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INTERNATIONAL CONTRIBUTIONS TO THE IMPROVEMENT AND MARKETING OF KANSAS WHEAT

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Kansas is so well known for its major crop that it is identified around the world as the "Wheat State." Wheat was a major factor in the settlement of Kansas in the 1800s, luring pioneers to the state and shaping its farms, towns, and agricultural traditions. Today, the crop supports thousands of producers; their communities; and large industries for supplies, transportation, processing, and marketing.

The lives of many Kansans revolve around the life cycle of wheat. Producers plant the crop when conditions are favorable in autumn; anxiously hope that the plants will survive cold, drought, and wind during winter and spring; and then suspend most other farming operations and social activities to harvest the grain in early summer. Equipment and fertilizer dealers extend their hours of operation to provide supplies that producers need during critical periods. Elevator operators add help and stay open late to take in the grain during harvest, and railroads and truckers add equipment to move it to market. Media and markets follow the progress of the crop, its condition, and the yield and quality of the harvested grain. Millers then process more wheat for food in Kansas than in any other state.

The crop that directly or indirectly provides the daily bread for so many Kansans is not native to the state or even to the US. Wheat originated centuries ago in a part of the world that gave mankind many of its most important foods, and the basic characteristics of the plant that we grow were shaped by early humans. Even today, many of the traits for developing improved varieties in Kansas come from numerous other countries.

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Origin and Spread of Wheat

Wheat originated in the "Fertile Crescent" area of Iran, Iraq, and Syria. It was domesticated about 10,000 years ago by nomadic hunters/gatherers, who harvested natural stands of wild wheat as they moved from place to place. Because men were hunters, women most likely gathered the wheat and domesticated it. In turn, wheat probably fostered the domestication of mankind. Besides being highly nutritious, the grain needed no preservation and was transported easily, qualities that enabled humans to end their nomadic ways, establish villages and cities, and trade for their needs.

The women gatherers' concept of yield was probably much different than our measurement of bushels per acre. They likely were concerned with the amount that could be gathered in a given time or for a given effort. In selecting plants that could be harvested rapidly and easily, they gradually changed the wild wheats into types that we know today. Wild wheats, for instance, often have diffuse spikes (heads) with only a few small kernels, but to speed harvest, the women gatherers likely selected compact spikes that contained many large kernels like modern wheats. Another change, one that defines domestication, was the evolution from shattering types that were self-seeding to nonshattering wheats that could be harvested with a stone sickle.

Domesticated wheat spread from the Fertile Crescent to Egypt, the Mediterranean region, Central Asia, and Europe from about 4000 to 5000 BC. It became the major food staple in many of these areas as agriculture changed from nomadic gathering to cultivated farming. Many of the leav-flat, and steamed breads that are consumed today were developed during this era.

By biblical times, the concept of yield had changed to the increased amount of seed harvested from the new crop. A fourfold increase was probably typical, so families had to give up one-fourth of their precious food reserve to plant the next year's crop. The inclination to use low seeding rates probably favored profuse tillering, which makes wheat highly adaptable to a wide range of conditions today. During the Middle Ages, as the population increased and land became limiting, the concept of yield as production per area became important.

Columbus introduced wheat into the West Indies during his second voyage, and the first crop was grown in the New World in 1494. Spaniards took bread wheat to Mexico during 1510 to 1520, from where it spread into the area that is now the southwestern US. Explorers later in that century took it to the East Coast, where settlers at several places grew the first wheat crops in the early 1600s.

Start of the Wheat State

The first crop of wheat in Kansas was produced by the Shawnee Methodist Mission in 1839. Production in the state grew steadily, reaching 10,000 acres in 1863; 100,000 acres in 1869; and 1,000,000 acres in 1876. Yields were low, usually 10 to 20 bushels per acre, and the first 1,000,000-bushel crop was not harvested until 1866.

Settlers coming to Kansas brought small quantities of the wheat varieties that they had grown in the eastern US and Europe. These varieties usually came from areas with mild climates, however, and were adapted poorly to the state's environment. Many different types were introduced. Spring wheat, which matured late and often was injured by heat and rust diseases, predominated until 1875. The winter wheat that was grown was mostly soft grain: it was easier to mill with the equipment available at the time, but plants often lacked winter hardiness.

