The Early History of Wheat Improvement in the Great Plains

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ABSTRACT

More than 60% of U.S. wheat is grown in the Great Plains. Three classes of common wheat (*Triticum aestivum* L.)—hard red spring, hard red winter, and hard white—and durum (*T. turgidum* L. var. *durum*) occupy 16 million ha in the region and provide most of the U.S. grain for baked goods and pasta. This article relates the early history of the four classes and the key persons involved in their establishment. Pioneers faced many difficulties in settling the Plains, but the need for adapted cultivars was paramount. Three cultivars—'Red Fife' hard red spring wheat, 'Turkey'-type hard red winter wheat, and 'Kubanka' durum wheat—were the foundation for the industry. Red Fife was selected by D.A. Fife of Ontario in 1842. The cultivar spread to the northern U.S. Plains during the 1860s and dominated production for 40 yr. Turkey hard red winter wheat was introduced to Kansas by Mennonite settlers from the Ukraine, particularly B. Warkentin, in 1873 and was advanced by C.C. Georgeson, who recognized its potential. Another cultivar, 'Kharkof', introduced by M.A. Carleton in 1900, stimulated spread of the class throughout the Plains. Carleton also introduced Kubanka in 1900 and promoted its utilization to start the U.S. durum industry. The most recent class, hard white wheat, was initiated by E.G. Heyne and approved by the USDA in 1990. These wheats transformed American agriculture by opening a vast area for production, shifting the center of cultivation to the Plains, and changing the country into a major grain exporter.

Wheat is the main crop in the Great Plains and the major food grain in the United States (Fig. 1). The four classes of wheat in the Plains—hard red spring, hard red winter, durum, and hard white—occupy one-third of the cultivated land in the region and account for more than 60% of the total wheat crop in the United States (National Agricultural Statistics Service, 2005). About 50% of the crop is exported, the most of any commodity; 36% is consumed domestically; 10% is fed to livestock; and 4% is used for seed (Kansas Wheat Commission, 2006).

Hard red spring wheat and hard red winter wheat for baked goods constitute about 40 and 48%, respectively, of the 16 million ha of the crop in the Plains; durum for pasta about 7%; and hard white wheat for baked goods about 5% (Lin and Vocke, 2004; National Agricultural Statistics Service, 2005). North Dakota and Montana lead in production of hard red spring wheat; Kansas, Nebraska, Oklahoma, and Texas in hard red winter wheat; North Dakota in durum wheat; and Colorado and Kansas in hard white wheat.

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EARLY NEEDS OF THE INDUSTRY

Settlers in the Great Plains, many of whom were unskilled at farming, encountered numerous obstacles in cultivating wheat. The prairie sod had to be broken, methods of preparing the soil and suitable dates and rates for sowing had to be learned, and natural hazards of drought, unfavorable temperatures, diseases, and insects had to be overcome (Salmon et al., 1953).

The need for adapted cultivars was paramount. Most early cultivars introduced by pioneers from the eastern United States and western Europe were ill-suited for the often harsh environment, and crop failures were common (Buller, 1919; Ball, 1930). Drought, winterkilling, stem rust (then called black rust) (*Puccinia graminis* f. sp. *tritici*), chinch bug (*Blissus leucopierus*), and other pests were particular perils that often completely destroyed the crop (Salmon et al., 1953).

A bulletin by Carleton (1900b), which was described as a "foundation paper" of the industry (Ball, 1930), identified cultivar traits that were needed for successful production of wheat in the different regions of the United States. The northern Plains, where the severe cold precluded winter wheats, required spring-habit cultivars that were early maturing and resistant to drought and pests. The central and southern Plains needed winter wheat cultivars, which matured earlier and had higher yield potential than spring wheats, that had the same traits plus cold hardiness. Production of durum wheat was concentrated in northcentral Texas and southwestern Oklahoma and Kansas, where cultivars that were hard-grained and resistant to drought and stem rust were necessary.

KEY INTRODUCTIONS

A small number of introductions, all of them from Russia and the Ukraine, were key to establishing wheat in the Great Plains.

