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4 Humans, Climate, and Plants: the Migration of Crested Wheatgrass and Smooth Brome grass to the Great Plains of North America

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4.1 Abstract

The cultivation practices that were used in Europe and the eastern half of North America were utilized in the initial settlement of the Great Plains. Unfamiliarity with the climate of the Great Plains and Midwest and insufficient knowledge and technology to adapt crop production systems to the soils and climate lead to a major agriculture disaster which resulted in millions of hectares of land that needed to be re-seeded to grasses. Unrestricted grazing on public lands in the intermountain west resulted in severe rangeland degradation. Lack of knowledge and technology for using native plants and some specific characteristics of native plants that made them difficult to use resulted in the use of crested wheatgrasses and smooth brome grass which had characteristics that met specific revegetation and production requirements. Crested wheatgrass and smooth brome grass plant materials were from regions that were climatic analogs of the Great Plains and were adapted. These two grasses literally preserved the remaining top soil on millions of hectares of land. In the subsequent half-century, agronomist, geneticists, and rangeland scientists have learned how to establish and manage native grasses such as switchgrass (*Panicum virgatum* L.), big bluestem (*Andropogon gerardii* Vitman), indiangrass [*Sorghastrum nutans* (L.) Nash] and others so they are now available for use in revegetation. Although native grasses are available for use in the Great Plains and the Midwest of North America, crested wheatgrass and smooth brome grass are now naturalized North American species and will continue to be vital to the economy of the USA and Canada. Their forage production patterns fits gaps in the forage production cycle for ruminant livestock that cannot be adequately met by native species in regions where brome grass and crested wheatgrasses are well adapted.

4.2 The Plants

Humans throughout history have migrated to new areas and taken their food plants and animals with them (Harlan 1975; Diamond 1997). They also have utilized plants indigenous to the area into which they have migrated. The Great Plains and Midwest of North America were vast grasslands prior to the migration and settlement by people of largely northern European origin. One hundred and fifty years later, significant land areas have been converted to cultivation and are in crop production. Millions of hectares of land also have been planted to crested wheatgrass (*Agropyron* spp.) and smooth brome grass (*Bromus inermis* Leyss.) which are non-native forage and pasture species. The purpose of this report is to describe the interactions of humans, plants, and climate that resulted in the migration and utilization of Eurasian grasses on millions of hectares of North American grasslands. The use and status of these species in North America continue to evolve as humans, plants, and their environment interact.

The genus *Agropyron* has contained many of the species of the perennial Triticeae but in current taxonomy it is restricted to species of the crested wheatgrass complex which is a polyploid series based on the 'P' genome (Asay and Jensen 1996). The genus consists of a series of diploid ($2n=14$), tetraploid ($2n=28$), and hexaploid ($2n=42$) species. The cultivated type species are *A. cristatum* or Fairway crested wheatgrass and *A. desertorum* (Fisch. ex Link) Schultes or Standard crested wheatgrass. The Standard type has been the most widely used in the USA; the Fairway type has been used in Canada in addition to the Standard type. Crested wheatgrasses are persistent, long-lived perennial bunchgrasses adapted to temperate sites receiving 200 to 450 mm of annual precipitation. The inflorescence is a spike, and culms range in height from 15 to more than 100 cm. Crested wheatgrasses are native to the steppe region of European Russia and southwestern Siberia (Asay and Jensen 1996). Crested wheatgrasses were apparently first cultivated in the Volga district east of Saratov (Asay and Jensen 1996). Crested wheatgrasses have excellent seed production and the seed is easy to harvest, clean, and plant. They have excellent seedling vigor, drought and cold resistance, and can tolerate heavy grazing. In areas where they are adapted, they typically produce equivalent or greater forage yields and livestock carrying capacity than native rangelands.