The situation changed slowly but steadily after the well-known introduction of Turkey Red hard red winter wheat from Crimea to south central Kansas by German Mennonites from the Ukraine. Turkey Red was not a pure-line variety, but a type with substantial genetic variability introduced from several areas of the Ukraine. Many other early names, particularly Crimean and Kharkof, are synonyms for this variety. The first crop of Turkey Red was planted in Marion County in 1873 and harvested in 1874. Production increased slowly because seed supplies were short, but the wide adaptation of Turkey Red, invention of the steel roller mill in 1878, and severe winter-killing of other varieties in the 1890s promoted its spread. Turkey Red occupied over 82 percent of the wheat acreage in Kansas and nearly 30 percent of the wheat acreage in the US in 1919, when the first variety survey was made. It remained the most popular variety in Kansas until 1939 and in the US until 1944. Turkey Red, without a doubt, established the wheat industry in Kansas and became the standard for judging all other varieties.

In contrast to the wheat seed, much of the technology for planting, growing, and harvesting the crop was home-grown. Conditions in the Great Plains were so unlike those that settlers had known in the eastern US or Europe that few familiar practices could be applied directly. The prairie sod had to be broken and the soil worked, first by oxen and in later years by horses and mules. Improper preparation of the land often formed poor seedbeds for planting, wasted soil moisture and nutrients, and encouraged weeds that competed with the new crop. Broadcasting the seed, the usual practice, caused uneven stands that easily winter-killed. Seeding rates used in eastern Kansas had to be reduced in western parts of the state, so that the plants didn't deplete the limited soil moisture. A further reduction was required when broadcast seeding with its inefficient seed coverage and plant establishment was replaced by the grain drill and its precise placement of seed in the soil. The

optimum planting date also was debated for many decades. Planting too early exhausted soil moisture and increased losses from pests and winter-killing, and planting too late didn't give seedlings time to become established and hardened before winter set in.

Production of wheat was extremely laborious with the equipment that settlers had. Although the steel plow was available for breaking the prairie sod in the 1830s, harrows were not widespread until the 1870s, grain drills until the 1890s, reapers until 1880-90, and tractors until the 1910s. The self-propelled combine, which probably typifies wheat production more than any other machine, was introduced in the 1920s.

Chemical fertilizers and pesticides became important for wheat production after World War II. Until then, producers depended on the native fertility of the prairie soil to provide the nutrients needed for growth of wheat and on cultural practices and resistant varieties to control weeds, diseases, and insects. During the 1940s, nitrogen fertilizers became available from converted ammunition plants, and pesticides such as 2,4-D were developed by research.

Improvement of Wheat for Kansas

Many agencies and individuals have contributed to improvement of wheat in Kansas over the years. Kansas State Agricultural College (now Kansas State University, KSU) and its branch experiment stations were involved from the beginning. Today, over two-thirds of the wheat acreage in Kansas is occupied by modern varieties developed by KSU.

Development of new crops typically follows the order of introduction of varieties from other areas, reselection of adapted varieties, and hybridization (genetic crossing) of adapted varieties to germplasm with desirable traits. Improvement of wheat for Kansas has followed these steps. Kansas State University began research on wheat, mainly evaluation of introductions, in 1874 and started a selection program in 1906. The first improved variety, Kanred, a selection from Crimean, was released in 1917. Reselection, which has yielded many other popular varieties, including Eagle and Karl 92, is possible because of the large genetic variability for many traits in adapted wheats. Hybridization to introduce new germplasm into wheat started at KSU about 1917, and the first hybridized variety, Tenmarq, was released in 1932.

Two Kansans were well-known plant explorers who introduced much of the germplasm for improvement of wheat. Mark Carleton, a USDA wheat scientist, during overseas explorations of the Ukraine and other areas in 1898-99 and 1900 collected hard red winter wheats that were used extensively in US breeding programs and hard amber spring wheats that helped start the US durum industry. S. C. Salmon, a former USDA wheat geneticist at KSU, introduced Norin 10 from Japan after World War II. This

semidwarf wheat, which was the basis for the Green Revolution in many developing countries, is now in the pedigrees of varieties that occupy about 90% of the Kansas wheat acreage.

