Preface

Knowledge of the growth and development of individual plant species is essential for the establishment of scientific standards for proper management of native rangelands (Dr Warren C. Whitman circa 1950). Range scientists conducting ecological research at the NDSU Dickinson Research Extension Center have strived to collect quantifiable information on individual plant species during 1946 to 2012. This information has been compiled into three reports organized by plant categories: 1) Grasses and Upland Sedges, 2) Forbs, and 3) Shrubs and Subshrubs.

Autecology of Grasses on the Northern Mixed Grass Prairie

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Prairie ecosystems are complex; exceedingly more complex than the most complicated machines ever built by humans. The long-standing standard process to understand complex systems is to initially investigate the separate component parts. The gained knowledge of each part combined with the synergistic effects resulting when the parts work together provide the information needed to develop an understanding of the whole ecosystem. This classical concept of biological systems was developed by the Greek philosopher/scientist Aristotle (384-322 BC) who taught that "the whole is greater than the sum of its parts".

The goals of this study were developed by Dr. Warren C. Whitman (c. 1950) and Dr. Harold Goetz (1963) which were to gain quantitative knowledge of each component species and to provide a pathway essential for the understanding of the whole prairie ecosystem that would result in the development and establishment of scientific standards for proper management of native rangelands of the Northern Plains.

This report is an autecological study of individual grass and upland sedge species living on northern mixed grass prairie ecosystems. The change in growth and development during the annual growing season life history and the changes in abundance through time are quantitatively described from data collected during 67 growing seasons for six ecological studies conducted at the Dickinson Research Extension Center over a time period from 1946 to 2012.

Grasses are herbaceous monocotyledons that have a long-lived, nonwoody, subterranian crown with vegetative buds that produce one to several tillers with 6 to 8 narrow, linear, two-rancked leaves with parallel veins. Each tiller lives for two growing seasons. Each leaf is attached to the hollow stem at a node and has an axillary bud that has the potential to develop into a vegetative secondary tiller.

Upland Sedges are perennial herbaceous monocotyledons that have a short nonwoody rootstock that produce three-angled solid or pithy stems that form three-ranked whorled narrow leaves with parallel veins. Upland sedges grow in well drained soils and do not grow in saturated or subirrigated soils.

Companion autecological studies provide quantitative descriptions of forb species and of shrub and subshrub species on the Northern Mixed Grass Prairie.

Autecology of Smooth Bromegrass on the Northern Mixed Grass Prairie

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The autecology of Smooth bromegrass, *Bromus inermis*, is one of the prairie plant species included in a long ecological study conducted at the NDSU Dickinson Research Extension Center during 67 growing seasons from 1946 to 2012 that quantitatively describes the changes in growth and development during the annual growing season life history and the changes in abundance through time as affected by management treatments for the intended purpose of the development and establishment of scientific standards for proper management of native rangelands of the Northern Plains. The introduction to this study can be found in report DREC 16-1093 (Manske 2016).

Smooth bromegrass, *Bromus inermis* Leyss., is a member of the grass family, Poaceae, tribe, Bromeae, and is a naturalized (introduced from the Russian Steppes or Hungarian Plains of Europe during the 1880's), long lived perennial, monocot, cool-season, tall grass, that is cold hardy, moderately tolerant of drought, fairly resistant to saline and slightly acidic soils, grows best with 18 inches or more rain per year, and can invade into prairie where the grasses have been weakened by poor management. The first North Dakota record is Moran 1937. Early aerial growth consists of basal leaves from the crown and rhizome tiller buds. Basal leaf blades are 9-21 cm (3.5-8.3 in) long, 4.5-10 mm wide, smooth above and below, has a "M" or "W" constriction where blade starts to taper to a point. The sheath is closed with a notch at the top. The collar is narrow, continuous and divided by the midvein. The membranous ligule has varying length from 2 to 3 mm and longer in the center. The auricles are absent. The creeping rhizome system is extensive. The stout rhizomes are primarily in the top 15 cm (6 in) of soil. Single aerial stems are produced per node at progressive intervals. The extensive fibrous root system has thick main roots arising from stem crowns and rhizome nodes growing obliquely downward to depth of 46 cm (18 in) deep with a few long main roots descending to depths of 1.2 or 1.5 m (4-5 ft) in loose soil. Several lateral roots 2.5-3.8 cm (1-1.5 in) long arise from main roots. Regeneration is primarily asexual propagation by rhizome tiller buds. Seedlings are only successful in moist soil where competition from established plants is nonexistent. Flower stalks are erect, 40-120 cm (16-47 in) tall and has several cauline leaves. Inflorescence is a moderately open panicle, 10-20 cm (4-8 in) long, with ascending branches arising mainly in whorls at nodes. Terminal spikelets with 4-10 florets are 1.5-3.0 cm (0.6-1.2 in) long. Flower period is from early to late June. Aerial parts are palatable and nutritious before flowering. Fire consumes aerial parts. Fire causes great reductions in biomass production and tiller density. This summary information on growth development and regeneration of Smooth bromegrass was based on works of Stevens 1963, Zaczkowski 1972, Dodds 1979, Great Plains Flora Association 1986, Howard 1996, Bush 2006, Johnson and Larson 2007, and Stubbendieck et al. 2011.

Procedures

The 1946-1947 Study

Grass and upland sedge species samples to determine crude protein and phosphorus content were collected weekly during the growing seasons of 1946 and 1947 from two seeded domesticated grasslands and a native rangeland pasture at the Dickinson Research Extension Center located at Dickinson in western North Dakota. Current year's growth of lead tillers of each species was included in the sample; previous year's growth was separated and discarded. Ungrazed samples were collected for each species except for Kentucky bluegrass, which only grew along a watercourse where almost all of the plants had been grazed and remained in an immature vegetative stage, however, a small number of plants escaped grazing and developed normally providing the phenological development data. Crude protein (N X 6.25) content was determined by the procedure outlined in the Official and Tentative Methods of Analysis (A.O.A.C. 1945). Phosphorus content was determined by the method outlined by Bolin and Stamberg (1944). Data were reported as percent of oven-dried weight.

Plant condition by stage of plant development and growth habit was collected for each species on sample dates. These data are reported as phenological growth stage in the current report. The grass nutritional quality and phenological growth data were published in Whitman et al. 1951.

The 1969-1971 Study

The range of flowering time of grasses and upland sedges was determined by recording daily observations of plants at anthesis on several prairie habitat type collection locations distributed throughout 4,569 square miles of southwestern North Dakota. The daily observed flowering plant data collected during the growing seasons of 1969 to 1971 from April to August were reported as flower sample periods with 7 to 8 day duration in Zaczkowski 1972.

The 1954-1962 Study

The Uniform Bromegrass Nursery Trial was seeded at the Dickinson Experiment Station in the spring of 1953 resulting in excellent stands. Ten released cultivars of smooth bromegrass (Bromus inermis) were seeded into plots arranged in a randomized block design with four replications. The trial was designed to evaluate the performance of the cultivars in western North Dakota on the basis of mean dry weight aboveground herbage production. Multiple hand clipped frames were sampled from each replication one time per growing season. Mean oven dried weights in pounds per acre were reported annually, 1954-1962, (Whitman 1962).

The 1959-1965 Study

A grass and alfalfa mixture trial was seeded at the Dickinson Experiment Station in the spring of 1958 with favorable moisture conditions at the time of seeding. The plots which were arranged in a randomized block design with four replications were seeded on ground which had been in corn for one year followed by a year of fallow resulting in a relatively favorable seedbed. The trial was designed to evaluate the performance of smooth bromegrass (Bromus inermis) cultivars straight and the cultivars and alfalfa in a mixture in western North Dakota on the basis of mean dry weight aboveground herbage production. Multiple hand clipped frames were sampled from each replication one time per growing season. Mean oven dried weights in pounds per acre were reported annually, 1959-1965, (Whitman 1965).

The 1980-1985 Study

A Bromegrass Variety Trial was seeded at the Dickinson Experiment Station in the spring of 1979. Ten released cultivars of smooth bromegrass (Bromus inermis) was seeded into 10 X 25 foot plots arranged in a randomized block design with four replications. The alleys between plots were 5 feet wide. The trial was designed to evaluate the performance of the cultivars in western North Dakota on the basis of mean dry weight aboveground herbage production. Multiple hand clipped to ground level frames were sampled from each replication one time per growing season during late June or early July. Mean oven dried weights in pounds per acre were reported annually, 1980-1985, (Manske and Goetz 1985).

