The Agronomic Legacy of Mark A. Carleton

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MARK A. CARLETON is known by members as the first president of the American Society of Agronomy. However, he also shaped development of the hard red winter wheat (*Triticum aestivum* L.) and durum wheat (*T. turgidum* L. var. *durum*) industries in the USA. The objective of this article is to describe Carleton's agronomic legacy: introduction of adapted wheat cultivars, dryland production of wheat, investigations of wheat diseases, and scientific knowledge of wheat. Carleton was the first scientist to recognize the superiority of 'Turkey' hard red winter wheat, which came to dominate the central and southern Great Plains; introduced 'Kharkof' wheat, which became an important cultivar in the central and northern Plains; introduced 'Crimean' wheat, which was a parent of many early improved cultivars; and introduced 'Kubanka' and promoted its production to start the durum wheat industry in the northern Great Plains. He gave the common name to leaf rust (caused by *Puccinia recondita* f. sp. *tritici*), determined the physiological relationships among known races of leaf rust and stem rust (caused by *P. graminis* f. sp. *tritici*), and was among the first to investigate fungicides for controlling rust diseases. Research directed by Carleton developed suitable methods of dryland farming for the Great Plains and established the relationship between soil moisture and gluten quality of wheat. His publications were a blueprint for development of the U.S. wheat industry, and his book, *The Small Grains*, became a classic.

Members of the American Society of Agronomy should be aware of Carleton's achievements because he was considered the most respected agronomist in the USA during his career (Isern, 2000), and he defined the profession in principle and in practice (e.g., Carleton, 1907–1909, 1915a). It is particularly appropriate to recognize his agronomic legacy because of the controversy that surrounded latter aspects of Carleton's life (de Kruif, 1928).

INTRODUCTION TO THE LEGACY

Carleton was born in Ohio in 1866, reared in Kansas, and earned a B.S. degree in agriculture from Kansas State Agricultural College (KSAC) (now Kansas State University) in 1887. After teaching at Garfield University (now Friends University) at Wichita from 1888 to 1890, he returned to KSAC for an M.S. degree, which was conferred in 1893. He then was assistant botanist at KSAC until 1894, when he transferred to the USDA and served his most productive years as cerealist and chief of cereal investigations.

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A small group of persons, including Carleton, met at the University of Chicago on 31 Dec. 1907, to form the American Society of Agronomy (Slate, 1952). Carleton had conducted much of the correspondence that led to organization of the Society and was unanimously selected as its first president (Ball and Warburton, 1925). The early growth and development of the Society were greatly influenced by him.

An extraordinary agronomic legacy was left by Carleton in addition to his contributions to the American Society of Agronomy. Carleton, more than any other person, shaped the early hard red winter wheat and durum wheat industries in the USA. As noted by Parker (1935), "Hard red winter wheats are a monument to the far-sightedness of M.A. Carleton in agronomy, plant pathology, and plant breeding," and according to Salmon et al. (1953), "The early development of the (durum) industry was due largely to the initiative and vision of M.A. Carleton." Ball (1948) concluded that "To Carleton goes the credit due the discoverer, the pioneer who made our wheat industry what it is today."

BACKGROUND OF THE LEGACY

An understanding of Carleton's contributions must be placed in the context of Great Plains agriculture during the late 19th and early 20th centuries. Settlers from the eastern USA and western Europe had homesteaded the region, bringing the seeds and technology for growing crops from their native lands. Many types of wheat were introduced, most of them ill-adapted to the environment, and the settlers' familiar farming practices were mostly inappropriate for Great Plains conditions. Spring wheat predominated in the region, and soft wheat was favored because of its ease of milling (Heyne, 1987).

Two important advances in production of wheat in the central and southern Great Plains occurred during the 1870s. Turkey hard red winter wheat from the Crimea was introduced to central Kansas by Mennonite settlers from the Ukraine in 1873. The new cultivar was well adapted—winter hardy, drought resistant, and produced excellent quality grain for baked products. The invention of the steel roller mill in 1878 facilitated milling of the new cultivar and eliminated widespread discounts on hard grain (Heyne, 1987).