Some Variety Milestones

Certain varieties are recognized as significant advances in improvement of wheat for Kansas over the years. Most wheat producers and scientists would agree that these varieties include Turkey Red, Blackhull, Tenmarq, Triumph, Comanche, Pawnee, Wichita, Bison, Scout/Scout 66, Eagle, Newton, Karl/Karl 92, TAM 107, Jagger, and 2137. They significantly advanced yield potential; grain quality; or resistance to diseases, insects, and environmental stresses in Kansas and are the only ones that were grown on over 20 percent of the state's wheat acreage.

The pedigrees of these significant varieties illustrate the importance of germplasm from other countries. Blackhull was selected in 1912 from a field of Turkey Red (the introduction from Russia) and released in 1917 by Earl G. Clark, a 14 year-old farm boy from Sedgwick, KS. It was grown on 34.9 percent of the Kansas wheat acreage in 1934. Tenmarq, the first hybridized variety released by KSU, was a cross between Marquis and a selection from Crimean. Marquis was a Canadian spring wheat from a cross between Hard Red Calcutta from India and Red Fife, also a Canadian spring wheat that purportedly was selected from a shipment from Poland to Scotland. Marquis greatly contributed to the excellent milling and baking qualities of Kansas wheat and made Tenmarq a popular parent for many later varieties. Tenmarq occupied 36.8 percent of the state's wheat acreage in 1944.

Triumph is the name for a group of varieties released by Joseph Danne of El Reno, OK in the 1940s and 1950s. All of their pedigrees contain Blackhull, Kanred, and Florence, a spring wheat from Australia. The Triumph varieties, which were noted for early maturity and excellent quality, accounted for 28.3 percent of the Kansas acreage in 1963.

Comanche was the first of a number of varieties released by KSU in the 1940s that contained the excellent grain properties of Tenmarq. This cross between Oro (a selection from Turkey Red) and Tenmarq was released in 1942; it had good resistance to rust and virus diseases and high yields of excellent quality grain. Pawnee, a cross between Kawvale (a soft red winter wheat from Indiana) and Tenmarq, was released by KSU in 1943. Its high yield and test weight; short, stiff straw; and resistance to several diseases made Pawnee one of the most popular varieties of its era in Kansas. It was grown on 38.7 percent of the acreage in 1951. Wichita, released by KSU in 1944, was a cross between Early Blackhull and Tenmarq. The variety matured early, which enabled it to escape many diseases, and produced grain that had high test weight and fair

milling and baking properties. It was the most popular variety in the state in 1955, accounting for 26.0 percent of the acreage. Bison, a cross between Ore-Tenmarq and ChiefKan (another variety developed by Earl G. Clark from Blackhull and a soft wheat) was released by KSU in 1956. It was a hardy variety that produced a good yield of grain with excellent baking properties. Bison was the leading variety in the state in 1961, occupying 27.1 percent of the acreage.

Scout-type wheats dominated production in Kansas during the late 1960s through the 1970s. These varieties included Scout and Scout 66, released by the University of Nebraska in 1963 and 1967, respectively, and Eagle, released by KSU in 1971. All of them had the pedigree Nebred-Hope-Turkey x Cheyenne-Ponca. Scout 66 and Eagle were selections from Scout: Nebred and Cheyenne were selections from Turkey; Hope was a spring wheat from Marquis x Yaroslav, an emmer wheat from the USSR; and Ponca was a Kansas variety with Kawale, Tenmarq, and Marquillo (a variety from a cross between Marquis and an Italian durum wheat) in its pedigree. Production of Scout/Scout 66 reached 48.1 percent of the Kansas acreage in 1970, and that of Eagle reached 23.0 percent in 1978. The varieties combined excellent hardiness and yields with exceptional milling and baking properties.

