Autecology of Winterfat on the Northern Mixed Grass Prairie

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The autecology of Winterfat, *Ceratoides lanata*, 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).

Winterfat, *Krascheninnikovia lanata* (Pursh) Meeuse & Smit, (*Ceratoides lanata*), is a member of the goosefoot family, Chenopodiaceae, and is a native, long lived perennial (to 136 years), cool season subshrub that is tolerant of cold and saline conditions, and intolerant of shade, acidic soils, and flooding. Aerial growth has numerous erect annual secondary herbaceous stems 1-2 feet (0.3-0.6 m) tall arising from a central woody stem base that develops from a woody root crown. Two sets of leaves are produced each growing season. Spring buds produce large succulent leaves with sparse hairs; during midsummer, the spring leaves die and are gradually replaced by smaller compact leaves densely covered with hairs. By early August, almost all photosynthesis and transpiration has ceased. The small leaf foliage is retained through the winter and contains greater than 10% crude protein. The root system has a deep taproot that descends to 25 feet (7.6 m) in depth and has numerous branching lateral roots that remain within the top 3.3 feet (1 m) of soil extending 4.8 feet (1.5 m) outward. Regeneration is by vegetative and sexual reproduction. Vegetative growth is by sprouts from adventitious buds on the root crown and by aerial stem growth from perennating buds on the central woody stem base located at or just above the ground surface. Sexual reproduction is mostly from monoecious, imperfect, unisexual, inconspicuous flowers that emerge during June with separate male and female organs on the same plant. The fruit, which is an utricle, ripen during August. Seeds are produced only during wet growing seasons, dispersed short distances by wind, and have high germination rates in moist soil, however, establishment of seedlings is difficult. Moderate browsing activates sprouts from buds on the central stem base. Damage or top kill by fire activates sprouts from buds on the root crown. Severe fires can kill parts or all of the stem base and root crown. This summary information on growth development and regeneration of winterfat was based on the works of Stevens 1963, Great Plains Flora Association 1986, Mozingo 1987, Carey 1995, Johnson and Larson 2007, Stubbendieck et al. 2011, and Ogle et al. 2012b.

Procedures

The 1969-1971 Study

The range of flowering time of Winterfat 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 study on change in abundance of Winterfat 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 Winterfat 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 that community during a growing season. Density importance value ranks the forbs 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 values 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

Winterfat resumed growth during early spring and developed numerous erect annual herbaceous stems 20-60 cm (8-24 in) tall arising from a long-lived woody stem base just below ground level that developed from a woody root crown. Rapid root growth occurred early in the growing season at 4.5° to 15.5° C (40° to 60° F) (Mozingo 1987). The extensive branching lateral root system is important for winterfat to be able to extract soil water from very dry soils. To reduce transpiration, leaf curl is revolute, with the leaf edges rolled lengthwise backward toward the underside. Two sets of leaves are produced each growing season. The first set are large linear succulent leaves (1-4 cm long, 1.7-2.5 mm wide) with sparse hairs. These spring leaves die and are replaced with smaller compact axillary leaves covered with fine hairs. The small hairy leaves are retained through most of the winter and contain more than 10% crude protein (Carey 1995, Ogle et al. 2012). The plants active period during a growing season is short, only a little more than three months long. Photosynthesis and transpiration nearly cease by early August. The unisexual flowers are separate on the same plant (monoecious) with the male flowers above the female flowers in leaf axils of the upper parts of the stems. The flower period extended from mid June to mid July during the 1969-1971 study (table 1) (Zaczkowski 1972).

Plant species composition in rangeland ecosystems is variable during a growing season and dynamic among growing seasons. Relative stem abundance of winterfat, as measured by density and basal cover importance values (tables 2 and 3), was scarce to absent during the 30 year study of 1983 to 2012. The mean importance values on the shallow sites were extremely low. The mean basal cover importance value on the shallow site of the nongrazed treatment was 0.17. The mean density importance value on the shallow site of the seasonlong treatment was 0.12 and on the twice-over treatment was 0.16. The mean importance values on the silty sites were also low. The mean density and basal cover importance values on the silty site of the seasonlong treatment were 0.28 and 0.14, respectively. The mean basal cover importance values on the ungrazed and grazed silty sites of the

twice-over treatment were 0.41 and 0.17, respectively. The mean density importance values on the ungrazed and grazed silty sites of the twice-over treatment were 1.24 and 4.74, respectively. The basal cover importance value was greater on the ungrazed silty site than that on the grazed silty site and the density importance value was greater on the grazed silty site than that on the ungrazed silty site of the twice-over treatment (tables 2 and 3).

On the sandy sites of the nongrazed, seasonlong, and twice-over treatments, Winterfat was not documented to be present during the years that density and basal cover data were collected (tables 2 and 3).

On the shallow site of the nongrazed treatment, Winterfat was present during 0.0% and 15.4% of the years that density and basal cover data were collected, with a mean 0.02% basal cover, respectively. Winterfat was not present on the shallow site of the nongrazed treatment during the early years (1983-1992), and was present during 0.0% and 26.7% of the later years (1998-2012), with a mean 0.04% basal cover, respectively (tables 2 and 3).

