Autecology of Grasses on the Northern Mixed Grass Prairie

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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.

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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 Needle and Thread on the Northern Mixed Grass Prairie

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The autecology of Needle and Thread, *Hesperostipa comata*, 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).

Needle and Thread, *Hesperostipa comata* (Trin. & Rupr.) Barkworth, is a member of the grass family, Poaceae, tribe, Stipeae, Syn.: *Stipa comata* Trin. & Rupr., and is a native, long lived perennial, monocot, cool-season, mid grass, that is highly drought resistant. The first North Dakota record is Bergman 1910. Early aerial growth consists of basal leaves arising from crown tiller buds. Needle and thread consistently reaches the 3.5 (+) new leaf stage by 1 June, however, it rarely retains more than 2 full basal leaves during the early portion of the growing season, eliminating it as an indicator of physiological grazing readiness of native grasses. Basal leaf blades are 10-30 cm (3.9-11.8 in) long, 1-3 mm wide, tapering to a point, with strong ridges on upper surface. Leaves roll inward when dry. The split sheath has overlapping translucent margins. The indistinct collar is continuous and narrow. The ligule is a conspicuous membrane, 3-6 mm long, continuous with sheath margins, often split or frayed. The auricles are absent. This grass is generally considered to be exclusively a bunch grass, however, under proper management, short rhizome tillers can be produced. The extensive fibrous root system is primarily shallow with greater than 50% of the biomass in the top 18 cm (7 in) of soil. The main roots are 1 mm thick and branch profusely with numerous lateral roots. The lateral spread extends 36 cm (14 in) outward from the crown. Several main roots descend down to 91 cm (3 ft) deep with a few main roots extending to 1.8 m (5 ft) deep. Regeneration is primarily asexual propagation by crown tillers. Seedling success is low as a result of poor gemination and competition from established plants. Flower stalks are erect, 30-60 cm(12-24 in) tall. Inflorescence is a narrow panicle with several loosely spreading ascending branches, each with several one flowered spikelets. Flowers are rarely observable because of the prevalence of self fertilization (cleistogamy) within the closed sheath. Floret has a hard sharp pointed base and tip with a 10-13 cm (4-5 in) long awn that curls as it dries, twisting the seed into the soil. Flower period is late May to late June. The sharp pointed seed with a long awn can cause problems for livestock in hay, however, they rarely cause problems for grazing livestock. Leaves are highly palatable to livestock. Fire top kills aerial parts and fire can consume the entire crown when the soil is dry. Fire halts the processes of the four major defoliation resistance mechanisms and causes great reductions in biomass and tiller density. This summary information on growth development and regeneration of Needle and thread was based on works of Stevens 1963, Zaczkowski 1972, Dodds 1979, Great Plains Flora Association 1986, Zlatnik 1999, Ogle et al. 2006, Larson and Johnson 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 1955-1962 Study

Grass and upland sedge tiller growth in height of leaves and stalks were collected from ungrazed plants during the growing seasons of 1955-1962. Basal leaves were measured from ground level to the tip of the extended leaves. Culm leaves were measured from ground level to the apex of the uppermost leaf. Stalk measurements were from ground levels to the tip of the stalk or to the tip of the inflorescence after it had developed. An average of 10 plants of each species were measured at approximate 7 to 10 day intervals from early May until early September. In addition, phenological growth stages were recorded to include stalk initiation, head emergence, flowering (anthesis), seed development, seed maturity, earliest seed shedding, and an estimation of percent of leaf dry in relation to total leaf area. The grass growth in height and phenological data were reported in Goetz 1963.

The 1964-1969 Study

Phenological data of grass and upland sedge at anthesis stage was determined by recording observation dates. Leaf senescence by date was determined as an estimation of percentage of dry leaf in relation to total leaf area. Grass and upland sedge tiller growth in height of leaves were collected from ungrazed plants during the growing seasons of 1964-1966. Basal leaves were measured from ground level to the tip of the extended leaf. Culm leaves were measured from ground level to the apex of the uppermost leaf. An average of 20 plants at approximately 7 to 10 day intervals during the growing season from mid April to late August from control treatment on sandy, silty, overflow, and thin claypan ecological sites. Phenological data of anthesis stage, leaf senescence, and growth in leaf height were reported in Goetz 1970. Crude protein content of grasses and upland sedges was determined from a composite of 10 samples of each species collected systematically at biweekly intervals from mid May to early September, 1964-1969 on sandy, silty, overflow, and thin claypan ecological sites. Plant material was oven dried at 105°F. Analysis of the samples were made by the Cereal Technology Department, North Dakota State University, using standard crude protein determinations and reported in Goetz 1975.

The 1969-1971 Study

The range of flowering time of grasses and upland sedges were 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 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 will be reflected in the data summary tables as an 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

Needle and thread increases growth activity shortly after snow melt. Leaf growth in cool season grasses continues very slowly during the entire winter. The top portion of these carryover leaves become exposed to low temperatures causing the cell walls to rupture. The lower portion of the carryover leaves have intact cell walls and regreen with active chlorophyll when liquid water becomes available in the soil for at least during the daylight hours. The green portions of the carryover leaves provide a large quantity of carbohydrates and fixed energy used in the production of new leaves. Growth of new leaves is visible between 8 and 19 April (tables 1 and 2). Needle and thread consistently produce 3.5 new leaves by 1 June, however, the first and second leaves dry and break off early. Tillers rarely retain more than two leaves during the growing season. Lead tillers at the 3.5 new leaf stage are physiologically capable of positive response to partial defoliation of 25% to 33% of leaf weight by graminivores. On 1 June, the tallest basal leaf has reached 73% of maximum leaf height (table 2), and the lead tiller contain 15.2% crude protein and 0.265% phosphorus on silty ecological sites (table 1). Leaf growth in height is rapid during June (table 2). The flower stalk reaches the boot stage around 19-23-29 May, and reaches the flower (anthesis) stage between 6-23 June (tables 1, 3, 4, and 5). The flower period occurs during June (table 4). Needle and thread is cleistogamous and exposed flowers are rarely observed. At the end of June, the basal leaf growth has reached 97% of maximum height, seed stalk growth has reached 84.7% of maximum height, and the lead tiller still contains 12.0% crude protein (tables 1, 2, and 3). The seeds are maturing from 2 to 22 July and being shed from 16 to 26 July (tables 1 and 5). The lead tiller crude protein content had dropped below the requirements of lactating cows during the first week of July (tables 1and 6). Basal leaf maximum height is reached around 1 July and seed stalk maximum height is reached around 8 July (tables 2 and 3). Leaf dryness starts during late July and continues through August into early September (tables 1 and 5). The phosphorus content of lead tillers drops below the requirements of lactating cows during late July (tables 1 and 6). Needle and thread phenological development seems to be affected little by differences in characteristics of ecological sites (tables 7, 8, and 9). Lead tillers on several ecological sites drop below the crude protein requirements of lactating cows during early July. Leaf dryness starts to occur during early August. Leaf heights appear to be slightly shorter on sandy sites during April and May, then seem to catch up during June to the leaf heights on silty sites. Leaf heights on overflow sites seem to be the same as those on silty sites (tables 1, 2, 4, 5, 6, 7, 8, and 9). Unless the grazing management practice has properly manipulated the stimulation of an adequate quantity of Needle and thread vegetative secondary tillers, lactating cows will be grazing forage below their requirements after early July.

Grass species composition in rangeland ecosystems is variable during a growing season and dynamic among growing seasons. Patterns in the changes of individual grass species abundance was followed for 30 growing seasons during the 1983-2012 study on the sandy, shallow, and silty ecological sites of the long-term nongrazed, traditional seasonlong, and twice-over rotation management treatments (tables 10 and 11).

On the sandy site of the nongrazed treatment, Needle and thread was present during 100.0% of the years that basal cover data were collected with a mean 2.90% basal cover during the total 30 year period. During the early period (1983-1992), Needle and thread was present during 100.0%

of the years with a mean 2.74% basal cover. During the later period (1998-2012), Needle and thread was present during 100.0% of the years with a mean 2.97% basal cover. The percent present remained at 100.0% and basal cover increased on the sandy site of the nongrazed treatment over time (tables 10 and 11).

On the sandy site of the ungrazed seasonlong treatment, Needle and thread was present during 40.0% of the years that basal cover data were collected with a mean 1.37% basal cover during the total 30 year period. During the early period (1983-1992), Needle and thread was not present. During the later period (1998-2012), Needle and thread was present during 66.7% of the years with a mean 2.28% basal cover. Needle and thread was not present during the early period and all basal cover observations were made during the later period when basal cover had increased to typical abundance (tables 10 and 11).

On the sandy site of the grazed seasonlong treatment, Needle and thread was present during 100.0% of the years that basal cover data were collected with a mean 3.30% basal cover during the total 30 year period. During the early period (1983-1992), Needle and thread was present during 100.0% of the years with a mean 2.47% basal cover. During the later period (1998-2012), Needle and thread was present during 100.0% of the years with a mean 3.39% basal cover. The percent present remained at 100.0% and the basal cover increased on the sandy site of the grazed seasonlong treatment over time (tables 10 and 11). The percent present and basal cover were greater on the sandy site of the grazed seasonlong treatment than those on the sandy site of the ungrazed seasonlong treatment.

On the sandy site of the ungrazed twice-over treatment, Needle and thread was present during 100.0% of the years that basal cover data were collected with a mean 2.69% basal cover during the total 30 year period. During the early period (1983-1992), Needle and thread was present during 100.0% of the years with a mean 3.12% basal cover. During the later period (1998-2012), Needle and thread was present during 100.0% of the years with a mean 2.01% basal cover. The percent present remained at 100.0% and the basal cover decreased on the sandy site of the ungrazed twice-over treatment over time (tables 10 and 11).

On the sandy site of the grazed twice-over treatment, Needle and thread was present during 100.0% of the years that basal cover data were collected with a mean 3.33% basal cover during the total 30 year period. During the early period (1983-1992), Needle and thread was present during 100.0% of the years with a mean 2.80% basal cover. During the later period (1998-2012), Needle and thread was present during 100.0% of the years with a mean 3.56% basal cover. The percent present remained at 100.0% and the basal cover increased on the sandy site of the grazed twice-over treatment over time (tables 10 and 11). The percent present was the same at 100.0% and the basal cover was greater on the sandy site of the grazed twice-over treatment than those on the sandy site of the ungrazed twice-over treatment.

On the shallow site of the nongrazed treatment, Needle and thread was present during 100.0% of the years that basal cover data were collected with a mean 4.37% basal cover during the total 30 year period. During the early period (1983-1992), Needle and thread was present during 100.0% of the years with a mean 4.75% basal cover. During the later period (1998-2012), Needle and thread was present during 100.0% of the years with a mean 4.28% basal cover. The percent present remained at 100.0% and basal cover decreased on the shallow site of the nongrazed treatment over time (tables 10 and 11).

On the shallow site of the ungrazed seasonlong treatment, Needle and thread was present during 38.5% of the years that basal cover data were collected with a mean 1.81% basal cover during the total 30 year period. During the early period (1983-1992), Needle and thread was not present. During the later period (1998-2012), Needle and thread was present during 66.7% of the years with a mean 3.15% basal cover. Needle and thread was not present during the early period and all basal cover observations were made during the later period when basal cover had increased to typical abundance (tables 10 and 11).

On the shallow site of the grazed seasonlong treatment, Needle and thread was present during 96.2% of the years that basal cover data were collected with a mean 3.64% basal cover during the total 30 year period. During the early period (1983-1992), Needle and thread was present during 100.0% of the years with a mean 3.65% basal cover. During the later period (1998-2012), Needle and thread was present during 100.0% of the years with a mean 3.84% basal cover. The percent present remained the same and basal cover increased on the shallow site of the grazed seasonlong treatment over time (tables 10 and 11). The percent present and basal cover were greater on the shallow site of the grazed seasonlong treatment than those on the shallow site of the ungrazed seasonlong treatment.

On the shallow site of the ungrazed twice-over treatment, Needle and thread was present during 100.0% of the years that basal cover data were collected with a mean 3.77% basal cover during the total 30 year period. During the early period (1983-1992), Needle and thread was present during 100.0% of the years with a mean 3.86% basal cover. During the later period (1998-2012), Needle and thread was present during 100.0% of the years with a mean 3.38% basal cover. The percent present remained at 100.0% and basal cover decreased on the shallow site of the ungrazed twice-over treatment over time (tables 10 and 11).

On the shallow site of the grazed twice-over treatment, Needle and thread was present during 100.0% of the years that basal cover data were collected with a mean 3.02% basal cover during the total 30 year period. During the early period (1983-1992), Needle and thread was present during 100.0% of the years with a mean 3.71% basal cover. During the later period (1998-2012), Needle and thread was present during 100.0% of the years with a mean 2.82% basal cover. The percent present remained at 100.0% and basal cover decreased on the shallow site of the grazed twice-over treatment over time (tables 10 and 11). The percent present remained the same at 100.0% and the basal cover was greater on the shallow site of the ungrazed twice-over treatment than that on the shallow site of the grazed twice-over treatment.

On the silty site of the nongrazed treatment, Needle and thread was present during 100.0% of the years that basal cover data were collected with a mean 4.43% basal cover during the total 30 year period. During the early period (1983-1992), Needle and thread was present during 100.0% of the years with a mean 4.93% basal cover. During the later period (1998-2012), Needle and thread was present during 100.0% of the years with a mean 3.85% basal cover. The percent present remained at 100.0% and the basal cover decreased on the silty site of the nongrazed treatment over time (tables 10 and 11).

On the silty site of the ungrazed seasonlong treatment, Needle and thread was present during 100.0% of the years that basal cover data were collected with a mean 3.98% basal cover during the total 30 year period. During the early period (1983-1992), Needle and thread was present during 100.0% of the years with a mean 3.43% basal cover. During the later period (1998-2012), Needle and thread was present during 100.0% of the years with a mean 4.39% basal cover. The percent present remained at 100.0% and basal cover increased on the silty site of the ungrazed seasonlong treatment over time (tables 10 and 11).

On the silty site of the grazed seasonlong treatment, Needle and thread was present during 100.0% of the years that basal cover data were collected with a mean 2.71% basal cover during the total 30 year period. During the early period (1983-1992), Needle and thread was present during 100.0% of the years with a mean 3.25% basal cover. During the later period (1998-2012), Needle and thread was present during 100.0% of the years with a mean 2.63% basal cover. The percent present remained at 100.0% and basal cover decreased on the silty site of the grazed seasonlong treatment over time (tables 10 and 11). The percent present was the same at 100.0% and the basal cover was greater on the silty site of the ungrazed seasonlong treatment than that on the silty site of the grazed seasonlong treatment.

On the silty site of the ungrazed twice-over treatment, Needle and thread was present during 100.0% of the years that basal cover data were collected with a mean 2.38% basal cover during the total 30 year period. During the early period (1983-1992), Needle and thread was present during 100.0% of the years with a mean 3.96% basal cover. During the later period (1998-2012), Needle and thread was present during 100.0% of the years with a mean 0.63% basal cover. The percent present remained at 100.0% and basal cover decreased greatly on the silty site of the ungrazed twice-over treatment over time (tables 10 and 11).

On the silty site of the grazed twice-over treatment, Needle and thread was present during 100.0% of the years that basal cover data were collected with a mean 2.15% basal cover during the total 30 year period. During the early period (1983-1992), Needle and thread was present during 100.0% of the years with a mean 2.76% basal cover. During the later period (1998-2012), Needle and thread was present during 100.0% of the years with a mean 1.41% basal cover. The percent present remained at 100.0% and basal cover decreased on the silty site of the grazed twice-over treatment over time (tables 10 and 11). The percent present was the same at 100.0% and basal cover was greater during the early period and was lower during the later period on the silty site of the ungrazed twice-over treatment than those on the silty site of the grazed twice-over treatment.

On the sandy site, Needle and thread was present during 88.0% of the years with a mean 2.72% basal cover. On the shallow site, Needle and thread was present during 86.9% of the years with a mean 3.32% basal cover. On the silty site, Needle and thread was present during 100.0% of the years with a mean 3.13% basal cover. Technically, the percent present and basal cover values on the three ecological sites were not significantly different indicating that Needle and thread was not affected differently by the three different ecological sites. Numerically, basal cover was greater on the shallow site and percent present was greater on the silty site.

On the sandy site of the nongrazed treatment, Needle and thread was present during 100.0% of the years with a mean 2.90% basal cover. On the sandy site of the seasonlong treatment, Needle and thread was present during 70.0% of the years with a mean 2.33% basal cover. On the sandy site of the twice-over treatment, Needle and thread was present during 100.0% of the years with a mean 3.01% basal cover. The percent present was 100.0% on the sandy site of the nongrazed and twice-over treatments and basal cover was greater on the twice-over treatment. On the shallow site of the nongrazed treatment, Needle and thread was present during 100.0% of the years with a mean 4.37% basal cover. On the shallow site of the seasonlong treatment, Needle and thread was present during 67.3% of the years with a mean 2.73% basal cover. On the shallow site of the twice-over treatment, Needle and thread was present during 100.0% of the years with a mean 3.40% basal cover. The percent present was 100.0% on the shallow site of the nongrazed and twice-over treatments and basal cover was greater on the nongrazed treatment.

On the silty site of the nongrazed treatment, Needle and thread was present during 100.0% of the years with a mean 4.43% basal cover. On the silty site of the seasonlong treatment, Needle and thread was present during 100.0% of the years with a mean 3.34% basal cover. On the silty site of the twice-over treatment, Needle and thread was present during 100.0% of the years with a mean 2.27% basal cover. The percent present was 100.0% on the silty site of the nongrazed, seasonlong, and twice-over treatments and basal cover was greater on the nongrazed treatment.

Needle and thread was present on the not grazed treatments during 86.5% of the years with a mean 3.08% basal cover. Needle and thread was present on the grazed treatments during 99.4% of the years with a mean 3.02% basal cover. Technically, the percent present and basal cover values were not significantly different indicating that Needle and thread was not affected differently by being grazed or not grazed.

During the drought growing season of 1988, Needle and thread had 4.6% basal cover on the nongrazed treatment, had 4.1% basal cover on the grazed seasonlong treatment, and had 3.7% basal cover on the grazed twice-over treatment. Technically, not significantly different, indicating that Needle and thread was not affected differently by drought conditions on the three different management treatments.

