora, Mexico since 1770, while archaeological evidence of two club and two common wheats can be found in the adobe bricks of the mission buildings in California (Ball, 1930:53). However, prior to 1850, wheat was never important in California outside the mission gardens (Wells, 1969:87).

California agriculture developed in conjunction with the population increase brought about by the Gold Rush in 1848-50. Vegetables and fruits were the first products grown (Cochrane, 1979: 87-88). However, ranchers soon learned to use spring wheat to take advantage of winter rains by planting the crop in the late fall just before the rains came. This method made the best use of California's limited rainfall. The grain could be harvested, threshed, and left standing in the fields in sacks since the California summers were rainless (Wells, 1969:82).

After 1860, particularly during the drought of 1863-64, the livestock industry which had occupied many of the prime lands in the Central Valley declined, and this land was taken over by new farmer-settlers (Cochrane, 1979:88). These settlers who grew wheat in California were more speculators than farmers as many had no prior experience in agriculture. One individual's holding could consist of as much as 40 to 50,000 acres all of it planted in wheat. Gang plows followed by broadcast seeders were used. In early spring, harvesters some 30 feet wide would cut the grain which would be elevated to trailing wagons. The wagons in turn would transport the wheat to enormous steam driven threshing machines. Eighty percent of the harvests, 6 million bushels in 1860 and 16 million in 1870, were exported to Great Britain which coveted the California wheat. The peculiar growing season plus the long sea voyage to Liverpool brought the grain in after the spring wheat crops of Russia, Germany and Canada, which was an advantage to the California growers (Wells, 1969:80-83).

Wheat was not grown out of the Central Valley without irrigation, and irrigated lands could bring a better return if planted in fruits and grapes. Overcropping, competition from other markets, and most particularly, soaring land prices, forced many growers out of the wheat business prior to World War I (Cochrane, 1979:88). However, California had made an important contribution to the West Coast grain market, and California varieties travelled up the coast to become important in Oregon and Washington wheat fields (Shepherd, 1980:53).

California Club was the variety first grown. It is a strong, bearded, white wheat presumably of Spanish ancestry, with a short head and low yield. In 1853, new varieties were shipped in from Australia and Chile, known respectively as Australian Red and Chile Club. These two varieties added beardlessness and fuller heads (Wells, 1969:82). It was, however, the development of Little Club from the original California Club which became so important to later settlements in Oregon and Washington (Ball, 1930:53), as will be described below.

Westward expansion of settlement from the East Coast brought settlers into increasingly drier climates. This new (to America) environment required a more drought resistant wheat than that which came from the East Coast. Part of the answer to this need was found by David Fife of Ontario, Canada in a selection made of a single plant in a spring sowing of winter wheat. This wheat was among a shipload which went from Danzig to a mill in Glascow, a major world grain shipping center, where it was to be milled. A small packet was mailed to Fife from Glascow (Ball, 1930:55-56).

Fife had asked a friend in Glascow to supply him with samples of wheat for testing under Canadian conditions. The Fife wheat was the first hard, red, spring wheat to reach the American continent, and it became important to many of the mid-western States. It was introduced into the United States in 1860 in Wisconsin. The farmer who grew it found it ripened fast enough for him to harvest it prior to an early frost, while his neighbors were all left with frozen, inmature grain (Colwell, 1979:71).

Red Fife caught on quickly, and soon many farmers across the Mid-West were growing the variety. Spring wheat growers relied on Fife until well into the twentieth century.

A problem developed between the growers and the millers over this new wheat, however. It was so hard that the wheat was often scorched in milling and filled with bran. Nonetheless, it could be milled into the highest quality flour to that date. The difficulty lay in the cumbersome stone mills used to grind the flour. In ordinary practice, using water or animal power, the stones would be set with paper thin spaces between them. In addition, the stones had to be dismantled so that the grooves which permitted the grain to flow could be refabricated. The Red Fife grains required such heavy pressure that the grain was scorched, caused the stones to wear faster, and was imperfectly ground as grooves became worn. The millers in the Minneapolis-St. Paul area were the first to utilize two new methods to overcome these difficulties. In 1870, they began the installation of an American invention known as the purifier. This machine successfully separated the bran from the middlings. But perhaps more importantly to future wheat growers, in 1881, with great reluctance, some of these millers agreed to employ the system of high-speed steel rollers that had been developed in Budapest, Hungary. The new process used seven pairs of rollers, each pair set consecutively closer together. The willingness of the Minneapolis-St. Paul millers to accept new methods set the stage for the Twin Cities area to become the producer of the largest quantity of the finest flour from the world's biggest flour mills (Colwell, 1969).