The 1978-1990 Study

A study to reduce escaped smooth bromegrass in grasslands with fire was part of a larger study to investigate the possibilities of using repeated prescribed burning treatments in the restoration of degraded mixed grass prairie.

The prescribed burning strategy that used an every-other-year burn regime was designed to reduce the invading western snowberry and escaped exotic grasses and to renovate the prairie ecosystem. Annual burn treatments were not possible because of insufficient annual production of plant biomass for fuel (Smith 1985). The study area was divided into 15 prescribed burn management units separated by fire breaks with an average size of 530.5 acres (214.9 ha) and 6 control management units of no burning with an average size of 436.8 acres (176.9 ha). The prescribed burns were conducted during four seasons: early spring (mid-late April), spring (May-mid June), early summer (mid June-July), and mid summer (early-mid August). The number of repeated every-other-year burn treatments was: 1 burn, 2 burns, 3 burns, and 4 burns in a 13 year period. Control treatments of no burns had no wildfires or prescribed burns for over 100 years prior to the start of the study in 1978.

Plant species composition was determined between mid July and mid August during peak growth by the plant shoot cover method (% shoot frequency) (Cook and Stubbendieck 1986), with one hundred 0.1 m^2 quadrats placed systematically along designated landscape transects to include summit, shoulder, back, foot, and toe slope plant communities for each management unit and burn treatment recording each plant species present in each frame placement.

Endomycorrhizal fungal infection in roots of selected species was evaluated. Three replicated soil cores 4 inches (10.2 cm) in diameter and 4 inches (10.2 cm) in depth were collected for each plant species; samples from nearly level loam soils along the permanent landscape transects of each control and prescribed burn treatment were collected with a golf cup cutter. Roots were washed over sieving, and current year's roots were removed from plant crowns by clipping. Root samples of each replicate were stored in individual vials and preserved in a solution of glycerin and lactic acid. In the laboratory, root samples were cleared and stained to enhance mycorrhizal structures using procedures described by Phillips and Hayman (1970) and modified by Kormanik and McGraw (1982). Fungal colonization in the root samples was scanned through a Nikon 107733 type 104 microscope, and percent fungal infection was assessed using a nonsystematic modification of the grid-intersect method (Giovannetti and Mosse 1980), with presence or absence (P/A) of fungal structures recorded for 100 intersected root segments.

Soil microorganism activity was monitored by the quantity of available soil inorganic (mineral) nitrogen, both ammonium NH_4 and nitrate NO_3, collected during mid June and mid August. Five replicated soil cores 1 inch (2.54 cm) in diameter and 6 inches (15.24) in depth were collected from nearly level loam soils along the permanent landscape transects of each control and prescribed burn treatment and air dried. In the laboratory, subsamples of the five soil cores were evaluated for total incubated mineralizable nitrogen with procedures outlined by Keeney (1982). Inorganic forms of nitrogen, ammonium NH_4 and nitrate NO_3, were extracted and analyzed by steam distillation (Keeney and Nelson 1982) and reported in pounds per acre.

The 2006-2011 Study

A study to reduce escaped smooth bromegrass in grasslands with proper grazing management was part of a larger study designed to restore the native grassland ecosystem through implementation of biologically effective grazing management of a degraded untilled mixed grass prairie that had been invaded by undesirable domesticated grasses.

The twice-over rotation grazing management strategy was the biologically effective management practice implemented to restore the degraded mixed grass prairie plant communities. The study area had not been grazed during the previous 13 years. As a result of the nondefoliation management by complete rest, the land became severely degraded and dominated with undesirable introduced cool season domesticated grasses primarily Kentucky bluegrass and smooth bromegrass. The total area was divided into 4 pastures with 3 pastures grazed and 1 pasture ungrazed as the control. The three grassland pastures were grazed from early June until mid October, with each pasture grazed for two periods. Each of the three pastures in the rotation was grazed for 14 to 16 days during the first period, the 45 day interval from 1 June to 15 July, during which the four main defoliation resistance mechanisms can be activated with partial defoliation by grazing. During the second period, the 90 days after mid July and before mid October, each pasture was grazed for double the number of days that it was grazed the first period. Two of the grazed pastures and the control pasture were invaded primarily by Kentucky bluegrass and the third grazed pasture was invaded by 62.5% smooth bromegrass and 37.5% Kentucky bluegrass. The effects of the grazing management on this Pasture NR3 was compared to the control of no grazing on Pasture NR4 from late May through mid October during six growing seasons, 2006 to 2011.

Permanent sample plots were established in each pasture on silty ecological sites and organized in a paired-plot design. A 16' X 32' (4.88 m X 9.75 m) stock panel exclosure prevented livestock access on an ungrazed plot and a grazed plot on an adjacent area of equal size was accessible by livestock. Ecosystem changes in plant species basal cover and % composition, and rhizosphere biomass, were the data evaluated.

Plant species basal cover was determined by the ten-pin point frame method (Cook and Stubbendieck 1986), with 2000 points collected along permanent transect lines at each sample site both inside (ungrazed) and outside (grazed) each exclosure during peak growth between mid July and mid August. Basal cover plant species data were sorted into biotype categories: domesticated smooth bromegrass, domesticated Kentucky bluegrass, cool season grasses, warm season grasses, sedges, forbs, and litter. Relative percent composition of basal cover biotype categories were determined.

Rhizosphere biomass was collected at each sample site outside (grazed) each exclosure by three replicated soil cores 3 inches (7.6 cm) in diameter and 4 inches (10.2 cm) in depth during 3 grazing season periods: pregrazing (May), first rotation (July), and second rotation (October), with the mean of 3 used as the annual level, using a humane soil beastie catcher (Manske and Urban 2012). The fresh rhizosphere material, which included the rhizosphere organisms, the active plant roots, and the adhered soil particles, was separated from matrix soil by meticulous excavation with fine hand tools. Both wet and dry rhizosphere weights were collected. Rhizosphere biomass per volume of soil were determined from the soil core rhizosphere weight data and reported as kilograms per cubic meter.

The 1983-2012 Study

A long-term change in grass and upland sedges species abundance study was conducted during active plant growth of July and August each growing season of 1983 to 2012 (30 years) on native rangeland pastures at the Dickinson Research Extension Center ranch located near Manning, North Dakota. Effects from three management treatments were evaluated: 1) long-term nongrazing, 2) traditional seasonlong grazing, and 3) twice-over rotation grazing. Each treatment had two replications, each with data collection sites on sandy, shallow, and silty ecological sites. Each ecological site of the two grazed treatments had matching paired plots, one grazed and the other with an ungrazed exclosure. The sandy, shallow, and silty ecological sites were each replicated two times on the nongrazed treatment, three times on the seasonlong treatment, and six times on the twice-over treatment.

During the initial phase of this study, 1983 to 1986, the long-term nongrazed and seasonlong treatments were at different locations and moved to the permanent study locations in 1987. The data collected on those two treatments during 1983 to 1986 were not included in this report.

Abundance of each grass and upland sedge species was determined with plant species basal cover by the ten-pin point frame method (Cook and Stubbendieck 1986). The point frame method was used to collect data at 2000 points along permanent transect lines at each sample site both inside (ungrazed) and outside (grazed) each exclosure. Basal cover, relative basal cover, percent frequency, relative percent frequency, and importance value were determined from the ten-pin point frame data. Point frame data collection period was 1983 to 2012 on the twice-over treatment and was 1987 to 2012 on the long-term nongrazed and on the seasonlong treatments. However, point frame data was not collected during 1992 on the sandy ecological sites of all three treatments.

During some growing seasons, the point frame method did not document the presence of a particular plant species which was reflected in the data summary tables as a 0.00 or as a blank spot.

The 1983-2012 study attempted to quantify the increasing or decreasing changes in individual plant species abundance during 30 growing seasons by comparing differences in the importance values of individual species during multiple year periods. Importance value is an old technique that combines relative basal cover with relative frequency producing a scale of 0 to 200 that ranks individual species abundance within a plant community relative to the individual abundance of the other species in the community during the growing season. Basal cover importance value ranks the grasses, upland sedges, forbs, and shrubs in a community. The quantity of change in the importance value of an individual species across time indicates the magnitude of the increases or decreases in abundance of that species relative to the changes in abundance of the other species.