Durum wheat was a minor crop in the northern Great Plains at the turn of the century, with only about 2500 Mg of grain produced in 1901 (Salmon et al., 1953). The only cultivar that was grown commercially was 'Arnautka', which was brought to the Dakotas by immigrants from Russia sometime before 1898 (Clark, 1936).

Technology for wheat production was labor-intensive and crop failures were frequent. Information was particularly needed on seedbed preparation, conservation of soil moisture, and control of pests. However, "A farmer was much more likely to consult his almanac than the experiment station to determine when to sow wheat…" (Salmon et al., 1953).

Abbreviations: KSAC, Kansas State Agricultural College; KAES, Kansas Agricultural Experiment Station.

A LEGACY OF HARD RED WINTER WHEAT

Initial spread of Turkey wheat in the Great Plains was slow, because the Mennonite community in Kansas was close-knit and seed of the new cultivar was scarce (Heyne, 1987). Carleton was widely acknowledged as the first scientist to recognize the advantage of Turkey wheat (Ball, 1930, 1948; Clark, 1936). He probably became acquainted with the cultivar when he was at Garfield University, which is near the area where the Mennonites settled. Carleton had a keen eye for variation in plants and led university expeditions to collect specimens in the area (Carleton, 1891–1892a, 1891–1892b). However, he never claimed credit for identifying the value of Turkey, stating only that "…its merits did not become generally known until about 1890" (Carleton, 1916).

The Kansas Agricultural Experiment Station (KAES) compared Turkey with several popular soft red winter wheat cultivars and reported it as "…coming to the front as a heavy yielder" and "…perhaps the hardiest wheat of any we have tested" (Georgeson et al., 1896). Official recognition of its superiority and serious freeze damage to other cultivars during the late 1890s prompted general acceptance of Turkey. By 1919, when the first official cultivar survey was made, Turkey occupied more than 82% of the Kansas wheat area. It remained the most popular cultivar in the state until 1939 and in the USA until 1944. Today, hard red winter wheat is the most important class in the USA, being grown on more than 40% of the country's wheat area.

The excellent adaptation of Turkey to the Great Plains motivated Carleton to seek other useful cultivars in Russia (Carleton, 1897). In expeditions to there and Siberia for the USDA during 1898–1899 and 1900, he returned with many new crops, including Kharkof and Crimean hard red winter wheat and Kubanka durum wheat (Carleton, 1900a). Carleton established ties with state agricultural experiment stations to test the new cultivars, a course that was unprecedented in the USDA (Isern, 2000). Kharkof became a popular cultivar in its own right in the Great Plains. Official surveys are unavailable, however, because farmers and statisticians commonly labeled all cultivars from Russia as *Turkey*. Estimates of the area credited to Turkey that was actually occupied by Kharkof range from about half of the Kansas wheat crop in 1914 (Carleton, 1915a) to 20% in 1919 (Anonymous, 1920). Kharkof also expanded the hard red winter wheat region into Nebraska and Montana, where spring wheat predominated into the 1900s, because of its greater winter hardiness than Turkey (Salmon et al., 1953). According to Carleton (1915a), Montana "…has practically been made a wheat state by the use of Kharkof…", and by 1919, "…by far the greater part" of the U.S. crop of hard red winter wheat was sown with Kharkof (de Kruif, 1928). Ball (1948) considered Kharkof "…the greatest import this country has ever enjoyed."

Crimean became an important cultivar in the Great Plains and excelled as a parent of other cultivars. 'Kanred', the first improved cultivar released by the KAES (in 1917), and 'Cheyenne', an early, important cultivar developed by the Nebraska Agricultural Experiment Station (in 1930), were direct selections from Crimean. A selection from Kanred, P-1066, was a parent of 'Tenmarq', the first improved cultivar from hybridization released by the KAES (in 1932).