Discussion

Needle and thread, *Hesperostipa comata*, is a native, long-lived perennial, cool season, mid grass, monocot, of the grass family that is common on healthy mixed grass prairie plant communities. Needle and thread can grow on sandy, shallow, silty, and overflow ecological sites. Data from 5 studies and 49 growing seasons did not identify an ecological site nor management treatment preference for Needle and thread. Needle and thread is drought resistant. Needle and thread tillers live for two growing seasons. Early season activity starts with regreening with active chlorophyll the portions of the carryover leaves that have intact cell walls from the previous growing season vegetative tillers and/or fall tillers. The green portion of the carryover leaves provides large quantities of carbohydrates and fixed energy for the production of new leaves. New leaves of Needle and thread are visible between 8 and 19 April. Needle and thread lead tillers are derived from carryover vegetative tillers and produces 3.5 new leaves by 1 June consistently, except the first and second leaves may be missing and sometimes a broken stub remains. Lead tillers at the 3.5 new leaf stage are physiologically capable of positive response to partial defoliation of 25% to 33% of leaf weight by graminivores. The tallest basal leaf is at 73.0% of maximum height on 1 June and the lead tiller contains 15.2% crude protein and 0.265% phosphorus on silty ecological sites during early June. The flower stalks reach the boot stage around 19 to 29 May and reach the flower stage around 6-23 June, with a four week flower period during June. Leaf growth and stalk growth in height is rapid during June. Basal leaves reach 97.0% of maximum height, seed stalks reach 84.7% of maximum height, and lead tillers contain 12.0% crude protein at the end of June. Basal leaves and seed stalks reach maximum height and the lead tillers drop below the crude protein requirements of lactating cows during the first week of July. Seeds mature during 2 to 22 July and are shed during 16 to 26 July. The phosphorus content drops below a lactating cows requirements at the end of July. Leaf dryness starts during early August and continues through September. Lead tillers of Needle and thread contribute little to forage value after mid July.

Vegetative tillers are derived mostly from carryover tillers that were most likely fall tillers from the previous growing season and some are derived from early season initiated tillers. Vegetative tillers have slightly slower growth rates than lead tillers during the early portion of the growing season. Vegetative tillers reach the 3.5 new leaf stage shortly after the lead tillers and become independent. When lead tiller growth rates decrease greatly during mid July, the vegetative tiller growth rates do not slow down. Grazing management practices that have less than 100 lbs/ac of available mineral nitrogen have less than a third of the quantity of vegetative tillers as grazing management practices that can produce greater than 100 lbs/ac available mineral nitrogen . Vegetative tillers provide around three fourths of the forage weight after mid July.

Secondary tillers are derived from growing season initiated tillers. With most initiated during May and June. Few secondary tillers are initiated during the period when lead tillers have high resource demand as they progress through the flower stage and seed production. Most of the secondary tillers on traditional grazing practices are terminated during the high resource demand period resulting in only about 3% surviving secondary tillers compared to those on the twice-over system. Surviving secondary tillers become independent of the lead tillers when the fourth leaf is near full development. These secondary tillers contribute to the forage weight after mid July. The quantity of vegetative and secondary tillers, and the quantity and quality of forage after mid July depends on the type of grazing management practices used during June and the first two weeks of July. Traditional grazing practices have low quantities of forage value vegetative and secondary tillers after mid July. Needle and thread is a valuable asset on the Northern Mixed Grass Prairie.

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Table 1. Hesperostipa comata, Needle and thread, 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 Stages
Apr 1			
13			
19	21.0	0.284	Early leaf greenup
25	25.3	0.263	
May 4	18.0	0.231	Active leaf growth
10	16.7	-	
16	16.4	0.274	
23	16.4	0.226	Flower stalk developing
28	14.2	0.236	
Jun 6	15.2	0.265	
13	13.3	0.251	Seed developing
19	13.8	0.234	
26	12.0	0.219	
Jul 2	10.6	0.222	Seed maturing
8	9.7	0.209	
16	9.2	0.184	Seed Shedding
24	8.5	0.188	
30	7.0	0.161	Drying
Aug 6	7.0	0.149	
13	6.2	0.144	
20	7.0	0.156	
26	5.7	0.146	Drying
Sep 3	6.4	0.137	
12	5.6	0.130	
21	-	-	
29	6.2	0.111	Drying
Oct			
Nov 5	5.4	0.010	Drying

Data from Whitman et al. 1951.

Table 2. Mean leaf height in cm and percent of maximum leaf height attained by Hesperostipa comata, Needle and thread, 1955-1962.

			April		
	1	8	15	22	29
cm		2.5	4.0	4.2	4.6
%		12.0	19.0	20.0	22.0
			May		
	1	8	15	22	29
cm	5.0	7.0	8.4	12.3	13.0
%	24.0	34.0	40.0	59.0	62.0
			June		
	1	8	15	22	29
cm	15.3	16.2	17.0	18.6	20.2
%	73.0	78.0	81.0	89.0	97.0
			July		
	1	8	15	22	29
cm	20.9				
%	100.0				
			August		
	1	8	15	22	29
cm					
%					

Data from Goetz 1963.

Table 3. Mean stalk height in cm and percent of maximum stalk height attained by Hesperostipa comata, Needle and thread, 1955-1962.

	April				
	1	8	15	22	29
cm					
%					
	May				
	1	8	15	22	29
cm					17.7
%					39.2
	June				
	1	8	15	22	29
cm	19.0	25.1	30.4	36.6	38.2
%	42.1	55.7	67.4	81.2	84.7
	July				
	1	8	15	22	29
cm	42.8	45.1			
%	94.2	100.0			
	August				
	1	8	15	22	29
cm					
%					

Data from Goetz 1963.

Table 4. First flower and flower period of Hesperostipa comata, Needle and thread.

	Apr	May	Jun	Jul	Aug	Sep
First Flower						
1955-1962						
Earliest			6			
Mean			23			
Flower Period						
1969-1971			XX XX			

First Flower Data from Goetz 1963 and Whitman et al. 1951.
Flower Period Data from Zaczkowski 1972.

Table 5. Flower stalk seed development and percent leaf dryness of Hesperostipa comata, Needle and thread.

	Flower Stalk Development			Seed Development	
Data Period	Boot	Emerge	Flower	Mature	Shed
1955-1962	19 May	9 Jun	23 Jun	22 Jul	26 Jul

		Percent Leaf Dryness			
Data Period	Leaf Tip Dry	0-25 %	25-50 %	50-75 %	75-100 %
1955-1962	31 Jul	17 Aug	25 Aug	9 Sep	

Data from Goetz 1963.

Table 6. 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 7. Mean date of first flower and date of percentage categories of leaf senescence for Needle and thread, 1964-1966.

Ecological Site	Anthesis	Leaf Tip Dry	Leaf 0-25% Dry	Leaf 25%-50% Dry	Leaf 50%-75% Dry
Sandy	26 Jun	25 Jun	19 Aug	9 Sep	1 Oct
Silty	6 Jul	7 Jun	11 Aug	15 Aug	1 Oct
Overflow	24 Jun	26 Jun	6 Aug	17 Aug	9 Sep
Thin claypan	No Data				

Data from Goetz 1970.

Table 8. Mean leaf height in cm for Needle and thread, 1964-1966.

Ecological Site	15 Apr	30 Apr	15 May	31 May	15 Jun	30 Jun	15 Jul	31 Jul	15 Aug	31 Aug	Maximum Height
Sandy	2.50	3.99	5.99	8.99	16.41	19.89	26.49	26.49	26.49	26.49	26.70
Silty	3.00	5.11	11.00	16.00	21.31	23.60	28.70	26.01	24.51	24.51	28.91
Overflow	2.90	5.11	11.00	16.00	21.31	23.60	28.70	26.01	24.51	24.51	28.91
Thin claypan	No Data										

Data from Goetz 1970.

Table 9. Percent crude protein for Needle and thread, 1964-1966.

Ecological Site		1 Jun	15 Jun	1 Jul	15 Jul	1 Aug	15 Aug	1 Sep	Mean
Sandy		14.2	13.8	7.9	8.1	6.7	6.4	5.9	9.0
Silty		12.3	9.9	7.7	7.9	6.9	6.7	6.1	8.2
Overflow	No Data								
Thin claypan	No Data								

Data from Goetz 1975.

Table 10. Autecology of Hesperostipa comata, Needle-and-thread, with growing season changes in basal cover, 1983-2012.					
Ecological Site Year Period	Nongrazed	Seasonlong		Twice-over	
		Ungrazed	Grazed	Ungrazed	Grazed
Sandy					
1983-1987	1.75	0.00	3.47	2.68	3.21
1988-1992	2.99	0.00	2.23	3.55	2.28
1993-1998	2.54	0.00	3.60	3.61	3.26
1999-2003	1.96	0.75	4.01	1.69	3.30
2004-2009	3.25	2.94	2.53	1.83	3.40
2010-2012	4.72	4.27	4.42	3.10	4.95
Shallow					
1983-1987	5.25	0.00	4.50	3.73	4.42
1988-1992	4.65	0.00	3.48	3.97	3.00
1993-1998	3.81	0.00	2.97	4.46	2.21
1999-2003	3.13	1.06	4.27	3.82	2.90
2004-2009	4.48	3.74	2.99	2.86	2.28
2010-2012	6.58	6.48	5.18	3.88	4.01
Silty					
1983-1987	4.35	2.50	3.00	3.41	2.81
1988-1992	5.05	3.61	3.29	4.40	2.70
1993-1998	4.89	3.34	2.11	4.18	2.84
1999-2003	2.75	3.21	3.09	0.64	1.29
2004-2009	4.42	4.38	1.62	0.48	1.23
2010-2012	5.37	6.84	4.36	0.75	2.01

Table 11. Autecology of Hesperostipa comata, Needle-and-thread, 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	16.59	0.00	25.62	21.98	21.40
1988-1992	23.84	0.00	19.57	28.02	20.65
1993-1998	26.31	0.00	21.62	25.04	24.78
1999-2003	17.88	5.89	29.73	17.98	25.85
2004-2009	30.36	27.80	20.96	22.05	28.55
2010-2012	38.30	40.47	34.55	35.02	38.28
Shallow					
1983-1987	41.62	0.00	32.42	26.96	28.76
1988-1992	40.64	0.00	30.70	36.03	28.31
1993-1998	34.00	0.00	23.45	28.08	17.89
1999-2003	25.92	7.36	30.83	29.52	19.99
2004-2009	38.77	31.28	21.21	25.71	17.66
2010-2012	50.02	50.40	32.51	33.05	27.63
Silty					
1983-1987	33.45	21.87	21.81	23.87	18.30
1988-1992	38.85	29.22	27.47	33.06	25.20
1993-1998	40.66	24.15	16.41	28.09	17.35
1999-2003	24.75	23.33	23.30	6.72	10.90
2004-2009	42.77	36.98	13.36	6.24	10.47
2010-2012	49.43	54.14	29.15	8.27	14.28

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Autecology of Green Needlegrass on the Northern Mixed Grass Prairie

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The autecology of Green needlegrass, *Nassella viridula*, 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).

Green needlegrass, *Nassella viridula* (Trin.) Barkworth, is a member of the grass family, Poaceae, tribe, Stipeae, Syn.: *Stipa viridula* Trin., and is a native, long lived perennial, monocot, cool-season, mid grass, that is drought and cold tolerant, disease resistant, moderately tolerant of flooding, and has a weak tolerance to shade. The first North Dakota record is Moran 1937. Early aerial growth consists of basal leaves arising from crown tiller buds. Basal leaf blades are 20-50 cm (8-20 in) long, 2-5.5 mm wide, tapering to a threadlike tip, with many prominent ridges on upper surface. Leaves roll inward when dry. The split sheath has overlapping margins and long soft hairs at the top of the throat. The narrow collar is continuous and has long hairs at the margins. The membranous ligule is 1–2 mm long, with a flat entire upper edge. The auricles are absent. The fibrous root system is extensive with the main roots 1 mm thick and well branched. The lateral spread extends 35.6 cm (14 in) in the next 15 cm (6 in) of soil. Abundant rootlets develop on the main roots in the top 76 cm (2.5 ft) of soil. A few long main roots extend downward to 1.5 m (5 ft) deep. Regeneration is primarily asexual propagation by crown tillers. Seedling success is low but better than most native grasses. Flower stalks are erect, 55-100 cm(21.6 -39.4 in) tall with fine, short hairs below the nodes. Inflorescence are dense, compact panicles 10-25 cm (4-10 in) long. The spikelets have one floret with a long slender tip and an attached awn that is twice bent and twisted. Flower period is from early June to mid July. Leaves are highly palatable to livestock. Fire top kills aerial parts and can consume the entire crown when the soil is dry. Fire halts the processes of the four major defoliation resistance mechanisms and causes great reductions in biomass production and tiller density. This summary information on growth development and regeneration of Green needlegrass was based on works of Stevens 1963, Zaczkowski 1972, Dodds 1979, Great Plains Flora Association 1986, Taylor 2001, Knudson 2005, and Johnson and Larson 2007.

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 1955-1962 Study

Grass and upland sedge tiller growth in height of leaves and stalks were collected from ungrazed plants during the growing seasons of 1955-1962. Basal leaves were measured from ground level to the tip of the extended leaves. Culm leaves were measured from ground level to the apex of the uppermost leaf. Stalk measurements were from ground levels to the tip of the stalk or to the tip of the inflorescence after it had developed. An average of 10 plants of each species were measured at approximate 7 to 10 day intervals from early May until early September. In addition, phenological growth stages were recorded to include stalk initiation, head emergence, flowering (anthesis), seed development, seed maturity, earliest seed shedding, and an estimation of percent of leaf dry in relation to total leaf area. The grass growth in height and phenological data were reported in Goetz 1963.

The 1964-1969 Study

Phenological data of grass and upland sedge at anthesis stage was determined by recording observation dates. Leaf senescence by date was determined as an estimation of percentage of dry leaf in relation to total leaf area. Grass and upland sedge tiller growth in height of leaves were collected from ungrazed plants during the growing seasons of 1964-1966. Basal leaves were measured from ground level to the tip of the extended leaf. Culm leaves were measured from ground level to the apex of the uppermost leaf. An average of 20 plants at approximately 7 to 10 day intervals during the growing season from mid April to late August from control treatment on sandy, silty, overflow, and thin claypan ecological sites. Phenological data of anthesis stage, leaf senescence, and growth in leaf height were reported in Goetz 1970. Crude protein content of grasses and upland sedges was determined from a composite of 10 samples of each species collected systematically at biweekly intervals from mid May to early September, 1964-1969 on sandy, silty, overflow, and thin claypan ecological sites. Plant material was oven dried at 105°F. Analysis of the samples were made by the Cereal Technology Department, North Dakota State University, using standard crude protein determinations and reported in Goetz 1975.

The 1969-1971 Study

The range of flowering time of grasses and upland sedges were 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.

Results

Green needlegrass increases growth activity shortly after snow melt. Leaf growth in cool season grasses continues very slowly during the entire winter. The top portion of these carryover leaves become exposed to low temperatures causing the cell walls to rupture. The lower portion of the carryover leaves have intact cell walls and regreen with active chlorophyll when liquid water becomes available in the soil for at least during the daylight hours. The green portion of the carryover leaves provide a large quantity of carbohydrates and fixed energy used in the production of new leaves. Growth of new leaves of Green needlegrass is visible by 13 April (tables 1). All native cool season grasses produce 3.5 new leaves at or shortly after 1 June, when lead tillers are physiologically capable of positive response to partial defoliation of 25% to 33% of leaf weight by graminivores. On 1 June, the tallest leaf has reached 66% of maximum leaf height (table 2). The flower stalk reaches the boot stage between 16 and 26 May, head emergence is reached around 12 June, and the flower (anthesis) stage is reached between 28 May and 16 June with the 5 week flower period from early June to mid July (tables 1, 3, 4, and 5). Lead tiller crude protein content is 23.5% at boot stage, 18.0% at head emergence and flower stage (table 1). Leaf growth is rapid during June reaching maximum height on 22 June (table 2). Seed stalks reach maximum height on 29 June and still contain 14.4% crude protein (tables 1 and 3). Seeds are developing between 13 June and 2 July, seeds are being shed between 12 and 16 July, and lead tillers drop below the crude protein requirements of lactating cows at the end of July (tables 1, 5, and 6). Leaf dryness starts on 29 July and continues through August into September (tables 1 and 5). Lead tillers drop below the phosphorus requirements of lactating cows in mid August (tables 1 and 6). Green needlegrass tillers growing on the overflow ecological site tend to produce taller leaf height after late May, have about the same rate of leaf dryness, and have greatly reduced crude protein content during the entire growing season than tillers growing on silty ecological sites (tables 7, 8, and 9). Unless grazing management practice has properly manipulated the stimulation of an adequate quantity of Green needlegrass vegetative secondary tillers, lactating cows will be grazing forage below their crude protein requirements after late July.

Discussion

Green needlegrass, *Nessella viridula*, is a native, long-lived perennial, cool season, mid grass, monocot, of the grass family that is common on healthy mixed grass prairie plant communities. Green needlegrass generally grows on medium to fine textured soils of loams to clay loams on silty and overflow ecological sites. Mixed grass prairie areas that the climate is semi arid with evapotranspiration greater than precipitation, Green needlegrass tends to grow on sites that receive some additional water as runin moisture. When Green needlegrass has sufficient spacing, the plants become robust, however, when other native grass species densities increase and encroach upon the Green needlegrass plants, Green needlegrass densities decrease. Green needlegrass is drought and cold tolerant, disease resistant, moderately tolerant of flooding for short periods, and has a weak tolerance to shade. The drought tolerance of Green needlegrass is greatly inferior to the drought tolerance of Needle and thread.