Smooth brome grass is a leafy, tall-growing, sod-forming perennial cool-season grass adapted to temperate regions (Vogel et al. 1996). The commonly grown form of smooth brome grass is an autoallooctaploid with a chromosome number of $2n=56$ while the lesser used tetraploid ($2n=28$) is an allotetraploid. The flowering culms are 50 to 100 cm in height. The inflorescence is a panicle that is erect and 7 to 20 cm long with whorled branches, and becomes contracted and purplish brown at maturity (Vogel et al. 1996). It is of Eurasian origin and it is a polymorphic species which can be divided into several subspecies or ecotypes that are related to their origin (Tsvelev 1984). Zerebina (1931, 1933, 1938), whose research was subsequently summarized by Knowles and White (1949), recognized two main ecological-geographical groups: the "meadow" group or northern climatype, and

the "steppe" group or southern climatype. Descriptions of these groups correspond to the northern and southern types of smooth brome grass later recognized in North America (Newell and Keim 1943). The meadow types were found from Murmansk in the north to the Caucasus in the south, although south of the central Chernozem region they were found only in valleys and moist habitats. The steppe type was found with the meadow type in the central Chernozem region and was the principal ecotype in the dry steppe areas of the mid and lower Volga districts, Kazakhstan, the northern Caucasus, the eastern Ukraine, and the southern Altai regions of the former USSR. Smooth brome grass is widely adapted because of the ecotypic variation that exists in the species in its native range. It is similar to the crested wheatgrasses in that it is an excellent seed producer, seed is easy to harvest and clean, and it has excellent seedling vigor and establishes rapidly. It can tolerate mismanagement and heavy grazing pressure and is very productive if well managed. It is not as drought tolerant as crested wheatgrass but has better drought tolerance than other mesic cool-season grasses such as perennial ryegrass (*Lolium perenne* L.), timothy (*Phleum pratense* L.), or cocksfoot (*Dactylis glomerata* L.; Vogel et al. 1996). It produces significantly more forage than crested wheatgrasses in regions where annual precipitation exceeds 500 mm.

4.3 Settlement, Agriculture and War

The Great Plains of the United States were settled by people of largely northern European origin (Morison 1965). The Midwest was settled from about 1820 to 1865 (Morison 1965). The conclusion of the American Civil War in 1865 marked the beginning of the primarily settlement period of the Great Plains which ended about 1900 (Morison 1965). When the prairies and grasslands were first settled, there were abundant grasslands for farmers' cattle and horses. Farmers plowed areas of their farms for grain crop production, primarily maize, oats, and wheat, but retained grasslands for use by their livestock. Although the crops that the settlers brought with them were adequately adapted to the Great Plains, the production systems that the settlers brought with them were not. These systems involved yearly plowing and intensive cultivation for weed control. This left the soil bare and subject to wind and water erosion.

In the prairies and plains of these sections of North America, most of the grasslands contained grasses which had the C_4 photosynthesis system. These warm-season grasses did not have the production patterns of cool-season or C_3 grasses to which the settlers were accustomed (Moser and Vogel 1995). Warm-season grasses start growing 4 to 6 weeks later in the spring than cool-season grasses and go dormant as temperatures drop in the autumn. They require different management than cool-season grasses. As a result, the native pastures were often mismanaged and overgrazed and gradually were reduced in productivity. Farmers wanted new pasture plants that could produce more forage than the native grassland and which would provide grazing in spring and autumn. Plant explorers were

employed by the United States Department of Agriculture (USDA) to collect plant material for use in these and other regions of the United States.

The demand for grain crops including wheat before and after World War I resulted in additional millions of hectares of land being plowed during the period 1905 to 1920 and used for grain production (Dillman 1946). This included land in marginal crop production areas that had not been converted to grain crop agriculture in the initial settlement period. Prices for grain crops were high and climatic conditions were favorable for grain crop production which encouraged farmers to convert grasslands to cultivated croplands.

