Autecology of Prairie Trefoil on the Northern Mixed Grass Prairie

Llewellyn L. Manske PhD
Research Professor of Range Science
North Dakota State University
Dickinson Research Extension Center
Report DREC 17-1118

The autecology of Prairie trefoil, *Lotus purshianus,* 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 trefoil, *Lotus purshianus* Clem. & Clem., is a member of the legume (bean, pea) family, Fabaceae, syn.: *Lotus unifoliolatus* (Hook.) Benth., *Lotus americanus* (Nutt.) Bisch., and is a native, annual, dicot, herb that occurs during years with good spring rain. The first North Dakota record is Bolley and Lee 1891. Aerial growth has a single, slender, erect, much branched stem 30-50 cm (11.8-19.7 in) tall. Stem leaves are alternate, subsessile, with 3 leaflets (trifoliolate), elliptic to lanceolate, 1-2 cm (0.4-0.8 in) long. Stems and leaves can be glabrous to densely pubescent. The root system is a slender taproot with fine lateral roots. Regeneration is by sexual reproduction. Inflorescences are solitary flowers on a short peduncle arising from an upper leaf axil. Flowers are perfect, pea shaped with yellowish white petals 4 mm long appearing during mid June to late July. Fruits are shiny slender pods 2-3 cm (0.8-1.2 in) long, dark brown, and dehiscent, splitting open at maturity. Aerial parts are not eaten by livestock and are totally consumed by fire. This summary information on growth development and regeneration of prairie trefoil was based on works of Stevens 1963, Zaczkowski 1972, Great Plains Flora Association 1986, Johnson and Larson 2007.

Procedures

The 1955-1962 Study

Prairie trefoil, plant growth in height was determined by measuring ungrazed stems from ground level to top of leaf or to the tip of the inflorescence of an average of 10 plants of each species at approximately 7 to 10 day intervals during the growing seasons of 1955 to 1962 from early May until early September. Dates of first flower (anthesis) were recorded as observed. These growth in height and flower data were reported in Goetz 1963.

The 1969-1971 Study

The range of flowering time of Prairie trefoil 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 1984-1985 Study

Prairie trefoil plant growth in height was determined by measuring stems from ground level to top of stem or leaf or to the tip of the inflorescence of 47 ungrazed specimens randomly selected on three replications of grazed sandy, shallow, silty, and clayey ecological sites biweekly during June, July, and August of the growing seasons of 1984 and 1985. Phenological growth stage of each specimen was recorded as vegetative, budding, anthesis, seed developing, seed shedding, or mature. Percentage of stem dryness of each specimen was recorded as 0, 0-2, 2-25, 25-50, 50-75, 75-98, or 100 percent dry. Mean stem weight was determined by clipping at ground level 16 specimens at typical phenological growth stages at biweekly sample dates on separate grazed areas of the sandy, shallow, silty, and clayey ecological sites. Clipped stems at each sample site were placed in separate labeled paper bags of known weight, oven dried at 62° C (144° F), and weighed in grams.

The 1983-2012 Study

A long-term study on change in abundance of Prairie trefoil 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 Prairie trefoil was determined with plant species stem density by 0.1 m^2 frame density method and with plant species basal cover by the ten-pin point frame method (Cook and Stubbendieck 1986).

The stem density method was used to count individual stems of each plant species rooted inside twenty five 0.1 m^2 quadrats placed along permanent transect lines at each sample site both inside (ungrazed) and outside (grazed) each exclosure. Stem density per 0.1 m^2 quadrat, relative stem density, percent frequency, relative percent frequency, and importance value were determined from the stem density data. Plant species stem density data collection was 1984, 1986 to 2012 on the twice-over treatment and was 1987 to 2012 on the long-term nongrazed and seasonlong treatments. However, stem density data was not collected during 1991, 1993 to 1997 on the sandy, shallow, and silty ecological sites of all three management treatments, stem density data was not collected during 1992 on the sandy ecological site of all three management treatments, and stem density data was not collected during 1999 on the sandy and silty ecological sites of the long-term nongrazed treatment.

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 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 or the stem density 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 density or 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 a growing season. Density importance value ranks the forb and shrubs and 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 trefoil started growth from a seed during growing seasons with adequate spring rains. A single stem with many branches above and taproot would develop. A solitary flower on a short peduncle and perfect, pea shaped petals would arise from the upper leaf axils. On the fall grazed pastures of the1955-1962 study, the earliest first flowers appeared 21 June, the mean first flowers occurred on 4 July, and the six week flower period, from the 1969-1971 study, extended from mid June to late July (table 1) (Goetz 1963, Zaczkowski 1972). A mean mature stem height of 20.0cm (7.9 in) with an annual variance in height from 11.0 cm (4.3 in) to 45.0 cm (17.9 in) was reached during August (table 2) (Goetz 1963). The reported normal mature stem height in the Northern Plains ranged from 30 cm to 50 cm (11.8-19.7 in) tall. The mean stem heights from the 1955-1962 study were shorter than the reported normal mature stem heights in the Northern Plains.