Green needlegrass tillers live for two growing seasons. Early season activity starts by regreening with active chlorophyll in the portions of the carryover leaves that have intact cell walls from the previous growing season vegetative tillers and fall tillers. The green portion of the carryover leaves provides large quantities of carbohydrates and fixed energy for the production of new leaves. Growth of new leaves of Green needlegrass are visible between 8 and 13 April. Green needlegrass lead tillers are derived from carryover vegetative tillers and produces 3.5 new leaves on or near 1 June. Lead tillers at the 3.5 new leaf stage are physiologically capable of positive response to partial defoliation of 25% to 33% of leaf weight by graminivores. The tallest leaf is at 66.0% of maximum height on 1 June and the lead tiller contains 17.9% crude protein and 0.262% phosphorus on silty ecological sites during early June. The flower stalks reach the boot stage around 16 to 26 May and reach the flower stage around 28 May to 16 June, with a five week flower period from early June to mid July. Some Green needlegrass flower heads are cleistogamous and exposed flower parts are rarely observed. Leaf growth and stalk growth in height is rapid during June and both reach maximum height during late June when lead tillers contain 14.4% crude protein. Seeds are developing between 13 June and 2 July, seeds are being shed between 12 and 16 July, and lead tillers drop below the crude protein requirements of lactating cows at the end of July. Leaf dryness starts on 29 July and continues through August into September. The phosphorus content of lead tillers drops below the requirements of lactating cows in mid August. Lead tillers contribute little to forage value after late July.

Vegetative tillers are derived mostly from carryover tillers that were most likely fall tillers from the previous growing season and some are derived from early season initiated tillers. Vegetative tillers have slightly slower growth rates than lead tillers during the early portion of the growing season. Vegetative tillers reach the 3.5 new leaf stage shortly after the lead tillers and become independent. When lead tiller growth rates decrease greatly during mid to late June, the vegetative tiller growth rates do not slow down and may increase some. Grazing management practices that have less than 100 lbs/ac of available mineral nitrogen have less than a third of the quantity of vegetative tillers as grazing management practices that can produce greater than 100 lbs/ac available mineral nitrogen. Vegetative tillers provide around three fourths of the quality forage weight after mid July.

Secondary tillers are derived from growing season initiated tillers. With most useful tillers initiated during May and June. Few secondary tillers are initiated during the period when lead tillers have high resource demand as they progress through the flower stage and seed production. Most of the secondary tillers on traditional grazing practices are terminated during the high resource demand period resulting in only about 3% surviving secondary tillers compared to those on the twice-over system. Surviving secondary tillers become independent of the lead tillers when the fourth leaf is near full development. These secondary tillers contribute high nutrient quality to the forage weight after mid July. The quantity of vegetative and secondary tillers, and the quantity and quality of forage after mid July depends on the type of grazing management practices used during June and the first two weeks of July. Traditional grazing practices have low quantities of forage value vegetative and secondary tillers and the lactating cows much consume forage that is below their nutritional requirements after mid or late July. Fall tillers are the most common secondary tiller type on traditional management practices. Fall tillers of cool season grasses initiate from mid August to late September or later during some years. These fall tillers become the vegetative tillers during the next growing season if they are not grazed during the current growing season. Green needlegrass is a valuable asset on the Northern Mixed Grass Prairie.

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Table 1. Nassella viridula, Green needlegrass, 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 Stages
Apr 1			
13	23.2	0.332	Early leaf greenup
19	26.4	0.346	
25	24.2	0.369	
May 4	23.8	0.332	Active leaf growth
10	20.2	0.368	
16	22.1	0.315	Flower stalk developing
23	18.2	0.239	
28	23.5	0.249	
Jun 6	17.9	0.262	
13	18.0	0.271	Seed developing
19	18.3	0.224	
26	14.4	0.213	
Jul 2	13.9	0.220	Seed maturing
8	12.1	0.217	
16	14.7	0.239	Seed Shedding
24	9.9	0.207	
30	10.6	0.205	Drying
Aug 6	8.3	0.184	
13	7.7	0.183	Drying
20	7.5	0.176	
26	7.5	0.173	
Sep 3	4.7	-	
12	4.8	-	Drying
21	-	-	
29	6.5	0.118	Drying
Oct			
Nov 5	4.4	0.222	Drying

Data from Whitman et al. 1951.

Table 2. Mean leaf height in cm and percent of maximum leaf height attained by Nassella viridula, Needle and thread, 1955-1962.

			April		
	1	8	15	22	29
cm		4.0	7.0	8.7	10.0
%		12.0	21.0	26.0	29.0
			May		
	1	8	15	22	29
cm	12.0	13.5	16.0	20.3	22.3
%	35.0	40.0	47.0	60.0	66.0
			June		
	1	8	15	22	29
cm	22.3	25.6	32.0	34.0	
%	66.0	75.0	94.0	100.0	
			July		
	1	8	15	22	29
cm					
%					
			August		
	1	8	15	22	29
cm					
%					

Data from Goetz 1963.

Table 3. Mean stalk height in cm and percent of maximum stalk height attained by Nassella viridula, Needle and thread, 1955-1962.

	April				
	1	8	15	22	29
cm					
%					
	May				
	1	8	15	22	29
cm					25.7
%					45.4
	June				
	1	8	15	22	29
cm	26.0	28.5	37.4	45.0	56.5
%	46.0	50.4	66.2	79.6	100.0
	July				
	1	8	15	22	29
cm					
%					
	August				
	1	8	15	22	29
cm					
%					

Data from Goetz 1963.

Table 4. First flower and flower period of Nassella viridula, Green needlegrass.

	Apr	May	Jun	Jul	Aug	Sep
First Flower						
1955-1962						
Earliest		28				
Mean			16			
Flower Period						
1969-1971			XX XX X			

First Flower Data from Goetz 1963 and Whitman et al.
Flower Period Data from Zaczkowski 1972.

Table 5. Flower stalk seed development and percent leaf dryness of Nassella viridula, Green needlegrass.

	Flower Stalk Development			Seed Development	
Data Period	Boot	Emerge	Flower	Mature	Shed
1955-1962	26 May	12 Jun	16 Jun	2 Jul	12 Jul

		Percent Leaf Dryness			
Data Period	Leaf Tip Dry	0-25 %	25-50 %	50-75 %	75-100 %
1955-1962	19 Jun	29 Jul	26 Aug	11 Sep	

Data from Goetz 1963.

Table 6. 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 7. Mean date of first flower and date of percentage categories of leaf senescence for Green needlegrass, 1964-1966.

Ecological Site	Anthesis	Leaf Tip Dry	Leaf 0-25% Dry	Leaf 25%-50% Dry	Leaf 50%-75% Dry
Sandy	No Data				
Silty	No Data				
Overflow	29 Jun	7 Jun	1 Jul	23 Aug	12 Sep
Thin claypan	No Data				

Data from Goetz 1970.

Table 8. Mean leaf height in cm for Green needlegrass, 1964-1966.

Ecological Site	15 Apr	30 Apr	15 May	31 May	15 Jun	30 Jun	15 Jul	31 Jul	15 Aug	31 Aug	Maximum Height
Sandy	No Data										
Silty	No Data										
Overflow	3.91	8.99	13.00	26.01	36.80	43.79	50.50	45.01	43.99	43.99	50.50
Thin claypan	No Data										

Data from Goetz 1970.

Table 9. Percent crude protein for Green needlegrass, 1964-1966.

Ecological Site		1 Jun	15 Jun	1 Jul	15 Jul	1 Aug	15 Aug	1 Sep	Mean
Sandy	No Data								
Silty	No Data								
Overflow		14.9	12.5	9.7	9.1	6.8	7.1	7.3	9.6
Thin claypan	No Data								

Data from Goetz 1975.

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Autecology of Western Wheatgrass on the Northern Mixed Grass Prairie

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The autecology of Western wheatgrass, *Pascopyrum smithii*, 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).

Western wheatgrass, *Pascopyrum smithii* (Rydb.) A. Love, is a member of the grass family, Poaceae, tribe, Triticeae, syn., *Elymis smithii*, (Rydb.) Gould*, Agropyron smithii* Rydb., and is a native, long-lived perennial, monocot, cool-season, mid grass, that is tolerant of cold, drought, and periodic flooding, has a high tolerance to alkali and saline soils, and moderately shade tolerant. The first North Dakota record is Potter and Greene 1958. Early aerial growth consists of basal leaves arising from rhizome tiller buds. Leaf blades are 5-25 cm (2-10 in) long, 2-4 mm wide, stiff, thick, deeply ridged on the upper surface, tapering to a point. The split sheath has overlapping margins that open toward the top and has a brown or purplish base. The collar is not well defined, continuous, and medium broad. The ligule is a short flat membrane less than 1 mm long. The auricles are long and clasping, sometimes purplish. The creeping rhizome system is extensive. The aggressive rhizomes are primarily in the top 7.6-10.2 cm(3-4 in) of soil. The frequent branches are 15-91 cm (6-36 in) long, produce single or small groups of aerial stems per node at short progressive intervals. The extensive root system has tough, white or light colored main roots 0.5-1.5 mm thick arising from stem crowns and rhizome nodes growing vertically downward regularly producing profuse quantities of short branches that almost completely occupy the soil. Depth of root penetration varies with soil conditions, usually ranging from 1.2 m (4 ft) to 2.1 m (7 ft) deep. Regeneration is primarily asexual propagation by rhizome tiller buds. Seedling success is low as a result of competition from established plants. Flower stalks are erect, hollow, 30-90 cm(11.8-35 in) tall. Inflorescence is an erect compact spike, 3-16 cm (1.2-6.3 in) long, with overlapping solitary spikelets of 3 to 8 florets. Flower period is June. Aerial parts are highly palatable to livestock. Fire consumes aerial parts halting the process of the four major defoliation resistence mechanisms and causing great reductions in biomass production and tiller density. This summary information on growth development and regeneration of Western wheatgrass was based on works of Weaver 1954, Stevens 1963, Zaczkowski 1972, Dodds 1979, Great Plains Flora Association 1986, Trimenstein 1999, Larson and Johnson 2007, Ogle et al. 2009, 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 1955-1962 Study

Grass and upland sedge tiller growth in height of leaves and stalks were collected from ungrazed plants during the growing seasons of 1955-1962. Basal leaves were measured from ground level to the tip of the extended leaves. Culm leaves were measured from ground level to the apex of the uppermost leaf. Stalk measurements were from ground levels to the tip of the stalk or to the tip of the inflorescence after it had developed. An average of 10 plants of each species were measured at approximate 7 to 10 day intervals from early May until early September. In addition, phenological growth stages were recorded to include stalk initiation, head emergence, flowering (anthesis), seed development, seed maturity, earliest seed shedding, and an estimation of percent of leaf dry in relation to total leaf area. The grass growth in height and phenological data were reported in Goetz 1963.

The 1964-1969 Study

Phenological data of grass and upland sedge at anthesis stage was determined by recording observation dates. Leaf senescence by date was determined as an estimation of percentage of dry leaf in relation to total leaf area. Grass and upland sedge tiller growth in height of leaves were collected from ungrazed plants during the growing seasons of 1964-1966. Basal leaves were measured from ground level to the tip of the extended leaf. Culm leaves were measured from ground level to the apex of the uppermost leaf. An average of 20 plants at approximately 7 to 10 day intervals during the growing season from mid April to late August from control treatment on sandy, silty, overflow, and thin claypan ecological sites. Phenological data of anthesis stage, leaf senescence, and growth in leaf height were reported in Goetz 1970. Crude protein content of grasses and upland sedges was determined from a composite of 10 samples of each species collected systematically at biweekly intervals from mid May to early September, 1964-1969 on sandy, silty, overflow, and thin claypan ecological sites. Plant material was oven dried at 105°F. Analysis of the samples were made by the Cereal Technology Department, North Dakota State University, using standard crude protein determinations and reported in Goetz 1975.

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 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 will be reflected in the data summary tables as an 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

Western wheatgrass increases growth activity shortly after snow melt. Leaf growth in cool season grasses continues very slowly during the entire winter. The top portion of these carryover leaves become exposed to low temperatures causing the cell walls to rupture. The lower portion of the carryover leaves have intact cell walls and regreen with active chlorophyll when liquid water becomes available in the soil for at least during the daylight hours. The green portions of the carryover leaves provide a large quantity of carbohydrates and energy used in the production of new leaves. Growth of new leaves is visible by 19 April (table 1). All native cool season grasses produce 3.5 new leaves at or shortly after 1 June, when lead tillers are physiologically capable of positive response to partial defoliation of 25% to 33% of leaf weight by graminivores. On 1 June, the tallest culm leaf has reached 79% of maximum leaf height (table 2), and the lead tiller contain 15.4% crude protein and 0.281% phosphorus on silty ecological sites (table 1). Leaf growth in height is rapid during June (table 2). The flower stalk reaches the boot stage between 15 and 19 June, and reaches the flower (anthesis) stage between 2 and 14 July (tables 1, 4, and 5). An observed flower period occurred in 1969 to 1971 during the last two weeks of June (table 4). During mid July, the culm leaf growth has reached 93% of maximum height, the rate of growth has greatly slowed and leaf senescence has started, the flower stalk has reached 98% of maximum height, the seeds are developing, and the lead tillers content of crude protein has decreased to 10.6% (tables 1, 2, 3, and 5). During the third week of July, crude protein content of the lead tillers has dropped below the requirements of lactating cows (tables 1 and 6). Leaf and stalk maximum height is reached at the end of July (tables 2 and 3), and the percent leaf dryness increases after late July through August and into September (table 5). The phosphorus content of lead tillers drops below the requirements of lactating cows during early August (tables 1 and 6). Western wheatgrass phenological development is somewhat variable and affected by differences in characteristics of ecological sites (tables 7, 8, and 9). The previous discussion was based on data collected on silty ecological sites. Western wheatgrass tillers growing on the thin claypan ecological site tends to produce shorter leaf height, earlier leaf senescence, and is deficient in crude protein content after July. Western wheatgrass tillers growing on the overflow ecological site tends to produce taller leaf height through mid July and slightly greater crude protein content into the first week of August. Western wheatgrass tillers growing on the sandy ecological site tends to produce shorter leaf height after early June and slightly delayed leaf senescence until October (tables 7, 8, and 9). Peak herbage biomass of Western wheatgrass lead tillers is reached during the last two weeks of July and after 15 August, vegetative secondary fall tillers produce from 140 to 200 lbs/ac of new growth herbage biomass (table 10). Unless the grazing management practice has properly manipulated the stimulation of an adequate quantity of vegetative secondary tillers, lactating cows will be grazing forage below their requirements after mid to late July.

Grass species composition in rangeland ecosystems is variable during a growing season and dynamic among growing seasons. Patterns in the changes of individual grass species abundance was followed for 30 growing seasons during the 1983-2012 study on the sandy, shallow, and silty ecological sites of the long-term nongrazed, traditional seasonlong, and twice-over rotation management treatments (tables 11 and 12).

On the sandy site of the nongrazed treatment, Western wheatgrass was present during 84.0% of the years that basal cover data were collected with a mean 0.57% basal cover during the total 30 year period. During the early period (1983-1992), Western wheatgrass was present during 40.0% of the years with a mean 0.30% basal cover. During the later period (1998-2012), Western wheatgrass was present during 100.0% of the years with a mean 0.50% basal cover. The percent present and basal cover increased on the sandy site of the nongrazed treatment over time (tables 11 and 12).

On the sandy site of the ungrazed seasonlong treatment, Western wheatgrass was present during 28.0% of the years that basal cover data were collected with a mean 0.08% basal cover during the total 30 year period. During the early period (1983-1992), Western wheatgrass was not present. During the later period (1998-2012), Western wheatgrass was present during 46.7% of the years with a mean 0.14% basal cover. Western wheatgrass was not present during the early period and all basal cover observations were made during the later period that indicated low abundance (tables 11 and 12).

On the sandy site of the grazed seasonlong treatment, Western wheatgrass was present during 68.0% of the years that basal cover data were collected with a mean 0.30% basal cover during the total 30 year period. During the early period (1983-1992), Western wheatgrass was present during 80.0% of the years with a mean 0.53% basal cover. During the later period (1998-2012), Western wheatgrass was present during 66.7% of the years with a mean 0.13% basal cover. The percent present and basal cover decreased on the sandy site of the grazed seasonlong treatment over time (tables 11 and 12). The percent present and basal cover were greater on the sandy site of the grazed seasonlong treatment than those on the sandy site of the ungrazed seasonlong treatment.

On the sandy site of the ungrazed twice-over treatment, Western wheatgrass was present during 89.7% of the years that basal cover data were collected with a mean 0.48% basal cover during the total 30 year period. During the early period (1983-1992), Western wheatgrass was present during 100.0% of the years with a mean 0.97% basal cover. During the later period (1998-2012), Western wheatgrass was present during 86.7% of the years with a mean 0.12% basal cover. The percent present decreases and basal cover decreases greatly on the sandy site of the ungrazed twice-over treatment over time (tables 11and 12).

On the sandy site of the grazed twice-over treatment, Western wheatgrass was present during 93.1% of the years that basal cover data were collected with a mean 0.45% basal cover during the total 30 year period. During the early period (1983-1992), Western wheatgrass was present during 77.8% of the years with a mean 0.60% basal cover. During the later period (1998-2012), Western wheatgrass was present during 100.0% of the years with a mean 0.23% basal cover. The percent present increased and basal cover decreased on the sandy site of the grazed twice-over treatment over time (tables 11 and 12). During the early period, the percent present and basal cover were greater on the sandy site of the ungrazed twice-over treatment. During the later period, the percent present and basal cover were greater on the sandy site of the grazed twice-over treatment.

On the shallow site of the nongrazed treatment, Western wheatgrass was present during 84.6% of the years that basal cover data were collected with a mean 0.35% basal cover during the total 30 year period. During the early period (1983-1992), Western wheatgrass was present during 83.3% of the years with a mean 0.21% basal cover. During the later period (1998-2012), Western wheatgrass was present during 80.0% of the years with a mean 0.33% basal cover. The percent present decreased and basal cover increased on the shallow site of the nongrazed treatment over time (tables 11 and 12).

On the shallow site of the ungrazed seasonlong treatment, Western wheatgrass was present during 34.6% of the years that basal cover data were collected with a mean 0.14% basal cover during the total 30 year period. During the early period (1983-1992), Western wheatgrass was not present. During the later period (1998-2012), Western wheatgrass was present during 60.0% of the years with a mean 0.24% basal cover. Western wheatgrass was not present during the early period and all basal cover observations were made during the later period that indicated low abundance (tables 11 and 12).