4.4 Disaster - The Drought of the 1930s

In the 1930s or the “Dust Bowl” era, a major drought affected large parts of North America resulting in massive soil erosion problems, particularly on lands that were only marginally suited for crop production. In seven of the ten years between 1928 and 1937, average annual precipitation was below the long-term average (Lorenz 1986). The drought resulted in severe wind erosion and soil drift onto cropland, and loss of plants on overgrazed grasslands. By the end of the 1930s millions of hectares of land in the former prairie and plains states of the USA and Canadian provinces needed to be reseeded to grasslands to preserve the soil and the ecosystems. This drought resulted in the realization that considerable land had been plowed that needed to be rapidly converted into grasslands, and severely damaged grasslands needed to be restored by reseeding.

There were problems with using native species. Native grasslands had been abundant and common and as a result almost no information was available on seed production and establishment of native species. Many of the native species have seed with chaffy appendages which made harvesting, cleaning, and planting difficult and only limited amounts of seed could be obtained from native harvests (Cornelius 1950; Masters et al. 1993). Research was initiated on native grasses beginning in the mid-1930s but a more immediate solution to the revegetation problem was needed. The introduced species that survived the drought, had good seed yields, and that could be readily established were smooth brome grass and the crested wheatgrasses. Grasses such as cocksfoot and timothy often did not survive the drought in the midwestern USA. After their introduction in the late 1880s, experiment stations in both the USA and Canada had evaluated the available germplasm and made selections. Research had been conducted on seed production, establishment, forage production, and grazing management. By the end of the 1930s, plant materials and the associated technology were available for a rapid increase in use of the species (Dillman 1946; Lorenz 1986; Rogler and Lorenz 1983; Newell 1973; Vogel et al. 1996).

4.5 Crested Wheatgrass Story

Crested wheatgrasses were first introduced into North America in 1892 by N.E. Hansen of the South Dakota Experiment Station (Dillman 1946; Rogler and Lorenz 1983; Lorenz 1986). Hansen was born in Denmark in 1866 and immigrated with his family at the age of seven to the USA (Taylor 1941). His family lived in Iowa and he attended Iowa State College (now Iowa State University) where he received B.S. and M.S. degrees. Even as a student, he was interested in the history and migration of plants and their improvement (Taylor 1941). In 1895, he went to South Dakota State College at Brookings, SD, as Professor of Horticulture. While there, he was contracted by USDA to do plant exploration and collection because of his knowledge of plants and languages (Taylor 1941). He was the first official plant explorer for the USDA. In his first collection trip, which was in 1897-1898, he collected five railroad cars of several hundred kinds of grains, grasses, and plants from Russia, Turkestan, China, Siberia, and Transcaucasus. The material, which included seed of crested wheatgrass from the eastern Volga region and Siberia, was shipped to USDA, Division of Seed and Plant Introduction, Washington, D.C., for distribution to experiment stations. On this trip, he also obtained 12 tons of brome grass seed from the Volga region of Russia. This seed was distributed to several experiment stations but no permanent plantings or seed increases of crested wheatgrasses were apparently made (Dillman 1946; Lorenz 1986; Asay and Jensen 1996).

N.E. Hansen received a second importation of crested wheatgrass in 1906 from the Valuiki Experiment Station in Russia which consisted of five *A. desertorum* seedlots (PIs 19537-19541) and one *A. cristatum* seedlot (PI 19536). Seed was distributed to 15 experiment stations (Dillman 1946). The first known research planting of these accessions was at the Belle Fourche, SD, research station in 1908. A.C. Dillman was a USDA agronomist at the station and maintained plantings of the crested wheatgrass from 1908 to 1915. He harvested and supplied seed to other stations including what is now the Agricultural Research Service (ARS), USDA Laboratory at Mandan, ND (Dillman 1946; Rogler and Lorenz 1983; Lorenz 1986). Plantings made in 1915 at Mandan were the foundation from which the initial cultivar released in the United States was developed. Over 100 kg of seeded was distributed to experiment stations and farms in the Dakotas, Montana, and Wyoming from 1920 to 1923 (Dillman 1946). Before the release of the first cultivar, over 1800 kg of seed of four of the better accessions was distributed to farmers for testing (Dillman 1946). The first pasture trial was established in 1923 at the Ardmore, SD, field station and performance trials with dairy cattle were successful (Lorenz 1986). The first grazing trial with beef cattle was established at Mandan, ND, in 1932. The pasture was still in production in 1983 (Rogler and Lorenz 1983; Lorenz 1986). The first farm planting was in Montana. Direct increases in the available accessions were used in the initial plantings of the crested wheatgrasses. The first commercial seed field was started by a farmer near Dickinson, ND, in 1926 and first seed was offered for sale in 1928. This farmer had over 80 ha in seed production when the demand for seed came in 1933 as a result

