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Keeping Up With Research 136

A HISTORY OF WHEAT IMPROVEMENT AT KANSAS STATE UNIVERSITY

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Wheat is the most important crop in Kansas. It supports growers, their communities, and an array of industries as well as feeding millions of people around the world. Kansas didn't become the "Wheat State" by accident. Settlers introduced numerous kinds of wheat, learned to grow them by trial and error, and suffered crop failures during many years. Today's growers, in contrast, have varieties adapted to Kansas; modern methods and machinery for producing the crop; and up-to-date information on tilling the soil, protecting the plants against adverse conditions, and marketing the grain.

Most of the improved varieties and much of the modern technology for producing wheat in Kansas were developed at Kansas State University (K-State). Over three-fourths of the 2003 Kansas wheat crop was planted to K-State varieties (Figure 1). These varieties became popular because they are productive, yield high-quality grain, and resist the pests and adverse weather that often damage wheat in the state. Their annual contribution to Kansas agriculture amounts to hundreds of millions of dollars.

The high percentage of K-State varieties in the 2003 crop continues a long tradition of improving wheat for Kansas growers. Thirty-six varieties have been released since 1917, each an improvement in some respect over its predecessors (Table 1). In addition to improved productivity and resistance to pests and weather, all of the quality traits of Kansas wheat have been maintained and many of them have been enhanced (Table 2). It is difficult to improve some traits, such as protein, as yield increases because of an inverse relationship between

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those traits and yield. However, new varieties have been developed with the same protein level as old varieties plus a longer mixing time, larger loaf volume, better crumb structure, and a much higher quality rating.

Development of new crops for a region typically follows a sequence of evaluation of introduced varieties, selection of genotypes from the genetic diversity in introduced varieties, and hybridization to create new genotypes. Improvement of wheat at K-State followed the same course. Early researchers tested numerous varieties from around the world, selected strains from the best introductions to develop the first improved variety, and then began crossing parents with desirable traits to create new varieties.

Introduction of Wheat in Kansas

The first wheat crop in Kansas was grown at the Shawnee Methodist Mission near Fairway in Johnson County in 1839. Production spread westward as the state was settled during the 1800s, but yields were low. The state's harvests didn't reach 1,000,000 bushels until 1866 and 100,000,000 bushels in 1914, but production then climbed to over 500,000,000 bushels in 1997. Yields averaged less than 20 bu/a until 1914 and 30 bu/a until 1969 but then reached 40 bu/a in 1983 and the record of 49 bu/a in 1998.

Lack of suitable varieties was a major cause of low wheat production during the early years. Settlers mostly used familiar varieties they brought with them to Kansas from the eastern U.S. or western Europe. Most of these wheats were ill-adapted to the state. Spring wheat predominated until the 1870s, but delayed maturity exposed it to attack by rust diseases and the hot, dry conditions of late spring and early summer. Winter wheats were mostly soft grain varieties that lacked adequate hardiness to freezing during winter and drought during spring. The few hard wheats that were available were heavily discounted by millers because of difficulty in their processing.

Four introductions were particularly important for improving productivity of wheat in Kansas. The first was the well-known import of "Turkey" hard red winter wheat from the Crimea to southcentral Kansas by German Mennonite settlers who arrived from the Ukraine in 1873. Both "Turkey" wheat and the traditional production practices of the Mennonites were well-suited to Kansas and often enabled them to successfully grow a crop when other settlers' crops failed.

Two important introductions of "Turkey"-type wheats were made by M.A. Carleton, a graduate (B.S. 1887, M.S. 1893) and former faculty (1893-94) of K-State. Carleton, a cerealist and plant explorer for the U.S. Department of Agriculture, introduced 'Crimean' and 'Kharkof' hard red winter wheats from Russia in 1900. 'Crimean' became the parent of the first improved wheat varieties developed by K-State. 'Kharkof', being hardier than 'Turkey', extended production of hard red winter wheat throughout Kansas and into more northern states.

The fourth important introduction was 'Norin 10' and other semidwarf wheats by S.C. Salmon, also a graduate (M.S. 1913)

and former professor (1913-31) at K-State. The short, stocky wheats were collected by Salmon while serving as a crop consultant with the U.S. Army of Occupation in Japan in 1946. Similar lines were used by CIMMYT in Mexico to create the varieties that started the Green Revolution in developing countries and are in the pedigrees of over 95% of the varieties grown in Kansas today.