On the shallow site of the grazed seasonlong treatment, Western wheatgrass was present during 88.5% of the years that basal cover data were collected with a mean 0.58% basal cover during the total 30 year period. During the early period (1983-1992), Western wheatgrass was present during 66.7% of the years with a mean 0.26% basal cover. During the later period (1998-2012), Western wheatgrass was present during 100.0% of the years with a mean 0.76% basal cover. The percent present and basal cover increased on the shallow site of the grazed seasonlong treatment over time (tables 11 and 12). The percent present and basal cover were greater on the shallow site of the grazed seasonlong treatment than those on the shallow site of the ungrazed seasonlong treatment.

On the shallow site of the ungrazed twice-over treatment, Western wheatgrass was present during 100.0% of the years that basal cover data were collected with a mean 1.00% basal cover during the total 30 year period. During the early period (1983-1992), Western wheatgrass was present during 100.0% of the years with a mean 0.59% basal cover. During the later period (1998-2012), Western wheatgrass was present during 100.0% of the years with a mean 1.09% basal cover. The percent present remained the same and basal cover increased on the shallow site of the ungrazed twice-over treatment over time (tables 11 and 12).

On the shallow site of the grazed twice-over treatment, Western wheatgrass was present during 96.7% of the years that basal cover data were collected with a mean 0.64% basal cover during the total 30 year period. During the early period (1983-1992), Western wheatgrass was present during 90.0% of the years with a mean 0.42% basal cover. During the later period (1998-2012), Western wheatgrass was present during 100.0% of the years with a mean 0.62% basal cover. The percent present and basal cover increased on the shallow site of the grazed twice-over treatment over time (tables 11 and 12). The percent present was slightly greater and basal cover was greater on the shallow site of the ungrazed twice-over treatment than those on the shallow site of the grazed twice-over treatment.

On the silty site of the nongrazed treatment, Western wheatgrass was present during 96.2% of the years that basal cover data were collected with a mean 1.60% basal cover during the total 30 year period. During the early period (1983-1992), Western wheatgrass was present during 83.3% of the years with a mean 1.42% basal cover. During the later period (1998-2012), Western wheatgrass was present during 100.0% of the years with a mean 1.41% basal cover. The percent present increased and basal cover remained the same on the silty site of the nongrazed treatment over time (tables 11 and 12).

On the silty site of the ungrazed seasonlong treatment, Western wheatgrass was present during 100.0% of the years that basal cover data were collected with a mean 2.20% basal cover during the total 30 year period. During the early period (1983-1992), Western wheatgrass was present during 100.0% of the years with a mean 1.59% basal cover. During the later period (1998-2012), Western wheatgrass was present during 100.0% of the years with a mean 1.60% basal cover. The percent present and basal cover remained the same on the silty site of the ungrazed seasonlong treatment over time (tables 11 and 12).

On the silty site of the grazed seasonlong treatment, Western wheatgrass was present during 100.0% of the years that basal cover data were collected with a mean 1.58% basal cover during the total 30 year period. During the early period (1983-1992), Western wheatgrass was present during 100.0% of the years with a mean 1.70% basal cover. During the later period (1998-2012), Western wheatgrass was present during 100.0% of the years with a mean 1.21% basal cover. The percent present remained the same and basal cover decreased on the silty site of the grazed seasonlong treatment over time (tables 11 and 12). The percent present were the same and basal cover was greater on the silty site of the ungrazed seasonlong treatment than that on the silty site of the grazed seasonlong treatment.

On the silty site of the ungrazed twice-over treatment, Western wheatgrass was present during 100.0% of the years that basal cover data were collected with a mean 3.91% basal cover during the total 30 year period. During the early period (1983-1992), Western wheatgrass was present during 100.0% of the years with a mean 2.83% basal cover. During the later period (1998-2012), Western wheatgrass was present during 100.0% of the years with a mean 4.22% basal cover. The percent present remained the same and basal cover increased on the silty site of the ungrazed twice-over treatment over time (tables 11 and 12).

On the silty site of the grazed twice-over treatment, Western wheatgrass was present during 100.0% of the years that basal cover data were collected with a mean 3.00% basal cover during the total 30 year period. During the early period (1983-1992), Western wheatgrass was present during 100.0% of the years with a mean 2.74% basal cover. During the later period (1998-2012), Western wheatgrass was present during 100.0% of the years with a mean 3.38% basal cover. The percent present remained the same and basal cover increased on the silty site of the grazed twice-over treatment over time (tables 11 and 12). The percent present were the same and basal cover was greater on the silty site of the ungrazed twice-over treatment than that on the silty site of the grazed twice-over treatment.

On the sandy site, Western wheatgrass was present during 72.6% of the years with a mean 0.38% basal cover. On the shallow site, Western wheatgrass was present during 80.9% of the years with a mean 0.54% basal cover. On the silty site, Western wheatgrass was present during 99.2% of the years with a mean 2.46% basal cover. The percent present and basal cover were greater on the silty site.

On the sandy site of the nongrazed treatment, Western wheatgrass was present during 84.0% of the years with a mean 0.57% basal cover. On the sandy site of the seasonlong treatment, Western wheatgrass was present during 48.0% of the years with a mean 0.19% basal cover. On the sandy site of the twice-over treatment, Western wheatgrass was present during 91.4% of the years with a mean 0.46% basal cover. On the sandy site, Western wheatgrass percent present was greater on the twice-over treatment and basal cover was greater on the nongrazed treatment.

On the shallow site of the nongrazed treatment, Western wheatgrass was present during 84.6% of the years with a mean 0.35% basal cover. On the shallow site of the seasonlong treatment, Western wheatgrass was present during 61.5% of the years with a mean 0.36% basal cover. On the shallow site of the twice-over treatment, Western wheatgrass was present during 98.3% of the years with a mean 0.82% basal cover. On the shallow site, Western wheatgrass percent present and basal cover was greater on the twice-over treatment.

On the silty site of the nongrazed treatment, Western wheatgrass was present during 96.2% of 26 years with a mean 1.60% basal cover. On the silty site of the seasonlong treatment, Western wheatgrass was present during 100.0% of 26 years with a mean 1.89% basal cover. On the silty site of the twice-over treatment, Western wheatgrass was present during 100.0% of 30 years with a mean 3.46% basal cover. On the silty site, Western wheatgrass percent present and basal cover was greater on the twice-over treatment.

Western wheatgrass was present on the nongrazed treatment during 88.3% of the years with a mean 0.84% basal cover. Western wheatgrass was present on the seasonlong treatment during 69.9% of the years with a mean 0.81% basal cover. Western wheatgrass was present on the twice-over treatment during 96.6% of the years with a mean 1.58% basal cover. The percent present and basal cover were greater on the twice-over treatment.

Discussion

Western wheatgrass, *Pascopyrum smithii*, is a native, long-lived perennial, cool season, mid grass, monocot, of the grass family that is abundant on healthy mixed grass prairie plant communities. Western wheatgrass can grow on sandy, shallow, silty, overflow, and thin claypan ecological sites. It grows better on silty sites and grows best on the silty sites managed with the twice-over treatment. Western wheatgrass is tolerant of cold, drought, and periodic flooding, has a high tolerance to alkali and saline soils, and moderately shade tolerant. Western wheatgrass tillers live for two growing seasons. Early season activity starts with regreening with active chlorophyll the portions of the carryover leaves that have intact cell walls from the previous growing season vegetative tillers and/or fall tillers. The green portion of the carryover leaves provides large quantities of carbohydrates and energy for the production of new leaves. New leaves are visible by 19 April. Western wheatgrass lead tillers are derived from carryover vegetative tillers produce 3.5 new leaves shortly after 1 June with the tallest culm leaf at 79% of the maximum leaf height. No new leaves were produced during development of the flower stalks. The lead tillers reach the boot stage between 15 and 19 June and reach the flower stage between 2 and 14 July at about 98% maximum stalk height and dropping below the crude protein requirements of lactating cows during the third week of July. Culm leaves and seed stalks reach maximum height by the end of July. Peak herbage biomass of Western wheatgrass lead tillers is reached during the last weeks of July. Seeds develop during late July reaching full maturity soon after mid August. The phosphorus content drops below a lactating cows requirements during early August. Leaf dryness reaches greater than 50% after mid August. Lead tillers contribute little to forage value after the third week of July.

Vegetative tillers are derived mostly from carryover tillers that were most likely fall tillers from the previous growing season. Vegetative tillers have slightly slower growth rates than lead tillers during the early portion of the growing season. Vegetative tillers reach the 3.5 new leaf stage shortly after the lead tillers and become independent. When lead tiller growth rates decrease greatly during mid July, vegetative tiller growth does not slow down. Grazing management practices that have less than 100 lbs/ac of available mineral nitrogen have less than a third of the quantity of vegetative tillers as grazing management practices that can produce greater than 100 lbs/ac available mineral nitrogen. Vegetative tillers provide around three fourths of the forage weight after mid July.

Secondary tillers are derived from growing season initiated tillers. With most initiated during May and June and few initiated during the period when lead tillers have high resource demand progressing through the flower stage and seed production. Most of the secondary tillers on traditional grazing practices were terminated during the high resource demand period resulting in only about 3% surviving secondary tillers as on the twice-over system. Surviving secondary tillers become independent when the fourth leaf is near full development. These secondary tillers contribute to the forage weight after mid July. The quantity of vegetative and secondary tillers, and the quantity and quality of forage after mid July depends on the type of grazing management practices used during June and the first two weeks of July. Traditional grazing practices have low quantities of forage value vegetative and secondary tillers after mid July. Western wheatgrass is a valuable asset on the Northern Mixed Grass Prairie.

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Table 1. Pascopyrum smithii, Western wheatgrass, 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 Stages
Apr 1			
13			
19	26.4	0.400	Early leaf greenup
25	23.2	0.310	
May 4	24.3	0.416	Active leaf growth
10	19.6	0.298	
16	21.8	0.319	
23	18.5	0.305	
28	17.9	0.281	
Jun 6	15.4	0.281	
13	15.8	0.307	
19	14.5	0.286	Flower stalk developing
26	12.0	0.278	
Jul 2	13.5	0.266	Flower (Anthesis)
8	12.9	0.251	
16	10.6	0.256	Seed developing
24	9.2	0.222	
30	8.2	0.214	
Aug 6	7.7	0.175	Seed maturing
13	7.7	0.172	
20	7.4	0.174	Seed mature
26	6.9	0.150	Drying
Sep 3	6.7	0.149	
12	5.4	0.108	
21	-	-	
29	6.5	0.130	Drying
Oct			
Nov 5			

Data from Whitman et al. 1951.

Table 2. Mean leaf height in cm and percent of maximum leaf height attained by Pascopyrum smithii, Western wheatgrass, 1955-1962.

	April				
	1	8	15	22	29
cm		2.0	4.0	6.0	6.7
%		8.0	17.0	25.0	28.0
	May				
	1	8	15	22	29
cm	7.5	10.3	12.8	15.9	16.3
%	32.0	43.0	54.0	67.0	69.0
	June				
	1	8	15	22	29
cm	18.7	19.0	19.2	20.6	22.0
%	79.0	80.0	81.0	87.0	92.0
	July				
	1	8	15	22	29
cm	22.0	22.0	22.1	22.2	23.8
%	92.0	92.0	93.0	93.0	100.0
	August				
	1	8	15	22	29
cm					
%					

Data from Goetz 1963.

Table 3. Mean stalk height in cm and percent of maximum stalk height attained by Pascopyrum smithii, Western wheatgrass, 1955-1962.

	April				
	1	8	15	22	29
cm					
%					
	May				
	1	8	15	22	29
cm					
%					
	June				
	1	8	15	22	29
cm			23.9	32.0	40.8
%			53.5	71.3	90.9
	July				
	1	8	15	22	29
cm	42.2	43.4	44.0	44.5	44.9
%	93.9	96.7	97.9	99.1	100.0
	August				
	1	8	15	22	29
cm					
%					

Data from Goetz 1963.

Table 4. First flower and flower period of Pascopyrum smithii, Western wheatgrass.

	Apr	May	Jun	Jul	Aug	Sep
First Flower						
1955-1962						
Earliest				2		
Mean				14		
Flower Period						
1969-1971			XX			

First Flower Data from Goetz 1963 and Whitman et al. 1951.
Flower Period Data from Zaczkowski 1972.

Table 5. Flower stalk seed development and percent leaf dryness of Pascopyrum smithii, Western wheatgrass.

	Flower Stalk Development			Seed Development	
Data Period	Boot	Emerge	Flower	Mature	Shed
1955-1962	19 Jun	30 Jun	14 Jul	5 Aug	16 Aug

			Percent Leaf Dryness		
Data Period	Leaf Tip Dry	0-25 %	25-50 %	50-75 %	75-100 %
1955-1962	13 Jun	25 Jul	13 Aug	24 Aug	9 Sep

Data from Goetz 1963.

Table 6. 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 7. Mean data of first flower and date of percentage categories of leaf senescence for Western wheatgrass, 1964-1966.

Ecological Site	Anthesis	Leaf Tip Dry	Leaf 0-25% Dry	Leaf 25%-50% Dry	Leaf 50%-75% Dry
Sandy	17 Jul	14 Jun	6 Aug	-	1 Oct
Silty	17 Jul	7 Jun	31 Jul	-	1 Oct
Overflow	11 Jul	10 Jun	9 Jul	7 Sep	1 Oct
Thin claypan	12 Jul	1 Jun	1 Jul	5 Aug	2 Sep

Data from Goetz 1970.

Table 8. Mean leaf height in cm for Western wheatgrass, 1964-1966.

Ecological Site	15 Apr	30 Apr	15 May	31 May	15 Jun	30 Jun	15 Jul	31 Jul	15 Aug	31 Aug	Maximum Height
Sandy	4.50	6.40	11.99	15.01	16.61	22.61	22.71	22.81	22.81	22.81	22.81
Silty	6.50	7.39	11.00	15.01	23.09	26.11	30.20	30.10	29.79	29.79	30.30
Overflow	5.21	7.59	14.00	21.01	27.00	34.01	39.29	30.00	27.99	27.99	39.29
Thin claypan	3.91	4.70	8.61	8.99	15.01	18.59	22.30	22.30	22.30	22.30	22.30

Data from Goetz 1970.

Table 9. Percent crude protein for Western wheatgrass, 1964-1966.

Ecological Site		1 Jun	15 Jun	1 Jul	15 Jul	1 Aug	15 Aug	1 Sep	Mean
Sandy	No Data								
Silty		15.2	11.7	12.3	9.7	8.3	6.5	6.3	10.0
Overflow		17.1	15.7	12.2	11.7	10.1	9.0	8.8	12.1
Thin claypan		16.2	13.3	14.6	12.9	8.0	8.6	8.7	11.8

Data from Goetz 1975.

Table 10. Herbage biomass (lbs/ac) and percent of total weight of Western wheatgrass from an ungrazed area it was dominant, 1958-1962.

		1 May	15 May	1 Jun	15 Jun	1 Jul	15 Jul	1 Aug	15 Aug	1 Sep	Mean
Western wheatgrass	lbs/ac	163.28	403.41	499.46	681.95	941.29	960.50	931.68	1104.57	1162.20	897.38
	%	33.3	64.6	63.4	66.4	70.0	71.4	73.5	69.7	71.6	69.4

Data from Goetz 1963.

Table 11. Autecology of Pascopyrum smithii, Western wheatgrass, 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	0.20	0.20	0.29
1988-1992	0.51	0.00	0.62	1.74	0.99
1993-1998	0.85	0.00	0.49	0.71	0.73
1999-2003	0.20	0.07	0.24	0.13	0.21
2004-2009	0.57	0.19	0.12	0.13	0.33
2010-2012	1.03	0.22	0.00	0.11	0.10
Shallow					
1983-1987	0.00	0.00	0.17	0.25	0.43
1988-1992	0.25	0.00	0.32	0.86	0.50
1993-1998	0.50	0.00	0.36	1.23	1.01
1999-2003	0.24	0.38	1.13	1.00	0.62
2004-2009	0.44	0.44	0.59	1.32	0.64
2010-2012	0.37	0.17	0.62	1.15	0.69
Silty					
1983-1987	0.00	0.65	1.30	2.08	3.28
1988-1992	1.70	1.78	1.78	3.43	2.21
1993-1998	1.99	4.01	2.19	4.86	2.91
1999-2003	0.33	1.18	1.86	5.01	3.31
2004-2009	1.64	1.81	0.88	4.09	3.20
2010-2012	3.18	2.28	1.08	4.34	4.64

Table 12. Autecology of Pascopyrum smithii, Western wheatgrass, 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	1.58	1.59	1.81
1988-1992	4.37	0.00	4.94	19.95	8.84
1993-1998	10.15	0.00	3.20	6.56	6.46
1999-2003	1.95	0.58	1.86	1.44	1.72
2004-2009	6.40	2.34	1.03	1.79	2.95
2010-2012	9.46	2.48	0.00	1.56	0.87
Shallow					
1983-1987	0.00	0.00	1.37	1.99	2.15
1988-1992	2.54	0.00	2.96	7.84	5.07
1993-1998	7.39	0.00	3.19	9.76	8.00
1999-2003	1.89	2.81	7.13	8.50	4.94
2004-2009	4.29	3.79	4.33	12.50	4.92
2010-2012	2.96	1.48	4.50	10.43	5.06
Silty					
1983-1987	0.00	6.08	8.99	13.99	16.63
1988-1992	12.01	18.17	15.50	27.79	20.08
1993-1998	19.81	24.96	16.66	37.91	20.47
1999-2003	3.43	9.91	13.48	52.33	24.58
2004-2009	16.10	15.78	6.52	47.77	25.91
2010-2012	32.16	19.67	7.24	47.09	32.36

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Autecology of Thickspike Wheatgrass on the Northern Mixed Grass Prairie

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Report DREC 17-1156

The autecology of Thickspike wheatgrass (Northern wheatgrass), *Elymus lanceolatus*, 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).