of government revegetation programs (Lorenz 1986. In the 25- period between 1906 when N.E. Hansen received his second shipment of crested wheatgrass germplasm and 1933, agronomists at several experiment stations developed the basic agronomic information that was needed for it to become a widely utilized grass. The standard crested wheatgrass cultivar "Nordan" was released by the Mandan, ND, station in 1953 and was the most widely used cultivar in the United States for many years (Asay and Jensen 1996).

In Canada, crested wheatgrass research began in 1916 at Saskatoon, Saskatchewan, by L.E. Kirk who at that time was a graduate assistant (Dillman 1946). Seed was obtained from the USA and included PI 19536 and PI 19540 which were among those received by N.E. Hansen in 1906. Other seed lots were sent to Saskatoon at a later date from Mandan, ND. The first crested wheatgrass cultivar, "Fairway" was a mass selection of fine leafy plants from PI 19536 which were harvested in 1925 (Dillman 1946). Breeding work has continued on crested wheatgrass at several research stations in both the United States and Canada and improved cultivars and management practices are periodically documented and released (Asay and Jensen 1996).

4.6 Bromegrass Story

Smooth bromegrass was introduced into the USA and Canada in the 1880s (Newell 1973; Vogel et al. 1996). The first introduction was by the California Experiment Station in 1884 which distributed seed to other experiment stations (Newell 1973). Major introductions were from central Europe including Hungary, northern Germany, and the Russian collections of N.E. Hansen (Taylor 1941; Newell 1973). By the late 1890s bromegrass was being grown in the Midwest and Great Plains of the USA and Canada. Bromegrass identified as "Hungarian" bromegrass was sown on the University of Nebraska Experiment Station farm at Lincoln, NE, in 1897 in a small field (Lyon 1899). Seed and forage yields were determined. In 1898, a 6.5-ha pasture was established that was used in grazing trials by cattle and horses. In his summary, Lyon (1899) noted that its advantages over the native prairie grasses was that it became green fully a month earlier in the spring and remained green later into the autumn. He indicated that it was not as good for butter and milk production as bluegrass (*Poa pratensis* L.) and white clover (*Trifolium repens* L.) from dairy cattle but that it was safe and widely adaptable. Similar results were being obtained from other experiment stations (Waldron and Porter 1919). The initial spread and distribution of smooth bromegrass in North America were based on the simple increase and distribution of the introduced strains from experiment stations to farmers. The first recorded breeding work on smooth bromegrass was conducted in the early 1900s by two Kansas farmers, the Achenbach brothers, who did mass selection on one of their best bromegrass fields to develop "Achenbach" bromegrass (Vogel et al. 1996). Initial breeding work by several experiment stations was initiated between 1910 and 1920 but did not lead to the development of any cultivars and was not re-initiated until the drought of

the 1930s stimulated breeding work at several locations. During the 30-year period from the late 1890s to the early 1930s, agronomic information was obtained on the management of smooth brome grass at locations throughout the prairie regions of the United States and Canada.