Changes in phenological growth stages from the 1984-1985 study are summarized on tables 3, 4,

5, and 6. A total of 3,067 Prairie trefoil stems were sampled during this study with, 639 stems (20.8%) from the sandy sites, 735 stems (24.0%) from the shallow sites, 930 stems (30.3%) from the silty sites, and 763 stems (24.9%) from the clayey sites. Prairie trefoil can grow on sandy, shallow, silty, and clayey ecological sites, but it appears to grow best on the silty sites. The mean mature stem height reached during August were not significantly different with, 12.4 cm (4.9 in) on the sandy sites, 9.6 cm (3.8 in) on the shallow sites, 11.8 cm (4.6 in) on the silty sites, and 10.8 cm (4.3 in) on the clayey sites. The mean stem heights from the 1984-1985 study were all shorter than the reported normal mature stem heights in the Northern Plains.

During the growing season, the percentage of Prairie trefoil stems that had passed through the anthesis phenological growth stages was 29.6% by early July, 67.9% by late July, 79.0% by early August, and 95.5% by late August. About 4.5% of the stems remained at vegetative growth stages (tables 3, 4, 5, and 6). Mean Prairie trefoil stem weights were not significantly different at 0.11 g on the sandy sites, 0.08 g on the shallow sites, 0.09 g on the silty sites, and 0.08 g on the clayey sites.

Plant species composition in rangeland ecosystems is variable during a growing season and dynamic among growing seasons. Patterns in the changes in individual plant 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.

On the sandy site of the nongrazed treatment, Prairie trefoil was present during 55.6% and 28.0% of the years that density and basal cover data were collected, with a mean 2.9 stems/m^2 density and a mean 0.02% basal cover during the total 30 year period, respectively. During the early period (1983-1992), Prairie trefoil was present during 25.0% and 20.0% of the years, with a mean 0.05 stems/m^2 density and a mean 0.01% basal cover, respectively. During the later period (1998-2012), Prairie trefoil was present during 64.3% and 40.0% of the years, with a mean 3.7 stems/m^2 density and a mean 0.04% basal cover, respectively. The percent present, stem density, and basal cover all increased on the sandy sites of the nongrazed treatment over time (tables 7, 8, and 9).

On the sandy site of the ungrazed seasonlong treatment, Prairie trefoil was present during 47.4% and 40.0% of the years that density and basal cover data were collected, with a mean 2.4 stems/m^2 density and a mean 0.05% basal cover during the total 30 year period, respectively. During the early period (1983-1992), Prairie trefoil was not present where density data were collected and was present during 20.0% of the years that basal cover data were collected, with a mean 0.03% basal cover. During the later period (1998-2012), Prairie trefoil was present during 60.0% and 53.3% of the years, with a mean 3.1 stems/m^2 density and a mean 0.07% basal cover, respectively. The percent present, stem density, and basal cover all increased on the sandy site of the ungrazed seasonlong treatment over time (tables 7, 8, and 9).

On the sandy site of the grazed seasonlong treatment, Prairie trefoil was present during 68.4% and 44.0% of the years that density and basal cover data were collected, with a mean 5.2 stems/m^2 density and a mean 0.09% basal cover during the total 30 year period, respectively. During the early period (1983-1992), Prairie trefoil was not present on the sandy site of the grazed seasonlong treatment. During the later period (1998-2012), Prairie trefoil was present during 86.7% and 60.0% of the years, with a mean 6.6 stems/m^2 density and a mean 0.06% basal cover, respectively. The percent present, stem density, and basal cover all increased on the sandy site of the grazed seasonlong treatment (tables 7, 8, and 9). The percent present and stem density were greater on the grazed management than those on the ungrazed management of the seasonlong treatment.

On the sandy site of the ungrazed twice-over treatment, Prairie trefoil was present during 57.1% and 20.7% of the years that density and basal cover data were collected, with a mean 0.21 stems/m^2 density and a mean 0.01% basal cover during the total 30 year period, respectively. During the early period (1983-1992), Prairie trefoil was present during 33.3% and 12.5% of the years, with a mean 0.20 stems/m^2 density and a mean 0.01% basal cover, respectively. During the later period (1998-2012), Prairie trefoil was present during 66.7% and 13.3% of the years, with a mean 0.22 stems/m^2 density and a mean 0.001% basal cover, respectively. The percent present and stem density increased slightly and the basal cover decreased on the sandy site of the ungrazed twice-over treatment over time (tables 7, 8, and 9).

