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	3^{rd} 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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