Breeding programs for brome grass were initiated at several experiment stations beginning in the mid-1930s to develop grasses for reseeding the lands ravaged by the drought. Typically, the breeders worked on multiple species. The breeding programs used available germplasm resources, primarily domestic germplasm sources such as old plantings that had been in existence for sufficient periods of time to have become naturalized (Vogel et al. 1996). The evaluation work documented the existence of "southern" and "northern" strains of smooth brome grass (Newell and Keim 1943; Knowles and White 1949). The southern types, which were believed to trace from the Hungarian introductions, were the best adapted to the Central Great Plains and the southern part of the Corn Belt, while the northern strains were best adapted to the Northern Plains, the upper Midwest and northeastern states, and to the adjacent provinces of Canada, and traced to some of the accessions originally collected by Hansen in 1897 and to other accessions from northern Europe (Vogel et al. 1996). The first series of cultivars did not involve any formal breeding work other than selection among existing ecotypes or strains. For example, seed from several old plantings in Nebraska proved superior to other germplasm sources and were traced to a common origin. These fields were certified and were the source of the cultivar "Lincoln" which is still a widely used (Vogel et al. 1996; Casler et al. 2000). Brome grass breeding and management research have been continued to the present at several locations in both the USA and Canada.

4.7 The Success Story

The early evaluation and management work enabled seed production of crested wheatgrass to be rapidly expanded. Information on establishment practices including planting dates enabled land to be rapidly and efficiently re-vegetated during the 1940s and 1950s. Because it was often the only adapted grass for which seed was available in quantity for its area of adaptation, it was often seeded in monocultures. Crested wheatgrass salvaged vast areas of deteriorated rangelands and abandoned cropland in the central and northern plains of North America that were severely damaged during the "dust bowl" period of the 1930s (Rogler and Lorenz 1983; Lorenz 1986). Many of these plantings remain and are still productive. Crested wheatgrass also has become the most important domestic grass in the arid intermountain West of the United States. In the intermountain West, excessive and unregulated livestock grazing by sheep and cattle in the late 1800s and early 1900s led to severe rangeland degradation and to a change in the vegetation community (Harrison et al. 2003). By 1932, the vegetation in the some areas of the Great Basin region had changed from 49 to 81% perennial grass and 10% sagebrush to mainly sagebrush ground cover (Harrison et al. 2003). Re-vegetation

was needed to restore these degraded rangelands and to combat invading noxious weeds. In this region, many of the native cool-season plants do not tolerate heavy grazing (Asay and Jensen 1996). Crested wheatgrasses were found to be well adapted in trials that began in the late 1930s (Harrison et al. 2003). The annual poisonous forb, halogeton became a serious threat to livestock on intermountain rangelands during the 1940s. Crested wheatgrass proved to be an effective biological suppressor of this weed (Mathews 1986; Young and Evans 1986). Agricultural statistics are not available on the land area that has been seeded and is currently vegetated by crested wheatgrasses, but it is estimated that 5.1 million and 800,000 ha had been seeded to crested wheatgrass in the USA and Canada, respectively, by the early 1980s (Rogler and Lorenz 1983; Asay and Jensen 1996). It is primarily used north of 40°N lat. and west of 100°W long. It is used in lower latitudes at higher elevations in the intermountain area. Pasture and rangeland planted to crested wheatgrass are primarily used for grazing.

Similar to the crested wheatgrass, the early work on smooth brome grass enabled it to be rapidly increased and utilized to restore degraded lands following the 1930s drought. For example, by 1945, almost 500,000 ha had been seeded in the state of Nebraska (Frolik 1945). It was and continues to be primarily utilized in North America in regions north of 40°N lat. and east of 100°W long. that have 500 mm or more annual precipitation, or in areas that have similar temperature ranges because of elevation (Vogel et al. 1996). It is estimated that the Midwest and eastern states of the USA and the adjacent provinces of Canada each have over 500,000 ha of smooth brome grass. The principal use of smooth brome grass is as a cool-season pasture grass in this region (Vogel et al. 1996). It is the principal component of these pastures, although legumes, particularly alfalfa (*Medicago sativa* L.), are usually included in the plantings. In addition, it remains the most important grass for conservation purposes in this region where it is used on roadsides, grass waterways, and field borders for erosion control.