A LEGACY OF DURUM WHEAT

Annual production of durum wheat in the USA increased from its low point in 1901 to about 1 850 000 Mg on 2 100 000 ha in North Dakota and surrounding states during 1925–1929 (Salmon et al., 1953). This dramatic increase was due almost solely to the initiative of Carleton (Ball, 1930; Clark, 1936). In addition to introducing Kubanka in 1900, he also brought additional supplies of Arnautka from Russia, increased and distributed seed of both cultivars in the Dakotas, and promoted production of the new wheat class by farmers (Carleton, 1901a; Salmon et al., 1953). Kubanka became the most popular durum cultivar and the standard for rating the quality of all other cultivars (Salmon et al., 1953). The cultivar was so popular that it was usually known as *durum wheat*, and it continued to dominate production into the 1940s (Joppa, 1988).

Kubanka was as important for developing improved cultivars as for producing grain. 'Nudak' from North Dakota, 'Mondak' from North Dakota and Montana, and 'Acme' from South Dakota were direct selections from Kubanka. One of the first improved cultivars of durum wheat developed by hybridization by the North Dakota Agricultural Experiment Station was named after Carleton in 1943.

A LEGACY OF DISEASES OF WHEAT

Carleton's abiding interest was stem rust of wheat. His early investigations also concerned leaf rust, and Chester (1946) credited Carleton (1899) with coining the common name for the disease. However, Carleton was not convinced that the disease was a problem.

According to legend, Carleton began studying the rust diseases on his parent's farm at the age of 11 and was a self-trained botanist when he entered college (Ball, 1948). The thesis for his M.S. degree concerned germination of rust spores (Carleton, 1893a, 1893b), and his early work as a scientist was among the first in the USA to evaluate fungicides for control of rust diseases on cereals (Hitchcock and Carleton, 1893, 1894).

Carleton's greatest contribution to knowledge of rust diseases was in determining their physiological relationships. He was among the early workers who noted that cereal cultivars were resistant to rust diseases in some countries and susceptible in other countries, a phenomenon that was previously attributed to differences in the constitution of plants from changes in the climate (Chester, 1946). Concurrent with scientists in Sweden, Hitchcock and Carleton (1894) concluded that their experiments "…seem to show that the rusts of various cereals are probably physiological species," which was among the first recognition that differences in susceptibility were due to specialization of the causal organism. After establishing the physiological relationships among most of the rust diseases in the USA, Carleton went on to demonstrate that cereal cultivars reacted differently to the fungi and ranged in susceptibility to them (Carleton, 1899). His work with rust diseases made Carleton "…the leading plant pathologist of America" (de Kruif, 1928).

The work of Carleton with rusts contributed greatly to understanding host–parasite relationships and improving disease

resistance of cereals. However, some of his inferences were erroneous. He considered leaf rust to be benign and even beneficial because preventing excessive foliage aided growth of the grain (Carleton, 1899). His influence caused other scientists to feel that they were "…wasting much time attending to the spotting rust" in their breeding programs (Chester, 1946). Carleton also believed that the transition from spring wheat to winter wheat had largely eliminated the problems of rust diseases in the Great Plains, and he advocated that only one cultivar should be grown in a locality or state (Carleton, 1915b). Today, of course, rusts continue to be important diseases, and genetic vulnerability to new races is a major cause of the profusion of wheat cultivars.

A LEGACY OF PRODUCING AND PROCESSING WHEAT

Technology for producing and processing wheat was as deficient as suitable cultivars for the Great Plains during the late 19th century. In an early publication, Carleton (1897) realized the limitations of soil moisture and advocated deep, early plowing; fine, mellow seedbed; rough soil surface; and early sowing of appropriate cultivars. He also recommended the *new feature* of hybridization to add vigor to self-pollinated wheat and introduction of new seed to counter *running out* of cultivars.

His expeditions to Russia to collect seeds of new crops also familiarized Carleton with production conditions that were even more extreme than in the Great Plains. Peasants in Russia, through long practice, had learned to cope with drought, harsh temperatures, and other adversities, and those experiences made them especially successful at growing wheat when they immigrated to the USA. Carleton (1900a) made detailed notes of the climate in Russia and Siberia, where he collected seeds and of the methods used by farmers to till the soil, sow the seed, and harvest the grain.