Wheat Improvement by Evaluation

Early researchers at Kansas State Agricultural College (KSAC; now K-State) faced the same uncertainties with wheat as settlers. The types of wheat that were adapted to the state, preparation of the soil, fertility requirements, the optimum date and rate of seeding, and control of the major diseases and insects were all unknown. Research on wheat at K-State was started by J.S. Hougham, the first Professor of Agricultural Science. Spring wheat sown by him in March 1868 on land bequeathed to K-State when it was formed in 1863 yielded 20 bu/a of "first class grain." Winter wheat planted in September 1868 also gave a good harvest, but six varieties sown in October were destroyed by freezes in February and March.

Progress was slow during the early years because the new college lacked facilities for research. F.E. Miller became Professor of Agriculture and Farm Superintendent in 1873. He initiated research on variety evaluations, soil preparation, crop rotations, and fertilizers for wheat and was the first scientist to emphasize grain quality as well as yield. Miller was replaced in 1874 by E.M. Shelton, who focused on mixed farming of crops and livestock but also conducted considerable experimentation with wheat. In addition to testing numerous varieties, he evaluated wheat for pasture; rotations; use of manure, salt, and plaster (gypsum) as fertilizers; and started a 1-acre plot of continuous winter wheat to measure the long-term fertility of the soil. Although wheat was well-established in the state, failed crops during 1885, 1886, and 1887, primarily from winterkilling, prompted him to advance "The argument for wheat-raising in Kansas" (KSAC Bulletin 7, 1889).

The soft red winter wheats 'Little May', 'Big May', 'Red May', and 'Zimmerman', which Shelton considered to be "local names for one and the same variety" (KSAC Bulletin 7), were named by K-State as its standard varieties in 1889. When C.C. Georgeson replaced Shelton in 1890, he substituted 'Currell', another soft red winter wheat, for general cropping (KSAC Bulletin 33, 1892).

Appreciation of the merits of 'Turkey' hard red winter wheat came slowly. A number of varieties known as 'Russian', 'Red Russian', and 'Turkey' had been tested without distinction by K-State during the 1880s. On October 6, 1890, Georgeson received and planted a variety labeled 'Turkey'(Steck.) (KSAC Bulletin 20, 1891). This variety was no better than its predecessors the first year, yielding only 14.94 bu/a. By 1896, after six years of testing, Georgeson described the variety as "rapidly coming to the front as a heavy yielder" and "perhaps the hardiest wheat of any we have tested" (KSAC Bulletin 59).

Table 1. Wheat varieties released by Kansas State University and their class, pedigree, year released, and highest percentage of state wheat area. HRWW = hard red winter wheat, SRWW = soft red winter wheat, HWWW = hard white winter wheat. Data were compiled from Kansas Agricultural Statistics Service reports.