Red Fife remained the staple of the spring wheat area until well into the 1900's even though many new introductions of winter wheat varieties were being made in Kansas during that period. Unfortunately for Red Fife, however, it required 130 days to develop, and it became necessary to find a wheat more drought resistant and of shorter growing time to be useful in the northern Great Plains of the United States and Canada.

The breakthoough came with the Saunders family. William Saunders was the Director of the Experimental Farms System of Canada. As Director, he sent his son Percy to the Indian Head Experimental Farm and other stations in western Canada to make crosses between (East) Indian wheats and Red Fife. The aim was to combine the early maturing characteristics of the Indian wheat with the high quality and high yield of the Red Fife. It should be remembered that at this point, the principles of genetics were not generally understood, and would not be for another eight years. Thus, working from less than ideal technical comprehension, Percy Saunders attempted crosses between Red Fife and Campbell's White Chaff Ladoga, White Russian, Gehun and Hard Red Calcutta (Morrison 1960:183).

When Charles Saunders, Percy's brother, took over from his father as Director, he continued pressing the search for a suitable cross. The final product, Marquis, was brought out in 1907. Marquis had been produced by selecting a strain from the variety Markham. Markham was originally derived from a cross made by Percy Saunders at the Agassiz Station in 1892 between Red Fife and Hard Red Calcutta (male and female, respectively). The progeny were then transferred from the experimental farm to Ottawa. In making the final selection, Charles Saunders employed a chewing test to determine the quality of gluten in the experimental plants. He also milled and baked small amounts. Finally, he sent some seeds back to the experiment station for growing tests. Marquis B, grown at Indian Head in 1907, outproduced all other varieties and ripened early enough to avoid the frosts (Morrison, 1960:87).

Because of the limited supply, Marquis was not shipped to the United States until 1913. From then until 1935, Marquis was the overwhelming favorite of wheat growers from the Dakotas, Minnesota and Montana for spring wheat farming. A rust infestation badly damaged Marquis wheat in that year. However, a rust resistant wheat known as Thatcher had been developed at the Minnesota Agricultural Experiment Station in 1921 by crossing two Marquis progeny in what is called a "double cross". Thatcher virtually replaced all Marquis in the spring wheat area after 1937 (Colwell, 1979:72). Despite efforts of wheat breeders, the rest continues to be virulent in this part of the United States, and epidemics periodically recur (Reitz, 1976:11).

During the last quarter of the nineteenth century, introductions of hard, common winter wheat and spring sown durum wheat were taking place in the central and southern Midwest. Kansas and Nebraska farmers had brought soft red winter wheat like Fultz, Lancaster, and even Red May as seed crop. The spring wheats of Red Fife, Iowa, and Bluestem were also grown (Quisenberry and Reitz, 1974:100). Winter wheat fared better than spring, but winter kill, grasshoppers, cinch bugs and rest made many wheat farmers quit and turn back East. Parts of western Kansas lost half its population between 1980 and 1894 (Colwell, 1979:73). Nonetheless, a real estate dealer named T. C. Henry speaking to the Farmers Institute at Manhattan in 1878 advocated the use of Red May and spoke disparingly of the introduction of new varieties (Quisenberry and Reitz 1974:101). However, an unusual set of events was taking shape which would turn the problems around and make Kansas into one of the top wheat producing states in the country. A small group of German Mennonites immigrants introduced a new winter variety of hard wheat called Turkey Red.