Results

Smooth bromegrass starts early leaf greenup in mid April (table 1). The smooth bromegrass tillers have three and a half new leaves around early May which is four or so weeks earlier than native cool season grasses. These early new leaves are highly nutritious forage and grazing can start 1 May. Smooth bromegrass is sensitive to early season heavy grazing. Early boot stage occurs in mid May, stalk emergence occurs in early June, and stalks with flowers appear during early June (tables 1 and 2). Most of the lead tillers reach the flower stage during June (table 2). Seed development occurs after the flower stage and seeds reach maturity during the first week of July (table 1) (Whitman et al. 1951, Manske 1999b).

The nutritional quality of ungrazed lead tillers of smooth bromegrass changes with the tillers' phenological development (table1). Early season growth stages are high in crude protein and water. The early vegetative leaf stages contain levels of crude protein above 18% during early to mid May. As seed stalks begin to develop in mid May, crude protein levels begin to decrease. At the flower stage, lead tillers contain 14.4% crude protein. The flower stage is when the greatest weight of crude protein per acre occurs. After the flower stage, crude protein levels remain above 9.6% until late June (tables 1 and 3, figure 1). As the ungrazed lead tillers mature, the fiber content increases and percent crude protein, water, and digestibility decrease. By early July, crude protein levels drop below 9.5% and below 8.0% in early August (table 1, figure 1). Phosphorus levels drop below 0.18% during early July (tables 1 and 3).

The patterns of change in nutritional quality are similar from year to year because tiller phenological development is regulated primarily by photoperiod (changes in the length of daylight). Slight variations in nutritional quality result from annual variations in temperature, evaporation, and water stress. Nutritional quality can also be slightly altered by changes in rates of tiller growth and plant senescence. Growth rates are affected by the level of photosynthetic activity, which is affected by air and soil temperature, cloud cover, and availability of hydrogen (from water) for carbohydrate synthesis. Senescence rates increase with high temperatures, precipitation deficiency, and water stress (Whitman et al. 1951, Manske 1999b).

Zaczkowski (1972) determined that escaped smooth bromegrass plants had a four week flower period during June (table 2).

Smooth bromegrass, unfortunately, has a Dr. Jekyll and Mr. Hyde complex of good and evil. Smooth bromegrass is a beneficial grass for early spring pasture during May or cut for hay between the boot stage and late flower stage. The same characteristics of high viability of seed and strong seedling vigor that permit easy establishment and long stand longevity also permit it to escape and invade plant communities where it is not wanted. Research at the Dickinson Research Extension Center has been conducted to address both the good and evil sides of smooth bromegrass.

Smooth bromegrass is native to Hungary, France, Germany, Russia, and northern Asia. Several early introductions have been instrumental in development of the cultivars grown in North America. The first known introduction was into California from Hungary in 1884. Increase seeds from this introduction were widely distributed throughout the United States as trial packets. Seed from northern Germany was sent to Canada in 1888. A large seed shipment from the Penza region of the Volga Upland in the Russian Steppe was received in South Dakota in 1898. An Asian source of seed was sent from Manchuria to Washington.

Two strains of smooth bromegrass are recognized and separated by the origination of the source material. The Northern Type germ plasm originated from the Russian Steppe and Northern Germany and the Southern Type germ plasm originated from the Hungarian Plains and France. The Northern Type has mainly stem leaves, weakly rhizomatous producing mostly crown tillers forming tussocks (bunches), it has short glumes, develops more seeds, and grows slower but more evenly through the growing season producing lower peak aboveground herbage biomass. The Southern Type has both basal leaves and stem leaves, strongly rhizomatous producing mostly rhizome tillers resulting in sod forming, it has long glumes, develops less seeds, and grows rapidly early in the growing season for a short period producing greater peak aboveground herbage biomass.

Smooth bromegrass breeding programs at numerous North American locations have emphasized forage and seed production, aftermath production, leafiness, disease resistence, seed quality, seedling vigor, forage quality, stand persistence, and adaptation to local conditions (Barnes, Miller, and Nelson eds. 1995). Several important smooth bromegrass cultivars developed in North America have been included in variety trials conducted in western North Dakota at the Dickinson Research Extension Center (table 4).

The old southern cultivars ‘Lincoln’, ‘Achenback’, ‘Fischer’, and ‘Elsberry’ were derived from fields originating from the earliest introductions of seed from the Hungarian Plains. An old northern cultivar ‘Homesteader’ was developed from fields originating from an introduction of seed from the Penza region in the Russian Steppe. The old cultivar ‘Manchar’ was developed from a Manchurian introduction, it was classified at first as a Northern type with a Asian source and later reclassified as an Intermediate type, and ranked high in second-harvest yields. ‘Lyon’ and ‘Lancaster’ were developed from selections of Lincoln with higher seed quality and forage type. ‘Fox’ and ‘Martin’ were developed with good forage yield and improved brown leaf spot resistance. ‘Baylor’, ‘Blair’, ‘Barton’, and ‘Beacon’ were developed for high yield and improved brown leaf spot resistance. ‘Rebound’ was developed from selections of Saratoga with increased aftermath production, greater leaf disease resistance, restricted rhizomatous spreading habit, improved in vitro dry matter digestibility (IVDMD), and higher forage yield. The ‘Lincoln’ cultivar has been transformed into smooth bromegrass ‘common’ throughout most of the midwest region of the United States.

The 1954-1962 Uniform Bromegrass Nursery Trial was seeded in the spring of 1953 and developed excellent stands. The study plots were accidently mowed in 1956 before the plots could be harvested for yield data. Low precipitation was received during some of the growing season months; in 1959 it was April, July, and August and in 1961 it was May, June, and July. The low precipitation received during 1959 greatly affected the plots of Manchar, Martin, and Kuhl which were noticeably less vigorous and thinner during 1960. All of the plots suffered stand damage during the low precipitation period of 1961. The mean herbage yield of the top five cultivars was 1203 lbs/ac. The mean herbage yield of the bottom five cultivars was 1108 lbs/ac. This was less than 100 lbs/ac difference (table 5) (Whitman Annual Reports).

The 1959-1965 Grass and Alfalfa Mixture Trial was seeded in the spring of 1958 into a favorable seed bed with good moisture conditions, however, the stands obtained were not uniform and some plots had not yet fully established during the second growing season. The alfalfa in the mixture plots did not make much contribution to the yield during 1959 and 1960. During 1960, the Ladak with Lincoln contributed 35.4% of the yield, the Teton with Lincoln contributed 22.7% of the yield, and the Ladak with Manchar contributed 8.0% of the yield. The growing season of 1961 received low precipitation during May, June, and July. The Northern brome cultivar was severely damaged during 1961 and never fully recovered. After 1962, the alfalfa in the mixture plots improved. During 1965, the Ladak with Lincoln contributed 42.4% of the yield, the Teton with Lincoln contributed 52.3% of the yield, and the Ladak with Manchar contributed 33.7% of the yield. The mean herbage yield of the three grass-alfalfa mixtures was 2583 lbs/ac. The mean herbage yield of the top three bromegrass alone cultivars was 2009 lbs/ac. With a difference of greater than 500 lbs/ac for the grass-alfalfa mixtures (table 6) (Whitman Annual Reports).

The 1980-1985 Bromegrass Variety Trial was seeded in the spring of 1979. The drought conditions of 1980 had a 26.5% reduction in growing season precipitation with grasses in water stress conditions during April, May, and July. All smooth bromegrass cultivars produced greater than 1300 lbs/ac by late June of 1980. The bromegrass varieties in this trial have performed satisfactory under the environmental conditions of western North Dakota. All nine southern type cultivars had six year mean herbage yield above 1600 lbs/ac. Seven cultivars had mean herbage production over 1700 lbs/ac. Four cultivars had mean herbage yield over 1800 lbs/ac. One cultivar, ‘Baylor’, had six year mean herbage production over 2000 lbs/ac. The top three cultivars had six year mean yields at 1971 lbs/ac, the 2nd three cultivars had mean yields at 1779 lbs/ac, and the 3rd three cultivars had mean yields at 1670 lbs/ac. All nine southern type cultivars show good potential for use as tamegrass spring pastures or as hayland in western North Dakota (table 7) (Manske and Goetz Annual Reports).