Variety	Class	Pedigree	Year	Area (%)
Kanred	HRWW	Selection from Crimean	1917	19
Tenmarq	HRWW	Marquis/P-1066	1932	37
Kawvale	SRWW	Selection from Indiana Swamp	1932	6
Comanche	HRWW	Oro/Tenmarq	1942	21
Pawnee	HRWW	Kawvale/Tenmarq	1942	39
Wichita	HRWW	Early Blackhull/Tenmarq	1944	25
Kiowa	HRWW	Chiefkan//Oro/Tenmarq	1950	13
Ponca	HRWW	Kawvale/Marquillo//Kawvale/Tenmarq	1951	14
Bison	HRWW	Chiefkan//Oro/Tenmarq	1956	27
Kaw/Kaw 61	HRWW	Oro//Mediterranean/Hope/Early Blackhull/Tenmarq	1960/65	16
Ottawa	HRWW	Mediterranean/Hope//Pawnee/Oro/Illinois no. 1// Comanche	1960	9
Parker	HRWW	Quivira/Kanred/Hard Federation//Prelude/Kanred/ Kawvale/ Marquillo//Kawvale/Tenmarq	1966	9
Parker 76	HRWW	Parker/Agent	1976	
Shawnee	HRWW	Selection from Ottawa	1967	1
Eagle	HRWW	Selection from Scout	1970	23
Cloud	HRWW	Scout/Agent	1973	1
Kirwin	HRWW	Parker/Bison	1973	—
Sage	HRWW	Agent/Scout	1973	15
Trison	HRWW	Triumph/Bison	1973	2
Larned	HRWW	Ottawa/ Scout	1976	12
Newton	HRWW	Pitic 62/Chris sib//Sonora 64/Klein Rendidor/Scout	1977	41
Arkan	HRWW	Sage/Arthur	1982	15
Dodge	HRWW	KS73H530 (Newton sib)/KS76HN1978-1 (Arkan sib)	1986	—
Norkan	HRWW	Plainsman V/(KS76H3705) Larned/Eagle//Sage	1986	—
Karl/Karl 92	HRWW	Plainsman V/Kaw/Atlas 50// Parker/Agent	1988/92	24
Ike	HRWW	Dular/Eagle//Cheney/Larned/Colt	1993	11
Jagger	HRWW	KS82W418/Stephens	1994	45
2137	HRWW	W2440/W9488A//2163	1995	23
Betty	HWWW	KS82W418/Stephens	1998	—
Heyne	HWWW	KS82W422/SWM754308/KS831182/KS82W422	1998	—
Trego	HWWW	KS87H325/Rio Blanco	1999	2
Lakin	HWWW	KS89H130/Arlin	2000	—
Stanton	HRWW	PI220350/KS87H57//TAM200/KS87H66/KS87H325	2000	—
2145	HRWW	HBA142A/HBZ621A//Abilene	2001	—

This was the first official report of the superiority of 'Turkey' hard red winter wheat over several years. In 1898, 'Turkey' became K-State's standard hard red winter wheat and 'Zimmerman' continued as its standard soft white wheat (KAES Press Bulletin 1).

Establishment of the Hays Branch Experiment Station in 1901 expanded research with wheat to an area that was more representative of the major production regions of Kansas than the Manhattan location. Early work at Hays emphasized evaluation of 'Kharkof' and 'Turkey', their cultural requirements, and seed production. The station later became an important source of new varieties for western Kansas.

The Manhattan and Hays stations promoted wheat production by increasing seed supplies of the best varieties, particularly 'Kharkof'. The KSAC Press Bulletin No. 134 in 1909 announced that sufficient seed of improved varieties was available to plant one-half of the acreage in the state and "the problem of wheat improvement in Kansas will have been solved." Recognition of the value of 'Turkey'-type wheat and distribution of improved seed helped make Kansas the "Wheat State." By 1919, when the first official survey was taken, 'Turkey'-type wheat, about half of it 'Kharkof', occupied over 82% of the 11,600,000 acres of the crop in the state. However, the need to improve wheat did not end. New opportunities and technologies, new races of pests, and the necessity of being competitive mandated continuing genetic improvement of wheat by selection and hybridization.

Wheat Improvement by Selection

The first improved variety released by K-State was developed by H.F. Roberts, a Professor of Botany. Roberts planted 554 rows of wheat, each of them from one spike of the variety 'Crimean', in 1906. Selections were replanted in rows from 1907 to 1910 and in field plots from 1911 onward. Seed of the best line was distributed to 1,500 farmers for testing in 1914 and released by K-State as the variety 'Kanred' in 1917 (Table 1). The new variety was earlier in maturity, hardier, and more productive than 'Crimean' or 'Turkey'.

The only soft red winter wheat released by K-State also resulted from selection. 'Kawvale' was selected from 'Indiana Swamp' by J.H. Parker, Professor of Agronomy from 1917 to 1938 (Table 1). It had high yield and resistance to leaf rust, and was intended for production in southeastern Kansas. 'Kaw 61', a hard red winter wheat, was a repurification of 'Kaw' by E.G. Heyne, Professor of Agronomy from 1947 to 1982. Heyne also selected 'Shawnee' for improved baking properties from 'Ottawa' and released it in 1967.

The variety 'Eagle' was selected from 1,800 spikes of 'Scout' in a project began in 1962 by R.D. Livers, leader of the Hays wheat program from 1962 to 1979. The new variety had exceptional breadmaking properties (Table 2).