On the sandy site of the grazed twice-over treatment, Prairie trefoil was present during 71.4% and 24.1% of the years that density and basal cover data were collected, with a mean 0.24 stems/m^2

density and a mean 0.01% basal cover during the total 30 year period, respectively. During the early period (1983-1992), Prairie trefoil was present during 50.0% and 11.1% of the years, with a mean 0.18 stems/m^2 density and a mean 0.002% basal cover, respectively. During the later period (1998-2012), Prairie trefoil was present during 80.0% and 33.3% of the years, with a mean 0.27 stems/m^2 density and a mean 0.01% basal cover, respectively. The percent present, stem density, and basal cover all increased on the sandy site of the grazed twice-over treatment over time (tables 7, 8, and 9). The percent present and stem density was slightly larger on the grazed management than that on the ungrazed management of the twice-over treatment.

During the 30 year period of the 1983-2012 study on the sandy sites, the percent present, stem density, and basal cover of Prairie trefoil was greatest on the grazed seasonlong treatment and stem density and basal cover were lowest on the ungrazed and grazed twice-over treatments.

On the shallow site of the nongrazed treatment, Prairie trefoil was present 36.8% and 19.2% of the years that density and basal cover data were collected, with a mean 0.30 stems/m^2 density and a mean 0.01% basal cover during the total 30 year period, respectively. During the early period (1983-1992), Prairie trefoil was not present where density data were collected and was present during 33.3% of the years where basal cover data were collected, with a mean 0.02% basal cover. During the later period (1998-2012), Prairie trefoil was present during 50.0% and 13.3% of the years, with a mean 0.37 stems/m^2 density and a mean 0.005% basal cover, respectively. The percent present of density data and the stem density increased. The percent present of basal cover data and the basal cover decreased on the shallow site of the nongrazed treatment over time (tables 7, 8, and 9).

On the shallow site of the ungrazed seasonlong treatment, Prairie trefoil was present during 45.0% and 15.4% of the years that density and basal cover data were collected, with a mean 1.29 stems/m^2 density and a mean 0.006% basal cover during the total 30 year period, respectively. During the early period (1983-1992), Prairie trefoil was present during 20.0% of the years density data were collected with a mean 0.14 stems/m^2 density and was not present during the years basal cover were collected. During the later period (1998-2012), Prairie trefoil was present during 53.3% and 26.7% of the years, with a mean 1.67 stems/m^2 density and a mean 0.01% basal cover, respectively. The percent present, stem density, and basal cover all increased on the shallow site of the ungrazed seasonlong treatment over time (tables 7, 8, and 9).

On the shallow site of the grazed seasonlong treatment, Prairie trefoil was present during 65.0% and 19.2% of the years that density and basal cover data were collected, with a mean 1.49 stems/m^2 density and a mean 0.01% basal cover, during the total 30 year period, respectively. During the early period (1983-1992), Prairie trefoil was present during 60.0% of the years density data were collected with a mean 0.58 stems/m^2 density and was not present during the years basal cover data were collected. During the later period (1998-2012), Prairie trefoil was present during 66.7% and 26.7% of the years, with a mean 1.79 stems/m^2 density and a mean 0.02% basal cover, respectively . The percent present, stem density, and basal cover all increased on the shallow site of the grazed seasonlong treatment over time (tables 7, 8, and 9). The percent present, stem density, and basal cover were slightly larger on the grazed management than that on the ungrazed management of the seasonlong treatment.

On the shallow site of the ungrazed twice-over treatment, Prairie trefoil was present during 90.9% and 69.0% of the years that density and basal cover data were collected, with a mean 6.86 stems/m^2 density and a mean 0.17% basal cover during the total 30 year period, respectively. During the early period (1983-1992), Prairie trefoil was present during 71.4% and 66.7% of the years, with a mean 2.90 stems/m^2 density and a mean 0.12% basal cover, respectively. During the later period (1998-2012), Prairie trefoil was present during 100.0% and 73.3% of the years, with a mean 8.71 stems/m^2 density and a mean 0.11% basal cover, respectively. The percent present and stem density increased and the basal cover decreased on the shallow site of the ungrazed twice-over treatment over time (tables 7, 8, and 9).