Lincoln, Lancaster, Lyon, and Manchar were carryover cultivars from the 1954-1962 Study, and Lincoln and Manchar have been included in all three bromegrass variety trials. Lincoln is an old southern type cultivar selected from early fields seeded with germ plasm from the Hungarian Plains developed by USDA and Nebraska AES and released in 1942. Lancaster and Lyon were selections from Lincoln. Manchar is an old northern type cultivar selected from seed introduced from Manchuria in northern Asia developed in Washington and released in 1943. Later it was reclassified as an intermediate type. Manchar had the lowest herbage yield during 3 years, the second lowest yield during 2 years, and the lowest six year mean herbage yield in the trial. However, Manchar has slow steady growth of forage all growing season, has fast recovery growth after grazing or haying, has high seedling vigor, and produces viable seed in quantity. For these latter characteristics is why I think Dr. Whitman selected Manchar to be a control cultivar in all three of the smooth bromegrass variety trials conducted at the Dickinson Research Extension Center.

The 1978-1990 study prescribed burn treatments were intended to decrease and then remove western snowberry and smooth bromegrass from degraded mixed grass prairie and restore ecosystem processes.

Western snowberry, *Symphoricarpos occidentalis*, aboveground shoot frequency decreased 68.3% after 1 burn, decreased an average of 40.0% after 2 burns, decreased an average of 67.1% after 3 burns, and decreased an average of 58.4% after 4 burns (table 8). The number of repeated burns caused no additional shoot reduction after one burn. Shoot frequency decreased 91.4% from early spring burns, decreased 83.7% from spring burns, decreased only 32.9% from early summer burns, and decreased 63.1% from mid summer burns (table 8). The greatest reduction in shoot frequency occurred from early spring (mid-late April) burns and significant reductions occurred from spring (May-mid June) burns. Early summer (mid Jun-Jul) and mid summer (early-mid August) burns were less effective at reducing shoot frequency. The aboveground biomass produced by shrubs was greatly reduced after the third and fourth burns.

Smooth bromegrass, *Bromus inermis*, aboveground shoot frequency decreased 86.7% after 1 burn, decreased 93.3% after 2 burns, decreased

96.2% after 3 burns, and decreased 97.2% after 4 burns (table 8). Additional burns, after the first burn, progressively increased slightly the additional decrease in shoot frequency. Shoot frequency decreased 100.0% from early spring burns, decreased 90.0% from spring burns, decreased 98.6% from early summer burns, and decreased 87.2% from mid summer burns (table 8). The greatest reduction in shoot frequency occurred from early spring (mid-late April) burns and significant reductions occurred from early summer (mid June-July) burns.

Western snowberry and smooth bromegrass reproduce vegetatively from buds on rhizomes and crowns. Removal of all or most of the aboveground shoots with fire does not stop the vegetative reproduction processes.

Endomycorrhizal fungi do not colonize the entire root. Fungal infection occurs at the portions of current years' roots that are biologically active. Previous years' roots, mature root portions, and young growing root portions do not host fungal structures. Percent fungal infection of root segments is primarily a factor of the proportion of biologically active root portions to the amount of mature and young growing root portions included in the sample. Identification of biologically active root portions from mature root portions is difficult in the field, with the naked eye or low-power hand lens.

The less than 100% fungal infection in the western snowberry root samples should be considered to indicate the percent biologically active root portions within the root sample. About 86% of the western snowberry root sample was biologically active and infected. The fungal infection was 86.3% on 1 burn, 84.3% on 2 burns, 86.2% on 3 burns, and 84.3% on 4 burns (table 8) and these levels of infection are not significantly different. The fungal infection was 92.3% on early spring burns, 86.3% on spring burns, 82.0% on early summer burns, and 86.6% on mid summer burns (table 8) and these levels of infection are not significantly different.

The smooth bromegrass root samples were different from the native grass and western snowberry samples. The smooth bromegrass root samples contained very little young and mature root portions, almost all of the samples consisted of biologically active root portions. There was almost no fungal colonization within the root tissue. Nearly all of the fungal infection observed in the smooth bromegrass samples were restricted to the root hairs. About 45% of the smooth bromegrass root segments had fungal infection of the root hairs. The fungal infection was 53.4% on 1 burn, 54.7% on 2 burns, 34.9% on 3 burns, and 43.8% on 4 burns (table 8) and these levels of infection are not significantly different. The fungal infection was 42.1% on spring burns, 37.1% on early summer burns, and 65.7% on mid summer burns (table 8) and these levels of infection are not significantly different.

The prescribed burning treatments did not affect the fungal infection levels on the roots of western snowberry and smooth bromegrass.

Grassland soils have abundant quantities of nitrogen, however, most of this is stored in the organic form and unavailable for direct use by plants. Grassland plants can use nitrogen only in the inorganic (mineral) form. Soil microorganisms of the rhizosphere mineralize soil organic nitrogen into inorganic nitrogen (Ingham et al. 1983). Grassland ecosystems with greater biomass of rhizosphere organisms mineralize greater quantities of organic nitrogen into inorganic nitrogen (Coleman et al. 1983). Measurements of the quantity of available inorganic nitrogen is a proxy indication for the relative quantity of rhizophere organisms. The growing season (June + August) quantity of mineral nitrogen was 31.2 lbs/ac on the no burns, 30.8 lbs/ac on the 1 burn, 32.1 lbs/ac on the 2 burns, 16.8 lbs/ac on the 3 burns, and 20.4 lbs/ac on the 4 burns (table 9) and these quantities are not significantly different. The growing season quantity of mineral nitrogen was 11.9 lbs/ac on the early spring burns, 28.1lbs/ac on the spring burns, 29.8 lbs/ac on the early summer burns, and 23.1 lbs/ac on the mid summer burns (table 9) and these quantities are not significantly different.

The prescribed burning treatments did not affect the quantity of organic nitrogen mineralized into available inorganic nitrogen thus the prescribed burning treatments did not stimulate the biomass and activity of the rhizosphere organisms.

Available soil mineral nitrogen is the major limiting factor of herbage growth on native rangeland ecosystems (Wight and Black 1979). Deficiencies in mineral nitrogen limit herbage production more often than water in temperate grasslands (Tilman 1990). A minimum rate of mineralization that supplies 100 pounds of mineral nitrogen per acre is required to sustain herbage production at biological potential levels on rangelands (Wight and Black 1972). Soil mineral nitrogen available at the threshold quantity of 100 lbs/ac is required for activation of the ecological biogeochemical processes important for rangeland grass production. Wight and Black (1972, 1979) determined that the processes associated with precipitation (water) use efficiency in grass plants were not fully activated unless 100 lbs/ac of mineral nitrogen was available. Manske (2010a, b) found evidence that the other defoliation resistance mechanisms (Manske 1999a, 2011b) had threshold requirements for activation at 100 lbs/ac of mineral nitrogen.

The presence of fire does not prove that grasslands need or are caused by fire (Heady 1975). The existence of a shrub component in a grassland is not an ecologically beneficial relationship as shrubs and grasses are adversarial inhibitive competitors. They compete for sunlight, mineral nitrogen, other essential elements, and soil water. Fire in grasslands cannot prevent the invasion of, or cause the removal of, shrubs, and trees that are able to reproduce by vegetative secondary suckers (Wright and Bailey 1982, Manske 2006a, b). Almost all deciduous woody plants reproduce vegetatively, except big sagebrush (Artemisia tridentata) (Manske 2014). Seedlings of trees, shrubs, weedy forbs, and introduced grasses cannot become established in grasslands containing grasses with full nutrient resource uptake competitiveness (Peltzer and Kochy 2001). Intrusive seedlings can only be established after a grassland has been degraded by poor management practices. Repeated prescribed fire can modify the composition of the aboveground vegetation in degraded grasslands which have been invaded by shrubs. The composition of introduced escaped cool season grasses may change, and early succession and weedy forbs, and shrub aerial stems decrease temporarily after four repeated prescribed fires (Manske 2007, 2011a). However, the fundamental problems of weak nutrient resource uptake, reduced water use efficiency, nonfunctional compensatory physiological mechanisms, impaired vegetative reproduction by tillering, and diminished biogeochemical processes will remain in the degraded grassland ecosystem following repeated fire events. None of the biological, physiological, or asexual mechanisms within grass plants and none of the rhizosphere microbes or biogeochemical processes they perform are activated by fire (Manske 2007, 2011a). Almost all of the essential elements in the aboveground herbage are volatilized when a grassland is burned, and if the soil is dry, some of the belowground essential elements are also lost (Russelle 1992). When the losses of essential elements are greater than the quantity of captured essential elements, the result is degradation of the grassland (McGill and Cole 1981). Fire does not improve grassland ecosystems biologically or ecologically and fire cannot replace the partial defoliation achieved by grazing graminivores in managing healthy and productive grassland ecosystems.

The 2006-2011 study (Manske 2012) evaluates reduction of escaped smooth bromegrass on pastures of degraded mix grass prairie with proper grazing management practices compared to nongrazing management.