Another high-quality variety, 'Karl 92', was selected from 'Karl' by R.G. Sears, leader of the Manhattan wheat program from 1982 to 2000. 'Karl 92' had higher yield and better disease resistance than its parent variety.

Wheat Improvement by Hybridization

Hybridization of wheat at K-State started in 1899, before the rediscovery of Mendel's Laws of Inheritance. Press bulletin No. 1 from the Farm Department announced that 3,000 crosses were made that summer and the progeny would be planted in the autumn.

The first variety developed by hybridization was 'Tenmarq' from a cross between 'P-1066' (a selection from 'Crimean') and 'Marquis' (a Canadian hard red spring wheat) (Table 1). The cross was made by M.N. Levine, an assistant in Plant Pathology, under the direction of Parker in 1917, and the initial selection of the new variety was done in 1921. 'Tenmarq' was noted for early maturity, high yield, and excellent quality (Table 2).

Many other well-known varieties – 'Comanche', 'Pawnee', 'Wichita', 'Ponca', 'Kiowa', and 'Bison' – originated from Parker's program (Table 1). 'Comanche', which came from a cross in 1928, had high yield and test weight and good resistance to many diseases. 'Pawnee', also from a cross in 1928, was selected at the University of Nebraska; it had many excellent characteristics and was highly popular because of its wide adaptation. L.P. Reitz succeeded J.H. Parker, who became Director of the Kansas Wheat Improvement Association in 1938. Several of the varieties that originated in Parker's program were selected and released by Reitz from

1939 to 1946, including 'Wichita', which was intended to replace the variety 'Early Blackhull' because of its good yield and quality (Table 1).

Two important varieties were developed by A.F. Swanson at the Hays Branch Experiment Station during the 1950s (Table 1). 'Kiowa', from a cross made by Parker in 1938, was released in 1950 because of its high yield and excellent adaptation to western Kansas. 'Bison' came from the same cross and was selected for improved breadmaking quality.

Eight varieties were developed by hybridization by Heyne during his career (Table 1). 'Ponca' came from a cross by Parker in 1935 and was resistant to Hessian fly and had excellent baking properties. 'Kaw', from a cross in 1941, was resistant to leaf rust and bunt and had stable grain quality under adverse conditions. The cross for 'Ottawa' was made in 1943, and the variety was released for its excellent resistance to Hessian fly and soil-borne mosaic virus. 'Parker' originated from a series of crosses began in 1920; it matured early and was resistant to Hessian fly and leaf rust. Seed of 'Parker'/'Agent' from Colorado State University was backcrossed to 'Parker' in 1967, and a single spike was increased and released as 'Parker 76' for resistance to leaf rust and Hessian fly. 'Cloud' also came from a composite of lines from a cross at Colorado State University that were screened for resistance to leaf and stem rusts. 'Trison' was developed for early maturity and enhanced dough and baking properties. The last variety released by Heyne, 'Newton', came from a single plant selected out of 6,400 lines of a cross by Pioneer Hi-Bred International. The variety was the

Table 2. Grain quality traits of wheat varieties released by Kansas State University relative to 'Turkey' hard red winter wheat.*

Variety	Quality trait						
	Flour yield (%)	Flour protein (%)	Absorption (%)	Mixing time (min)	Loaf volume (mL)	Crumb grain score	Quality index
Turkey	72	11.5	56	2.4	935	6.3	14.7
Tenmarq	75	12.0	56	2.7	943	8.0	18.6
Comanche	74	12.0	58	3.1	917	7.0	18.5
Pawnee	73	11.4	55	2.0	928	6.8	13.8
Wichita	76	11.2	54	2.2	946	7.2	15.3
Bison	74	11.7	56	2.9	985	7.7	24.0
Eagle	75	12.3	58	4.6	922	8.0	23.9
Newton	72	10.9	55	3.3	980	7.7	21.7
Karl	75	11.9	58	5.1	1003	8.0	28.1

*Adapted from Cox, T.S., M.D. Shogren, R.G. Sears, T.J. Martin, and L.C. Bolte. 1989. Genetic improvement in milling and baking quality of hard red winter wheat cultivars, 1919 to 1988. *Crop Science* 29:626-631.