During the late eighteenth century, the Russian Tsar Catherine the Great bacame interested in providing for settlement of lands in the upper Volga and Crimea with industrious farmers. Among those she recruited with promises of free land, exemption from taxation and military service, and payments of expenses for the move, were Mennonites from the area around Danzig which had fallen to Prussia. The Mennonites created religious enclaves in the sparsely settled country of the Crimea. By the mid-nineteenth century, the time table of the exemptions was running out, and the descendents of the Mennonites became concerned that they would be persecuted by the new Russian rulers. A delegation was sent to the United States to search for new farm properties. Recruited by Carl Schmidt of the Santa Fe railroad, the group settled on Kansas as the most likely place to create a new settlement (Saul, 1974:41-47).

At this point, historians disagree whether the Mennonites introduced hard red winter wheat which they brought from the Crimea or whether they obtained this wheat in some other way. Herbert Friesen (1961) a descendent of the Kansas Mennonites, maintains that the Mennonites brought seed from Switzerland in the fifteenth century when they moved to Danzig. He also believes that they went to Turkey to get new varieties of wheat or cross breeding material, and that each family brought a little wheat with them to Kansas. Friesen's own ancestors are supposed to have brought two gallons (250,000 seeds) of "carefully chosen wheat". There is no corroborating evidence. Mark Carlton who was later to become famous for his work in introducing new varieties of wheat to Kansas and the United States, repeated this story in the 1914 Yearbook of Agriculture (Quisenberry and Reitz, 1974:102). Robert Dunbar (1974) seriously doubted the story, but Quisenberry and Reitz (1974) accepted the idea.

Norman Saul has stated his disbelief in the myth (1974). He felt that it would be impossible logistically for a family to carry enough seed wheat to bring the 200,000 acres they had under cultivation. In addition, the Mennonites were used to planting spring wheat and the new variety attributed to them was a winter wheat (Saul, 1974: 60). As has been noted previously, no wheat has only one growth pattern, and it is remotely possible that spring sown wheat from Russia could become winter sown wheat in Kansas.

The Kansas Mennonites had sold their farms to other Mennonites who remained in Russia with the crops standing in the fields, and had gotten excellent prices. With money in their pockets, they were able to transact good deals with the Sante Fe railroad from whom they purchased the Kansas land. One of the deals was that the railroad was to supply the settlers with the first year's seed wheat, (Saul, 1974:56). It is possible that the Mennonites used the railroad's seed for the first year's production, while they grew and developed their own seed wheat for later use. Or, it may be that the new variety came from the railroad's seed. Hard winter wheat was imported by the Mennonites from Russia in 1902 (Quisenberry and Reitz, 1974:105). The new wheat may have come from an imported batch which arrived after the Mennonites. On the other hand, it is known that varieties called Turkey Red were grown in America prior to the arrival of the Mennonites (Colwell, 1979:74).

In any event, after the grasshopper plague of 1873 wiped out both corn and spring wheat crops, Kansas turned only to winter wheat. The Mennonites arrived in August of 1874. The newcomers were able to be successful at farming in Kansas while others were not. They had had experience in farming similar land, and either brought or knew how to produce suitable equipment to work the land. The Turkey Red the Mennonites grew matured earlier than the contemporary Kansas wheats, although it is considered late by today's standards. It had a tendency to lodge if the growth was heavy. It was not particularly more resistant to the common diseases. Its real value to Kansas was its winter-hardiness, and its drought and wind resistance (Quisenberry and Reitz, 1974:104).

Like the hard spring wheats, Turkey Red was not found immediately acceptable by the millers, and it brought a lower price than the soft wheats. The Kansas City Board of Trade established a separate market class for the hard red wheat for that purpose (Colwell, 1979:74). But, in part because they were able to get the wheat inexpensively, millers in the Kansas City area finally made concessions, to introduce the new techniques for grinding wheat. Particularly after the hard winter of 1899-1900 which killed many other varieties, Turkey Red found a new market and a new following (Quisenberry and Reitz, 1974:105-6).

In 1887, the United States Congress passed the Hatch Act which established agricultural experiment stations throughout the country. Wheat research had begun at the Kansas Agricultural College in 1874, and was transferred to the Kansas Experiment Station in 1887. Moreover, in 1887, Mark Carlton graduated from the Kansas Agricultural College. He became the Chief Agronomist of the U.S. Department of Agriculture in 1894. Because of the Mennonites, Carlton learned the Russian language and made several trips, beginning in 1898, to the Russian Steppes to collect samples of wheat from that area. He also wanted to establish that the Turkey Red of Kansas was identical to some grown in the Crimea (Colwell, 1979:75). Previously, beginning in 1895, Carlton had begun growing 1,000 varieties of wheat from all over the world in test plots in Maryland, Kansas and Colorado. He had made careful observations about the resistance of these wheats to rust as well as other characteristics (Ball, 193:64).