Semidwarf wheats, which are now the most widely grown varieties in Kansas, became popular in the 1980s. Newton, a variety that contains Pitic 62, a Chris sib, Sonora, Klein Rendidor, and Scout in its pedigree, was released by KSU in 1977 and was grown on 41.1 percent of the state's wheat acreage in 1982. Pitic 62 was a semi-dwarf variety from Mexico; Chris was a spring wheat from North Dakota with Kanred; Marquis; and varieties from Brazil, Ethiopia, South Africa, and the Mediterranean in its pedigree; Sonora was a local variety from Mexico; and Klein Rendidor was a variety from Argentina. Newton was widely adapted, produced outstanding yields, and had excellent resistance to diseases and lodging.

Karl and Karl 92, released by KSU in 1988 and 1992, respectively, combined high yields with exceptional grain quality. Their pedigrees contain Plainsman V, Kaw, Atlas 50, Parker, and Agent. The pedigree of Plainsman V, a high-protein variety from Goertzen Seed Research of Scott City, KS, is unclear but probably consists of an unknown variety crossed with *Aegilops ovata*, a wild relative of wheat, and backcrossed with other varieties. Kaw and Parker are Kansas varieties; Atlas 50 is another high-protein variety derived from Frondoso, a variety from Brazil; and Agent is an Oklahoma variety that contains *Agropyron elongatum*, another wild relative of wheat. Karl/Karl 92 were grown on 23.6 percent of the Kansas wheat acreage in 1994.

TAM 107, released by Texas A&M University in 1984, was from a cross between TAM 105 and Amigo. TAM 105

was from a cross of an unknown short wheat with Scout, and Amigo was a germplasm line from Oklahoma that contained several varieties of wheat and part of a chromosome from Argentine rye. TAM 107 was popular with growers because of its high yields and excellent resistance to stress; it occupied 20.6 percent of the state's wheat acreage in 1995.

Jagger, a cross of KS82W418 and Stephens, was released by KSU in 1994 and became the leading variety in the state in 1999, accounting for 29.2 percent of the wheat acreage. KS82W418 was a KSU experimental line from a cross between Plainsman V and KS75216 (a white wheat sib of Newton), and Stephens was an Oregon soft white winter wheat that contained the French variety Nord Desprez in its pedigree. Jagger produced high yields of excellent quality grain, was used widely for pasture, and was resistant to a large number of diseases and to aluminum toxicity.

The variety 2137 was released by KSU in 1995 from lines donated by Pioneer Hi-Bred International. It has a complex pedigree of Sturdy, TAM 101, a commercial variety, and several experimental lines from Missouri. Sturdy, a Texas variety, contains wheats from Argentina and Korea in its pedigree, and TAM 101, also a Texas variety selected from germplasm developed at KSU, contains wheats from Japan and the Mediterranean. Excellent yields, test weight, and resistance to leaf rust made 2137 popular with Kansas growers, and it was grown on 22.0 percent of the wheat acreage in 1999.

Changes in Characteristics of Kansas Wheat Varieties

Modern varieties of winter wheat in Kansas have many of the traits that were selected by early gatherers and farmers. They all also contain, on average, about 50 percent of Turkey Red hard red winter wheat in their pedigrees. However, present-day varieties have been changed considerably from these older wheats. They are more productive, shorter, and responsive to fertilizers; mature early; resist pests; and have better quality grain for bread and other products.

Recent research at KSU identified the traits that contributed most to increasing yields and quality of wheat in Kansas. The major changes from Turkey Red to the newest varieties were in the harvest index (the ratio of the weight of the grain to the weight of the whole plant) and the number of kernels per area of soil. Modern varieties produced only slightly more total dry matter than old varieties, but their harvest index was much higher because they were more efficient in translocating nutrients from the straw to the grain. The number of kernels per unit of soil was greater in modern varieties because more of their tillers survived to form spikes, and the spikes were longer and set more kernels. Semidwarf wheats from Japan and Korea

contributed most to these characteristics of Newton, Karl/Karl 92, TAM 107, Jagger, and 2137.