On the shallow sites of the seasonlong treatment, Winterfat was present during 5.0% and 0.0% of the years that density and basal cover data were collected, with a mean 0.02 stems/m^2 density, respectively. Winterfat was not present on the shallow site of the seasonlong treatment during the early years and was present during 6.7% and 0.0% of the later years, with a mean 0.03 stems/m^2 density, respectively (tables 2 and 3).

On the shallow sites of the twice-over treatment, Winterfat was present during 4.5% and 0.0% of the years that density and basal cover data were collected, with a mean 0.04 stems/m^2 density, respectively. Winterfat was not present on the shallow site of the twice-over treatment during the early years and was present during 6.7% and 0.0% of the later years, with a mean 0.05 stems/m^2 density, respectively (tables 2 and 3).

On the silty site of the nongrazed treatment, Winterfat was not present during the years that density and basal cover data were collected (tables 2 and 3).

On the silty sites of the seasonlong treatment, Winterfat was present during 5.0% and 3.8% of the years that density and basal cover data were collected, with a mean 0.06 stems/m^2 density and a mean 0.02% basal cover, respectively. Winterfat was present during 10.0% of the early years (1983-1992), with a mean 0.04% basal cover and was present during 6.7% of the later years (1998-2012), with a mean 0.08 stems/m^2 density (tables 2 and 3).

On the silty sites of the twice-over treatment, Winterfat was present on the ungrazed silty site during 22.7% and 26.7% of the years, with a mean 0.16 stems/m^2 density and a mean 0.04% basal cover, and on the grazed silty site during 50.0% and 23.3% of the years that density and basal cover were collected, with a mean 0.42 stems/m^2 density and a mean 0.02% basal cover, respectively. Winterfat was present on the ungrazed silty site during 0.0% and 10.0% of the early years, with a mean 0.05% basal cover and during 33.3% and 46.7% of the later years, with a mean 0.24 stems/m^2 density and a mean 0.05% basal cover, respectively. Winterfat was present on the grazed silty site during 0.0% and 40.0% of the early years, with a mean 0.04% basal cover, and during 73.3% and 20.0% of the later years, with a mean 0.61 stems/m^2 density and a mean 0.01% basal cover, respectively (tables 2 and 3).

Winterfat was not present on the sandy sites and was rarely present on the shallow sites of the nongrazed (4 years), seasonlong (1 year), and twice-over (1 year) treatments with none of the observations during the first nineteen years of the study. Winterfat was not present on the silty site of the nongrazed treatment and was present on the silty sites of the seasonlong treatment only two years (1989 and 2012). Winterfat was present on the silty sites of the twice-over treatment during 19 years, with 4 years occurring during the early years (1983 to 1992) and then again during each year of the 15 later years (1998 to 2012).

The limited data collected during this study would indicate that winterfat has an aversion to sandy sites, has a limited use of shallow sites, and has a small preference for silty sites. However, winterfat has been shown to have a broad tolerance to soil variables (Mozingo 1987). The variances among the soils of the sandy, shallow, and silty ecological sites were narrower than the magnitude of tolerance of soil variability of winterfat. The quantity or abundance and distribution of winterfat on the study area landscape was not caused by differences in soil characteristics.

Discussion

Winterfat, *Ceratoides lanata*, is a long lived perennial, cool season, native, subshrub that is present, but not abundant, on the northern mixed grass prairie. Winterfat has affinity to the plant communities of the southwestern desert and is near its northeastern limit in western North Dakota (Zaczkowski 1972). The rate of migration movement

for winterfat is classified as low (Mozingo 1987). Seed dispersal is mostly within 30.5 cm (12 in) of the source and seedling establishment is difficult, primarily because of water stress (Carey 1995). Vegetative reproduction does not extend far from the parent plant.

Winterfat has a wide tolerance to soil characteristics (Ogle et al. 2012) and soil types did not appear to affect distribution. Winterfat has a high tolerance to grazing; it can tolerate 25% removal during the growing season and up to 50% removal during early winter, however, heavy grazing during late winter or early spring can cause serious decreases in production and abundance (Ogle et al. 2012). The management practices of this study, nongrazed, seasonlong, and twice-over treatments, did not cause the differential abundance and distribution of winterfat.

Winterfat is shade intolerant (Carey 1995). Plant density of northern mixed grass prairie communities is magnitudes greater than that of the plant communities of the southwestern desert where winterfat is the dominate, co-dominate, or a major component. Winterfat seedlings would have few places with full sunlight all day for the 3 to 5 years required for a young plant to mature. The likelihood of a winterfat seed to be deposited at a site with full sunlight long enough for that plant to become established maybe the factor that limits the abundance and distribution of winterfat in the northern mixed grass prairie.

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Table 1. Flower period of Ceratoides lanata, Winterfat.

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

Flower Period Data from Zaczkowski 1972.