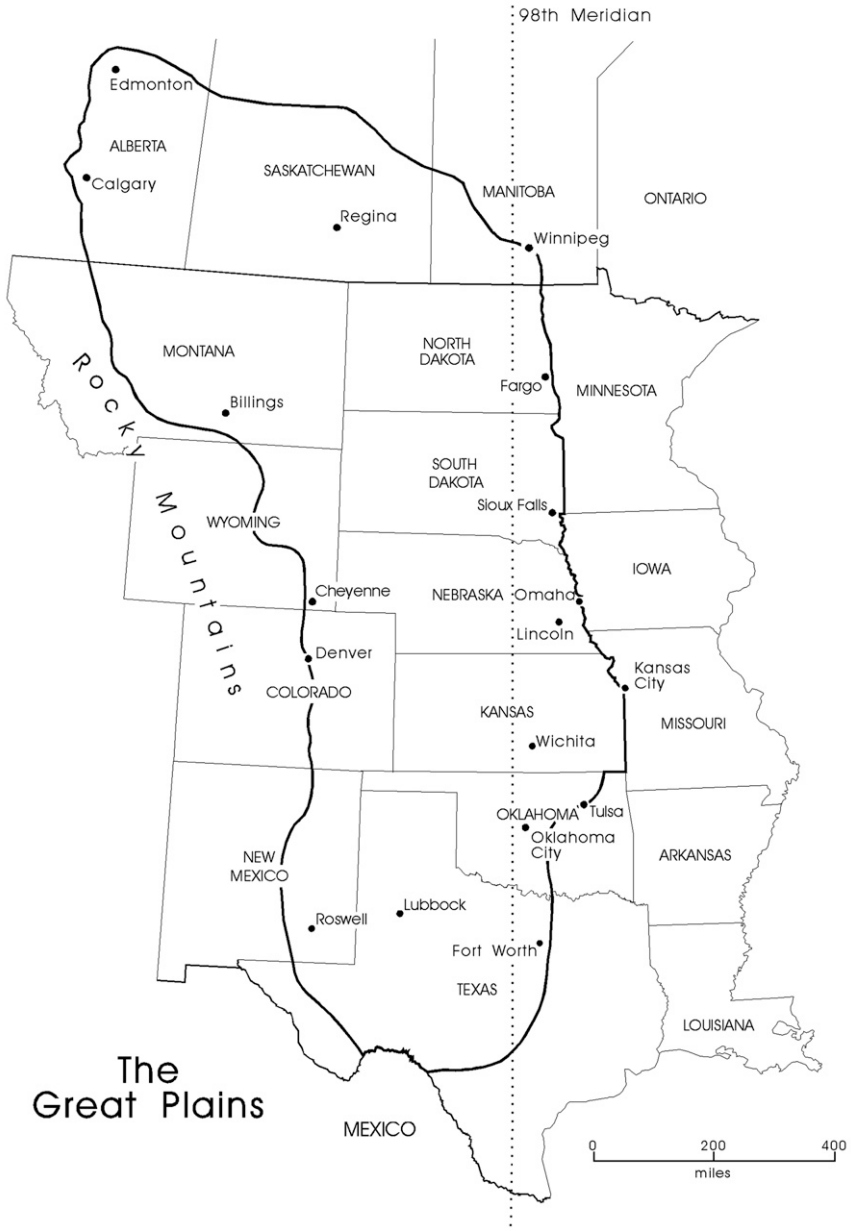

Fig. 1. Map of the Great Plains of North America. Illustration courtesy of the Univ. of Nebraska Center for Great Plains Studies.

Red Fife was the foundation for hard red spring wheat in the northern Plains (Buller, 1919; Clark, 1936) and, as a parent of 'Marquis' (Red Fife × 'Hard Red Calcutta'), is still the basis of breeding programs for the class in the United States and Canada (Symko, 2002). Turkey and closely related cultivars such as 'Crimean' and Kharkof were the foundation for hard red winter wheat in the central and southern Plains (Quissenberry, 1974; Quissenberry and Reitz, 1974; Schmidt, 1974). These introductions dominated production in the region and became parents of many early improved cultivars. About half of the genes in modern cultivars were traced to the Turkey-type wheats (Cox, 1991). Widespread production of durum wheat in the northern Plains began with the introduction and promotion of Kubanka (Carleton, 1901, 1915). The cultivar is still the standard for durum wheat quality and is in the pedigree of many improved cultivars (Joppa, 1988).

The three cultivars—Red Fife hard red spring wheat, Turkey-type hard red winter wheat, and Kubanka durum wheat—transformed American agriculture. They opened a vast new area to profitable production of a staple crop, shifted the heart of U.S. wheat cultivation from the eastern and central states to the Great Plains, and changed the country from a potential importer into a major exporter of grain. Their impact on U.S. agriculture was likened to the industrial revolution initiated by the steam engine, the Bessemer process, and electricity (Olmstead and Rhode, 2002).

Success of the three cultivars in the Great Plains was attributed to their excellent adaptation and superb quality for foodstuffs. The prairie soils of the Plains were highly similar to the Chernozem soils of the Steppes, and drought and temperature stress were less severe in the Plains than in analogous regions of Russia and the Ukraine (Carleton, 1900a). The excellent quality of the three cultivars was also related to their origin, because "...as a general rule, sorts which are able to withstand the most rigorous extremes of climate are also of the class which makes the best quality of bread and macaroni..." (Carleton, 1900b).

The historical succession of wheat cultivars in the Great Plains has been reviewed periodically based on USDA quintennial surveys from 1919 to 1984 (e.g., Clark et al., 1922; Dalrymple, 1988). Much of the early history of wheat in the Plains remains unresolved, however. The early accounts of the hard red spring wheat industry are fairly mundane, because introduced cultivars were reasonably well-adapted and the northern climate limited the viability of alternative classes (Salmon et al., 1953). However, the origin of the key cultivar, Red Fife, is questioned (Carleton, 1900b; Buller, 1919; Symko, 2002). The beginning of the hard red winter wheat industry is more contentious. Contributions of the different introductions of Turkey-type wheats and recognition of their merits are disputed (Ball, 1930; Parker, 1935; Clark, 1936). Standard accounts hardly mention important cultivars (Malin, 1944; Quissenberry and Reitz, 1974; Schmidt, 1974) and have even been labeled myths (Saul, 1989). The prominence of durum wheat in the northern Plains is largely attributable to the perseverance of one person and a serendipitous act of nature (Carleton, 1905, 1915). The resurgence of hard white wheat in the region is much more recent than the introduction of the other classes and has not been adequately documented.

This article reviews the early history of the establishment of the four wheat classes in the Great Plains from an agronomic perspective. Recognition is given to the key scientists and other cerealists, some of whose contributions are unheralded. Some misstatements are corrected, and some previously overlooked

information that relates to the importance of different cultivars is reviewed. The recent establishment of a new class, hard white wheat, is also documented.

ESTABLISHMENT OF HARD RED SPRING WHEAT

Background of the Region

Wheat was first grown in North Dakota near Pembina about 1812 (Buller, 1919). The crop was produced by Selkirk colonists, a group of impoverished Scottish immigrants under the auspices of the Hudson Bay Company, for settlers in present-day Winnipeg. The Pembina area was part of Canada at the time that was ceded by Britain to the United States when the border was realigned in 1818 (Symko, 2002).

The Selkirk colonists faced extreme difficulties. The prairie sod had to be broken with hoes and the grain harvested with sickles (Symko, 2002). Early wheat cultivars were not productive, and weather and pests destroyed much of the first crops that the settlers were able to grow. However, other problems were generally less severe over time than those encountered by later settlers in more southern areas. After spring wheat was introduced, broadcasting seed, the usual practice, was more successful than with winter wheat because of more favorable moisture conditions in the spring than in the autumn (Salmon et al., 1953). Diseases and insects were usually less destructive, and weeds did not become a factor until the end of the 19th century (Salmon et al., 1953).

The wheat cultivar that was grown by the Selkirk settlers in 1812 is unknown but was probably a winter type from Scotland (Symko, 2002). According to Pritchett (1942) and Murray (1967) [both as cited by Olmstead and Rhode (2002)], the winter wheat failed and the fields were resown with a spring wheat. That crop also failed, and another spring wheat cultivar was obtained for planting in 1813–1814. An insect plague in 1819 left the colony without seed, and the settlers trekked overwinter to southwestern Wisconsin, where they purchased 250 bu (6800 kg) of another, also unknown, spring cultivar and laboriously transported it to their settlement in 1820 (Buller, 1919). This 'Prairie du Chien' wheat was their main cultivar until Red Fife was introduced (Olmstead and Rhode, 2002).