The mixed grass prairie study area in ungrazed control pasture NR4 was a degraded silty ecological site dominated by Kentucky bluegrass. Control pasture NR4 was not grazed during the six years of the study and was not grazing during the 13 years prior to this study. At the start of the study (May 2006), the relative percent composition of the aboveground herbage biomass consisted of 72.3% standing dead and litter and 27.7% live herbage. The live herbage biomass was 95.2% escaped domesticated grasses (95.2% Kentucky bluegrass and 0.0% Smooth bromegrass), 2.5% native grasses (2.0% cool season grasses, 0.4% upland sedges, and less than 0.1% warm season grasses), and 2.4% forbs (table 10).

After 6 growing seasons of nongrazing, the relative percent composition of the aboveground herbage biomass consisted of 61.7% standing dead and litter and 38.3% live herbage. The live herbage biomass was 85.1% escaped domesticated grasses (85.1% Kentucky bluegrass and 0.0% Smooth bromegrass), 8.1% native grasses (5.6% warm season grasses, 2.1% cool season grasses, and 0.4% upland sedges), and 6.8% forbs (table 10). During the 6 years the study the composition of standing dead decreased permitting additional sunlight to penetrate deeper into the plant community. A small remnant colony of prairie sandreed, a tall native grass, was able to grow above the shading of the Kentucky bluegrass mat, and a few mid succession forbs were able to take advantage of the additional sunlight.

The mixed grass prairie study area in grazed pasture NR3 was a degraded silty ecological site dominated by smooth bromegrass and Kentucky bluegrass. This site was selected to represent the extreme challenge for grazing defoliation management to convert back to a functioning mixed grass prairie ecosystem. At the start of the study (May 2006), the relative percent composition of the aboveground herbage biomass consisted of 68.0% standing dead and litter and 32.0% live herbage. The live herbage biomass was 93.9% escaped domesticated grasses (51.4% smooth bromegrass, and 42.5% Kentucky bluegrass), 4.3% native grasses

(2.2% upland sedges, 1.8% cool season grasses, and 0.3% warm season grasses), and 1.8% forbs (table 10).

After 6 grazing seasons managed with the twice-over rotation system on pasture NR3, the relative percent composition of the aboveground herbage biomass consisted of 35.6% standing dead and litter and 64.4% live herbage. The live herbage biomass was 89.6% escaped domesticated grasses (62.0% Kentucky bluegrass and 27.6% smooth bromegrass), 5.5% native grasses (2.0% upland sedges, 2.0% cool season grasses and 1.5% warm season grasses), and 4.9% forbs (table 10).

The escaped smooth bromegrass on the 2006-2011 study had numerous long aggressive rhizomes like the escaped smooth bromegrass on the 1978-1990 study. The aggressive rhizomes classified the smooth bromegrass on both studies as southern type. The clean roots, without adhered soil particles disclosing no rhizosphere present, classified these smooth bromegrass plants as nonmycorrhizal indicating that they do not readily develop symbiotic relationships with rhizosphere microbes. A degraded mixed grass prairie dominated with escaped nonmycorrhizal smooth bromegrass would have an extremely low population of rhizosphere microbes and have a slim chance to repopulate with native grasses dependent on rhizosphere microbes to mineralize organic nitrogen and other essential elements.

Smooth bromegrass and Kentucky bluegrass both have labile roots that readily break down and can easily support new growth of these grasses without soil microbes. Native grass roots require 4 to 5 years for dead root material to break down with the assistance from numerous soil microorganisms. Kentucky bluegrass is facultative and can live with or without a relationship with rhizosphere microbes.

The basal cover relative percent composition of Kentucky bluegrass on the ungrazed control pasture NR4 had changed from 77% in 2006 to 86% in 2011 for a 12% increase (table 11). The basal cover of smooth bromegrass fluctuated with little change from 3.0% to 4.9% while the basal cover of Kentucky bluegrass increased 511% from 1.8% to 11.0% during six years of twice-over rotation grazing on pasture NR3. The basal cover relative percent composition in 2006 was 52.2% smooth bromegrass and 31.3% Kentucy bluegrass and by 2011 the basal cover relative percent composition had changed to 64.7% Kentucky bluegrass and 28.8% smooth bromegrass (table 11). The change in dominance from smooth bromegrass to Kentucky bluegrass resulted from the 106.7% increase in basal cover relative percent composition and was associated with a 226.0% increase in rhizosphere weight from 51.3 kg/m^3 to 167.1 kg/m^3 on grazed pasture NR3 after six years of grazing treatment (table 11).

The increase in basal cover of Kentucky bluegrass and weight of the rhizosphere started slow. The rhizosphere weight on pasture NR3 was slightly less than but not significantly different from the rhizosphere weight on control pasture NR4 during the first two years, 2006 and 2007. The rhizosphere weight on the ungrazed control pasture increased at a mean rate of 13.2 kg/m^3 per year from the second year to the sixth year. The fluctuations in rhizosphere weight on the nongrazed control were related to changes in growing season precipitation and related changes in grass growth and carbon energy leakage. The rhizosphere weights increased on the grazed pasture NR3 from the second year to the sixth year, 2007 to 2011, at a mean rate of 23.8 kg/m^3 per year which was 80.8% greater than the rate of increase on the ungrazed control pasture. The rhizosphere weight on pasture NR3 increase each year from the second year to the sixth year was significantly greater than the rhizosphere weight on the ungrazed control pasture NR4 during each respective year from 2008 to 2011 (table 11). The changes in rhizosphere weight on the grazed NR3 were related to the increase in basal cover relative composition of Kentucky bluegrass and to the annual partial defoliation by grazing that removed 25% to 33% of the aboveground leaf biomass of the lead tillers between the 3.5 new leaf stage and the flower stage which caused greater quantities of exudates containing simple carbon chain energy into the rhizosphere stimulating the rhizosphere microbes to increase in biomass and activity levels.

The rhizosphere weight of 167.1 kg/m^3 was 41.1% of the potential weight of 406.4 kg/m^3 and would be adequate to support the initial stages of conversion from a Kentucky bluegrass community to a native grass community.

The escaped smooth bromegrass plants of the 1978-1990 study, the 2006-2011 study, and the 1983-2012 study were all southern type with long aggressive rhizomes and nonmycorrhizal giving the strong impression that all escaped smooth bromegrass had similar characteristics. However, one example of an exception exists. Dr. Zaczkowski found an escaped smooth bromegrass with rhizosphere on the roots (figure 2) in southwestern North Dakota in 1970. This plant appears to be a Northern Type.

There is one small rhizome, no basal leaves, and a growth form of an open bunch grass. It is difficult to determine the source founder plants of escaped plants. The origin could be from plantings during the 1950's to increase forage production, plantings during the 1930's to revegetate abandoned homesteaders cropland, or plants from the early 1900's to provide forage for homesteaders livestock. If this specimen is a Northern Type, it could be a Manchar cultivar, or it could be a remnant from the numerous seed packets mailed to Dakota homesteaders by N.E. Hansen while working for South Dakota AES during the first two decades of the 1900's.

The 1983-2012 study follows the patterns in the changes of individual grass species abundance for 30 growing seasons on the sandy, shallow, and silty ecological sites of the long-term nongrazed, traditional seasonlong, and twice-over rotation management treatments (tables 12 and 13). Grass species composition in rangeland ecosystems is variable during a growing season and dynamic among growing seasons.

The presence of smooth bromegrass indicates that it had escaped and invaded a native rangeland ecological site. On the sandy site of the nongrazed treatment, Smooth bromegrass was present during 28.0% of the years that basal cover data were collected with a mean 0.25% basal cover during the total 30 year period. During the early period (1983-1992), Smooth bromegrass was not present. During the later period (1998-2012), Smooth bromegrass was present during 46.7% of the years with a mean 0.41% basal cover. Smooth bromegrass was present for a few years, then it was ecologically terminated from the sandy site of the nongrazed treatment (tables 12 and 13).

On the sandy site of the ungrazed twice-over treatment, Smooth bromegrass was present during 3.6% of the years that basal cover data were collected with a mean 0.02% basal cover during the total 30 year period. Smooth bromegrass was present for one growing season, then it was ecologically terminated from the sandy site of the ungrazed twice-over treatment (tables 12 and 13).