On the shallow site of the grazed twice-over treatment, Prairie trefoil was present during 95.5% and 60.0% of the years that density and basal cover data were collected, with a mean 3.88 stems/m^2 density and a mean 0.10% basal cover during the total 30 year period, respectively. During the early period (1983-1992), Prairie trefoil was present during 85.7% and 50.0% of the years, with a mean 2.86 stems/m^2 density and a mean 0.07% basal cover, respectively. During the later period (1998-2012), Prairie trefoil was present during 100.0% and 73.3% of the years, with a mean 4.35 stems/m^2 density and a mean 0.07% basal cover, respectively. The percent present and stem density increased and the basal cover remained

the same on the shallow site of the grazed twice-over treatment (tables 7, 8, and 9). The stem density and basal cover were lower on the grazed management than that on the ungrazed management of the twice-over treatment.

During the 30 year period of the 1983-2012 study on the shallow sites, the stem density and basal cover of Prairie trefoil was greatest on the ungrazed twice-over treatment and lowest on the nongrazed treatment.

On the silty site of the nongrazed treatment, Prairie trefoil was present during 52.6% and 23.1% of the years that density and basal cover data were collected, with a mean 4.23 stems/m^2 density and a mean 0.03% basal cover during the total 30 year period, respectively. During the early period (1983-1992), Prairie trefoil was present during 20.0% of the years density data was collected, with a mean 0.35 stems/m^2 density and was not present during the years basal cover was collected. During the later period (1998-2012), Prairie trefoil was present during 64.3% and 40.0% of the years, with a mean 5.27 stems/m^2 density and a mean 0.05% basal cover, respectively. The percent present, stem density, and basal cover all increased on the silty site of the nongrazed treatment over time (tables 7, 8, and 9).

On the silty site of the ungrazed seasonlong treatment, Prairie trefoil was present during 65.0% and 30.8% of the years that density and basal cover data were collected, with a mean 3.39 stems/m^2 density and a mean 0.04% basal cover during the total 30 year period, respectively. During the early period (1983-1992), Prairie trefoil was present during 40.0% and 16.7% of the years, with a mean 1.14 stems/m^2 density and a mean 0.01% basal cover, respectively. During the later period (1998-2012), Prairie trefoil was present during 73.3% and 40.0% of the years, with a mean 4.14 stems/m^2 density and a mean 0.04% basal cover, respectively. The percent present, stem density, and basal cover all increased on the silty site of the ungrazed seasonlong treatment over time (tables 7, 8, and 9).

On the silty site of the grazed seasonlong treatment, Prairie trefoil was present during 85.0% and 50.0% of the years that density and basal cover data were collected, with a mean 2.97 stems/m^2 density and a mean 0.13% basal cover during the total 30 year period, respectively. During the early period (1983-1992), Prairie trefoil was present during 80.0% and 50.0% of the years, with a mean 1.40 stems/m^2 density and a mean 0.24% basal cover, respectively. During the later period (1998-2012), Prairie trefoil was present during 86.7% and 46.7% of the years, with a mean 3.49 stems/m^2 density and a mean 0.03% basal cover, respectively. The percent present for density data and stem density increased and the percent present for basal cover data and basal cover decreased on the silty site of the grazed seasonlong treatment over time (tables 7, 8, and 9). The stem density was lower on the grazed management than that on the ungrazed management of the seasonlong treatment.

On the silty site of the ungrazed twice-over treatment, Prairie trefoil was present during 95.5% and 69.0% of the years that density and basal cover data were collected, with a mean 2.93 stems/m^2 density and a mean 0.17% basal cover during the total 30 year period, respectively. During the early period (1983-1992), Prairie trefoil was present during 100.0% and 77.8% of the years, with a mean 2.01 stems/m^2 density and a mean 0.16% basal cover, respectively. During the later period (1998-2012), Prairie trefoil was present during 93.3% and 66.7% of the years, with a mean 3.36 stems/m^2 density and a mean 0.07% basal cover, respectively. The stem density increased and the percent present and basal cover decreased on the silty site of the ungrazed twice-over treatment over time (tables 7, 8, and 9).

On the silty site of the grazed twice-over treatment, Prairie trefoil was present during 90.0% and 80.0% of the years that density and basal cover data were collected, with a mean 6.20 stems/m^2 density and a mean 0.16% basal cover during the total 30 year period, respectively. During the early period (1983-1992), Prairie trefoil was present 85.7% and 80.0% of the years, with a mean 1.63 stems/m^2 density and a mean 0.13% basal cover, respectively. During the later period (1998-2012), Prairie trefoil was present during 93.3% and 86.7% of the years, with a mean 8.33 stems/m^2 density and a mean 0.13% basal cover, respectively. The percent present and the stem density increased and basal cover remained the same on the silty site of the grazed twice-over treatment over time (tables 7, 8, and 9). The stem density and basal cover were greater on the grazed management than that on the ungrazed management of the twice-over treatment.