Production of spring wheat gradually spread over the region as the northern prairie was settled. The total wheat area was only about 250,000 ha, however, and total production averaged only about 380 Gg annually from 1866 to 1869 (Salmon et al., 1953).

Introduction of Red Fife Spring Wheat

Red Fife hard red spring wheat was selected by D.A. Fife of Ontario (Fig. 2) (Buller, 1919; Morrison, 1960). A progressive farmer, Fife traveled to Scotland in 1840 to obtain wheats that he hoped would resist the rust diseases in his area, but the introductions were no better than the existing cultivars. Then, in 1842, a friend sent Fife a quantity of grain obtained on the docks of Glasgow from a shipment from Danzig, Germany (now Gdansk, Poland). Fife sowed the seed in spring 1842; only one plant produced grain, the majority of them being winter wheat. According to legend, the Fife's cow ate two of the five spikes on the single maturing plant before the rest were rescued by Mrs. Fife (Buller, 1919; Symko, 2002).

The surviving wheat was unaffected by the rust diseases that attacked farmers' fields in the area, and the grain matured slightly earlier and was harder than other cultivars (Symko, 2002). The grain also later proved to have excellent quality for breadmaking (Clark et al., 1922). Fife gradually increased the seed supply and distributed it to neighbors. The cultivar became generally known as 'Fife', Red Fife, 'Halychanka', 'Scotch', and 'Glasgow' and by "a dozen or more" strains that were developed from it (Carleton, 1900b).

Spread of Red Fife Spring Wheat

Red Fife became "the premier hard spring wheat cultivated in North America" during the late 19th century (Olmstead and Rhode, 2002). It initially spread through Ontario and the Upper Midwest of the United States, where it was introduced about 1855 (Symko, 2002). It received little attention in the Plains, however, until a Wisconsin farmer wrote a letter extolling its virtues to a popular agricultural magazine (Clarke, 1860). Red Fife and cultivars from it were widespread throughout the northern Great Plains by 1870 and dominated the region for more than 40 yr. Production of spring wheat increased to 4.25 million ha and more than 4100 Gg of grain annually during 1890 to 1899 (Salmon et al., 1953). In the process, Red Fife fostered the settlement of the region, the founding of towns and railroads, and the development of large flour industries (Ball, 1930).

The only major contemporary cultivar of Red Fife was 'Haynes Bluestem', and "a large proportion of the farmers of this region know no wheat which does not belong to one of these types" (Carleton, 1900b). However, Haynes Bluestem was not well adapted. "In the Great Plains area, it always has been a poor yielder owing to its late maturity..." (Clark and Martin, 1922).

Red Fife continued to dominate the region until its offspring, Marquis, was introduced in 1912 (Clark and Martin, 1922). Marquis rapidly replaced most of the Red Fife: by 1919, it increased to 67% and Red Fife declined to 4% of the U.S. hard red spring wheat area (Clark et al., 1922). Another Red Fife offspring, 'Preston' ('Ladoga' × Red Fife), was second at 13%.

Objections to Hard Red Spring Wheat

Early growers of Red Fife, "the first truly hard red spring wheat known on this continent" (Ball, 1930), were the first to encounter objections to their grain that were later faced by producers of hard red winter wheat and then durum wheat. According to Carleton (1915), hard red spring wheat, now

Fig. 2. David A. Fife, who selected Red Fife hard red spring wheat. Photograph courtesy of the Canadian Agricultural Hall of Fame Association.

ranked the finest class for baked goods, was "...a 'despised' wheat and considered quite unfit for making bread" when it was introduced. The stone burrs used at the time were unable to grind hard wheat satisfactorily or to separate the bran, and consumers disdained the flour. As a consequence, the grain was heavily discounted by millers (Ball, 1930).

Introduction of the purifier from France to the United States in 1870, invention of steel rollers in 1878, and technology for tempering the grain eventually enabled millers to process hard wheats of all classes (Ball, 1930). Millers' experience with hard red spring wheat facilitated their use of the even more difficult hard red winter wheat and durum wheat when they were later introduced (Carleton, 1915). However, the other classes were still discounted when they came on the market.

Origin of Red Fife Spring Wheat

The origin of Red Fife wheat is undetermined but is widely believed to be in or near the Ukraine. It did not originate in Scotland or Germany, because hard red spring wheat was not grown in those countries (Carleton, 1915). Saunders, who organized Canada's system of experiment stations and conducted much of the country's early research on wheat, concluded that Red Fife was the same as 'Galician' from a province in the Ukraine that has also been a part of Austria and Poland during the past 200 yr (Buller, 1919; Clark, 1936). Introductions by the USDA and Canada from the region in 1904 were identical to Red Fife (Clark et al., 1922). The cultivar was also known as Halychanka in Canada for its supposed source in northwestern Ukraine (Symko, 2002). All of the various strains of Red Fife were regarded as "...similar to the Ghirkas of the Volga region" of Russia by Carleton (1900b).

ESTABLISHMENT OF HARD RED WINTER WHEAT

Background of the Region

Wheat was first grown in Texas in 1833 (Atkins et al., 1960), in Kansas in 1839 (Malin, 1944), and in Nebraska sometime after 1870 (Quissenberry and Reitz, 1974). 'Red May', a soft red winter wheat, was the first cultivar in Texas (Atkins et al., 1960). It was also a leading cultivar in Kansas, along with 'Odessa', 'Little May', 'Zimmerman', and, later, 'Currell' (Clark et al., 1922; Malin, 1944). Soft wheats were favored because of their ease of milling with the stone burrs that were universally used at the time (Heyne, 1987). However, their inadequate hardiness caused frequent crop losses from freezing during winter and drought during spring (Carleton, 1915).