Carleton applied his experiences in Russia to improving wheat production in the USA when he was named chief of cereal investigations by the USDA in 1901. The Bureau of Plant Industry of the USDA initiated a Dryland Agriculture Program, and Carleton directed much of the research on farming methods in semiarid areas of the USA (Carleton, 1901c, 1915b). The recognition of the relationship between soil moisture and gluten content and quality of wheat was an important result (Ball and Warburton, 1925).

Establishing durum as a new crop presented several problems (Carleton, 1901b). Besides increasing and distributing seed of adapted cultivars, farmers in the Dakotas had to be convinced to grow the new class of wheat. The campaign was facilitated by Carleton's vigorous promotion of durum and failure of the hard red spring wheat in the region from an epidemic of stem rust (Carleton, 1905; Clark, 1936). Carleton also directed extensive milling and baking tests to determine the quality of durum produced in the northern Plains (Carleton and Chamberlain, 1904). However, millers, who were accustomed to producing flour for pasta from common wheat, had to be persuaded to accept the extremely hard durum (Carleton, 1915a). Early harvests were mostly exported to Europe and some even went to Russia in 1905. By 1911, however, domestic millers had largely accepted durum, even at premium prices.

A LEGACY OF KNOWLEDGE OF WHEAT

Four publications among those authored by Carleton stand out. The first paper reported the physiological relationships among the known races of stem rust (Carleton, 1899). The second publication was termed a *foundation paper* by Ball (1930), because it provided the basis for much of the subsequent development of the U.S. wheat industry. In the paper, Carleton (1900b) summarized his evaluation of the resistance of nearly 1000 cultivars of wheat to rust, drought, and cold as well as their grain quality traits. He also analyzed the characteristics of the different regions of the U.S. for producing wheat, the classes of wheat that were suited for each region, and the cultivar traits that were required for adaptation of each class. The analysis, in retrospect, was a blueprint for much of Carleton's subsequent efforts with wheat.

Although it appeared 3 yr before Carleton's career with wheat ended, an article in the 1914 *Yearbook of the USDA* was an epilogue of his accomplishments (Carleton, 1915a). The article described the development of the hard wheat industries in the USA—the introduction, adaptation, and characteristics of important cultivars; acceptance of the different classes by millers; and the impact on national production and marketing. Of the three classes of hard wheat in the USA (hard red spring, hard red winter, durum), Carleton had played a major role in two of them that accounted for more than half of the wheat in the country, and cultivars identified by him (Turkey, Kharkof, Kubanka) dominated production of those classes.

One of Carleton's final publications was his tome, *The Small Grains* (Carleton, 1916). A review called the book "interesting…commendable…very good" and "suitable for…colleges and every cereal farmer's library" (Hayes and Olson, 1917). The book was the most comprehensive and current text of its time, covering the major small-grain cereals and their morphology, nutrition, improvement, adaptation, cultivation, pests, and uses. His immediate experience and national perspective made Carleton uniquely qualified to author the book.

IMPACT OF THE LEGACY

Mark A. Carleton, as an organizer and first president of the American Society of Agronomy, influenced generations of agronomists. His accomplishments as an agronomist also benefitted many generations of other persons—wheat growers, millers, bakers, and consumers. One must agree with Parker that "Grain growers, the grain trade, and the grain processing industry in the United States owe an incalculable debt of gratitude to Mark Alfred Carleton" (Swanson, 1958).

The legacy of Carleton's contributions persists today. Hard red winter wheat and durum wheat are still major crops in the Great Plains and main sources of livelihoods for farmers, their families, and their communities. Modern cultivars of hard red winter wheat are greatly changed, but half of their genes still trace to Turkey and Kharkof (Cox, 1991). The durum wheat industry, which was largely created by Carleton, remains an important enterprise in the northern Great Plains. Kubanka, the original cultivar, has been displaced but is still the foundation of modern durums and the standard for rating their quality (Joppa, 1988).

Other crop introductions by Carleton had mixed success. 'Swedish Select' oat (*Avena sativa* L.), which was introduced from Russia in 1898 (Carleton, 1910), became the most pop-

ular cultivar in the Upper Midwest but diminished in importance as tractors replaced horses on farms (Isern, 2000). Emmer wheat (*T. dicoccum* Schrank), which was promoted as a feed grain, never caught on because other species were more productive (Carleton, 1910a; Isern, 2000).