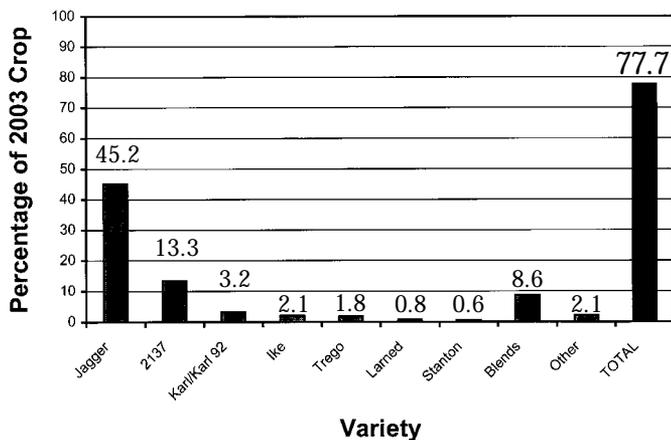


Figure 1. Percentage of 2003 Kansas wheat crop planted to varieties released by Kansas State University. Data are from a Kansas Agricultural Statistics Service release dated January 28, 2003.

first widely successful semidwarf wheat in Kansas. Development of hard white winter wheat for Kansas was initiated by Heyne in the early 1970s. Much of the wheat improvement at Manhattan and most of the program at Hays now emphasize hard white winter wheat.

Several excellent varieties were released by Livers at Hays in addition to 'Eagle' during the 1970s (Table 1). 'Kirin' resulted from crosses that began in 1958 and was selected in 1964 for resistance to Hessian fly and high test weight. 'Sage' came from crosses in 1964 and was selected in 1969 for high yield and resistance to leaf rust. Another variety, 'Larned', came from a series of crosses from 1963 through 1966 to transfer resistance to Hessian fly from 'Ottawa' to a 'Scout'-type wheat. Crosses for 'Arkan', 'Dodge', and 'Norkan' were made by Livers during 1970-71 and 1976-77. All of the varieties were selected and released by Livers' successor, T.J. Martin, leader of the Hays wheat program from 1979 to the present (Table 1). 'Arkan' had outstanding resistance to leaf rust and was intended primarily for southeastern and southcentral Kansas. Both 'Dodge' and 'Norkan' had excellent disease resistance and were adapted to western and northern areas of the state, respectively.

Two additional hard red winter wheats and two hard white winter wheats were developed by Martin (Table 1). 'Ike' was from a last cross made in 1982-83 and had high yield, disease resistance, and quality. 'Stanton' came from a final cross in 1988-89 and combined outstanding performance with resistance to Russian wheat aphid. The two hard white winter wheats, 'Trego' and 'Lakin', from crosses in 1988 and 1989, respectively, were recommended for production in western Kansas. 'Trego' had particularly exceptional yields under dryland conditions and resisted preharvest sprouting, a problem of white wheat.

Two varieties that occupied significant acreage, 'Karl' and 'Jagger', were released by Sears during 1988 and 1994, respectively (Table 1). 'Karl', from a cross made by Heyne in 1977, had superior breadmaking quality and was adapted to eastern and central Kansas. 'Jagger' was developed from a cross in 1984 and became popular across the state because of its high yield, disease resistance, and quality. Another release by Sears, '2137', was selected from lines donated by Pioneer Hi-Bred International; it produced high yields and resisted many diseases. A white wheat developed by Sears, 'Betty', was selected from a field of 'Jagger' in 1991 and released for production in western Kansas. Another white wheat, 'Heyne', had excellent disease resistance and was recommended for central and southcentral Kansas.

The most recent K-State variety, '2145', was selected from the Pioneer Hi-Bred International lines by Sears in 1994. It was released by Sears' successor, A.K. Fritz, primarily for production in central Kansas.

Other Contributors to Wheat Improvement at K-State

Development of new varieties is a team effort at K-State. Many scientists and agencies other than those mentioned here are essential to the program. Agronomists test the varieties, increase the seed, and develop improved production practices. Plant pathologists screen experimental lines for disease resistance and entomologists screen for insect resistance. Cereal chemists evaluate the milling and baking quality. Scientists from the U.S. Department of Agriculture contribute greatly to the program and cooperate in development and release of new varieties. The Kansas Crop Improvement Association increases and distributes seed to growers and provides funds for the wheat program. Additional funding is furnished by the Kansas Wheat Commission, USDA, and other agencies.

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