Spring wheat dominated production in Kansas until the 1870s and in Nebraska until the early 1900s because of insufficient cold hardiness of the winter wheats that were available (Salmon et al., 1953). 'Bluestem', Red Fife, and 'Java' were leading spring cultivars in both states (Quissenberry and Reitz, 1974). Late maturity subjected spring wheats to rust diseases and the high temperature and low moisture conditions of summer, and yields were generally low (Clark and Martin, 1922).

'Nicaragua' was the leading durum cultivar in southern parts of the region. Although it was well-adapted, yields were typical of spring-planted wheats and markets were not available (Carleton, 1900b).

Introduction of Turkey Hard Red Winter Wheat

Standard accounts of the introduction of Turkey hard red winter wheat to the Great Plains credit Mennonite settlers from the Ukraine and Crimea to Kansas in 1873 (Carleton, 1915; Ball, 1930; Malin, 1944; Krahn, 1949; Quissenberry and Reitz, 1974; Schmidt, 1974). These pioneers, followers of Menno Simons and originally from the Netherlands, were induced by Catherine the Great to move from Prussia to cultivate untamed lands in southern Russia beginning in 1788 (Krahn, 1949). Revocation of their exemption from military service and other privileges by Czar Alexander II in 1870, a shortage of farmland for their growing colony, and promotion of western U.S. agricultural land by railroads prompted many Mennonites to migrate to North America (Saul, 1974).

The Mennonites, like other pioneers, carried seeds of their familiar crops with them to their new homes (Krahn, 1949; Schmidt, 1974). The Turkey hard red winter wheat brought by the Mennonites, particularly those settling in central Kansas, and their technology for cultivating it proved to be well-adapted to the region. It was also advantageous that Turkey wheat and the people who knew how to grow it migrated together, and the Mennonites' practice of early, deep plowing followed by several light tillage operations eventually became the standard "dry farming" system for winter wheat in the Plains (Carleton, 1915).

Only about half of the Mennonite immigrants to the United States during the period settled in Kansas (Krahn, 1949; Saul, 1974). Those going to other states must also have brought Turkey wheat, but the import to Kansas is considered the significant one (Carleton, 1915; Quissenberry and Reitz, 1974).

Recognition of the Merits of Turkey Wheat

Appreciation of the importance of Turkey wheat and distribution of seed came slowly. The Mennonite colonists were close-knit (Heyne, 1987) and, as asserted by Malin (1944), they did not "...understand even remotely at the time the significance of what they were doing, and it was years afterward before they knew anything unusual had been done." Estimates of the amount of seed brought by the Mennonites differ widely, but supplies were undoubtedly short. They range from a tradition of only one peck (6.8 kg) by each of 24 families (164 kg total) (Malin, 1944) to one bushel (27 kg) by each of the 600 families that immigrated in 1873 (16,000 kg total) (Carleton, 1915; Quissenberry, 1974).

Credit for recognizing the attributes of Turkey wheat is usu-

Fig. 3. Mark A. Carleton, who introduced Kharkof hard red winter wheat and introduced and promoted Kubanka to start the U.S. durum wheat industry. Photograph from Dies (1949) courtesy of the Univ. of North Carolina Press.

ally given to M.A. Carleton (Fig. 3) (deKruif, 1928; Ball, 1930; Clark, 1936; Ball, 1948; Dies, 1949). However, Carleton never claimed credit for the discovery, stating that "...the good qualities of Turkey wheat were not generally known before the close of the last century, 25 yr after its introduction..." (Carleton, 1915). Also, there is no evidence that Turkey wheat was evaluated by him before his comparisons of nearly 1000 cultivars from around the world in Maryland in 1895 and in Kansas in 1896 and 1897 (Carleton, 1900b). His extensive report covers the growth; resistance to rust, cold, and drought; and grain quality of the entries but not their yield.

Two other persons, B. Warkentin (Fig. 4) and C.C. Georgeson (Fig. 5), recognized the merits of Turkey wheat and acted on their knowledge well before Carleton. Their endeavors greatly advanced the spread of Turkey wheat in the central Plains. According to Carleton (1915), "...Warkentin...was chiefly instrumental in introducing the Turkey wheat..." Warkentin was a Mennonite, the son of a Russian miller, who immigrated to Kansas, advised the Mennonite colonists on their travels, and built flour mills in the region where they settled (Haury, 1975) He was "...working among wheat..." as early as age 15 (Haury, 1975) and, as an experienced grainsman, was undoubtedly able to identify wheat cultivars from the appearance of the kernels and to assess their quality by chewing the grain. His awareness of the attributes of Turkey wheat and the need for seed prompted him to arrange for imports from Russia of 10,000 bu (273 Mg) in 1885–1886 and 15,000 bu (409 Mg) in 1900 for distribution to farmers (Quissenberry and Reitz, 1974). The 1885–1886 importation was the first seed lot available for sale to the general public (Coultis, 1920).

Official awareness of the merits of Turkey wheat was even slower than its local recognition. The first hard data on the cultivar's superior yielding ability were obtained by Georgeson, who conducted trials at Kansas State Agricultural College from 1890 to 1898. On 6 Oct. 1890, he received and promptly planted a cultivar labeled Turkey (Steck.) (Georgeson et al., 1891). The cultivar yielded only 14.9 bu/a (1004 kg/ha) the first year, but after 5 more years of trials with superb results, Georgeson et al. (1896) described it as a "heavy yielder" and "... perhaps the hardiest wheat of any we have tested." Turkey was soon proclaimed "the standard hard red wheat" of the college (Georgeson et al., 1896), a step that focused attention on the cultivar. The only earlier evaluation of Turkey wheat that was found was in the Letter of Transmittal to USDA Bulletin 23 (Carleton, 1900a). The item described the drought resistance of Turkey wheat in tests in western Kansas during 1888 to 1893 but, again, gave no yield data.

Fig. 4. Bernhard Warkentin, who introduced and promoted Turkey hard red winter wheat. Photograph courtesy of Bethel College.

Fig. 5. Charles C. Georgeson, who first recognized the superior yielding ability of Turkey hard red winter wheat. Photograph courtesy of Kansas State Univ. Archives.