Carleton did not share in the benefits of his legacy. Pyramiding debts to colleagues and grain dealers that began with the death of one child and hospitalization of another created a scandal that led to his resignation from the USDA in 1918 (Isern, 2000). His family lost their home and, brokenhearted, he drifted to a series of minor agricultural posts in Central and South America (Ball, 1948). He struggled to repay his obligations but died of heart disease exacerbated by acute malaria in Peru in 1925, "…most miserably neglected" and "…among almost total strangers, far from his family, friends, and native land" (de Kruif, 1928; Swanson, 1958). He is interred in the small village of Paita in Peru, with "…no memorial…proclaiming what he did for his home country" (Isern, 2000).

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REFERENCES

Anonymous. 1920. Analysis of data on wheat production in Kansas. p. 16–138. *In* Wheat in Kansas. Kansas State Board of Agric., Topeka, KS.

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

Ball, C.R., and C.W. Warburton. 1925. Mark Alfred Carleton. J. Am. Soc. Agron. 17:514–516.

Ball, J.W. 1948. Grain hunters of the west. Nation's Business 36(9):54–60.

Carleton, M.A. 1891–1892a. Variations in dominant species of plants. Trans. Kansas Acad. Sci. 13:24–28.

Carleton, M.A. 1891–1892b. List of plants collected by the Garfield University expedition of 1889. Trans. Kansas Acad. Sci. 13:50–57.

Carleton, M.A. 1893a. Studies in the germination of *Uredineae*. M.S. thesis. Kansas State Agric. College, Manhattan, KS.

Carleton, M.A. 1893b. Studies in the biology of *Uredineae*: I. Notes on germination. Bot. Gaz. 18:47–457.

Carleton, M.A. 1897. Improvements in wheat culture. p. 489–498. *In* 1896 Yearbook of the USDA. U.S. Gov. Print. Office, Washington, DC.

Carleton, M.A. 1899. Cereal rusts of the United States: A physiological investigation. USDA Div. Veg. Phys. Pathol. Bull. 16. U.S. Gov. Print. Office, Washington, DC.

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. Pathol. Bull. 24. U.S. Gov. Print. Office, Washington, DC.

Carleton, M.A. 1901a. Emmer: A grain for the semiarid regions. USDA Farmers' Bull. 139. U.S. Gov. Print. Office, Washington, DC.

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

Carleton, M.A. 1901c. Successful wheat growing in semi-arid districts. p. 529–542. *In* 1900 Yearbook of the USDA. 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. 1907–1909. Development and proper status of agronomy. J. Am. Soc. Agron. 1:17–23.

Carleton, M.A. 1910. Ten years' experience with the Swedish Select oat. USDA Bur. Plant Ind. Bull. 182. U.S. Gov. Print. Office, Washington, DC.

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

Carleton, M.A. 1915b. Problems of the wheat crop. J. Am. Soc. Agron. 7:78–84.

Carleton, M.A. 1916. The small grains. The MacMillan Co., New York, NY.

Carleton, M.A., and J.S. Chamberlain. 1904. The commercial status of durum wheat. USDA Bur. Plant Ind. Bull. 70. U.S. Gov. Print. Office, Washington, DC.

Chester, K.S. 1946. The cereal rusts. Chronica Botanica Co., Waltham, MA.

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

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.

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

Georgeson, C.C., F.C. Burtis, and D.H. Otis. 1896. Experiments with wheat. Kansas Agric. Exp. Stn. Bull. 59.

Hayes, H.K., and P.J. Olson. 1917. New books: The small grains. J. Am. Soc. Agron. 9:196–198.

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.

Hitchcock, A.S., and M.A. Carleton. 1893. Preliminary report on rusts of grain. Kansas Agric. Exp. Stn. Bull. 38.

Hitchcock, A.S., and M.A. Carleton. 1894. Second report on rusts of grain. Kansas Agric. Exp. Stn. Bull. 46.

Isern, T.D. 2000. Wheat explorer the world over: Mark Carleton of Kansas. Kansas 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.

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

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.

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

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