On the shallow site of the ungrazed twice-over treatment, Smooth bromegrass was present during 3.5% of the years that basal cover data were collected with a mean 0.03% basal cover during the total 30 year period. Smooth bromegrass was present for one growing season, then it was ecologically terminated from the shallow site of the ungrazed twice-over treatment (tables 12 and 13).

On the silty site of the nongrazed treatment, Smooth bromegrass was present during 30.8% of the years that basal cover data were collected with a mean 0.27% basal cover during the total 30 year period. During the early period (1983-1992), Smooth bromegrass was not present. During the later period (1998-2012), Smooth bromegrass was present during 40.0% of the years with a mean 0.46% basal cover. Smooth bromegrass was present for a few years, then it was ecologically terminated from the silty site of the nongrazed treatment (tables 12 and 13).

Smooth bromegrass did invade the sandy site of the nongrazed treatment for 7 years and did invade the silty site of the nongrazed treatment for 8 years. It was ecologically terminated from the sandy site and the silty site of the nongrazed treatment.

Smooth bromegrass did invade the sandy site of the ungrazed twice-over treatment for 1 year and did invade the shallow site of the ungrazed twice-over treatment for 1 year. It was ecologically terminated from the sandy and the shallow site of the ungrazed twice-over treatment. Smooth bromegrass did not invade any grazed ecological sites.

Discussion

Smooth bromegrass, *Bromus inermus*, is an introduced, long lived perennial, cool season, tall grass, monocot, of the grass family. Early introductions came to North America from the Hungarian Plains, the Russian Steppe, Northern Germany, and Manchuria in Northern Asia. Two strains are separated by the origination of the source material and growth characteristics. The Northern Type originated from the Russian Steppe and Northern Germany. The growth form mainly has stem leaves, weakly rhizomatous producing mostly crown tillers forming bunches, it has short glumes, develops more seeds, and grows slower but more evenly through the growing season producing lower peak aboveground herbage biomass. The Southern Type originated from the Hungarian Plains and France. The growth form has both basal leaves and stem leaves, strongly rhizomatous producing progressive rhizome tillers that are aggressive and invasive, it has long glumes, develops less seed, and grows rapidly early in the growing season for a short period producing greater peak aboveground herbage biomass. Smooth bromegrass became naturalized in North America early and escaped plants and plant communities established readily. Smooth bromegrass prefers clay loam and sandy loam soils.

Early aerial growth consists of leaf and stem development from crown and rhizome tiller buds during mid April. The extensive fibrous root system growth is activated early. Tillers produce three and a half new leaves by early May and grazing can start by 1 May. Early boot stage occurs in mid May, stalk emergence occurs in early June, and stalks with flowers appear during early June. Most lead tillers flower during June. Seed development soon follows with seeds reaching maturity during the first week of July. The early vegetative leaves contain above 18% crude protein during early to mid May. Crude protein levels decrease when seed stalks begin to develop. At the flower stage, lead tillers contain 14.4% crude protein and the greatest weight of crude protein per acre occurs. Crude protein remains above 9.6% as seeds mature until late June. Then the fiber content increases and crude protein, water, and digestibility decrease and by early July crude protein is below 9.5% and by early August below 8.0%. Phosphorus levels drop below 0.18% during early July.

Several important cultivars were developed from the original increase fields of the early introductions of smooth bromegrass that possess characteristics that remain beneficial today. Seed continues to be available for most of these early cultivars. The smooth bromegrass cultivars evaluated at DREC performed satisfactory under the environmental conditions of western North Dakota. Smooth bromegrass cultivars are beneficial when used for early spring pasture during May or cut for hay between the boot stage in mid May and the late flower stage ending in late June.

High seed viability and strong seedling vigor are characteristics of smooth bromegrass that facilitate success as a beneficial source of livestock pasture forage and harvested forage. These same characteristics permit smooth bromegrass to escape from places where it is wanted and invade places where it is not wanted. The term invade places negative connotations on smooth bromegrass as the sole bad guy, the same as if a hostile army invaded an innocent country. However, a hostile army cannot successfully invade an innocent country with a strong defense. The same as seedlings of trees, shrubs, weedy forbs, and introduced grasses cannot successfully invade and become established in grasslands containing healthy grasses with full nutrient resource uptake competitiveness (Peltzer and Kochy 2001). Intrusive plant seedlings can only be successful at establishment into grassland communities after the grassland ecosystem has been degraded by poor management practices. The manger is responsible for creating the habitat that permitted the invading plant species to become established.

Most grassland managers manage what they see above ground and do not know about the grass internal mechanisms of compensatory physiological activity, vegetative reproduction by tillering, water use efficiency, and nutrient resource uptake and that these mechanisms require a threshold quantity of available mineral nitrogen at 100 lbs/ac which must be mineralized from soil organic nitrogen by rhizosphere microbes that are limited by simple short chain carbon energy.

The presence of escaped smooth bromegrass that has successfully become established in a native grass pasture means that the manger has caused the above grass plant mechanisms and ecosystem processes to degrade. However, managers that cause these problems do not know they have caused these problems. Thus, the first activity against the invading plant is a direct attack with herbicide or fire which require multiple treatments. Even if these treatments have the effect of reducing the quantity of aboveground stems, the success is only short term. The application of herbicide and the implementation of prescribed burning treatments do not activate internal grass plant mechanisms or ecosystem processes and the effected ecosystems remain degraded, permitting the problem plants to reemerge.

Restoration of degraded grassland ecosystems requires returning the primary grass mechanisms and ecosystem processes to potential functioning levels. As an initial step, the rhizosphere organism biomass must be raised to increase the mineralization of nitrogen and other essential elements. Rhizosphere organisms are limited by accessing energy in the form of short carbon chains. Carbon energy can be released from grass lead tillers through the roots into the rhizosphere by removal of 25% to 33% of the aboveground leaf biomass by large grazing graminivores when the lead tillers are at the phenological growth stages between the three and a half new leaf stage and the flower stage during early June to mid July. Depending on the degree of degradation of the grassland, three to five or more growing seasons are required to increase the rhizosphere organism biomass to levels capable of mineralizing a threshold level of 100 lbs/ac or greater of available mineral nitrogen. Full activation of internal grass plant mechanisms requires mineral nitrogen to be available at this level. It also requires available carbon fixed through photosynthesis from 67% to 75% of the leaf area of predefoliated lead tillers before the flower stage, and from 50% of the leaf area after the flower stage. An increase in available essential elements permits the grass tillers to synthesize increasing quantities of carbohydrates, proteins, and nucleic acids to accelerate growth rates of replacement leaves and shoots, increase photosynthetic capacity of the remaining mature leaves, increase secondary tiller development from axillary buds, enhance the competitiveness of nutrient resource uptake and improve water use efficiency. The combination of increased ecosystem biogeochemical processes and improved functioning of the internal grass plant mechanisms results in increases in grass herbage production and in plant density (basal cover) of the desirable native grass species. Changes in the aboveground vegetation lag behind changes in the soil microorganism biomass and activity when a grassland ecosystem is degrading and also when it is aggrading.

When aggressive rhizomatous, nonmycorrhizal, Southern Type smooth bromegrass is the escaped grass that has invaded a degraded grassland, the rhizosphere microbe biomass cannot be increased on smooth bromegrass roots. A grass species that is facultative for mycorrhizal infection needs to be present in order to increase the rhizosphere microorganism biomass. In the Northern Plains, Kentucky bluegrass can be used for that role. The twice-over rotation system at 80% to 100% of the assessed stocking rate can be used to reduce the nonmycorrhizal smooth bromegrass and increase facultative for mycorrhiza Kentucky bluegrass. When the level of mycorrhiza biomass is large enough to support obligate native grasses, the twice-over rotation system can continue to be used to exchange the Kentucky bluegrass plants for the desirable native cool and warm season grasses.

If managers managed their grassland ecosystems to function at potential levels, the aggressive, nonmycorrhizal, Southern Type smooth bromegrass would not be able to escape places where it is wanted and invade places where it is not wanted.

Acknowledgment

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Table 1. Bromus inermis, weekly percent crude protein, percent phosphorus, and phenological growth stages of ungrazed lead tillers in western North Dakota, 1946-1947.