Introductions of Other Turkey-Type Wheats

The excellent adaptation of Turkey wheat, the Mennonites' success in growing the cultivar, and his comparisons of the climate and soils of the Steppes and Plains motivated Carleton to seek other wheats in Russia (Carleton, 1915). Many writers stress that Carleton had to cajole and even hector USDA officials to allow the trip (deKruif, 1928; Dies, 1949; Isern, 2000). "Carleton won his point simply by bulldozing everybody" (deKruif, 1928). However, the legend is disputed by Fairchild (1938), a college classmate and head of the USDA Section of Seed and Plant Introduction, who asserted, "I was as enthusiastic as Carleton about this expedition."

Carleton introduced 260 cultivars of wheat and other crops to the United States, many of them the result of epic treks as a USDA plant explorer to Russia and Siberia during 1898–1899 and 1900 (Germplasm Resources Information Network, 2005). Among the most important were Crimean and Kharkof Turkey-type hard red winter wheats and Kubanka durum wheat. Crimean excelled as a parent of other cultivars, including 'Kanred' and 'Tenmarq', the first improved wheats developed by selection and hybridization, respectively, by the Kansas Agricultural Experiment Station, and 'Cheyenne', an early cultivar released by the Nebraska Agricultural Experiment Station.

Assessments of the impact of Kharkof are difficult because farmers labeled all hard red winter wheats from Russia as *Turkey*, and statisticians' surveys did not differentiate them. Parker (1935) disparaged the influence of the cultivar as "never replacing much of the acreage of Kansas wheat." However, early Kansas seed growers emphasized Kharkof and were soon producing "...enough seed, if carefully distributed, to plant one-half the total wheat acreage of the State" and "...the problem of wheat improvement in Kansas will have been solved" (TenEyck, 1909). The latter estimate matched that of Carleton (1915), who credited about half of the 1914 Kansas wheat crop to Kharkof. There is no question that Kharkof was important in other states from Texas to Montana (Chilcott and Cole, 1917). Its greater drought hardiness than Turkey expanded winter wheat production in the southern Plains, and its greater cold hardiness enabled Nebraska and Montana to produce winter wheat for the first time (Salmon et al., 1953). According to Carleton (1915), Montana "...has practically been made a wheat state by the use of Kharkof..." By 1919, "...by far the greater part" of the U.S. hard red winter wheat crop was sown with Kharkof (deKruif, 1928), which was considered "...the greatest import this country has ever enjoyed" (Ball, 1948).

This first USDA official survey of wheat cultivars in 1919 found that Turkey-type cultivars occupied 83% of the wheat area in Nebraska, 82% in Kansas, 69% in Oklahoma, and 67% in Colorado (Clark et al., 1922). They were grown in 33 states on 30% of the U.S. wheat area, almost twice that of any other cultivar; accounted for 99% of U.S. hard red winter wheat; and remained the most popular cultivar until 1944 (Quissenberry, 1974; Quissenberry and Reitz, 1974).

Some Dissenting Views

Some writers were skeptical of the standard account of the introduction of Turkey wheat. The reservation of Malin (1944) that the contribution of the Mennonites was "...an accident of history" was only partly factual. The Mennonites had the foresight to relocate to a part of the world that was remarkably similar to their homeland and to bring a highly adapted wheat cultivar with them. The assertion by Malin (1944) that the Mennonites were slow to recognize the significance of Turkey wheat was countered by the import of additional seed by Warkentin during 1885–1886 (Quissenberry and Reitz, 1974), well before scientists were aware of the merits of the cultivar.

The traditional tale of Turkey wheat was termed a myth by Saul (1989). He claimed that Russian records indicated that 'Arnautka', which he variously described as a hard red winter wheat (Saul, 1989) and a "spring hard red wheat" that was adapted for winter planting (Saul, 1974) was imported to Kansas by the Mennonites to start the hard red winter wheat industry. Although settlers might have brought seed, Arnautka did not play a role in establishing hard red winter wheat in the Plains. The cultivar is a durum wheat (Carleton, 1900a, 1915; Salmon and Clark, 1913), which was introduced by the USDA in 1864 and was identical to the cultivar Nicaragua grown in the southern Plains (Clark et al., 1922).

Perhaps the misconception of Saul (1974, 1989) is understandable. Arnautka was grown primarily near the Sea of Azov in the Ukraine, the area that the Mennonites colonized (Salmon and Clark, 1913). Turkey wheat was introduced from the Crimea to the Mennonite colonies in the Ukraine only about 1860 (Carleton, 1915). Durum was known simply as "hard wheat" throughout Europe at the time, because it is the hardest of all classes (Carleton, 1900a). It was also the primary grain for breadmaking in southern Russia, for which it was milled with a smaller quantity of "softer red wheats" that were "fully as hard" as U.S. hard red spring wheat (Carleton, 1900b). Thus, some might confuse Arnautka durum wheat for bread in Russia with hard red wheat for bread in the United States.

ESTABLISHMENT OF DURUM WHEAT

Background of the Region

Durum wheat was introduced into the eastern United States in 1853 and into North Dakota in 1893 (Ball and Clark, 1918). However, it was unadapted to the humid conditions of the East and lacked a market in the Plains, and production remained low until the early 1900s. In addition, the class was heavily discounted and even rejected by millers, who were not equipped to process the hard grain (Ball, 1930).

Introduction of Kubanka Durum Wheat

Production of durum wheat increased markedly after 1900, and "The early development of the industry was due largely to the initiative and vision of M.A. Carleton..." (Salmon et al., 1953). Kubanka, the basis of the industry, was imported by Carleton from the Kirghiz Steppes near Orenburg. Historians commonly state that Carleton "discovered" Kubanka during his 1898–1899 expedition (deKruif, 1928; Ball, 1930; Dies, 1949), and the USDA dates its introduction to the United States as 1900 (Salmon and Clark, 1913). However, the report (Carleton, 1900b) of his 1895–1897 trials in Maryland and Kansas lists Kubanka, a durum with excellent drought resistance from Russia, as one of the entries. Although Carleton did import a large quantity of seed in 1900 (Clark et al., 1922), it appears that he had prior experience with the cultivar, and its introduction to the United States was earlier than is usually stated.