During the 30 year period of the 1983-2012 study, on the silty sites, the stem density of Prairie trefoil increased the greatest amount over time on the grazed twice-over treatment and increased the lowest amount over time on the ungrazed twice-over treatment. The basal cover of Prairie trefoil decreased the greatest amount over time on the grazed seasonlong treatment and increased the

greatest amount over time on the nongrazed treatment. The greatest stem density values for the management treatments were on the silty sites, except the greatest stem density for the ungrazed twice-over treatment was on the shallow site.

During the growing season of the drought year, 1988, Prairie trefoil was not present on any of the management treatments, except, there were a few stems present on the silty sites of the ungrazed twice-over treatment. The following growing season, 1989, Prairie trefoil was present at modest quantities on all ecological sites of all the management treatments, except, it was not present on the sandy site of the grazed seasonlong treatment and the shallow site of the ungrazed seasonlong treatment.

There appears to be a direct relationship between the quantity of precipitation received during April or May as a percent of the long-term mean and the mean stem density and basal cover on the sandy, shallow, and silty ecological sites during the growing season. i.e. when April or May receive above normal precipitation, the stem density and basal cover are also above normal and when precipitation received is below normal, the stem density and basal cover are also low. When April or May received above normal precipitation and the other month received below normal precipitation, the stem density and basal cover are usually low. Table 10 shows twelve April's or May's with high precipitation and high stem density and basal cover and shows fourteen April's or May's with low precipitation and low stem density and basal cover. During two growing seasons, 1993 and 2002, April or May did not receive high or low precipitation rates. The growing seasons of 1985 and 2010 had above precipitation during April or May, however, the stem density and basal cover were all low (table 10).

Discussion

Prairie trefoil, *Lotus purshianus*, is a mid succession annual forb of the legume family that is commonly present on healthy mixed grass prairie plant communities. Prairie trefoil was present when stem density data were collected during 60.0% of the years on the sandy sites with a mean 2.19 stems/m^2 density, during 66.6% of the years on the shallow sites with a mean 2.76 stems/m^2 density, and during 77.8% of the years on the silty sites with a mean 3.94 stems/m^2 density. Prairie trefoil can grow on sandy, shallow, silty, and clayey ecological sites, however, it grows best on the silty sites. Early spring aerial growth is from a seed during years with adequate spring rains. A single stalk with numerous branches develops. The mean first flower date is 4 July with a six week flower period from mid June to late July. The mean mature flower stalk height reached during August was 20.0 cm (7.9 in) on the 1955-1962 study and 11.2 cm (4.4 in) on the 1984-1985 study were both shorter than the reported normal Northern Plains mature stalk heights at 30 cm to 50 cm (11.8-19.7 in) tall. The mean stem weight was 0.09 g. During the growing season, 95.5% of stems had passed through the anthesis phenological growth stage and only 4.5% of the stems did not produce seeds. The stem density and basal cover were high when April or May received above normal precipitation and stem density and basal cover were low when April or May received below normal precipitation. There were no stems present on any management treatment except for a few stems on the silty site of the ungrazed twice-over treatment during the drought year of 1988. Prairie trefoil grows from seed each growing season and is dependent on early spring precipitation for germination.

Acknowledgment

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

Table 1. First flower and flower period of Lotus purshianus, Prairie trefoil.

	Apr	May	Jun	Jul	Aug	Sep
First Flower						
1955-1962						
Earliest			21			
Mean				4		
Flower Period						
1969-1971			XX	XX XX		

First Flower data from Goetz 1963.
Flower Period Data from Zaczkowski 1972.

Table 2. Autecology of Lotus purshianus, Prairie trefoil, with growing season changes in mature height.

				Percent of Mature Height Attained					
Data Period	Minimum Annual Mature Height cm	Maximum Annual Mature Height cm	Mean Mature Height cm	Apr %	May %	Jun %	Jul %	Aug %	Sep %
1955-1962	11.0	45.0	20.0		14.3	59.7	94.5	100.0	

Data from Goetz 1963.

Table 3. Phenological growth stage changes during the growing season for Lotus purshianus, Prairie trefoil, 1984-1985.