Thickspike wheatgrass (Northern wheatgrass), *Elymus lanceolatus* (Scribn. & J.G. Sm.) Gould, is one of the grass family, Poaceae, tribe, Triticeae, syn.: Agropyron dasystachym (Hook.) Scribn., and is a native, long lived perennial, monocot, cool-season, mid grass, that is tolerant of cold, drought, and periodic flooding, has a tolerance to slightly acidic to moderately saline soils, and moderately shade tolerant. The first North Dakota record is Moran 1937. Early aerial growth consists of basal leaves arising from rhizome tiller buds. Leaf blades are 5-25 cm (2-10 in) long, 2-4 mm wide, stiff, with numerous ridges on the upper surface, and tapering to a point. The split sheath has overlapping margins that open towards the top and has short, straight, stiff hairs at the base. The collar is not well defined. The ligule is a short flat membrane 0.6 mm long. The auricles are long and clasping. The creeping rhizome system is extensive. The aggressive rhizomes are primarily in the top 10 cm(4 in) of soil. The frequent branches are about 15 cm (6 in) long produce single or several stems per node at progressive intervals. The extensive root system has tough light colored main roots arising from stem crowns and rhizome nodes growing vertically downward regularly producing profuse quantities of short branches forming a dense mass that inhibits penetration by other species, with the densest roots in the top 83 cm (15 in) of soil. Regeneration is primarily asexual propagation by rhizome tiller buds. Seedling success is low as a result of competition from established plants. Flower stalks are erect, hollow, 15-90 cm(6-35 in) tall. Inflorescence is an erect compact spike, 3-12 cm (1.2-4.7 in) long, with overlapping solitary spikelets of 4 to 7 florets. Flower period is June. Aerial parts are highly palatable to livestock. Fire consumes aerial parts halting the process of the four major defoliation resistence mechanisms and causing great reductions in biomass production and tiller density. This summary information on growth development and regeneration of Thickspike wheatgrass was based on works of Stevens 1963, Zaczkowski 1972, Great Plains Flora Association 1986, Scher 2002, Johnson and Larson 2007, Ogle et al. 2013**.**

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 1955-1962 Study

Grass and upland sedge tiller growth in height of leaves and stalks were collected from ungrazed plants during the growing seasons of 1955-1962. Basal leaves were measured from ground level to the tip of the extended leaves. Culm leaves were measured from ground level to the apex of the uppermost leaf. Stalk measurements were from ground levels to the tip of the stalk or to the tip of the inflorescence after it had developed. An average of 10 plants of each species were measured at approximate 7 to 10 day intervals from early May until early September. In addition, phenological growth stages were recorded to include stalk initiation, head emergence, flowering (anthesis), seed development, seed maturity, earliest seed shedding, and an estimation of percent of leaf dry in relation to total leaf area. The grass growth in height and phenological data were reported in Goetz 1963.

The 1964-1969 Study

Phenological data of grass and upland sedge at anthesis stage was determined by recording observation dates. Leaf senescence by date was determined as an estimation of percentage of dry leaf in relation to total leaf area. Grass and upland sedge tiller growth in height of leaves were collected from ungrazed plants during the growing seasons of 1964-1966. Basal leaves were measured from ground level to the tip of the extended leaf. Culm leaves were measured from ground level to the apex of the uppermost leaf. An average of 20 plants at approximately 7 to 10 day intervals during the growing season from mid April to late August from control treatment on sandy, silty, overflow, and thin claypan ecological sites. Phenological data of anthesis stage, leaf senescence, and growth in leaf height were reported in Goetz 1970. Crude protein content of grasses and upland sedges was determined from a composite of 10 samples of each species collected systematically at biweekly intervals from mid May to early September, 1964-1969 on sandy, silty, overflow, and thin claypan ecological sites. Plant material was oven dried at 105°F. Analysis of the samples were made by the Cereal Technology Department, North Dakota State University, using standard crude protein determinations and reported in Goetz 1975.

The 1969-1971 Study

The range of flowering time of grasses and upland sedges were 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 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 will be reflected in the data summary tables as an 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

Thickspike wheatgrass and Western wheatgrass are difficult to separate in the field during ecological data collection. The standard morphological separation characteristics with Western wheatgrass having stiff blue-green leaves, single stems not tufted, no hairs on glumes, and purple auricles and thickspike wheatgrass having light green leaves, tufted stems, fine hairs on glumes, and white auricles are not truly definitive separators. All of these characteristics are highly variable with changing environmental conditions. As a result Western wheatgrass and Thickspike wheatgrass have become an ecological complex during these studies, with Western wheatgrass composing much greater than 50% of the complex. The ecological study results have been placed with the Western wheatgrass report, DREC 17-1155.

Acknowledgment

I am grateful to Sheri Schneider for assistance in the production of this manuscript and for development of the tables.

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Autecology of Prairie Junegrass on the Northern Mixed Grass Prairie

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Report DREC 17-1159

The autecology of Prairie Junegrass, *Koeleria macrantha*, 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).

Prairie Junegrass, *Koeleria macrantha* (Ledeb.) Schult, is a member of the grass family, Poaceae, tribe, Poeae, Syn.: *Koeleria pyramidata* (Lam.) Beauv., *Koeleria cristata* (L.) Pers., and is a native, perennial, monocot, cool-season, mid grass, that is cold and heat tolerant, and drought resistant. The first North Dakota record is Bell 1907. Early aerial growth consists of basal leaves arising from crown tiller buds. Prairie Junegrass consistently reaches the 3.5 new leaf stage by 1 June and is an excellent indicator of physiological grazing readiness of native grasses. Basal leaf blades are 8-18 cm (3-7 in) long, 1-3 mm wide, thick, with broad ribs above and a boat prow shaped tip. The split sheath has overlapping translucent margins with short hairs. The indistinctive collar is continuous. The ligule is membranous, 1.5 mm long, often split, continuous with sheath margins, and fringed with hairs. The auricles are absent. The fibrous root system is primarily shallow, with the greatest concentration in the top 3 cm (1.2 in) of soil. The lateral spread is 20-25 cm (8-10 in) outward from the crown. Most main roots are 0.2 mm thick and remain in the top 46 cm (1.5 ft) of soil, with a few main roots descending down to 76 cm (2.5 ft). Regeneration is primarily asexual propagation by crown tillers. Seedling success is low, primarily because of low seed production, and resulting from poor seedling vigor and high mortality. Flower stalks are erect, 30-60 cm (12-24 in) tall. Inflorescence is a narrow, condensed, panicle, 5-15 cm (2-6 in) long, that opens during flowering becoming plume like, then contracting to narrow spike shape after flowering. Spikelets contain 2 florets. Flowers period is early June to mid July. Leaves are highly palatable to livestock. Fire top kills aerial parts and can consume the entire crown when the soil is dry. Fire halts the processes of the four major defoliation resistance mechanisms and causes great reductions in biomass production and tiller density. This summary information on growth development and regeneration of Prairie Junegrass was based on works of Weaver 1954, Stevens 1963, Zaczkowski 1972, Dodds 1979, Great Plains Flora Association 1986, Simonin 2000, Ogle et al. 2006, Larson and Johnson 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 1955-1962 Study

Grass and upland sedge tiller growth in height of leaves and stalks were collected from ungrazed plants during the growing seasons of 1955-1962. Basal leaves were measured from ground level to the tip of the extended leaves. Culm leaves were measured from ground level to the apex of the uppermost leaf. Stalk measurements were from ground levels to the tip of the stalk or to the tip of the inflorescence after it had developed. An average of 10 plants of each species were measured at approximate 7 to 10 day intervals from early May until early September. In addition, phenological growth stages were recorded to include stalk initiation, head emergence, flowering (anthesis), seed development, seed maturity, earliest seed shedding, and an estimation of percent of leaf dry in relation to total leaf area. The grass growth in height and phenological data were reported in Goetz 1963.

The 1964-1969 Study

Phenological data of grass and upland sedge at anthesis stage was determined by recording observation dates. Leaf senescence by date was determined as an estimation of percentage of dry leaf in relation to total leaf area. Grass and upland sedge tiller growth in height of leaves were collected from ungrazed plants during the growing seasons of 1964-1966. Basal leaves were measured from ground level to the tip of the extended leaf. Culm leaves were measured from ground level to the apex of the uppermost leaf. An average of 20 plants at approximately 7 to 10 day intervals during the growing season from mid April to late August from control treatment on sandy, silty, overflow, and thin claypan ecological sites. Phenological data of anthesis stage, leaf senescence, and growth in leaf height were reported in Goetz 1970.

The 1969-1971 Study

The range of flowering time of grasses and upland sedges were 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 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 will be reflected in the data summary tables as an 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

Prairie Junegrass increases growth activity shortly after snow melt. Leaf growth in cool season grasses continues very slowly during the entire winter. The top portion of these carryover leaves become exposed to low temperatures causing the cell walls to rupture. The lower portion of the carryover leaves have intact cell walls and regreen with active chlorophyll when liquid water becomes available in the soil for at least during the daylight hours. The green portions of the carryover leaves provide a large quantity of carbohydrates and fixed energy used in the production of new leaves. Growth of new leaves of Prairie Junegrass is visible between 8 and 13 April (tables 1 and 2). Prairie Junegrass produces 3.5 new leaves on 1 June consistently. Unlike Needle and thread that sheds its early new leaves, Prairie Junegrass retains its early new leaves for several weeks. Lead tillers at the 3.5 new leaf stage are physiologically capable of positive response to partial defoliation of 25% to 33% of leaf weight by graminivores. On 1 June, the tallest basal leaf of Prairie Junegrass has reached 85% of maximum leaf height (table 2), and the lead tiller contains 15% crude protein and 0.22% phosphorus on silty ecological sites (table 1). Leaf growth in height is rapid during May, about one fourth that rate during June, and slower still during July (table 2). The flower stalk reaches the boot stage around 16-20-22 May, reaches head emergence on 5 to 6 June, and reaches flower (anthesis) between 19 and 26 June (tables 1, 3, 4, and 5). The 5 week flower period occurs during early June to mid July (table 4). At the end of June, the basal leaf growth has reached 93.0% of maximum height, seed stalk growth has reached 100.0% of maximum height, and the lead tiller still contains 11.3% crude protein (tables 1, 2, and 3). The seeds are developing from 26 June to 17 July and being shed during 16 July to 11 August (tables 1 and 5). The lead tiller crude protein content drops below the requirements of lactating cows during the first week of July and drops below their phosphorus requirements during the second week of July (tables 1 and 6). Maximum basal leaf height is reached at the end of July with a crude protein content of only 7.0% (tables 1 and 2). Leaf dryness starts during mid August and continues into September (tables 1 and 5). Leaf dryness appears to be more rapid on the sandy and the thin claypan sites (table 7) than that on the silty site (table 5). Flower stage appears to be similar and sandy and thin claypan sites (table 7) as on silty sites (tables 1, 4, and 5). Unless the grazing management practices has properly manipulated the stimulation of an adequate quantity of Prairie Junegrass vegetative secondary tillers, lactating cows will be grazing forage below their nutrient requirements after early July.

Grass species composition in rangeland ecosystems is variable during a growing season and dynamic among growing seasons. Patterns in the changes of individual grass species abundance was followed for 30 growing seasons during the 1983-2012 study on the sandy, shallow, and silty ecological sites of the long-term nongrazed, traditional seasonlong, and twice-over rotation management treatments (tables 8 and 9).

On the sandy site of the nongrazed treatment, Prairie Junegrass was present during 84.0% of the years that basal cover data were collected with a mean 0.66% basal cover during the total 30 year period. During the early period (1983-1992), Prairie Junegrass was present during 60.0% of the years with a mean 0.33% basal cover. During the later period (1998-2012), Prairie Junegrass was present during 100.0% of the years with a mean 0.97% basal cover. The percent present and basal cover increased on the sandy site of the nongrazed treatment over time (tables 8 and 9).

On the sandy site of the ungrazed seasonlong treatment, Prairie Junegrass was present during 40.0% of the years that basal cover data were collected with a mean 0.65% basal cover during the total 30 year period. During the early period (1983-1992), Prairie Junegrass was not present. During the later period (1998-2012), Prairie Junegrass was present during 66.7% of the years with a mean 1.09% basal cover. Prairie Junegrass was not present during the early period and all basal cover observations were made during the later period indicating moderate abundance (tables 8 and 9).

On the sandy site of the grazed seasonlong treatment, Prairie Junegrass was present during 100.0% of the years that basal cover data were collected with a mean 1.74% basal cover during the total 30 year period. During the early period (1983-1992), Prairie Junegrass was present during 100.0% of the years with a mean 0.89% basal cover. During the later period (1998-2012), Prairie Junegrass was present during 100.0% of the years with a mean 2.41% basal cover. The percent present remained at 100.0% and basal cover increased on the sandy site of the grazed seasonlong treatment over time (tables 8 and 9). The percent present and basal cover were greater on the sandy site of the grazed seasonlong treatment than those on the sandy site of the ungrazed seasonlong treatment.

On the sandy site of the ungrazed twice-over treatment, Prairie Junegrass was present during 100.0% of the years that basal cover data were collected with a mean 0.36% basal cover during the total 30 year period. During the early period (1983-1992), Prairie Junegrass was present during 100.0% of the years with a mean 0.79% basal cover. During the later period (1998-2012), Prairie Junegrass was present during 100.0% of the years with a mean 0.36% basal cover. The percent present remained at 100.0% and basal cover decreased on the sandy site of the ungrazed twice-over treatment over time (tables 8 and 9).

On the sandy site of the grazed twice-over treatment, Prairie Junegrass was present during 100.0% of the years that basal cover data were collected with a mean 1.35% basal cover during the total 30 year period. During the early period (1983-1992), Prairie Junegrass was present during 100.0% of the years with a mean 1.30% basal cover. During the later period (1998-2012), Prairie Junegrass was present during 100.0% of the years with a mean 1.56% basal cover. The percent present remained at 100.0% and basal cover increased on the sandy site of the grazed twice-over treatment over time (tables 8 and 9). The percent present was the same at 100.0% and basal cover was greater on the sandy site of the grazed twice-over treatment than that on the sandy site of the ungrazed twice-over treatment.

On the shallow site of the nongrazed treatment, Prairie Junegrass was present during 84.6% of the years that basal cover data were collected with a mean 0.85% basal cover during the total 30 year period. During the early period (1983-1992), Prairie Junegrass was present during 66.7% of the years with a mean 0.78% basal cover. During the later period (1998-2012), Prairie Junegrass was present during 100.0% of the years with a mean 1.09% basal cover. The percent present and basal cover increased on the shallow site of the nongrazed treatment over time (tables 8 and 9).

On the shallow site of the ungrazed seasonlong treatment, Prairie Junegrass was present during 38.5% of the years that basal cover data were collected with a mean 1.29% basal cover during the total 30 year period. During the early period (1983-1992), Prairie Junegrass was not present. During the later period (1998-2012), Prairie Junegrass was present during 66.7% of the years with a mean 2.23% basal cover. Prairie Junegrass was not present during the early period and all basal cover observations were made during the later period indicated good abundance (tables 8 and 9).

On the shallow site of the grazed seasonlong treatment, Prairie Junegrass was present during 84.6% of the years that basal cover data were collected with a mean 1.47% basal cover during the total 30 year period. During the early period (1983-1992), Prairie Junegrass was present during 83.3% of the years with a mean 1.26% basal cover. During the later period (1998-2012), Prairie Junegrass was present during 86.7% of the years with a mean 1.95% basal cover. The percent present and basal cover increased on the shallow site of the grazed seasonlong treatment over time (tables 8 and 9). The percent present was greater, basal cover during the early period was greater, and basal cover during the later period was lower on the shallow site of the grazed seasonlong treatment than those on the shallow site of the ungrazed seasonlong treatment.

On the shallow site of the ungrazed twice-over treatment, Prairie Junegrass was present during 100.0% of the years that basal cover data were collected with a mean 1.76% basal cover during the total 30 year period. During the early period (1983-1992), Prairie Junegrass was present during 100.0% of the years with a mean 2.58% basal cover. During the later period (1998-2012), Prairie Junegrass was present during 100.0% of the years with a mean 1.51% basal cover. The percent present remained at 100.0% and basal cover decreased on the shallow site of the ungrazed twice-over treatment over time (tables 8 and 9).

On the shallow site of the grazed twice-over treatment, Prairie Junegrass was present during 100.0% of the years that basal cover data were collected with a mean 2.55% basal cover during the total 30 year period. During the early period (1983-1992), Prairie Junegrass was present during 100.0% of the years with a mean 2.83% basal cover. During the later period (1998-2012), Prairie Junegrass was present during 100.0% of the years with a mean 2.67% basal cover. The percent present remained at 100.0% and basal cover decreased slightly on the shallow site of the grazed twice-over treatment over time (tables 8 and 9). The percent present remained the same at 100.0% and basal cover was greater on the shallow site of the grazed twice-over treatment than that on the shallow site of the ungrazed twice-over treatment.

On the silty site of the nongrazed treatment, Prairie Junegrass was present during 92.3% of the years that basal cover data were collected with a mean 0.54% basal cover during the total 30 year period. During the early period (1983-1992), Prairie Junegrass was present during 83.3% of the years with a mean 0.34% basal cover. During the later period (1998-2012), Prairie Junegrass was present during 100.0% of the years with a mean 0.66% basal cover. The percent present and basal cover increased on the silty site of the nongrazed treatment over time (tables 8 and 9).

On the silty site of the ungrazed seasonlong treatment, Prairie Junegrass was present during 92.3% of the years that basal cover data were collected with a mean 1.31% basal cover during the total 30 year period. During the early period (1983-1992), Prairie Junegrass was present during 66.7% of the years with a mean 1.16% basal cover. During the later period (1998-2012), Prairie Junegrass was present during 100.0% of the years with a mean 1.57% basal cover. The percent present and basal cover increased on the silty site of the ungrazed seasonlong treatment over time (tables 8 and 9).

On the silty site of the grazed seasonlong treatment, Prairie Junegrass was present during 92.3% of the years that basal cover data were collected with a mean 1.56% basal cover during the total 30 year period. During the early period (1983-1992), Prairie Junegrass was present during 66.7% of the years with a mean 0.91% basal cover. During the later period (1998-2012), Prairie Junegrass was present during 100.0% of the years with a mean 2.13% basal cover. The percent present and basal cover increased on the silty site of the grazed seasonlong treatment over time (tables 8 and 9). The percent present were the same and basal cover during the early period was lower and basal cover during the later period was greater on the silty site of the grazed seasonlong treatment than those on the silty site of the ungrazed seasonlong treatment.

On the silty site of the ungrazed twice-over treatment, Prairie Junegrass was present during 100.0% of the years that basal cover data were collected with a mean 0.76% basal cover during the total 30 year period. During the early period (1983-1992), Prairie Junegrass was present during 100.0% of the years with a mean 1.45% basal cover. During the later period (1998-2012), Prairie Junegrass was present during 100.0% of the years with a mean 0.47% basal cover. The percent present remained at 100.0% and basal cover decreased on the silty site of the ungrazed twice-over treatment over time (tables 8 and 9).