Carleton (1900a) clearly intended Kubanka for the southern Plains into New Mexico, Arizona, and California. A subsequent publication extended the recommended range over most of the High Plains from Mexico to Canada (Carleton, 1901). After the industry was established, Carleton (1915) claimed that "...the need appeared more urgent in the northern Plains states, making it desirable to secure a spring wheat able to resist more extreme conditions."

Carleton vigorously promoted Kubanka. He increased and distributed seed of the cultivar to experiment stations and farmers, disseminated recipes for pasta and other foods, and encouraged millers to purchase the grain (deKruif, 1928; Dies, 1949; Isern, 2000). However, millers did not accept durum wheat willingly. "Durum...met at once with the most violent opposition" and millers, wanting to discourage the new class, alleged that "...Mr. Carleton's enthusiasm has warped his judgement" (Carleton, 1915).

Spread of Durum Wheat

Superior yields of Kubanka over hard red spring wheat prompted farmers to grow durum, but opposition by millers limited the area that they were willing to plant. Production increased from something that "...commercially...did not exist" before the introduction of Kubanka to about 10 million bu (270 Gg) in 1903 (Carleton, 1915) and then soared to 50 million bu (1350 Gg) in 1906 (Ball and Clark, 1918).

The rapid gain in durum followed a widespread epidemic of stem rust in 1904 (Carleton, 1905). The disease destroyed much of the hard red spring wheat in the Dakotas, Minnesota, and Nebraska, causing an estimated 30 to 40% loss in production (Carleton, 1905; Ball and Clark, 1918). Kubanka was unaffected by the epidemic, and the area planted by farmers grew quickly the following years. The increase in production coincided with failures of the durum crop in Europe and the Mediterranean region. Durum wheat from the northern Plains was readily purchased by international buyers and, with growing demand by U.S. markets, was selling at a premium over hard red spring wheat by 1911 (Carleton, 1915).

Kubanka represented "practically all the durum wheat of this country..." by 1914 (Carleton, 1915), and it remained the premier cultivar for nearly 30 yr (Salmon et al., 1953). As production of durum wheat increased in the northern Plains, it virtu-

ally ceased in southern parts of the region when higher-yielding hard red winter wheat cultivars became available (Chilcott and Cole, 1917).

ESTABLISHMENT OF HARD WHITE WHEAT

Background of Hard White Wheat

Hard white wheat (spring and winter) was recognized as a separate class by the Federal Grain Inspection Service of the USDA in 1990. The move was prompted by demonstrated feasibility of the class by agronomists and interest by producers in selling a more competitive commodity on world markets. In response to its official recognition, wheat breeding programs in the Great Plains are devoting 20 to 75% of their effort to the new class, and most of the state experiment stations and several private companies in the region have released one or more cultivars (Lin and Vocke, 2004).

The impetus for white wheat comes from its higher flour extraction rate, greater demand in international markets, better suitability for whole-grain products, and more pleasing taste than red wheat (Paulsen and Heyne, 1981). The major agronomic disadvantage is its susceptibility to preharvest sprouting when the grain ripens under moist, humid conditions (Paulsen and Auld, 2004).

White wheat is not new to the Plains. Many of the early cultivars introduced by settlers had soft, white grain (Carleton, 1915), and several programs released hard white wheat cultivars throughout the years. E.G. Clark, a farmer/breeder who developed early, important hard red winter wheat cultivars such as 'Blackhull' and 'Chiefkan', for instance, released 'Cream' hard white winter wheat in 1972. The cultivar was mostly grown as a specialty crop but was also a source of preharvest sprouting resistance for recent cultivars (e.g., Sorrells and Anderson, 1998). Also, hard white wheat is not unknown to modern breeders in the Plains. Grain color is controlled by genes on three independent loci on the A, B, and D genomes of hexaploid wheat. Since few red wheats are homozygous for red grain on all three loci, many crosses yield a proportion of white-grain progeny. The white wheats were usually discarded by the red wheat breeders.

Beginning of the Hard White Wheat Class

The recent effort with hard white wheat was started by E.G. Heyne (Fig. 6). A 1968 sabbatical in Australia, where only white wheat is licensed for production, inspired him to begin evaluating the hard white winter wheat progeny in his breeding program. Other white wheats came from crosses between the white wheat progeny and hard red winter wheats.

Fig. 6. Elmer G. Heyne, who initiated development of hard white wheat for the Great Plains. Photograph courtesy of Kansas State Univ. Dep. of Communications.

Experimental lines developed by Heyne were tested in statewide and regional trials (e.g., Paulsen et al., 1983). Many of them proved to be well-adapted and high-yielding and to have excellent grain quality. Their major defect was susceptibility to preharvest sprouting, particularly in the eastern part of the region. Because of this problem, production of white wheat was generally recommended for west of the 96th meridian until resistant cultivars were available.

Production of Hard White Wheat

Hard white wheat cultivars occupied about 4.7% of the wheat area in the top five states during 2004 (Lin and Vocke, 2004). Colorado led with 8% followed by Kansas with 4%. About 75% of the white wheat was winter-type and 25% spring-type. Production of the class was promoted by temporary USDA incentives.

The advantages of white wheat, its potential for Asian noodles and Mexican tortillas, and use of the bran in breakfast cereals may increase demand for the class in the future (Lin and Vocke, 2004). However, expansion of the area will require development of improved cultivars, particularly with resistance to preharvest sprouting; production of reliable supplies for overseas markets; and implementation of identity-preserved systems for the grain.

EPITAPHS

Many persons contributed to the establishment of wheat in the Great Plains. Pioneers, farmer/breeders, agronomists, millers, and businesses introduced, adapted, and promoted the crop and made it a success. The efforts of the following persons were crucial to establishing each of the four classes of wheat in the region, however, and they deserve particular recognition.

David A. Fife

Fife (Fig. 2) was born in Scotland in 1805 and immigrated to Canada in 1820 (Symko, 2002). After selecting Red Fife wheat, he continued to farm in Otonabee, ON, until his death in 1877. Fife was posthumously inducted into the Canadian Agricultural Hall of Fame in 1963, and his log cabin became a part of the Lang Pioneer Village Museum. His grave and monument are in Fife's Cemetery near his farm.

Mark A. Carleton

Carleton (Fig. 3) was founding president of the American Society of Agronomy in 1907 and directed much of its early growth (Slate, 1952).