Site Sandy	8 Jun	23 Jun	8 Jul	23 Jul	8 Aug	23 Aug
% Population						
Veg	100.0	84.0	41.1	12.7	21.3	5.4
Bud		10.1	20.5	18.3	10.0	
Anth		1.7	19.6	8.5	1.3	
Seed Dev		4.2	17.9	53.5	42.5	8.1
Seed Shed			0.9		7.5	5.4
Mat				7.0	17.5	81.1
Mean Height (cm)						
Veg	9.7	5.8	6.1	4.8	8.9	8.1
Bud		7.5	8.5	13.5	11.9	
Anth		11.8	9.5	8.2	11.1	
Seed Dev		9.0	10.5	9.7	10.7	11.5
Seed Shed			7.1		15.1	12.1
Mat				14.0	15.7	13.6
% Dryness						
Veg	5.1	6.2	30.9	31.2	64.7	87.5
Bud		9.5	15.6	18.1	20.0	
Anth		2.0	1.8	17.0	25.0	
Seed Dev		20.4	45.8	12.6	43.6	25.7
Seed Shed			100.0		41.7	75.0
Mat				84.6	53.4	63.3
Mean Weight (g)	0.02	0.03	0.10	0.15	0.21	0.15

Phenological Growth Stages: Vegetative (Veg), Budding (Bud), Anthesis (Anth), Seed Developing (Seed Dev), Seed Shedding (Seed Shed), Mature (Mat).

Table 4. Phenological growth stage changes during the growing season for Lotus purshianus, Prairie trefoil, 1984-1985.

Site Shallow	8 Jun	23 Jun	8 Jul	23 Jul	8 Aug	23 Aug
% Population						
Veg	100.0	77.1	54.4	37.2	11.8	
Bud		18.1	19.9	10.5	3.5	2.9
Anth		4.2	6.6	2.3		
Seed Dev		0.7	19.1	33.7	52.9	8.7
Seed Shed				4.7	5.9	4.3
Mat				11.6	25.9	84.1
Mean Height (cm)						
Veg	5.3	4.4	4.8	5.6	5.4	
Bud		5.8	7.4	7.5	6.1	10.4
Anth		8.8	9.8	6.9		
Seed Dev		4.5	10.0	10.4	9.4	8.0
Seed Shed				7.0	12.4	8.7
Mat				9.9	10.2	10.8
% Dryness						
Veg	4.0	9.2	34.5	35.7	69.4	
Bud		14.7	17.4	17.8	1.3	25.0
Anth		29.8	1.8	13.5		
Seed Dev		25.0	64.2	41.3	46.5	25.7
Seed Shed				100.0	45.0	98.7
Mat				80.2	88.7	72.8
Mean Weight (g)	0.07	0.05	0.08	0.10	0.09	0.07

Phenological Growth Stages: Vegetative (Veg), Budding (Bud), Anthesis (Anth), Seed Developing (Seed Dev), Seed Shedding (Seed Shed), Mature (Mat).

Table 5. Phenological growth stage changes during the growing season for Lotus purshianus, Prairie trefoil, 1984-1985.

Site Silty	8 Jun	23 Jun	8 Jul	23 Jul	8 Aug	23 Aug
% Population						
Veg	97.6	78.9	57.7	14.8	13.4	7.8
Bud	2.4	17.2	19.6	3.7	8.2	
Anth		2.2	6.5	2.8		
Seed Dev		1.7	14.9	62.0	50.5	14.1
Seed Shed			0.6	0.9	16.5	
Mat			0.6	15.7	11.3	78.1
Mean Height (cm)						
Veg	7.1	6.4	7.6	7.1	7.2	8.5
Bud	7.1	7.8	9.3	9.4	8.2	
Anth		12.1	10.5	11.6		
Seed Dev		11.0	8.9	11.6	12.1	11.1
Seed Shed			11.5	7.6	12.3	
Mat			5.5	9.1	13.2	13.1
% Dryness						
Veg	4.8	13.0	39.3	76.7	91.9	60.4
Bud	1.0	19.0	8.0	31.8	41.4	
Anth		19.3	1.5	34.7		
Seed Dev		25.0	45.3	39.9	55.1	36.4
Seed Shed			98.0	100.0	70.5	
Mat			98.0	99.9	81.6	78.9
Mean Weight (g)	0.04	0.07	0.12	0.11	0.10	0.11

Phenological Growth Stages: Vegetative (Veg), Budding (Bud), Anthesis (Anth), Seed Developing (Seed Dev), Seed Shedding (Seed Shed), Mature (Mat).

Table 6. Phenological growth stage changes during the growing season for Lotus purshianus, Prairie trefoil, 1984-1985.