Genes for the semidwarf trait in wheat originated in Japan. Norin 10, a popular source of the semidwarf trait, was a Japanese variety with Fultz-Daruma and Turkey Red in its pedigree. Fultz was a selection from Lancaster, which itself was a selection from a Mediterranean wheat, and Daruma provided the dwarfing gene.

Two other changes in the wheat plant, early maturity and resistance to lodging, also added to yields. Early maturity, which enabled plants to escape hot, dry conditions during late spring, was developed by selecting from the natural variation in wheat. Resistance to lodging, which permitted high plant densities and use of nitrogen fertilizer for increased yields, was improved gradually by selection in early varieties. The greatest advance, however, came from genes for the short, stocky stems of semidwarf varieties from Asia.

Resistance to the diseases and insects that plague wheat has come from reselection of adapted varieties, hybridization with introduced germplasm, and introgression of genes from related species. For example, compared with their parent varieties, Kanred (the selection from Crimean released by KSU) had greater resistance to stem and leaf rusts, and Eagle (a selection from Scout) was more resistant to stem rust and loose smut. An early variety of durum wheat from Italy provided resistance to Hessian fly that is still used in many Kansas hard red wheats. Wild relatives of wheat from the Fertile Crescent and rye from Argentina are sources of resistance to several foliar diseases and vectors of virus diseases of Kansas varieties.

The baking quality of wheat largely depends on the protein content of the grain and the ability of the protein to produce desirable loaf characteristics. Turkey Red wheat milled easily and had excellent baking properties when the grain protein was adequate. However, the protein contents of most varieties fell as the native fertility of the prairie soils declined. Increasing the grain protein content was difficult because of an inverse relationship with the high yields of new varieties, so breeders focused on improving the quality of the protein. Marquis, the spring wheat from Canada, greatly enhanced the protein quality of the varieties that had it in their pedigrees. Steady advances also were made by selection; for instance, Eagle was noted for its excellent baking quality. The most progress came in the 1980s, when the protein quality that had been improved over years of selection was combined with genetics for high grain protein content that originated from the Brazil variety, Frondoso, and the wild relative, *Aegilops ovata*. The results were the high protein, high quality varieties Karl and Karl 92, the only ones for which millers paid premium prices to Kansas producers.

Overseas Markets and Food Aid

International markets are as important for selling Kansas wheat as international sources are for improving the crop. Countries on all of the continents that provided germplasm for developing new varieties for Kansas also purchase much of the grain that the state's growers produce. Wheat grain and flour exports for Kansas totaled \$774 million in 1998, which was 61.3 percent of the \$1.262 billion farm value of the crop and provided an average of over \$22,000 for each of the state's approximately 35,000 growers. Assuming an economic multiplier of 5, international sales of wheat added nearly \$3.9 billion to the state's economy in 1998.

Egypt, which purchased nearly 77 million bushels, was the largest buyer of US hard red winter wheat during the 1998-99 marketing year. Mexico, Nigeria, Japan, and Israel followed with total purchases of nearly 158 million bushels. The Near East, the location of the Fertile Crescent that provided wheat to mankind, bought more US hard red winter wheat than any other region, a total of 155 million bushels.

Overseas food aid is another important use of Kansas wheat. Shipments of wheat in many cases are life savers for people who are suffering hunger because of crop failures, wars, droughts, floods, hurricanes, and other calamities. The abundant wheat crop in Kansas enables the US to provide aid to people in other countries and relieve their suffering.

Donations of food to other countries in 1999 made the US government the largest wheat exporter in the country. Wheat was the major commodity donated to most countries, accounting for nearly 62 percent of the 8.1 million tons of nonemergency food shipments. Ironically, Russia, the source of much of the germplasm for improving wheat in Kansas, was the major recipient of food under the largest US aid program, and wheat grain and flour accounted for 91 percent of the food donated.

Conclusions

- Kansas owes its most important crop to international sources.
- Early humans and farmers of the Middle Ages developed the plant type of wheat that is grown today.
- Turkey Red hard red winter wheat from Crimea established the wheat industry in Kansas.
- Modern varieties of wheat grown in Kansas contain germplasm from many countries.
- International markets are as important for selling Kansas wheat as international sources are for improving the crop.

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