He was born in Ohio in 1866, reared and educated in Kansas, and employed as cerealist and chief of cereal investigations by the USDA from 1894 to 1918 (Paulsen, 2001). Many persons shared the sentiment of Ball (1948) that "To Carleton goes the credit due the discoverer, the pioneer who made our wheat industry what it is today." His impact was so profound that "There is hardly a time when I eat a piece of bread that I don't think of Mark Carleton..." (Pattison, 1951). Carleton's achievements were commemorated by the MGM 1939 movie, "Forgotten Victory," the Hallmark Hall of Fame 1953 program, "Giant of the Meadows," and by two cultivars of oat

(*Avena sativa* L.), one cultivar of durum wheat, and possibly one cultivar of barley (*Hordeum vulgare* L.) named after him by colleagues. He is among 35 persons, including Presidents Washington, Jefferson, and Lincoln, in the Hall of Fame at the National Agricultural Center. Carleton died in poverty in Peru in 1925 (Swanson, 1958). His family was too poor to return his remains to the United States, and he was interred in the public cemetery at Piata, Peru.

Bernhard Warkentin

Warkentin (Fig. 4) was born in the Ukraine in 1847 and came to the United States in 1871 (Haury, 1975). He became a successful businessman in central Kansas, establishing two mills and two banks in the area. He cofounded a Mennonite college and hospital and was a director of several insurance companies and other corporations (Connelley, 1918). Warkentin died on a trip to the Levant in 1908 when he was struck by a pistol shot fired by a passenger in an adjoining compartment of a train from Damascus to Beirut. He is interred in the family mausoleum in Newton, KS.

Charles C. Georgeson

Georgeson (Fig. 5) was born in Denmark in 1851, came to Michigan to go to school in 1873, and served as farm superintendent at Kansas State Agricultural College from 1890 to 1898. The U.S. Secretary of Agriculture sent Georgeson to Alaska in 1898 with instructions to "Treat the country as though it were your own and see what you can do with it" (Anonymous, 1931). He founded the Alaska Agricultural Experiment Station and several branch stations and introduced many new crops. His efforts to develop the territory made him "the father of Alaska agriculture." The Georgeson Botanical Garden at the University of Alaska is named after him. Georgeson retired in 1927 and died in 1931; he is buried in Evergreen Memorial Park near Seattle.

Elmer G. Heyne

Heyne (Fig. 6) was born in Nebraska in 1912; educated in Nebraska, Kansas, and Minnesota; and led the Kansas State University wheat improvement program from 1946 to 1982. During his career, he released 10 wheat cultivars, including 'Newton', which was the most popular cultivar in the United States when he retired. An early cultivar of hard white winter wheat released by the Kansas Agricultural Experiment Station was named after him. Heyne was a Fellow of ASA and CSSA and recipient of the ASA Agronomic Achievement Award, the CSSA DeKalb–Pfizer Crop Science Distinguished Career Award, and the University of Minnesota Outstanding Achievement Award. He initiated the *Annual Wheat Newsletter* in 1954 and edited it until his retirement and edited the 1987 Agronomy Monograph *Wheat and Wheat Improvement*. Heyne died of injuries from an automobile accident in 1997. His remains were cremated.

REFERENCES

Anonymous. 1931. Father of territory's agriculture is called: Man who put midnight sun to work dies. The Alaska Weekly 34:1 (3 Apr. 1931).

Atkins, I.M., K.B. Porter, K. Lahr, O. Merkel, and M.C. Futrell. 1960. Wheat production in Texas. Texas Agric. Exp. Stn. Bull. 948. Texas Agric. Exp. Stn., College Station.

Ball, C.R. 1930. The history of American wheat improvement. Agric. Hist. 4:48–71.

Ball, C.R., and J.A. Clark. 1918. Experiments with durum wheat. USDA Bur. Plant Ind. Bull. 618. U.S. Gov. Print. Office, Washington, DC.

Ball, J.W. 1948. Grain hunters of the West. Nations Bus. 36(9):54–60.

Buller, A.H.R. 1919. Essays on wheat. The MacMillan Co., New York.

Carleton, M.A. 1900a. Russian cereals adapted for cultivation in the United States. USDA Div. Bot. Bull. 23. U.S. Gov. Print. Office, Washington, DC.

Carleton, M.A. 1900b. The basis for the improvement of American wheats. USDA Div. Veg. Phys. Path. Bull. 24. U.S. Gov. Print. Office, Washington, DC.

Carleton, M.A. 1901. Macaroni wheats. USDA Bur. Plant Ind. Bull. 3. U.S. Gov. Print. Office, Washington, DC.

Carleton, M.A. 1905. Lessons from the grain rust epidemic of 1904. USDA Farmers' Bull. 219. U.S. Gov. Print. Office, Washington, DC.

Carleton, M.A. 1915. Hard wheats winning their way. p. 391–420. *In* 1914 Yearbook of the USDA. U.S. Gov. Print. Office, Washington, DC.

Chilcott, E.C., and J.S. Cole. 1917. Growing winter wheat on the Great Plains. USDA Farmers' Bull. 895. U.S. Gov. Print. Office, Washington, DC.

Clark, J.A. 1936. Improvement in wheat. p. 207–302. *In* 1936 Yearbook of the USDA. U.S. Gov. Print. Office, Washington, DC.

Clark, J.A., and J.H. Martin. 1922. The hard red spring wheats. USDA Farmers' Bull. 1281. U.S. Gov. Print. Office, Washington, DC.

Clark, J.A., J.H. Martin, and C.R. Ball. 1922. Classification of American wheat varieties. USDA Bull. 1074. U.S. Gov. Print. Office, Washington, DC.

Clarke, J.W. 1860. Characteristics of "Fife" spring wheat. Country Gentleman 16:282–283.

Connelley, W.E. 1918. A standard history of Kansas and Kansans. Lewis Publishing Co., Chicago, IL.

Coultis, H.P. 1920. The introduction and development of hard red winter wheat in Kansas. p. 217–219. *In* Wheat in Kansas. Kansas State Board of Agriculture, Topeka.