Site Clayey	8 Jun	23 Jun	8 Jul	23 Jul	8 Aug	23 Aug
% Population						
Veg	100.0	90.4	48.3	24.2	15.9	
Bud		9.6	20.0	7.1		1.7
Anth			7.5	2.0		
Seed Dev			21.7	47.5	47.6	15.5
Seed Shed			2.5	2.0	12.2	3.4
Mat				17.2	24.4	79.3
Mean Height (cm)						
Veg	6.2	5.6	6.6	6.6	7.2	
Bud		6.9	8.8	9.4		7.4
Anth			10.8	7.5		
Seed Dev			10.1	9.4	10.3	12.2
Seed Shed			6.5	11.0	10.7	10.0
Mat				8.2	9.8	12.8
% Dryness						
Veg	4.6	9.7	36.4	48.3	85.9	
Bud		12.1	5.7	39.1		25.0
Anth			3.9	26.0		
Seed Dev			44.4	42.9	64.0	33.6
Seed Shed			82.7	75.0	50.2	99.0
Mat				86.8	81.1	72.5
Mean Weight (g)	0.06	0.06	0.10	0.08	0.10	0.07

Phenological Growth Stages: Vegetative (Veg), Budding (Bud), Anthesis (Anth), Seed Developing (Seed Dev), Seed Shedding (Seed Shed), Mature (Mat).

Table 7. Autecology of Lotus purshianus, Deer vetch or Prairie trefoil, with growing season changes in density importance value, 1983-2012.

Ecological Site Year Period	Nongrazed	Seasonlong		Twice-over	
		Ungrazed	Grazed	Ungrazed	Grazed
Sandy					
1983-1987	3.35	0.00	0.00	0.20	0.52
1988-1992	0.00	0.00	0.00	2.10	1.61
1993-1998	0.00	0.00	0.97	0.84	0.00
1999-2003	1.58	4.48	12.79	0.91	1.48
2004-2009	17.76	14.73	20.72	1.44	1.80
2010-2012	7.48	2.13	6.61	0.95	0.97
Shallow					
1983-1987	0.00	4.49	0.95	10.04	8.73
1988-1992	0.00	0.00	4.63	24.46	13.82
1993-1998	0.00	0.00	0.00	9.44	9.62
1999-2003	0.00	2.40	6.46	14.53	13.03
2004-2009	4.71	9.40	8.92	22.49	12.90
2010-2012	3.14	0.94	5.10	8.27	8.30
Silty					
1983-1987	0.00	0.00	3.27	8.43	4.69
1988-1992	4.70	7.43	13.40	14.81	12.14
1993-1998	0.00	1.04	0.68	0.51	6.69
1999-2003	0.34	6.87	8.77	16.43	21.24
2004-2009	32.13	17.59	11.32	20.11	23.13
2010-2012	15.86	5.57	8.94	8.63	19.60

Table 8. Autecology of Lotus purshianus, Deer vetch or Prairie trefoil, 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	0.02
1988-1992	0.13	0.38	0.00	0.12	0.00
1993-1998	0.00	0.18	2.00	0.25	0.22
1999-2003	0.20	0.70	0.34	0.00	0.03
2004-2009	0.59	0.97	1.03	0.03	0.06
2010-2012	0.35	0.00	0.12	0.00	0.00
Shallow					
1983-1987	0.00	0.00	0.00	0.40	0.28
1988-1992	0.21	0.00	0.00	1.63	0.81
1993-1998	0.15	0.00	0.19	3.19	2.06
1999-2003	0.04	0.03	0.12	1.26	0.71
2004-2009	0.08	0.19	0.18	1.17	0.77
2010-2012	0.00	0.00	0.00	0.32	.14
Silty					
1983-1987	0.00	0.00	0.49	0.24	0.51
1988-1992	0.00	0.07	1.54	2.47	1.47
1993-1998	0.00	0.71	2.14	2.72	2.17
1999-2003	0.04	0.13	0.16	0.79	1.13
2004-2009	1.21	0.58	0.37	0.95	1.19
2010-2012	0.21	0.19	0.29	0.21	0.66

Table 9. Autecology of Lotus purshianus, Deer vetch or Prairie trefoil, with growing season changes in density, 1983-2012.

Ecological Site Year Period	Nongrazed	Seasonlong		Twice-over	
		Ungrazed	Grazed	Ungrazed	Grazed
Sandy					
1983-1987	0.02	0.00	0.00	0.00	0.01
1988-1992	0.00	0.00	0.00	0.04	0.03
1993-1998	0.00	0.00	0.01	0.01	0.00
1999-2003	0.03	0.25	0.48	0.02	0.03
2004-2009	0.70	0.54	1.18	0.03	0.04
2010-2012	0.28	0.03	0.12	0.02	0.01
Shallow					
1983-1987	0.00	0.87	0.01	0.25	0.22
1988-1992	0.00	0.00	0.07	0.32	0.34
1993-1998	0.00	0.00	0.00	0.25	0.19
1999-2003	0.00	0.07	0.14	0.70	0.42
2004-2009	0.06	0.36	0.27	1.40	0.57
2010-2012	0.07	0.01	0.13	0.32	0.27
Silty					
1983-1987	0.00	0.00	0.05	0.26	0.13
1988-1992	0.04	0.14	0.16	0.16	0.19
1993-1998	0.00	0.01	0.01	0.01	0.07
1999-2003	0.02	0.21	0.29	0.40	0.57
2004-2009	1.16	0.79	0.49	0.47	1.29
2010-2012	0.29	0.14	0.28	0.08	0.61

Table 10. Direct relationship of high or low stem density and basal cover of Prairie trefoil to high or low precipitation received during April or May.