On the silty site of the grazed twice-over treatment, Prairie Junegrass was present during 100.0% of the years that basal cover data were collected with a mean 1.71% basal cover during the total 30 year period. During the early period (1983-1992), Prairie Junegrass was present during 100.0% of the years with a mean 1.76% basal cover. During the later period (1998-2012), Prairie Junegrass was present during 100.0% of the years with a mean 1.86% basal cover. The percent present remained at 100.0% and basal cover increased on the silty site of the grazed twice-over treatment over time (tables 8 and 9). The percent present was the same at 100.0% and basal cover was greater on the silty site of the grazed twice-over treatment than that on the silty site of the ungrazed twice-over treatment.

On the sandy site, Prairie Junegrass was present during 84.8% of the years with a mean 0.95% basal cover. On the shallow site, Prairie Junegrass was present during 81.5% of the years with a mean 1.58% basal cover. On the silty site, Prairie Junegrass was present during 95.4% of the years with a mean 1.18% basal cover. The percent present was greater on the silty site and basal cover were greater on the shallow site.

On the sandy site of the nongrazed treatment, Prairie Junegrass was present during 84.0% of the years with a mean 0.66% basal cover. On the sandy site of the seasonlong treatment, Prairie Junegrass was present during 70.0% of the years with a mean 1.20% basal cover. On the sandy site of the twice-over treatment, Prairie Junegrass was present during 100.0% of the years with a mean 0.86% basal cover. On the sandy site, Prairie Junegrass percent present was greater on the twice-over treatment and basal cover was greater on the seasonlong treatment.

On the shallow site of the nongrazed treatment, Prairie Junegrass was present during 84.6% of the years with a mean 0.85% basal cover. On the shallow site of the seasonlong treatment, Prairie Junegrass was present during 61.5% of the years with a mean 1.38% basal cover. On the shallow site of the twice-over treatment, Prairie Junegrass was present during 100.0% of the years with a mean

2.16% basal cover. On the shallow site, Prairie Junegrass percent present and basal cover was greater on the twice-over treatment.

On the silty site of the nongrazed treatment, Prairie Junegrass was present during 92.3% of the years with a mean 0.54% basal cover. On the silty site of the seasonlong treatment, Prairie Junegrass was present during 92.3% of the years with a mean 1.43% basal cover. On the silty site of the twice-over treatment, Prairie Junegrass was present during 100.0% of the years with a mean 1.24% basal cover. On the silty site, Prairie Junegrass percent present was greater on the twice-over treatment and basal cover was greater on the seasonlong treatment.

Prairie Junegrass was present on the nongrazed treatment during 87.0% of the years with a mean 0.68% basal cover. Prairie Junegrass was present on the seasonlong treatment during 74.6% of the years with a mean 1.34% basal cover. Prairie Junegrass was present on the twice-over treatment during 100.0% of the years with a mean 1.42% basal cover. The percent present and basal cover were greater on the twice-over treatment.

Prairie Junegrass was present 100.0% of the years on the sandy, shallow, and silty ecological site of the twice-over with the greatest mean of 1.42% basal cover.

Discussion

Prairie Junegrass, *Koeleria macrantha*, is a native, perennial, cool season, mid grass, monocot, of the grass family that is common on healthy mixed grass prairie plant communities. Prairie Junegrass can grow on sandy, shallow, silty, and thin claypan ecological sites. It has greater percent present on the silty site and greater basal cover on the shallow site. The greatest percent present and basal cover were on the twice-over management treatment. Early season activity starts with regreening with active chlorophyll the portions of the carryover leaves that have intact cell walls from the previous growing season vegetative tillers, secondary tillers, and fall tillers. The green portion of the carryover leaves provides large quantities of carbohydrates and fixed energy for the production of new leaves. New leaves of Prairie Junegrass are visible between 8 and 13 April. Prairie Junegrass lead tillers are derived from carryover vegetative tillers and produce 3.5 new leaves on 1 June consistently, and can be used as a reliable indicator of grazing readiness. Lead tillers at the 3.5 new leaf stage are physiologically capable of positive response to partial defoliation of 25% to 33% of leaf weight by graminivores. The tallest basal leaf is at 85.0% of maximum height on 1 June and the lead tiller contains 15.1% crude protein and 0.22% phosphorus on the silty ecological site during early June. The flower stalks reach the boot stage around 16 to 22 May, reach head emergence on 5 to 6 June, and reach the early flower stage around 19 to 26 June, with a 5 week flower period from early June to mid July. Leaf growth in height is rapid during May, growth is slower during June, and slower still during July. Basal leaves reach 93.0% of maximum height by end of June and reach 100.0% of maximum height by late July. Seeds are developing between 26 June and 17 July and being shed during 16 July to 11 August. Seed stalks reach maximum height at the end of June and lead tillers contain 11.3% crude protein and 0.234% phosphorus. Lead tillers drop below the crude protein requirements of lactating cows during the first week of July and drop below the phosphorus requirements during the second week of July. Leaf dryness starts 14 August and continues through August into September. Lead tillers of Prairie Junegrass contribute little to forage value after mid July.

Vegetative tillers are derived mostly from secondary carryover tillers that were most likely fall tillers from the previous growing season and some are derived from early season initiated tillers. Vegetative tillers have slightly slower growth rates than lead tillers during the early portion of the growing season. Vegetative tillers reach the 3.5 new leaf stage shortly after the lead tillers and become independent. When lead tiller growth rates decrease greatly during early July, the vegetative tiller growth rates do not slow down. Grazing management practices that have less than 100 lbs/ac of available mineral nitrogen have less than a third of the quantity of vegetative tillers as grazing management practices that can produce greater than 100 lbs/ac available mineral nitrogen. Vegetative tillers provide around three fourths of the forage weight after mid July.

Secondary tillers are derived from growing season initiated tillers. With most useful tillers initiated during May and June. Few secondary tillers are initiated during the period when lead tillers have high resource demand as they progress through the flower stage and seed production. Most of the secondary tillers on traditional grazing practices are at less than the 3.5 new leaf stage and are terminated during the high resource demand period resulting in only about 3% surviving secondary tillers compared to the quantity of surviving tillers on the twice-over system. Surviving secondary tillers become independent of the lead tillers when the fourth new leaf is near full development. These early initiated secondary tillers contribute to the forage weight after mid or late July. The quantity of vegetative and secondary tillers, and the quantity and quality of forage after mid July depends on the type of grazing management practices used during June and the first two weeks of July. Traditional grazing practices have low quantities of forage value vegetative and secondary tillers after mid July, and lactating cows are grazing forage that is below their nutrient requirements. Prairie Junegrass is a valuable asset on the Northern Mixed Grass Prairie.

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Table 1. Koeleria macrantha, Prairie Junegrass, 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 Stages
Apr 1			
13	17.8	0.298	Early leaf greenup
19	20.0	0.352	
25	19.1	0.336	
May 4	20.1	0.286	Active leaf growth
10	16.7	0.243	
16	18.1	0.266	Flower stalk developing
23	13.9	0.200	
28	15.1	0.216	
Jun 6	12.9	0.241	Flower stalk emerging
13	13.6	0.266	
19	14.2	0.244	Flowering (Anthesis)
26	11.3	0.234	Seed developing
Jul 2	9.6	0.210	
8	8.6	0.187	Seed maturing
16	7.5	0.155	Seed mature
24	6.3	0.159	
30	7.0	0.154	Drying
Aug 6	5.3	0.117	
13	6.4	0.140	
20	5.6	0.123	
26	6.2	0.106	
Sep 3	4.8	0.083	Drying
12	4.3	-	
21			
29			
Oct			
Nov 5			Drying

Data from Whitman et al. 1951.

Table 2. Mean leaf height in cm and percent of maximum leaf height attained by Koeleria macrantha, Prairie Junegrass, 1955-1962.

	April				
	1	8	15	22	29
cm		1.0	4.5	5.6	6.7
%		8.0	37.0	46.0	55.0
	May				
	1	8	15	22	29
cm	6.8	6.8	8.8	10.0	10.3
%	55.0	55.0	72.0	81.0	84.0
	June				
	1	8	15	22	29
cm	10.5	10.6	10.8	10.9	11.5
%	85.0	86.0	88.0	89.0	93.0
	July				
	1	8	15	22	29
cm	11.7	12.0	12.1	12.2	12.3
%	95.0	98.0	98.0	99.0	100.0
	August				
	1	8	15	22	29
cm					
%					

Data from Goetz 1963.

Table 3. Mean stalk height in cm and percent of maximum stalk height attained by Koeleria macrantha, Prairie Junegrass, 1955-1962.

	April				
	1	8	15	22	29
cm					
%					

	May				
	1	8	15	22	29
cm				10.0	11.5
%				36.9	42.4

	June				
	1	8	15	22	29
cm	14.0	15.0	20.8	21.9	27.1
%	51.7	55.4	76.8	80.8	100.0

	July				
	1	8	15	22	29
cm					
%					

	August				
	1	8	15	22	29
cm					
%					

Data from Goetz 1963.

Table 4. First flower and flower period of Koeleria macrantha, Prairie Junegrass.

	Apr	May	Jun	Jul	Aug	Sep
First Flower						
1955-1962						
Earliest			19			
Mean			26			
Flower Period						
1969-1971			XX XX	X		

First Flower Data from Goetz 1963 and Whitman et al. 1951.
Flower Period Data from Zaczkowski 1972.

Table 5. Flower stalk seed development and percent leaf dryness of Koeleria macrantha, Prairie Junegrass.

	Flower Stalk Development			Seed Development	
Data Period	Boot	Emerge	Flower	Mature	Shed
1955-1962	20 May	5 Jun	26 Jun	17 Jul	11 Aug

			Percent Leaf Dryness		
Data Period	Leaf Tip Dry	0-25 %	25-50 %	50-75 %	75-100 %
1955-1962	15 Jul	14 Aug		22 Aug	9 Sep

Data from Goetz 1963.

Table 6. 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 7. Mean date of first flower and date of percentage categories of leaf senescence for Prairie Junegrass, 1964-1966.

Ecological Site	Anthesis	Leaf Tip Dry	Leaf 0-25% Dry	Leaf 25%-50% Dry	Leaf 50%-75% Dry
Sandy	24 Jun	3 Jul	27 Jul	9 Sep	-
Silty	23 Jun	24 Jun	27 Jul	-	-
Overflow	No Data				
Thin claypan	24 Jun	7 Jul	18 Jul	25 Aug	-

Data from Goetz 1970.

Table 8. Autecology of Koeleria macrantha, Prairie Junegrass, with growing season changes in basal cover, 1983-2012.					
Ecological Site Year Period	Nongrazed	Seasonlong		Twice-over	
		Ungrazed	Grazed	Ungrazed	Grazed
Sandy					
1983-1987	0.75	0.00	2.07	1.09	1.71
1988-1992	0.23	0.00	0.60	0.47	0.79
1993-1998	0.05	0.00	0.59	0.66	0.71
1999-2003	0.25	1.73	1.97	0.20	1.27
2004-2009	1.15	1.89	3.10	0.45	1.94
2010-2012	2.12	1.08	2.35	0.57	1.72
Shallow					
1983-1987	1.55	0.00	4.23	4.65	4.81
1988-1992	0.62	0.00	0.66	0.92	0.83
1993-1998	0.21	0.00	0.25	0.94	1.43
1999-2003	0.56	2.52	1.32	1.42	2.36
2004-2009	1.47	4.08	2.73	1.96	3.51
2010-2012	1.53	2.17	2.03	1.13	2.26
Silty					
1983-1987	0.75	4.15	3.87	2.33	2.71
1988-1992	0.26	0.56	0.32	0.75	0.80
1993-1998	0.35	0.65	0.59	0.37	1.07
1999-2003	1.02	1.48	2.28	0.57	1.98
2004-2009	0.40	2.15	2.51	0.58	2.33
2010-2012	0.77	0.93	1.66	0.19	1.19

Table 9. Autecology of Koeleria macrantha, Prairie Junegrass, 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	7.22	0.00	15.72	9.44	10.93
1988-1992	2.24	0.00	5.27	4.36	6.88
1993-1998	0.56	0.00	5.13	4.77	5.63
1999-2003	2.58	2.93	14.70	2.27	9.79
2004-2009	11.56	17.15	22.71	5.48	15.91
2010-2012	18.84	11.15	18.38	6.54	14.72
Shallow					
1983-1987	10.97	0.00	28.40	32.16	28.17
1988-1992	4.24	0.00	5.11	7.49	8.14
1993-1998	1.33	0.00	2.48	8.17	11.11
1999-2003	5.15	3.64	9.02	11.46	16.70
2004-2009	16.37	30.56	18.43	16.42	25.18
2010-2012	13.78	16.96	13.75	10.63	15.76
Silty					
1983-1987	6.09	34.31	25.53	15.91	16.88
1988-1992	2.27	4.86	2.80	6.67	7.95
1993-1998	3.50	5.08	5.28	3.59	8.05
1999-2003	9.16	11.85	16.28	6.19	16.09
2004-2009	4.24	16.72	19.07	6.00	17.26
2010-2012	7.89	8.48	12.14	2.22	8.78

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Autecology of Plains Reedgrass on the Northern Mixed Grass Prairie

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The autecology of Plains reedgrass, *Calamagrostis montanensis*, 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).

Plains reedgrass, *Calamagrostis montanensis* (Scribn.) Vasey, is a member of the grass family, Poaceae, tribe, Poeae, and is a native, perennial, monocot, cool-season, mid grass, that is cold and heat tolerant, and drought resistant. The first North Dakota record is Swallen 1939. Early aerial growth consists of basal leaves arising from tiller buds. Basal leaf blades are 10-18 cm (4-7 in) long, 1-3.5 mm wide, stiff with pronounced furrows on upper surface, tapering to a point. The split sheath has overlapping translucent margins. The collars is indistinct. The ligule is membranous, 2-4.5 mm long, usually cut or split, continuous with sheath margins. The auricles are absent. The slender rhizomes are 0.3-0.5 mm thick and progressive, producing tillers at short intervals. The fibrous root system is primarily shallow. The main roots are 0.3-0.5 mm thick and can descend to 91-110 cm (3-3.6 ft) in depth. Abundant lateral roots are 5-7.5 cm (2-3 in) long arise on the main roots below 25 cm (10 in) deep. Most of the root biomass is in the top 46 cm (1.5 ft) of soil. Regeneration is primarily asexual propagation by rhizome tillers. Seedling success is low as a result of competition from established plants. Flower stalks are erect, few or many crowded together, 10-45 cm (4-18 in) tall, usually with two stem leaves. Inflorescence is a narrow, condensed, panicle, 5-10 cm (2-4 in) long, 1-2 cm wide, that opens during flowering becoming plume like, then contracting to narrow spike shape after flowering. Flowers period is mid June to August. Leaves are highly palatable to livestock. Fire top kills aerial parts and can consume the entire crown when the soil is dry. Tiller growth can be activated from surviving rhizomes. Fire halts the processes of the four major defoliation resistance mechanisms and causes great reductions in biomass production and tiller density. This summary information on growth development and regeneration of Plains reedgrass was based on works of Stevens 1963, Zaczkowski 1972, Dodds 1979, Great Plains Flora Association 1986, and Hauser 2006.

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 1955-1962 Study

Grass and upland sedge tiller growth in height of leaves and stalks were collected from ungrazed plants during the growing seasons of 1955-1962. Basal leaves were measured from ground level to the tip of the extended leaves. Culm leaves were measured from ground level to the apex of the uppermost leaf. Stalk measurements were from ground levels to the tip of the stalk or to the tip of the inflorescence after it had developed. An average of 10 plants of each species were measured at approximate 7 to 10 day intervals from early May until early September. In addition, phenological growth stages were recorded to include stalk initiation, head emergence, flowering (anthesis), seed development, seed maturity, earliest seed shedding, and an estimation of percent of leaf dry in relation to total leaf area. The grass growth in height and phenological data were reported in Goetz 1963.

The 1964-1969 Study

Phenological data of grass and upland sedge at anthesis stage was determined by recording observation dates. Leaf senescence by date was determined as an estimation of percentage of dry leaf in relation to total leaf area. Grass and upland sedge tiller growth in height of leaves were collected from ungrazed plants during the growing seasons of 1964-1966. Basal leaves were measured from ground level to the tip of the extended leaf. Culm leaves were measured from ground level to the apex of the uppermost leaf. An average of 20 plants at approximately 7 to 10 day intervals during the growing season from mid April to late August from control treatment on sandy, silty, overflow, and thin claypan ecological sites. Phenological data of anthesis stage, leaf senescence, and growth in leaf height were reported in Goetz 1970.

The 1969-1971 Study

The range of flowering time of grasses and upland sedges were 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 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 will be reflected in the data summary tables as an 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

Plains reedgrass increases growth activity shortly after snow melt. Leaf growth in cool season grasses continues very slowly during the entire winter. The top portion of these carryover leaves become exposed to low temperatures causing the cell walls to rupture. The lower portion of the carryover leaves have intact cell walls and regreen with active chlorophyll when liquid water becomes available in the soil for at least during the daylight hours. The green portions of the carryover leaves provide a large quantity of carbohydrates and fixed energy used in the production of new leaves. Growth of new leaves of Plains reedgrass is visible around 8 April (table 2). Plains reedgrass produces 3.5 new leaves shortly after 1 June. Lead tillers at the 3.5 new leaf stage are physiologically capable of positive response to partial defoliation of 25% to 33% of leaf weight by graminivores. On 1 June, the tallest basal leaf of Plains reedgrass has reached 86% of maximum leaf height (table 2), and the lead tiller contains 12.3% crude protein and 0.205% phosphorus on silty ecological sites (table 1). Leaf growth in height is rapid during April and May, less than that rate during June, and much slower still during July (table 2). The flower stalk reaches the boot stage around 22 May, reaches head emergence on 6 to 8 June, and reaches first flower (anthesis) around 29 June (tables 1, 3, 4, and 5). The 6 week flower period occurs during mid June to late July (table 4). At the end of June, the basal leaf growth has reached 95.0% of maximum height, seed stalk growth has reached 100.0% of maximum height, and the lead tiller still contains 11.2% crude protein (tables 1, 2, and 3). The seeds are developing from 2 July, maturing during 26 July to 6 August, and being shed after 13 August (tables 1 and 5). The lead tiller crude protein content drops below the requirements of lactating cows during the first week of July and drops below their phosphorus requirements sometime during the period from early to mid July (tables 1 and 6). Maximum basal leaf height is reached at the end of July with a crude protein content of only 7.1% (tables 1 and 2). Leaf dryness starts during early August and continues into September (tables 1 and 5). Leaf dryness during the 1964-1969 study appears to start earlier (table 7) than that during the 1955-1962 study (table 5). First flower stages appears to be similar on the sandy site and later on the overflow site (table 7) than that on silty site (tables 4 and 5). Unless the grazing management practice has properly manipulated the stimulation of an adequate quantity of Plains reedgrass vegetative secondary tillers, lactating cows will be grazing forage below their nutrient requirements after early July.