Carlton then went to Russia and brought back varieties that were resistant to both rust and cold. He returned with Kharkov, Baloglina and Crimean (Dunbar, 1974:112). Working with the Kansas Agricultural experiment station, Carlton helped to create Kanred through a pure-line selection from Crimean between 1906 and 1917 (Dunbar, 1974:113). A later Kansas Station variety named Tenmarq was achieved by crossing a Kanred predecessor with Marquis (mentioned above). It was introduced in 1921. Turkey Red continued to be grown, however, until a 1932 cross between Termarq and Kanred produced a new variety named Pawnee. Pawnee replaced most Turkey Red in 1944 (Colwell, 1979:75). Turkey Red has an interesting series of progeny, including, in addition to the above varieties, Wichita, Commanche, Illinois number one, Blackhill, and Kaw and Ottawa which were introduced in 1961. In making these crosses, Yaroslav, an emmer,was introduced into the hybrid chain at one point (Heyer, 1964:594). In 1969, eleven varieties of hard red winter wheat were grown on one million or more acres, and all had Turkey Red as an ancestor. These varieties included the even newer Scout and Centurk (Quisenberry and Reitz, 1974:110).

During the late nineteenth and early twentieth centuries and attempt was also made to introduce durum wheat to the northern Great Plains. The U.S. Department of Agriculture had introduced a durum known as Arnautka in 1864. Other strains were grown on a small scale in the country until 1899. Mark Carlton first became interested in durum during his experimentation with varieties in the 1895-97 period because he believed they possessed great rust resistence. In 1898 he brought back a durum from Siberia known as Kubanka. Farmers on the Far Western Plains appeared to be less interested in the durums than those in the eastern sections. But in 1898, the North Dakota Agricultural Experiment Station reported that two durums were introduced by Carlton. Durum had been intended for the driest wheat regions. When grown in the more humid areas both the quality and yield deteriorated. However, because of their superior resistence to rust, durums continued to be grown in western North Dakota and western Minnesota (Hargreaves, 1968:212-14).

Unfortunately durums became embroiled in a controversy between farmers and agronomists on one side and millers on the other. Durums were known to be pastry and macaroni wheats, but Americans used little macaroni wheat. This meant the produce from American farms either had to be shipped overseas or blended with bread wheat to hide their supposed inferiority. The millers objected to the color (creamy) and the flavor (nutlike) of the durum wheats.

They overcame the color problem through ozone or nitrous peroxide bleaching around 1904. In 1906, however, using the newly passed Pure Foods Act, the Department of Agriculture prohibited bleaching stating that the process altered the natural color and left harmful residues (Hargreaves, 1968:223).

The disputes raged particularly between government scientists and the millers' organizations until 1928 when the European durum wheat market collaspsed and the bottom fell out of the North Dakota production. Durum wheat was grown in small amounts until 1954 when a new stem rust strain damaged all wheat crops of the area. In 1962, a new rust resistant durum variety (Mindum, later followed by Stewart and Carlton) was introduced and production rose dramatically in the 1960's. On July 17, 1981, the Denver Post reported that North Dakota for the first time since 1957 had surpassed Kansas as the nation's leading wheat producing state. Of the 364.57 million bushels of wheat North Dakota produced, the Post noted that nearly 138 million of them were durum wheat (pg. 40).

With the rediscovery in 1900 of Mendel's genetic principles, a new age began with wheat breeders. Agronomists soon began to recognize hereditary characteristics, and to note that while there is a tendency in progeny toward normalcy, some of the offspring of normal plants have extreme representations of any given characteristic (Ball, 1930:66). It was these extremes which the new plant breeders sought to exploit for the benefit of agricultural products.