Sample Date	Crude Protein %	Phosphorus %	Phenological Growth Satges
Apr 1			
13	17.5	0.269	Early leaf greenup
19	17.1	0.244	
25	19.5	0.264	
May 4	20.1	0.302	Active leaf growth
10	18.3	0.285	
16	18.8	0.236	Flower stalk developing
23	17.4	0.260	
28	14.8	0.247	
Jun 6	14.9	0.264	Flower stalk emerging
13	14.4	0.253	Flowering (Anthesis)
19	11.3	0.240	Seed developing
26	10.2	0.211	Seed maturing
Jul 2	9.3	0.210	Drying
8	9.4	0.153	Seed mature
16	8.5	0.167	
24	-	-	
30	7.7	0.168	Drying
Aug 6	6.4	0.147	
13	7.9	0.161	
20	7.4	0.186	
26	6.8	0.183	Drying
Sep 3	7.1	0.116	
12	5.0	0.089	
21			
29	-	-	
Oct			
Nov 5	-	-	Drying

Data from Whitman et al. 1951.

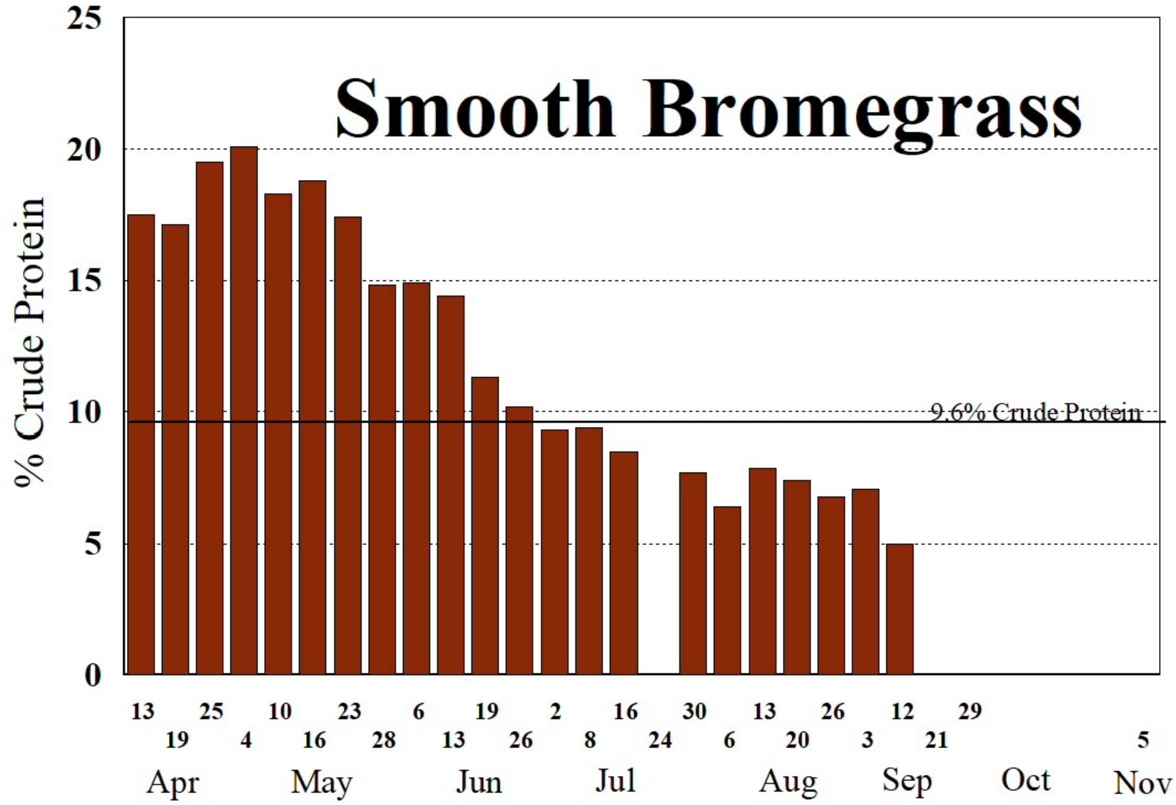

Fig 1. Mean percent crude protein of smooth bromegrass not cut for hay in western North Dakota, data from Whitman et al. 1951.

Table 2. First flower and flower period of Bromus inermis, Smooth bromegrass.

	Apr	May	Jun	Jul	Aug	Sep
First Flower						
Mean			13			
Flower Period 1969-1971			XX XX			

First Flower Data from Whitman et al. 1951.
Flower Period Data from Zaczkowski 1972.

Table 3. Intake nutrient requirements as percent of dry matter for range cows with average milk production.

	Dry Gestation	3rd Trimester	Early Lactation	Lactation (Spring, Summer, Fall)
1000 lb cows				
Dry matter (lbs)	21	21	24	24
Crude protein (%)	6.2	7.8	10.5	9.6
Phosphorus (%)	0.11	0.15	0.20	0.18
1200 lb cows				
Dry matter (lbs)	24	24	27	27
Crude protein (%)	6.2	7.8	10.1	9.3
Phosphorus (%)	0.12	0.16	0.19	0.18
1400 lb cows				
Dry matter (lbs)	27	27	30	30
Crude protein (%)	6.2	7.9	9.8	9.0
Phosphorus (%)	0.12	0.17	0.19	0.18

Data from NRC 1996.

Table 4. Smooth bromegrass cultivars evaluated for dry herbage yield in western North Dakota, 1954-1965, 1980-1985.

Smooth bromegrass Cultivar	Strain Origin	Originator or Developer	Year Released
Achenback	Southern	Kansas AES	1944
Baylor	Southern	Rudy-Patrick Co. Iowa	1964
Barton	Southern	Land O' Lakes Iowa	1973
Beacon	Southern	Land O' Lakes Iowa	1973
Blair	Southern	Rudy-Patrick Co. Iowa	1964
Elsberry	Southern	USDA-SCS, Missouri	1954
Fischer	Southern	Iowa	
Fox	Southern	Minnesota AES	1968
Homesteader	Northern	South Dakota	
Kuhl	Southern	Oregon	
Lancaster	Southern	Nebraska	
Lincoln	Southern	USDA, Nebraska AES	1942
Lyon	Southern	USDA, Nebraska AES	1950
Manchar	Asian, Intermediate	SCS, Washington, Idaho AES	1943
Martin	Southern	Minnesota	
Rebound	Southern	South Dakota AES	1978
Southland	Southern	Oklahoma	

Table 5. Uniform Bromegrass Nursery-Hay Yield lbs/ac at Dickinson Research Extension Center, 1954-1962.

Smooth bromegrass Cultivars	1954	1955	1956	1957	1958	1959	1960	1961	1962	Mean
Lincoln*	1606	1498		1459	1260	906	1103	432	1596	1232.5
Fischer	1637	1414		1408	1239	849	1093	461	1740	1230.1
Achenback*	1702	1463		1318	1159	734	1247	389	1771	1222.9
Elsberry*	1190	1548		1537	1184	952	995	438	1628	1184.0
Lancaster*	1275	1476		1397	1142	864	1086	405	1516	1145.1
Lyon*	1380	1511		1417	1140	707	1042	394	1524	1139.4
Kuhl	1334	1352		1486	1107	704	1059	401	1626	1133.6
Martin	1247	1335		1160	1179	951	971	384	1596	1102.9
Homesteader	1214	1433		1319	1099	677	996	402	1560	1087.5
Manchar*	1241	1478		1132	1126	746	997	448	1451	1077.4

Data from Whitman 1962. *Seed continues to be available.

Table 6. Grass and alfalfa mixture trial-Hay Yield lbs/ac at Dickinson Research Extension Center, 1959-1965.

Smooth bromegrass Smooth brome-Alfalfa	1959	1960	1961	1962	1963	1964	1965	Mean
Lincoln	2559	3107	971	2185	2507	799	2572	2100.0
Manchar	2332	2560	707	1937	2284	974	2391	1883.6
Southland brome	2344	3293	750	2141	2442	703	2640	2044.7
Northern brome	2324	2876	540	1818	2035	763	2075	1775.9
Lincoln-Ladak	2171	3272	903	2824	4542	1534	4105	2764.4
Lincoln-Teton	2329	2765	943	2682	4441	1698	3984	2691.7
Manchar-Ladak	2127	2764	692	2237	3654	1315	3259	2292.6

Data from Whitman 1965.

Table 7. Bromegrass Variety Trial-Annual herbage production in lbs/ac, at Dickinson Research Extension Center, 1980-1985.