Grass species composition in rangeland ecosystems is variable during a growing season and dynamic among growing seasons. Patterns in the changes of individual grass species abundance was followed for 30 growing seasons during the 1983-2012 study on the sandy, shallow, and silty ecological sites of the long-term nongrazed, traditional seasonlong, and twice-over rotation management treatments (tables 8 and 9).

Plains reedgrass and Prairie Junegrass are difficult to separate in the field during ecological data collection using standard morphological separation characteristics. Plains reedgrass generally grows as single stems or few to many together, leaves are green to grayish green with deep ribs and furrows that is rough, the tip tapers to a point, vegetative tillers are crown and rhizome tillers, culm leaves are long, ligules usually are greater than 2.0 mm long, and lemma has a ring of small white callus hairs. Prairie Junegrass generally grows as a small tuft with a few stems, leaves are green to dark green with deep ribs and furrows that is flat and tapers to a boat prow tip, vegetative tillers are mostly crown tillers, culm leaves are normaly short, ligules usually less than 1.5 mm long. During June, fresh ungrazed tillers generally can be identified as one or the other species, however, during July and August, the leaves are at various stages of senescence, the ligules are at stages of dryness, some tillers have insect damage, some tillers have been partially defoliated by graminivores and confidence in correct identification has diminished greatly. During the 1983-2012 study, efforts to separate Prairie Junegrass and Plains reedgrass were attempted from 1983 to 1989 (seven years). After that, Prairie Junegrass and Plains reedgrass became an ecological complex during these studies. The ecological study results have been placed with the Prairie Junegrass report, DREC 17-1159. The 1983-1989 results for Plains reedgrass follows in this report.

Plains reedgrass was not present on the sandy, shallow, and silty ecological sites of the nongrazed treatment during 1983-1989.

Plains reedgrass was not present on the sandy, shallow, and silty ecological sites of the ungrazed seasonlong treatment during 1983-1989.

On the sandy site of the grazed seasonlong treatment, Plains reedgrass was not present during 1983-1989.

On the sandy site of the ungrazed twice-over treatment, Plains reedgrass was present during 14.3% of the 7 year data collection period with a mean 0.26% basal cover during the total period. During the first 4 years (1983-1986), Plains reedgrass was present during 25.0% of the years with a mean 0.46% basal cover. During the later 3 years (1987-1989), Plains reedgrass was not present.

On the sandy site of the grazed twice-over treatment, Plains reedgrass was present during 71.4% of the 7 year data collection period with a mean 0.28% basal cover during the total period. During the first 4 years (1983-1986), Plains reedgrass was present during 75.0% of the years with a mean 0.43% basal cover. During the later 3 years (1987-1989), Plains reedgrass was present during 66.7% of the years with a mean 0.07% basal cover.

On the shallow site of the grazed seasonlong treatment, Plains reedgrass was present during 14.3% of the 7 year data collection period with a mean 0.01% basal cover during the total period. During the first 4 years (1983-1986), Plains reedgrass was not present. During the later 3 years (1987-1989), Plains reedgrass was present during 33.3% of the years with a mean 0.03% basal cover.

On the shallow site of the ungrazed twice-over treatment, Plains reedgrass was present during 28.6% of the 7 year data collection period with a mean 0.04% basal cover during the total period. During the first 4 years (1983-1986), Plains reedgrass was present during 50.0% of the years with a mean 0.08% basal cover. During the later 3 years (1987-1989), Plains reedgrass was not present.

On the shallow site of the grazed twice-over treatment, Plains reedgrass was present during 57.1% of the 7 year data collection period with a mean 0.25% basal cover during the total period. During the first 4 years (1983-1986), Plains reedgrass was present during 75.0% of the years with a mean 0.41% basal cover. During the later 3 years (1987-1989), Plains reedgrass was present during 33.3% of the years with a mean 0.03% basal cover.

On the silty site of the grazed seasonlong treatment, Plains reedgrass was present during 14.3% of the 7 year data collection period with a mean 0.01% basal cover during the total period. During the first 4 years (1983-1986), Plains reedgrass was not present. During the later 3 years (1987-1989), Plains reedgrass was present during 33.3% of the years with a mean 0.03% basal cover.

On the silty site of the ungrazed twice-over treatment, Plains reedgrass was present during 28.6% of the 7 year data collection period with a mean 0.17% basal cover during the total period. During the first 4 years (1983-1986), Plains reedgrass was present during 25.0% of the years with a mean 0.03% basal cover. During the later 3 years (1987-1989), Plains reedgrass was present during 33.3% of the years with a mean 0.37% basal cover.

On the silty site of the grazed twice-over treatment, Plains reedgrass was present during 14.3% of the 7 year data collection period with a mean 0.05% basal cover during the total period. During the first 4 years (1983-1986), Plains reedgrass was present during 25.0% of the years with a mean 0.08% basal cover. During the later 3 years (1987-1989), Plains reedgrass was not present.

On the sandy site, Plains reedgrass was present during 28.6% of the years with a mean 0.18% basal cover. On the shallow site, Plains reedgrass was present during 33.3% of the years with a mean 0.10% basal cover. On the silty site, Plains reedgrass was present during 19.1% of the years with a mean 0.08% basal cover. The percent present was greater on the shallow site and basal cover were greater on the sandy site.

Plains reedgrass was present on the grazed seasonlong treatment during 9.5% of the seven years with a mean 0.01% basal cover. Plains reedgrass was present on the ungrazed twice-over treatment during 23.8% of the seven years with a mean 0.16% basal cover. Plains reedgrass was present on the grazed twice-over treatment during 47.6% of the seven years with a mean 0.19% basal cover. The percent present and basal cover were greater on the grazed twice-over treatment.

During the drought growing season of 1988, Plains reedgrass was not identified as being present on any ecological site of any management treatment. As a result, Plains reedgrass was included with Prairie Junegrass as an ecological complex.

Discussion

Plains reedgrass, *Calamagrostis montanensis*, is a native, perennial, cool season, mid grass, monocot, of the grass family that is common on healthy mixed grass prairie plant communities. Plains reedgrass can grow on sandy, shallow, silty, and overflow ecological sites. It has greater percent present on the shallow site and basal cover was greater on the sandy site. The greatest percent present and basal cover were on the grazed twice-over treatment. Early season activity starts with regreening with active chlorophyll the portions of the carryover leaves that have intact cell walls from the previous growing season vegetative tillers, secondary tillers, and fall tillers. The green portion of the carryover leaves provides large quantities of carbohydrates and fixed energy for the production of new leaves. New leaves of Plains reedgrass are visible around 8 April. Plains reedgrass lead tillers are derived from carryover vegetative tillers and produce 3.5 new leaves shortly after 1 June. Lead tillers at the 3.5 new leaf stage are physiologically capable of positive response to partial defoliation of 25% to 33% of leaf weight by graminivores. The tallest basal leaf is at 86.0% of maximum height on 1 June and the lead tiller contains 12.3% crude protein and 0.205% phosphorus on the silty ecological site during early June. The flower stalks reach the boot stage around 22 May, reach head emergence on 6 to 8 June, and reach the early flower stage around 29 June, with a 6 week flower period from mid June to late July. Leaf growth in height is rapid during April and May, growth is slower during June, and slower still during July. Basal leaves reach 95.0% of maximum height by end of June and reach 100.0% of maximum height by late July. Seeds are developing from 2 July, maturing during 26 July to 6 August, and being shed after 13 August. Seed stalks reach maximum height at the end of June and lead tillers contain 11.2% crude protein and 0.217% phosphorus. Lead tillers drop below the crude protein requirements of lactating cows during the first week of July and drop below the phosphorus requirements during the period between early and mid July. Leaf dryness starts during early August and continues into September. Lead tillers of Plains reedgrass contribute little to forage value after mid July.

Vegetative tillers are derived mostly from secondary carryover tillers that were most likely fall tillers from the previous growing season and some are derived from early season initiated tillers. Vegetative tillers have slightly slower growth rates than lead tillers during the early portion of the growing season. Vegetative tillers reach the 3.5 new leaf stage shortly after the lead tillers and become independent. When lead tiller growth rates decrease greatly during early July, the vegetative tiller growth rates do not slow down. Grazing management practices that have less than 100 lbs/ac of available mineral nitrogen have less than a third of the quantity of vegetative tillers as grazing management practices that can produce greater than 100 lbs/ac available mineral nitrogen. Vegetative tillers provide around three fourths of the forage weight after mid July.

Secondary tillers are derived from growing season initiated tillers. With most useful tillers initiated during May and June. Few secondary tillers are initiated during the period when lead tillers have high resource demand as they progress through the flower stage and seed production. Most of the secondary tillers on traditional grazing practices are at less than the 3.5 new leaf stage and are terminated during the high resource demand period resulting in only about 3% surviving secondary tillers compared to the quantity of surviving tillers on the twice-over system. Surviving secondary tillers become independent of the lead tillers when the fourth new leaf is near full development. These early initiated secondary tillers contribute to the forage weight after mid or late July. The quantity of vegetative and secondary tillers, and the quantity and quality of forage after mid July depends on the type of grazing management practice used during June and the first two weeks of July. Traditional grazing practices have low quantities of forage value vegetative and secondary tillers after mid July, and lactating cows are grazing forage that is below their nutrient requirements. Plains reedgrass is a valuable asset on the Northern Mixed Grass Prairie.

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Table 1. Calamagrostis montanensis, Plains reedgrass, 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 Stages
Apr 1			
13			
19			
25			
May 4	21.2	0.242	Early leaf greenup
10	-	-	
16	12.6	0.206	
23	13.7	0.224	Active leaf growth
28	12.3	0.205	
Jun 6	14.3	0.214	Flower stalk developing
13	11.2	0.194	
19	14.6	0.231	
26	11.2	0.217	
Jul 2	9.7	0.222	Seed developing
8	8.0	0.159	
16	9.3	0.183	
24	7.5	0.155	
30	7.1	0.147	
Aug 6	5.8	0.122	Seed maturing
13	6.7	0.146	
20	6.1	0.138	Drying
26	6.4	0.131	
Sep 3	6.0	0.127	
12	4.4	-	Drying
21			
29			
Oct			
Nov 5			

Data from Whitman et al. 1951.

Table 2. Mean leaf height in cm and percent of maximum leaf height attained by Calamagrostis montanensis, Plains reedgrass, 1955-1962.

	April				
	1	8	15	22	29
cm		1.0	8.5	9.8	11.1
%		5.0	41.0	47.0	53.0
	May				
	1	8	15	22	29
cm	11.8	12.8	14.3	15.3	16.3
%	57.0	61.0	68.0	73.0	78.0
	June				
	1	8	15	22	29
cm	18.0	18.5	19.0	19.6	19.8
%	86.0	88.0	91.0	94.0	95.0
	July				
	1	8	15	22	29
cm	19.9	20.0	20.2	20.5	20.9
%	95.0	96.0	97.0	98.0	100.0
	August				
	1	8	15	22	29
cm					
%					

Data from Goetz 1963.

Table 3. Mean stalk height in cm and percent of maximum stalk height attained by Calamagrostis montanensis, Plains reedgrass, 1955-1962.

	April				
	1	8	15	22	29
cm					
%					
	May				
	1	8	15	22	29
cm					
%					
	June				
	1	8	15	22	29
cm		16.3	23.0	24.3	25.6
%		63.7	89.8	94.9	100.0
	July				
	1	8	15	22	29
cm					
%					
	August				
	1	8	15	22	29
cm					
%					

Data from Goetz 1963.

Table 4. First flower and flower period of Calamagrostis montanensis, Plains reedgrass.

	Apr	May	Jun	Jul	Aug	Sep
First Flower						
1955-1962						
Earliest						
Mean			29			
Flower Period						
1969-1971			XX	XX XX		

First Flower Data from Goetz 1963 and Whitman et al. 1951.
Flower Period Data from Zaczkowski 1972.

Table 5. Flower stalk seed development and percent leaf dryness of Calamagrostis montanensis, Plains reedgrass.

	Flower Stalk Development			Seed Development	
Data Period	Boot	Emerge	Flower	Mature	Shed
1955-1962	22 May	7 Jun	29 Jun	26 Jul	13 Aug
			Percent Leaf Dryness		
Data Period	Leaf Tip	0-25	25-50	50-75	75-100
	Dry	%	%	%	%
1955-1962	18 Jun	5 Aug	24 Aug		21 Sep

Data from Goetz 1963.

Table 6. 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 7. Mean date of first flower and date of percentage categories of leaf senescence for Plains reedgrass 1964-1966.

Ecological Site	Anthesis	Leaf Tip Dry	Leaf 0-25% Dry	Leaf 25%-50% Dry	Leaf 50%-75% Dry
Sandy	29 Jun	8 Jun	16 Jul	25 Aug	1 Oct
Silty	18 Jun	9 Jun	13 Jul	9 Sep	1 Oct
Overflow	7 Jula	2 Jul	30 Jul	9 Aug	-
Thin claypan	No Data				

Data from Goetz 1970.

Table 8. Autecology of Calamagrostis montanensis, Plains reedgrass, 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	0.46	0.35
1988-1992	0.00	0.00	0.00	0.00	0.03
1993-1998	0.00	0.00	0.00	0.00	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
Shallow					
1983-1987	0.00	0.00	0.10	0.08	0.35
1988-1992	0.00	0.00	0.00	0.00	0.00
1993-1998	0.00	0.00	0.00	0.00	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	0.10	0.30	0.07
1988-1992	0.00	0.00	0.00	0.00	0.00
1993-1998	0.00	0.00	0.00	0.00	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

Table 9. Autecology of Calamagrostis montanensis, Plains reedgrass, 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	3.35	2.09
1988-1992	0.00	0.00	0.00	0.00	0.32
1993-1998	0.00	0.00	0.00	0.00	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
Shallow					
1983-1987	0.00	0.00	0.83	0.64	1.95
1988-1992	0.00	0.00	0.00	0.00	0.00
1993-1998	0.00	0.00	0.00	0.00	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	0.73	1.93	0.30
1988-1992	0.00	0.00	0.00	0.00	0.00
1993-1998	0.00	0.00	0.00	0.00	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

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Autecology of Plains Rough Fescue on the Northern Mixed Grass Prairie

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The autecology of Plains rough fescue, *Festuca hallii*, 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).

Plains rough fescue, *Festuca hallii* (Vasey) Piper, is a member of the grass family, Poaceae, tribe, Poeae, syn.: *Festuca scrabrella* Torr., and is a native, long lived perennial, monocot, cool-season, mid grass, that is cold hardy and adapted to short growing seasons. Early aerial growth consists of basal leaves arising from crown and rhizome tiller buds. Leaf blades are quite stiff 10-30 cm (4-12 in) long, 0.5-2 mm wide, tapering to a point, strongly ridged above, and scabrous (rough) on both surfaces. Previous years stem and leaf bases are persistent during the following growing season. The split sheaths are mostly open and closed for less than 1/3 their length. The ligule is a short margin with raised ends, 0.1-0.6 mm long, and the margin is fringed with short hairs. The auricles are absent. The numerous short rhizomes form mats of 25-50 cm (10-20 in) diameter. The extensive fibrous root system has numerous main roots arising from stem crowns and rhizome nodes growing vertically downward to 122 cm (4 ft) deep. Most of the roots are shallow, about 73% are in the top 15 cm (6 in) of soil. Regeneration is primarily asexual propagation by crown and rhizome tillers. Seedling success is low as a result of poor and erratic seed production and competition from established plants. Flower stalks are erect, smooth, 30-60 cm (12-24 in) tall. Inflorescence is a narrow, condensed panicle, 5-15 cm (2-6 in) long. Flower period is from late May to late June. Aerial parts are highly palatable to livestock. Fire top kills aerial parts and crowns continue burning below the soil surface long after the flame front has passed when soil is dry. Fire halts the processes of the four major defoliation resistance mechanisms and causes great reductions in biomass production and tiller density. This summary information on growth development and regeneration of Plains rough fescue was based on works of Stevens 1963, Zaczkowski 1972, Great Plains Flora Association 1986, and Tirmenstein 2000.

Taxonomic Status

The rough fescue circumboreal complex, *Festuca scabrella* Torr., indigenous to North America was divided in 1984 into three distinct species separated by several morphological characteristics, rhizome development, ploidy level, growth habit, preferred habitat type, and geographic distribution. The following summary of the taxonomic status of three species from the rough fescue complex was based on the works of Tirmenstein 2000, ITIS n.d., and Barkworth et al. 2007.

Northern rough fescue, *Festuca altaica* Trin., growth form is caespitose bunches, rarely with short rhizomes, produces 5 to 10 culms, 40-60 cm (15.7-23.6 in) tall with 3-5 florets per spikelet, chromosomes are tetraploid, and foliage is yellowish to dark green. Preference is for arctic tundra meadows, taiga, rocky alpine, subalpine forests, and open boreal forest habitats with geographic distribution in Alaska, Northwest Territories, Bristish Columbia, and Alberta.

Mountain (Foothills) rough fescue, *Festuca compestris* Rydb., growth form is large dense caespitose bunches, with no rhizomes, the highly productive tussocks are up to 30 cm (11.8 in) in diameter, produces up to 25 culms, 40-90 cm (15.7-35.4 in) tall with 4-6 florets per spikelet, roots can descend to 120 cm (47.2 in) deep, chromosomes are octaploid, and foliage is bluish gray green with purplish sheaths at the base of leaves. Preference is for subalpine and montane meadows, and high elevation (above 2000 m, 6,526 ft) foothill prairie habitats with geographic distribution in Washington, Oregon, Idaho, western Montana, southern British Columbia, southwestern Alberta, and the plateau of Cypress Hills in southwestern Saskatchewan.