Perhaps no region better demonstrates the use of the knowledge of this new science of genetics than the Pacific Northwest. This region began growing wheat using the Little Club wheat introduced from California. It was grown in the Walla Walla (Washington) area as early as 1859. A common spring wheat was introduced from Australia in 1882. A winter wheat known as Forty-fold or Gold-coin was introduced from the Genessee Valley in New York. Gradually, winter wheat and white club wheats have come to predominate in the Pacific Northwest (Reitz, 1967:13).

In 1928, a Pacific Northwest Improvement Conference was held at Pullman with the result that a cooperative western regional wheat improvement program was organized. Idaho, Oregon and Washington formed the core of the group, with Arizona, California, Montana and Utah occasionally represented in the new association. A team approach was established with teams organized at Moro and Pendleton, Oregon; Moscow, Idaho; and Pullman, Washington, where the State Experiment Stations were situated. The group released three wheats between 1932 and 1940--Alial, Elgin and Rex. Alial and Elgin gave high yields, but they shattered at harvest and were found to be highly susceptible to stinking bunt, a form of smut. Harvesting a field of Elgin sometimes produced an enormous black cloud. Rex resisted shattering and bunt, but it turned out to have tight glumes, to be often afflicted with foot rot and to be susceptible to spring frost damage (Shepherd, 1980:57-58).

As World War II ended, commercial fertilizer came into heavy use. The fertilizer often caused the wheat to lodge or at least to produce unnecessary straw length. A young scientist named Orville Vogel at the Pullman Station was given the task of finding ways to shorten the straw and reduce the resistance to foot rot. For the foot rot problem, Vogel crossed four plants highly susceptible to the rot and for some unexplained reason achieved a variety which was resistant (Jenkins, 1967:121).

In 1946, an agricultural scientist serving with the army of occupation in Japan noticed Japanese farmers growing a short-strawed, high yielding wheat under heavy fertilization. This scientist, S. C. Salmon, brought sixteen varieties of this semi-dwarf wheat to California where they were grown under quarantine. Taken to Mesa, Arizona, the seed crops were increased. NORIN, as this variety is known, includes two varieties which came to Japan from the United States: Fultz and Turkey Red. Fultz was first crossed with Daruma a Japanese variety. This hybrid was in turn crossed with Turkey Red to produce NORIN (Reitz, 1968:237). The NORIN wheats were made available to all of the seven cooperating Western states. NORIN, arrived in Pullman in 1949. In 1950, Vogel used one of the NORIN varieties (#10) to cross with Brevor, a wheat he had developed in 1949. Number 14 of the F_1 hybrids showed promise (Shepherd, 1980:59). Overcoming problems with the NORIN producing male sterile hybrids, susceptibility to all diseases of the Pacific Northwest, and a brittle rachis took effort (Reitz, 1968:237). According to Vogel, it also took some luck. The seed that was finally to become Gaines was almost thrown away because Vogel had no space to grow it. A fellow agronomist offered space in his plot, however. The surprisingly high yield results at first took Vogel back. But he followed the original success with more selections, and finally in 1961 Gaines (named for one of the pioneer scientists at the Pullman Station) was released for commercial growing (Jenkins, 1967:122).

Unfortunately, Gaines had poor milling quality, and reports of foot rot were noted around Pullman. In 1965, a new selection called Nugains, with better milling qualities and more rot resistance was released (Shepherd, 1980:60). However, it seems as if the wheat breeders work is never done. Vogel lamented that "it usually takes about eight to twelve years to produce a new variety, and within five years after its release enough new diseases can develop to damage the yielding efficiency of the wheat seriously" (Jenkins, 1967:122). Vogel released Omar, a white club variety, in 1965 and he continues to work today. McDermid and Hyslop are now widely grown. Newer selections are expected soon, but the work seems to never cease.

Following the successes of the Pacific Northwest Stations, semi-dwarf germ plasm has now been used in all parts of the United States. Yorkstar was developed at Cornell, Blueboy in North Carolina, and Maricopa in Arizona (Reitz, 1968:239). Semi-dwarf NORIN hybrids have been used in Mexico with great success under a Rockefeller Foundation program to increase yields with heavy applications of irrigation and fertilizer. Between 1943 and 1963 Norman Borlaug and his associates trebled that country's average yield (Borlaug, 1965). Despite other gains in semi-dwarf breeding, the Cercosporella foot rot has proven a particularly difficult disease for which to breed resistance. The foot rot reached an epidemic level in the Northwest in 1978 (Shepherd, 1980:61). The fact that resistance to disease has been a product for which it is increasingly difficult to breed has led agronomists to search for new concepts in hybridization.