Cox, T.S. 1991. The contribution of introduced germplasm to the development of U.S. wheat cultivars. p. 25–47. *In* Use of plant introductions in cultivar development. CSSA Spec. Publ. 17. CSSA, Madison, WI.

Dalrymple, D.G. 1988. Changes in wheat varieties and yields in the United States, 1919–1984. Agric. Hist. 62:20–36.

deKruif, P. 1928. The wheat dreamer Carleton. p. 2–30. *In* Hunger fighters. Harcourt, Brace & World, New York.

Dies, E.J. 1949. Mark A. Carleton, wheat explorer. p. 141–149. *In* Titans of the soil. Univ. of North Carolina Press, Chapel Hill.

Fairchild, D. 1938. The world was my garden: Travels of a plant explorer. Charles Scribner's Sons, New York.

Georgeson, C.C., F.C. Burtis, and D.H. Otis. 1896. Experiments with wheat. Kansas State Agric. College Bull. 59, Manhattan.

Georgeson, C.C., H.M. Cottrell, and W.M. Shelton. 1891. Experiments with wheat. Kansas State Agric. College Bull. 20, Manhattan.

Germplasm Resources Information Network. 2005. Accessions with Carleton, M., USDA-Bureau of Plant Industry as source. Available at www.ars-grin.gov (verified 29 Jan. 2008). USDA-ARS National Plant Germplasm System, Beltsville, MD.

Haury, D.A. 1975. Bernhard Warkentin: A Mennonite benefactor. Mennonite Quart. Rev. 49:179–202.

Heyne, E.G. 1987. The development of wheat in Kansas. p. 41–56. *In* G.E. Ham and R. Higham (ed.) The rise of the wheat state. Sunflower Press, Manhattan, KS.

Isern, T.D. 2000. Wheat explorer the world over: Mark Carleton of Kansas. Kans. Hist. 23:12–25.

Joppa, L.R. 1988. Genetics and breeding of durum wheat in the United States. p. 47–68. *In* G. Fabriana and C. Lintas (ed.) Durum wheat chemistry and technology. Am. Assoc. of Cereal Chemists, St. Paul, MN.

Kansas Wheat Commission. 2006. Uses of wheat. Available at www.kswheat.com (verified 29 Jan. 2008). Kansas Wheat Commission and Kansas Assoc. of Wheat Growers, Manhattan.

Krahn, C. 1949. From the Steppes to the prairies. Mennonite Publication Office, Newton, KS.

Lin, W., and G. Vocke. 2004. Hard white winter wheat at a crossroads. Publ. WHS-04K-01. Available at www.ers.usda.gov (verified 29 Jan. 2008). USDA Economic Research Service, Washington, DC.

Malin, J.C. 1944. Winter wheat in the golden belt of Kansas. Univ. of Kansas Press, Lawrence, KS.

Morrison, J.W. 1960. Marquis wheat: A triumph of scientific endeavor. Agric. Hist. 34:182–188.

National Agricultural Statistics Service. 2005. Wheat: Area, yield, and production by major states, 1991–2005. Available at www.nass.usda.gov (verified 29 Jan. 2008). USDA, Washington, DC.

Olmstead, A.L., and P.W. Rhode. 2002. The red queen and the hard reds: Productivity growth in American wheat, 1800–1940. Publ. W8863. Available at http://papers.nber.org (verified 29 Jan. 2008). National Bureau of Economic Res., Washington, DC.

Parker, J.H. 1935. Wheat improvement in Kansas, 1874–1934. p. 139–164. *In* Twenty-ninth biennial report. Kansas State Board of Agriculture, Topeka.

Pattison, E.E. 1951. The world as I seed it. p. 322–333. *In* The Empire Club of Canada speeches. Available at www.empireclubfoundation.com (verified 29 Jan. 2008). The Empire Club Foundation, Toronto, Canada.

Paulsen, G.M. 2001. The agronomic legacy of Mark A. Carleton. J. Nat. Resour. Life Sci. Educ. 30:120–123.

Paulsen, G.M., and A.S. Auld. 2004. Preharvest sprouting of cereals. p. 199–219. *In* R.L. Benech-Arnold and R.A. Sanchez (ed.) Handbook of seed physiology. The Haworth Press, Binghamton, NY.

Paulsen, G.M., and E.G. Heyne. 1981. Development of hard white winter wheats for the Great Plains. WheatGrower 4(5):26–28.

Paulsen, G.M., E.G. Heyne, T.L. Walter, and R.C. Hoseney. 1983. Agronomic and quality attributes of sibling hard red and hard white winter wheats. Crop Sci. 23:859–862.

Quissenberry, K.S. 1974. Let's talk Turkey. Trans. Kans. Acad. Sci. 77:135–144.

Quissenberry, K.S., and L.P. Reitz. 1974. Turkey wheat: The cornerstone of an empire. Agric. Hist. 58:98–110.

Salmon, C., and J.A. Clark. 1913. Durum wheat. USDA Farmers' Bull. 534. U.S. Gov. Print. Office, Washington, DC.

Salmon, S.C., O.R. Mathews, and R.W. Leukel. 1953. A half century of wheat improvement in the United States. Adv. Agron. 5:1–151.

Saul, N.E. 1974. The migration of the Russian–Germans to Kansas. Kans. Hist. Q. 40:38–62.

Saul, N.E. 1989. Myth and history: Turkey red wheat and the "Kansas miracle." Heritage of the Great Plains 22:1–13.

Schmidt, J.W. 1974. Turkey wheat: A Mennonite contribution to Great Plains agriculture. Mennonite Life 30:67–69.

Slate, W.L. 1952. Agronomic research: Old and new. Agron. J. 44:1–3.

Sorrells, M.E., and J.A. Anderson. 1998. Registration of 'Cayuga' wheat. Crop Sci. 38:551–552.

Swanson, A.F. 1958. Mark Alfred Carleton: The trail's end. Agron. J. 50:722–723.

Symko, S. 2002. From a single seed: Tracing the Marquis wheat success story in Canada to its roots in the Ukraine. Available at www.agr.gc.ca (verified 29 Jan. 2008). Agric. Agri-Food Canada, Ottawa, ON, Canada.

TenEyck, A.M. 1909. Distribution of improved seed wheat. Kansas State Agric. College Press Bull. 172, Manhattan.