Smooth bromegrass Cultivars	1980 23 Jun	1981 30 Jun	1982 28 Jun	1983 23 Jun	1984 5 Jul	1985 3 Jul	Mean
Baylor*	1441	2557	3792	1546	1541	1722	2099.8
Lancaster*	1395	2975	2752	1263	1765	1394	1924.0
Rebound*	1557	2440	3239	1491	1274	1329	1888.3
Barton*	1441	2511	2364	1294	1784	1464	1809.7
Fox	1372	2357	2576	1604	1567	1272	1791.3
Lyon*	1411	2692	2342	1314	1360	1293	1735.3
Blair	1443	2427	2224	1407	1400	1333	1705.7
Lincoln*	1483	2385	2384	1135	1334	1238	1659.8
Beacon*	1473	2364	1902	1172	1488	1456	1642.5
Manchar*	1337	2356	1995	1310	1292	1234	1587.3

Data from Manske and Goetz 1985. *Seed continues to be available.

Table 8. Effects on % shoot frequency and % fungi infection for western snowberry and smooth bromegrass for prescribed burning treatments, 1978-1990.

	Western snowberry			Smooth bromegrass		
Treatment	% Shoot Frequency	% Difference	% Fungi Infection	% Shoot Frequency	% Difference	% Fungi Infection
No Burns	58.3		93.8	17.5		32.3
1 Burn						
Spring	7.0	-88.0	88.3	0.0	-100.0	48.3
Early Summer	31.5	-46.0	79.9	0.0	-100.0	58.4
Mid Summer	17.0	-70.8	90.7	7.0	-60.0	-
2 Burns						
Spring	12.0	-79.4	84.2	3.5	-80.0	35.8
Early Summer	79.0	35.5	76.7	0.0	-100.0	36.3
Mid Summer	14.0	-76.0	92.0	0.0	-100.0	92.0
3 Burns						
Early Spring	5.0	-91.4	92.3	0.0	-100.0	33.7
Early Summer	31.5	-46.0	82.0	0.0	-100.0	20.8
Mid Summer	21.0	-64.0	84.3	2.0	-88.6	50.3
4 Burns						
Early Summer	14.5	-75.1	89.2	1.0	-94.3	32.9
Mid Summer	34.0	-41.7	79.3	0.0	-100.0	54.7

Data from Manske 1992.

Table 9. Available mineral nitrogen in lbs/ac during June and August by burn treatment, 1978-1990.

	June			August		
Treatment	Ammonium NH_4	Nitrate NO_3	Nitrogen $NH_4 + NO_3$	Ammonium NH_4	Nitrate NO_3	Nitrogen $NH_4 + NO_3$
No Burns	17.85	25.88	43.69	11.94	6.72	18.66
1 Burn						
Spring	5.22	25.19	30.38	22.84	6.10	28.94
Early Summer	23.49	19.22	42.71	18.99	5.29	24.28
Mid Summer	34.36	16.09	50.41	8.29	0.00	8.29
2 Burns						
Spring	6.95	29.66	36.61	7.21	9.40	16.61
Early Summer	21.21	29.73	50.94	21.96	1.70	23.66
Mid Summer	19.25	33.84	53.09	9.53	1.99	11.52
3 Burns						
Early Spring	8.45	9.10	17.56	4.50	1.70	6.20
Early Summer	9.10	10.18	19.28	18.44	6.07	24.51
Mid Summer	7.73	11.52	19.25	10.08	3.98	14.06
4 Burns						
Early Summer	17.46	19.06	36.51	12.24	4.27	16.51
Mid Summer	12.76	4.70	17.46	7.57	3.43	10.96

Data from Manske 1992.

Table 10. Herbage biomass relative composition (%) from start to finish on the control pasture NR4 and grazed pasture NR3, 2006-2011.

	Control Pasture NR4			Grazed Pasture NR3		
	2006 Start	(%)	2011 Finish	2006 Start	(%)	2011 Finish
Standing dead & litter	72.3		61.7	68.0		35.6
Live herbage	27.7		38.3	32.0		64.4
Domesticated grasses	95.2		85.1	93.9		89.6
Kentucky bluegrass	95.2		85.1	42.5		62.0
Smooth bromegrass	0.0		0.0	51.4		27.6
Native grasses	2.5		8.1	4.3		5.5
Cool season	2.0		2.1	1.8		2.0
Warm season	0.1		5.6	0.3		1.5
Upland sedges	0.4		0.4	2.2		2.0
Forbs	2.4		6.8	1.8		4.9

Data from Manske 2012.

Table 11. Grass relative composition (%) and rhizosphere weight (kg/m^3) for the control pasture NR4 and grazed pasture NR 3, 2006-2011.

	Grass Basal Cover Relative Composition (%)					
	Control Pasture NR 4			Grazed Pasture NR 3		
	Smooth Bromegrass	Kentucky Bluegrass	% Difference	Smooth Bromegrass	Kentucky Bluegrass	% Difference
2006	0.0	76.95	100.00	52.17	31.30	-40.00
2007	0.0	78.08	100.00	46.94	40.82	-13.04
2008	0.0	65.31	100.00	37.77	52.52	39.05
2009	0.0	80.53	100.00	44.44	49.32	10.98
2010	0.0	83.10	100.00	41.79	50.53	20.91
2011	0.28	85.96	100.00	28.82	64.71	124.53

	Rhizosphere Weight (kg/m^3)		
	Control Pasture NR 4	Grazed Pasture NR 3	% Difference
Pregrazing 2006	52.23	51.25	-1.88
2006	64.24x	54.14x	-15.72
2007	77.82x	71.67x	-7.90
2008	70.67y	94.88x	34.26
2009	82.88y	113.05x	36.40
2010	86.85y	139.94x	61.13
2011	130.56y	167.05x	27.95

Means in the same row and followed by the same letter (x, y) are not significantly different ($P<0.05$).
Data from Manske 2012.

Figure 2. Escaped smooth bromegrass plant with rhizosphere on roots.

Table 12. Autecology of Bromus inermis, Smooth brome, with growing season changes in basal cover, 1983-2012.					
Ecological Site Year Period	Nongrazed	Seasonlong		Twice-over	
		Ungrazed	Grazed	Ungrazed	Grazed
Sandy					
1983-1987	0.00	0.00	0.00	0.00	0.00
1988-1992	0.00	0.00	0.00	0.00	0.00
1993-1998	0.00	0.00	0.00	0.10	0.00
1999-2003	0.22	0.00	0.00	0.00	0.00
2004-2009	0.85	0.00	0.00	0.00	0.00
2010-2012	0.00	0.00	0.00	0.00	0.00
Shallow					
1983-1987	0.00	0.00	0.00	0.00	0.00
1988-1992	0.00	0.00	0.00	0.00	0.00
1993-1998	0.00	0.00	0.00	0.17	0.00
1999-2003	0.00	0.00	0.00	0.00	0.00
2004-2009	0.00	0.00	0.00	0.00	0.00
2010-2012	0.00	0.00	0.00	0.00	0.00
Silty					
1983-1987	0.00	0.00	0.00	0.00	0.00
1988-1992	0.00	0.00	0.00	0.00	0.00
1993-1998	0.03	0.00	0.00	0.00	0.00
1999-2003	1.02	0.00	0.00	0.00	0.00
2004-2009	0.31	0.00	0.00	0.00	0.00
2010-2012	0.00	0.00	0.00	0.00	0.00

Table 13. Autecology of Bromus inermis, Smooth brome, with growing season changes in basal cover importance value, 1983-2012.					
Ecological Site Year Period	Nongrazed	Seasonlong		Twice-over	
		Ungrazed	Grazed	Ungrazed	Grazed
Sandy					
1983-1987	0.00	0.00	0.00	0.00	0.00
1988-1992	0.00	0.00	0.00	0.00	0.00
1993-1998	0.00	0.00	0.00	0.91	0.00
1999-2003	1.71	0.00	0.00	0.00	0.00
2004-2009	6.10	0.00	0.00	0.00	0.00
2010-2012	0.00	0.00	0.00	0.00	0.00
Shallow					
1983-1987	0.00	0.00	0.00	0.00	0.00
1988-1992	0.00	0.00	0.00	0.00	0.00
1993-1998	0.00	0.00	0.00	1.03	0.00
1999-2003	0.00	0.00	0.00	0.00	0.00
2004-2009	0.00	0.00	0.00	0.00	0.00
2010-2012	0.00	0.00	0.00	0.00	0.00
Silty					
1983-1987	0.00	0.00	0.00	0.00	0.00
1988-1992	0.00	0.00	0.00	0.00	0.00
1993-1998	0.26	0.00	0.00	0.00	0.00
1999-2003	7.47	0.00	0.00	0.00	0.00
2004-2009	2.58	0.00	0.00	0.00	0.00
2010-2012	0.00	0.00	0.00	0.00	0.00

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