4.8 The Alien Problem

Crested wheatgrass and smooth brome grass are not regarded favorably by everyone even though they saved millions of hectares of land from severe erosion and remain economically important grasses in both pasture and rangelands (Lesica and DeLuca 1996; Christian and Wilson 1999). Most of the criticism is based on the fact that they are not native species and that pure stands of the species lack biological diversity. Native species are considered by many ecologists to be more desirable than the introduced grasses. Both crested wheatgrass and smooth brome grass can be found on invasive species lists of environmental organizations on the internet (<http://www.americanlands.org>; <http://tncweeds.ucdavis.edu>; verified 29 September 2003). Some of these groups also list tall fescue (*Festuca arundinaceae* Schreb.) and white and yellow sweet clover (*Melilotus alba* Medikus and *M. officinalis* Lam., respectively) as invasive plants. Smooth brome grass and crested wheatgrass are viewed as invaders of native rangeland and remnant prairie sites.

Personal observation and published reports (Blankenpoor and May 1999; Broersma et al. 2000) indicate that neither grasses invades grasslands that are well managed and in good condition. Brome grass will invade disturbed areas and poorly managed native grasslands especially in the tallgrass prairie ecoregion. Crested wheatgrass is very non-invasive and usually does not spread from where it is planted. The soil quality of long-term crested wheatgrass fields or range sites has been reported to be below that in adjacent, unplowed prairie (Lesica and DeLuca 1996; Christian and Wilson 1999). The fact that the sites seeded to crested wheatgrass had been plowed and eroded before they were seeded to crested wheatgrass is often ignored or remains a confounding factor in research reports. Other reports indicate that grazed crested wheatgrass and native prairies produce similar amounts of root biomass (Krzic et al. 2000).

Crested wheatgrass will need to be used in the intermountain West of the USA and Canada for noxious weed control. Invasion of rangelands by the annual brome grass, *Bromus tectorum* L., or cheatgrass have created severe problems including rangeland fires that in the state of Utah alone burn almost 60,000 hectares annually (Harrison et al. 2003). Plants that can be used to control cheatgrass and other noxious weeds are needed, although vigorous cultivars such as Hycrest can effectively compete against noxious weeds such as cheatgrass and halogeton. A rapidly spreading noxious weed, spotted knapweed (*Centurea maculosa* auct. non Lam.), has been shown recently to release a phytotoxin from its roots that triggers the death of the root system of grasses native to the intermountain region in the western USA (Bais et al. 2003). European grasses were more resistant to the toxin and will likely be needed as part of the control strategy for this noxious weed.

Pumpelly's brome (*Bromus inermis* Leyss. ssp. *pumpellianus* (Scribn.) Wagon) is a perennial brome grass that is native to Alaska and the western and northern intermountain areas of North America. Based on genetic studies which have demonstrated that it has the same nuclear and cytoplasmic genomes as smooth brome grass with which it is fully fertile, it has been reclassified as a subspecies of smooth brome grass (Armstrong 1982; Pillay and Hilu 1990; Vogel et al. 1996). Pumpelly's brome probably migrated during periods when Asia and Northern America were connected via a land bridge between Alaska and Siberia, and because of isolation developed small differences in morphology while retaining the genome intact. It can be argued that smooth brome grass should be regarded as a native of North America because its genome was already present in Pumpelly's brome grass.

4.9 Conclusions

The crested wheatgrass and smooth brome grass are now naturalized species of North America. Their use in re-vegetation and conservation saved the topsoil on millions of hectares of land. They will continue to be used in production agriculture and in restoring degraded rangelands that have been invaded by noxious weeds.

4.10 References

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