	Stem Density			Basal Cover			Precipitation % of LTM		Relationship High or Low
Years	Sandy	Shallow	Silty	Sandy	Shallow	Silty	Apr	May	
1983	-	-	-	0.01	0.04	0.08	14.58	59.77	Low
1984	0.05	0.85	1.00	0.00	0.04	0.11	199.31	0.00	Low
1985	-	-	-	0.00	0.00	0.02	86.11	126.95	
1986	0.05	5.05	4.40	0.00	0.07	0.06	217.36	143.75	High
1987	0.06	0.62	0.26	0.00	0.02	0.02	6.94	53.91	Low
1988	0.00	0.00	0.22	0.00	0.00	0.00	0.00	72.27	Low
1989	0.40	5.22	2.44	0.05	0.18	0.46	202.78	67.58	High
1990	0.00	0.40	1.18	0.00	0.09	0.22	140.97	93.36	High
1991	-	-	-	0.00	0.02	0.00	136.81	45.31	Low
1992	-	0.18	1.66	-	0.00	0.04	56.25	26.56	Low
1993	-	-	-	0.01	0.03	0.36	97.92	66.80	
1994	-	-	-	0.00	0.00	0.004	59.72	57.03	Low
1995	-	-	-	0.31	0.64	0.81	70.14	168.75	High
1996	-	-	-	0.00	0.00	0.00	9.72	119.92	Low
1997	-	-	-	0.03	0.04	0.03	200.69	37.11	Low
1998	0.04	0.88	0.20	0.002	0.00	0.002	27.78	58.98	Low
1999	1.00	3.28	2.70	0.04	0.10	0.06	76.39	192.58	High
2000	0.06	0.88	0.26	0.00	0.004	0.002	87.50	74.22	Low
2001	2.38	5.00	7.60	0.06	0.05	0.10	187.50	20.70	High
2002	0.68	1.46	1.12	0.002	0.02	0.004	79.17	85.16	
2003	4.04	3.28	3.64	0.07	0.09	0.10	90.28	169.53	High
2004	0.36	0.32	0.30	0.03	0.05	0.01	61.81	51.17	Low
2005	2.82	4.94	5.56	0.13	0.13	0.24	66.67	234.77	High
2006	0.74	3.44	4.10	0.01	0.02	0.03	193.06	110.16	High
2007	6.96	9.94	12.46	0.04	0.06	0.05	109.72	181.25	High
2008	0.52	0.54	3.30	0.004	0.00	0.01	42.36	108.98	Low
2009	18.48	12.60	24.66	0.12	0.06	0.20	103.47	96.48	High
2010	0.30	0.46	0.86	0.00	0.002	0.004	99.31	144.53	
2011	2.44	4.24	7.36	0.03	0.03	0.10	115.28	268.36	High
2012	0.04	0.10	0.16	0.00	0.00	0.00	165.28	61.72	Low

Literature Cited

Cook, C.W., and J. Stubbendieck. 1986. Range research: basic problems and techniques. Society for Range Management, Denver, CO. 317p.

Goetz, H. 1963. Growth and development of native range plants in the mixed prairie of western North Dakota. M. S. Thesis, North Dakota State University, Fargo, ND. 165p.

Great Plains Flora Association. 1986. Flora of the Great Plains. University of Kansas, Lawrence, KS.

Johnson, J.R., and G.E. Larson. 2007. Grassland plants of South Dakota and the Northern Great Plains. South Dakota University. B 566 (rev.). Brookings, SD.

Manske, L.L. 2016. Autecology of prairie plants on the Northern Mixed Grass Prairie. NDSU Dickinson Research Extension Center. Range Research Report DREC 16-1093. Dickinson, ND.

Stevens, O.A. 1963. Handbook of North Dakota plants. North Dakota Institute for Regional Studies. Fargo, ND.

Zaczkowski, N.K. 1972. Vascular flora of Billings, Bowman, Golden Valley, and Slope Counties, North Dakota. PhD. Thesis. North Dakota State University, Fargo, ND. 219 p.