Plains rough fescue, *Festuca hallii* (Vasey) Piper, growth form is short, reduced density caespitose bunches with short rhizomes that can form mats up to 50 cm (20 in) in diameter, produces 3-5 culms, 20-40 cm (7.9-15.7 in) tall with 2-3 florets per spikelet that infrequently develops viable seed, chromosomes are tetraploid, and foliage is bluish or gray green. Preference is for the moist grassland-forest transition zone on lower elevation (below 2000 m, 6,562 ft) foothill grassland habitats with geographic distribution from alpine meadows of northern Colorado, northward into the lower east facing foothills of the Rocky Mountains in Wyoming, western Montana, and southwestern Alberta, and has prehistorically spread eastward from the Alberta foothills into the northern prairieland of Alberta, Saskatchewan, and Manitoba, and then more recently spread southward into the prairieland of North Dakota and eastern Montana.

Procedures

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 will be reflected in the data summary tables as an 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

Plains rough fescue increases growth activity shortly after snow melt. Leaf growth in cool season grasses continues very slowly during the entire winter. The top portion of these carryover leaves becomes exposed to low temperatures causing the cell walls to rupture. The lower portion of the carryover leaves have intact cell walls and regreen with active chlorophyll when liquid water becomes available in soil for at least during the daylight hours. The green portions of the carryover leaves provide a large quantity of carbohydrates and fixed energy used in the production of new leaves. Growth of new leaves of Plains rough fescue is usually visible around mid April with active leaf growth occurring during early May (table 1). Tiller growth is rapid during May and June. Like other cool season grasses, Plains rough fescue produces 3.5 new leaves around early June. Lead tillers at the 3.5 new leaf stage are physiologically capable of positive response to partial defoliation of 25% to 33% of the leaf weight by graminivores. During early June, the lead tillers contain 10.1% crude protein (table 1). The flower stalks develop in mid May. The flower period occurs from around late May to mid June. Maximum herbage biomass is produced by the end of June. Seeds develop during late June and seeds are easily shed during mid to late July. Lead tiller digestibility is around 55% during most of June and July. However, the lead tiller crude protein content presumably drops below the requirements of lactating cows during early to mid July (table 2). Senescence of lead tillers occurs rapidly after early August (table 1). Heavy grazing pressure, that removes greater than 50% of the aboveground herbage weight, causes remarkable reductions in Plains rought fescue plant abundance. Plains rough fescue grasslands do not improve with the removal of grazing animals and greatly decrease without the effects from grazing (Slogan 1997).

Prairie composition with rough fescue

The descriptions of prairie plant composition with rough fescue required adjustments as a result of the separation of the rough fescue complex into three distinct species. Two of the three rough fescue species grow in the Northern Plains. Northern rough fescue, *Festuca altaica*, prefers habitats at mountain elevations that do not occur in the Northern Plains.

Mountain (Foothills) rough fescue, *Festuca compestris*, is the dominant grass of the Fescue Prairie that lies along the eastern face of the Rocky Mountain Foothills in southwestern Alberta which consists of over 1.3 million ha (3.2 million ac), on rolling, hummocky, dissected glacial till with a subhumid climate and black soils at higher elevations of foothill slopes (Slogan 1997, Henderson 2000, Shorthouse 2010). Mountain (Foothills) rough fescue was also present on the plateau and upper slopes of the Cypress Hills with small open patches among the forest cover on the north facing slopes in southeastern Alberta and southwestern Saskatchewan (Slogan 1997, Shorthouse 2010). The Alberta Fescue Prairie extends southward to the foothill slopes of the Sweetgrass Hills at the Canada-United States border (Shorthouse 2010) and continues south along the higher elevations of east facing foothills through Montana (Thrift et al. 2013) to the Madison Range (Barker and Whitman 1989) which enters Wyoming at the northwestern corner.

Plains rough fescue, *Festuca hallii,* is the dominant grass in patches and small grasslands of the Northern Plains in Alberta, Saskatchewan, Manitoba, eastern Montana, and northern North Dakota (Stevens 1963, Cosby 1965, Barkworth et al. 2007, Shorthouse 2010, Thorpe et al. 2015). The greatest extent of the Plains rough fescue grassland occurs in Canada from west central Alberta through central Saskatchewan to southwestern Manitoba that lies between the Moist (Transition) Mixed Grass Prairie and the Northern Boreal Forest within the Aspen Parkland. The Plains rough fescue grasslands occurs in a subhumid climate on black and dark brown chernozem soils in open areas and as intermittent patches interspersed among the mosaic of trembling aspen groves on dark gray chernozem soils, with groves of bur oak included in the eastern portions. The stands of aspen grade from a groveland to a parkland into a closed woodland (Slogan 1997, Henderson 2000, Shorthouse 2010, Thorpe et al. 2015).

Plains rough fescue grasslands has also developed on the lower south facing slopes of the Cypress Hills and as patches on drier sites of the Turtle Mountain Upland and Pembina Hills (Shorthouse 2010). On the United States side of the Turtle Mountain Upland, patches of Plains rough fescue have been located on the slopes and a grassland has been located at the highest point of St. Paul Butte, Bottineau and Rolette counties, North Dakota (Stevens 1963, Cosby 1965). Patches of Plains rough fescue have been interspersed within the Moist (Transition) Mixed Grass Prairie; Wheatgrass-Bluestem-Needlegrass Type of Saskatchewan, Manitoba, and northern North Dakota as depicted in Dr. Whitman’s Map of the Vegetation of the Northern Great Plains (Barker and Whitman 1988, 1989) (see map included). Plains rough fescue has been identified to occur as patches in most of the municipalities of the southern prairieland portions of Alberta and Saskatchewan, and the southwestern prairieland portions of Manitoba within the Tall Grass Prairie with a humid climate and black soils, the Moist (Transition) Mixed Grass Prairie with a subhumid climate and dark brown chernozem soils, the Mixed Grass Prairie with a semiarid climate and brown soils, and the area of dry Mixed Grass (Northern Short Grass) Prairie with a semiarid climate and brown soils (Barkworth et al. 2007).

Incursions of Plains rough fescue have been identified from counties in North Dakota and eastern Montana by Stevens 1963, Cosby 1965, and Barkworth et al. 2007 (table 3). Incursions into the Tall Grass Prairie with a humid climate and Aquall soils have occurred in Pembina and Walsh counties of North Dakota (table 3). Incursions into the Transition (Moist) Mixed Grass Prairie with a subhumid climate and Udic Boroll soils have occurred in Barnes, Benson, Bottineau, Burke, Cavalier, McHenry, Renville, and Rolette counties of North Dakota (table 3). Incursions into the Mixed Grass Prairie with a semiarid climate and Typic Boroll soils have occurred in Divide, Mountrail, Ward, and Williams counties of North Dakota and Daniels county of Montana (table 3). Incursions into the Northern Short Grass Prairie with an arid climate and Aridic Boroll soils have occurred in Valley county of Montana (table 3).

Plains rough fescue has made incursions into every prairie ecoregion of Alberta, Saskatchewan, and Manitoba, Canada (Capels n.d, Barkworth et al. 2007) and every prairie type in the United States Northern Plains among the first and second northern tier counties of North Dakota (Stevens 1963, Cosby 1965, Whitman and Wali 1975, Whitman and Barker 1989) and in two first northern tier counties of eastern Montana (Barkworth et al. 2007). Barkworth et al. (2007) has also identified incursions of Plains rough fescue into Barnes county with a fifth tier position in North Dakota. Plains rough fescue no longer appears to retain its habitat requirements of moist, lower elevation foothill grasslands.

Grass species composition in rangeland ecosystems is variable during a growing season and dynamic among growing seasons. Patterns in the changes of individual grass species abundance was followed during the 1983-2012 study on the sandy and silty ecological sites of the long-term nongrazed, traditional seasonlong, and twice-over rotation management treatments (tables 4 and 5).

Plains rough fescue incursions into Dunn County, with a third tier position in North Dakota, were located on Mixed Grass Prairie native rangeland study sites on the Dickinson Research Extension Center (DREC) ranch, operated by North Dakota State University (NDSU), 20 miles north of Dickinson, and west of Manning at latitude 47° 14' N, longitude 102° 50' W.

While collecting vegetative data at the silty site of seasonlong grazing treatment pasture 11, John Urban, Range Research Technician, noticed a different type of grass, Plains rough fescue, during the summer of 2006. During the summer of 2007, John Urban found additional locations of Plains rough fescue growing west of silty site exclosure of seasonlong grazing treatment pasture 11 and growing east of silty site exclosure of twice-over grazing treatment pasture 1. None of the locations were on nongrazed treatments inside the exclosures.

During the growing season of 2010, Plains rough fescue was located on the twice-over rotation grazing treatment silty site with a 1.70% basal cover and located again during the growing season of 2011 on the grazed silty site with a 1.10% basal cover (tables 4 and 5). During the 2011 growing season, Plains rough fescue was also located on the seasonlong grazing treatment silty site with a 0.05% basal cover and on the seasonlong grazing treatment sandy site with a 0.25% basal cover (tables 4 and 5). Plains rough fescue has not been located on any shallow sites or any nongrazed treatment sites.

Discussion

Plains rough fescue, *Festuca hallii*, is a North American native, perennial, cool season, mid grass, monocot, of the grass family that is not common in the Northern Plains Mixed Grass Prairie. Plains rough fescue is common as incursion patches in the Moist (Transition) Mixed Grass Prairie and as grasslands interspersed among the mosaic of trembling aspen groves in the Aspen Parkland north of the prairieland of Canada. Plains rough fescue typically grows in moist, cool, areas on low elevation foothill grasslands. Something has happened in the not too distant past to permit Plains rough fescue to develop as incursion patches in the Tall Grass Prairie, the Transition (Moist) Grass Prairie, the Mixed Grass Prairie, and the Northern Short (dry portion of Mixed) Grass Prairie of the Northern Plains in Alberta, Saskatchewan, and Manitoba of Canada and eastern Montana and North Dakota of the United States. Only a few other grasses can survive on all the prairie types of the Northern Plains, blue grama, needle and thread, prairie Junegrass, and western wheatgrass.

Early season activity for Plains rough fescue starts with regreening with active chlorophyll portions of the carryover leaves that have intact cell walls from the previous growing season vegetative tillers, secondary tillers, and fall tillers. The green portion of the carryover leaves provides large quantities of carbohydrates and fixed energy for the production of new leaves. New leaves of Plains rough fescue are usually visible around mid April. Plains rough fescue lead tillers are derived from carryover vegetative tillers, with active leaf growth starting in early May, and producing 3.5 new leaves around early June. Lead tillers at the 3.5 new leaf stage are physiologically capable of positive response to partial defoliation of 25% to 33% of leaf weight by graminivores. The lead tillers contain 10.1% crude protein during early June. The flower stalks are developing around mid May, with a short flower period from late May to mid June. Seeds are developing between late June and mid July and seeds are shed from mid to late July. However, Plains rough fescue develops viable seed infrequently. Lead tillers drop below the crude protein requirements of lactating cows during early to mid July. The lead tiller digestibility remains around 55% during most of June and July. Leaf senescence occurs rapidly during early August. Plains rough fescue grasslands degrade from heavy grazing that removes greater than 50% of the aboveground herbage weight and from nongrazing after the removal of grazing animals. Plains rough fescue, like all other grasses, produces double the leaf mass than the plant needs for normal growth and development. However, if half the leaf mass is not removed through partial defoliation by graminivores, this extra leaf material becomes a detriment. The incursions of Plains rough fescue into prairie types that it previously had not been part of the plant community have occurred too recently to determine whether the results will have a beneficial or negative outcome.

Acknowledgment

I am grateful to Sheri Schneider for assistance in the production of this manuscript and for development of the tables.

Table 1. Festuca hallii, Plains rough fescue, conjectural percent crude protein and phenological growth stages in Northern Mixed Grass Prairie.

Growing Season Date		Crude Protein %	Phenological Growth Satges
Apr	early		
	mid		early leaf greenup
	late		
May	early	12.0	active leaf growth
	mid	13.7	flower stalk developing
	late		
Jun	early	10.1	flower period
	mid		
	late		seeds developing
Jul	early		
	mid		seeds shed
	late		
Aug	early	7.0	
	mid	6.6	
	late		
Sep	early		
	mid	4.7	cured
	late		
Oct	early		
	mid	4.5	
	late	4.2	weathered

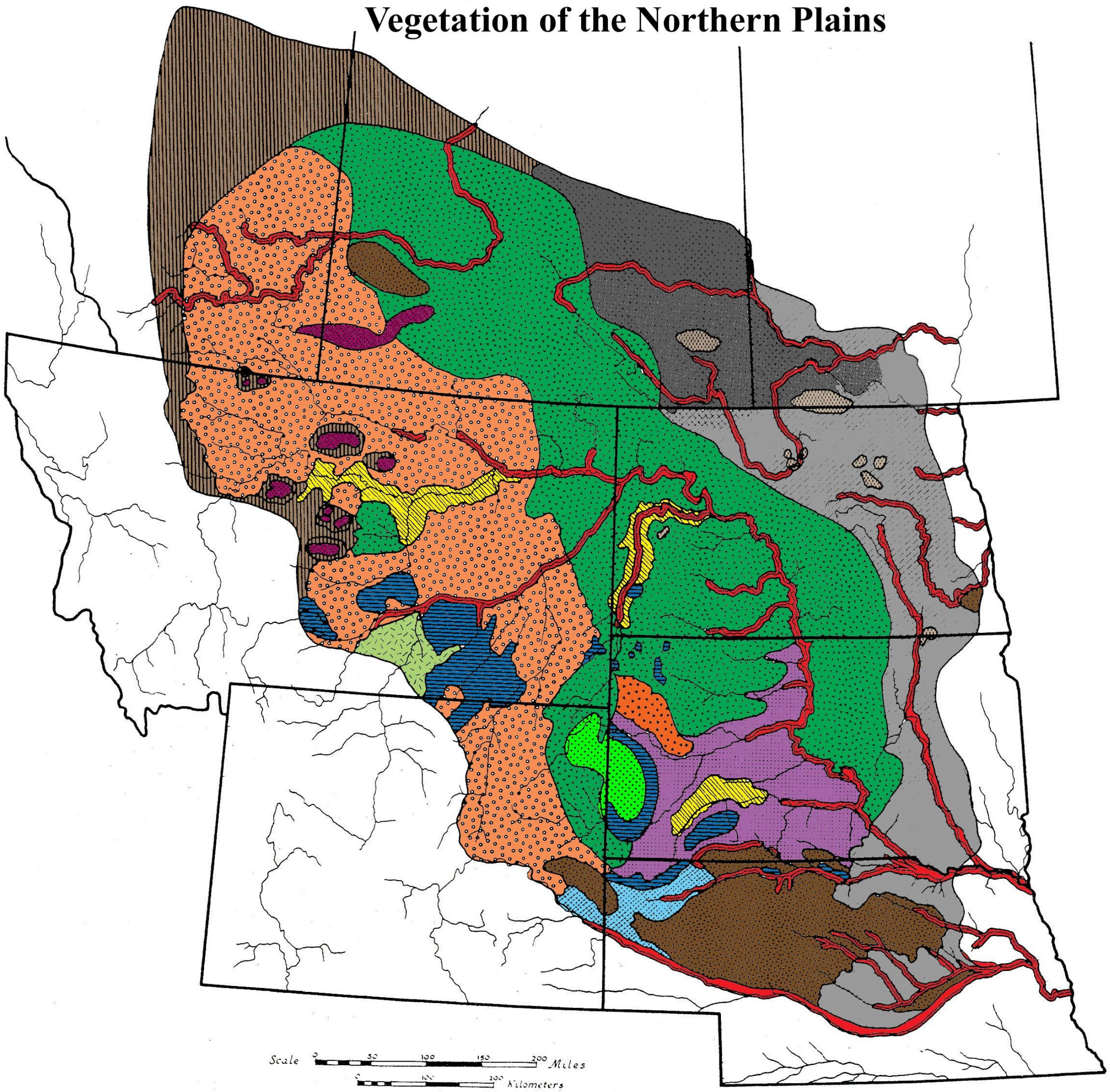
Partial Data Sets from Campbell et al. 1956 and Tirmenstein 2000.

Table 2. 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.

Vegetation of the Northern Plains



map from Barker and Whitman 1989

Table 3. Incursion of Plains rough fescue into Counties of North Dakota and eastern Montana.

Stevens, 1963 field work 1909-1950		Cosby, 1965 field work 1958-1964		Barkworth et al. 2007 Flora of North America, Vol. 24	
North Dakota		North Dakota		North Dakota	
1st Northern Tier Co.		1st Northern Tier Co.		1st Northern Tier Co.	
Burke	B.	Bottineau	B.	Bottineau	B.
Rolette	B.	Burke	B.	Burke	B.
		Divide	C.	Cavalier	B.
2nd Northern Tier Co.		Pembina	A.	Divide	C.
		Renville	B.	Rolette	B.
Benson	B.	Rolette	B.		
				2nd Northern Tier Co.	
		2nd Northern Tier Co.			
				Benson	B.
		Benson	B.	Mountrail	C.
		McHenry	B.	Ward	C.
		Mountrail	C.	Williams	C.
		Walsh	A.		
		Ward	C.	5th Northern Tier Co.	
				Barnes	B.
				Montana	
				1st Northern Tier Co.	
				Daniels	C.
				Valley	D.

Key to Vegetation Types of the Counties.

A. Tall Grass Prairie; Bluestem-Switchgrass-Indiangrass Type.
B. Transition Mixed Grass Prairie; Wheatgrass-Bluestem-Needlegrass Type.
C. Mixed Grass Prairie; Wheatgrass-Needlegrass Type.
D. Northern Short Grass Prairie; Grama-Needlegrass-Wheatgrass Type.

Table 4. Autecology of Festuca hallii, Plains rough fescue, 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	0.00	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	0.25	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	0.00	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	0.00	0.00	0.00	0.00	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	0.05	0.00	1.40

Table 5. Autecology of Festuca halii, Plains rough fescue, 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	0.00	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	2.04	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	0.00	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	0.00	0.00	0.00	0.00	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	0.42	0.00	7.35

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