Conclusion

We have come to a point where there are two distinct views about what should be the future of our agricultural evolution in which wheat has been one of the forerunners. On the one hand, so much success has been achieved by the breeding programs of the last 90 to 100 years, that it seems that man's genius can surely result in progress toward the goal of the ideal, high-yielding, disease resistant wheat able to live in climatic extremes. On the other hand, some scientists have expressed a great deal of concern about the expenditure of the earth's limited energy resources to achieve the high yields of our time.

There are still other scientists who are afraid of the lack of genetic variation in our present varieties. Wheat is a world crop, and many countries have contributed to the present crops everywhere. However, today there are fewer places where wild wheats can be found. Moreover, farmers worldwide tend to become dependent on hybrids provided by seed companies and government agencies, and to discard local variations and mutants. These factors tend to leave the world with fewer genetic resources to turn to in the event of a threat to or severe loss of the existing cultivars. There is also the possibility that hostility between countries might prevent access to genetic resources. Seed banks have been established in many regions as a stop gap against these or other as yet unseen events. But some scientists have urged breeders to move at this point in time to use wild varieties in an attempt to breed more genetic variations with new plants.

One example of the broad range of potentials present for including new species in wheat breeding programs is the creation of the new genus Triticale, a cross between wheat Triticum and Rye Secale. The work on this project began shortly after World War II in two separate experiments: in Iowa by Dr. J. G. O'Mara and in Spain by Dr. E. Sanches. The cross has been performed between a durum wheat and rye and between a common wheat and rye. Thus, the result in these crosses has been a hexaploid and an octaploid species, respectively (Cannon, 1965). To date Triticale has shown itself to be highly resistant to cold and to wheat diseases. The yields are high, but the quality is not good. Therefore, the grain is used only as an animal feed. But, a massive testing program is underway, and breeders have some fairly high hopes for this cross (Suzuki,et. al., 1981:290-91).

According to Ernest Sears and Moshe Feldman, the entire tribe Triticeae should be considered as breeding material for new hybrids (Feldman and Sears, 1981:102). Sears has done a great deal of experimental work in this direction. He has produced nullsomic wheat plants (one pair of chromosomes missing) for each of the 21 chromosomes in hexaploid wheat (Suzuki, et. al., 1981:296). Each nullsomic identified a missing set of genes. This classification permits the recognition of equivalent chromosomes in other genetic material and eases the understanding of material transferred during hybridization (Riley, 1965:114). In addition, Sears has crossed Chinese spring wheat, *T. aestivum*, with the diploid wild species which he names *Triticum longissimum*. He has produced seven different varieties by adding in each case a different pair of the seven pairs of *T. longissimum* chromosomes to the normal 21 pairs of chromosomes of the Chinese spring wheat (Feldman and Sears, 1981:108). All of this work was accomplished through the use of backcrossing.

Other types of variation currently being considered are expected to result in varieties which can overcome specific problems associated with wheat. For example, hybrid vigor is particularly high in first generation hybrids for commercial use. It has not yet proven to be economically feasible to use only F_1 hybrids in the field, when comared with the cost and yield of the self-pollinating hybrids, however. In another vein, an attempt to breed wheat with nitrogen fixing modules like legumes has been discussed (Shepherd, 1980:63). In all of this effort, however, breeders have complained of the pressure to solve problems on a short-lived, crisis basis, leaving no opportunity to look into long-term challenges.

Many past experiences in bringing into production new varieties of fundamental importance, Fultz, Red Fife, Turkey Red and Gaines for example, have involved some accident or happy coincidence. It can be assumed that good fortune will play a part in future breeding work. Therefore, it is logical to assume that if the long-term goals are well defined and broadly understood, breeding work, even if accomplished because of very short-sighted needs, will likely result in contributions to needs of a long-standing nature if pursued vigorously. It is on this kind of optimism that much of our country has been built to date, and since we have found it difficult to operate from any other standpoint, such an outlook will aid us in overcoming the difficulties which present themselves today.

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