Table 2. Autecology of Ceratoides lanata, Winterfat, 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	Few Plants Present				
1988-1992					
1993-1998					
1999-2003					
2004-2009					
2010-2012					
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	0.46	0.72	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	5.27
1999-2003	0.00	0.00	0.00	1.48	4.36
2004-2009	0.00	0.00	0.00	2.39	11.64
2010-2012	0.00	0.00	1.84	1.81	2.46

Table 3. Autecology of Ceratoides lanata, Winterfat, 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	Few Plants Present				
1988-1992					
1993-1998					
1999-2003					
2004-2009					
2010-2012					
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	0.27	0.00	0.00	0.00	0.00
2010-2012	0.97	0.00	0.00	0.00	0.00
Silty					
1983-1987	0.00	0.00	0.00	0.00	0.45
1988-1992	0.00	0.00	0.72	0.96	0.25
1993-1998	0.00	0.00	0.00	0.00	0.00
1999-2003	0.00	0.00	0.00	0.62	0.00
2004-2009	0.00	0.00	0.00	0.25	0.25
2010-2012	0.00	0.00	0.00	0.96	0.00

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Appendix
Autecology Data of Winterfat

Table 1.	Density analysis for native range on the 4.5 month seasonlong grazing system at the Dickinson Research Extension Center.					
System:	West/East/North					
Pasture:	NR-9-12				Relative	
Site:	Shallow, grazed		Relative	Percent	Percent	Importance
Species:	Ceratoides lanata	Density	Density	Frequency	Frequency	Value
1983		No Data				
1984		No Data				
1985		No Data				
1986		No Data				
1987						
1988						
1989						
1990						
1991		No Densities Collected				
1992						
1993		No Densities Collected				
1994		No Densities Collected				
1995		No Densities Collected				
1996		No Densities Collected				
1997		No Densities Collected				
1998						
1999						
2000						
2001						
2002						
2003		0.04	0.56	4.00	1.75	2.31
2004						
2005						
2006						
2007						
2008						
2009						
2010						
2011						
2012						

Table 2.	Density analysis for native range on the twice-over rotation grazing system at the Dickinson Research Extension Center.						
System:	West/East						
Pasture:	NR-1-6				Relative		
Site:	Shallow, ungrazed		Relative	Percent	Percent	Importance	
Species:	Ceratoides lanata	Density	Density	Frequency	Frequency	Value	
1983		No Densities Collected					
1984							
1985		No Densities Collected					
1986							
1987							
1988							
1989							
1990							
1991		No Densities Collected					
1992							
1993		No Densities Collected					
1994		No Densities Collected					
1995		No Densities Collected					
1996		No Densities Collected					
1997		No Densities Collected					
1998							
1999							
2000							
2001							
2002		0.08	1.18	6.00	2.43	3.61	
2003							
2004							
2005							
2006							
2007							
2008							
2009							
2010							
2011							
2012							

Table 3.	Points analysis for native range on the nongrazed grazing system at the Dickinson Research Extension Center.					
System:	West/East					
Pasture:	NG-W & E		Relative		Relative	
Site:	Shallow, ungrazed	Basal	Basal	Percent	Percent	Importance
Species:	Ceratoides lanata	Cover	Cover	Frequency	Frequency	Value
1983		No Data				
1984		No Data				
1985		No Data				
1986		No Data				
1987						
1988						
1989						
1990						
1991						
1992						
1993						
1994						
1995						
1996						
1997						
1998						
1999						
2000						
2001						
2002						
2003						
2004						
2005						
2006						
2007						
2008		0.05	0.25	0.50	0.35	0.60
2009		0.10	0.42	1.00	0.60	1.02
2010		0.35	1.19	2.50	1.32	2.51
2011						
2012		0.05	0.16	0.50	0.24	0.39

Table 4.	Density analysis for native range on the 4.5 month seasonlong grazing system at the Dickinson Research Extension Center.					
System:	West/East/North					
Pasture:	NR-9-12				Relative	
Site:	Silty, grazed		Relative	Percent	Percent	Importance
Species:	Ceratoides lanata	Density	Density	Frequency	Frequency	Value
1983	No Data					
1984	No Data					
1985	No Data					
1986	No Data					
1987						
1988						
1989						
1990						
1991	No Densities Collected					
1992						
1993	No Densities Collected					
1994	No Densities Collected					
1995	No Densities Collected					
1996	No Densities Collected					
1997	No Densities Collected					
1998						
1999						
2000						
2001						
2002						
2003						
2004						
2005						
2006						
2007						
2008						
2009						
2010						
2011						
2012		0.12	3.45	4.00	2.08	5.53

Table 5.	Density analysis for native range on the twice-over rotation grazing system at the Dickinson Research Extension Center.					
System:	West/East					
Pasture:	NR-1-6				Relative	
Site:	Silty, ungrazed		Relative	Percent	Percent	Importance
Species:	Ceratoides lanata	Density	Density	Frequency	Frequency	Value
1983	No Densities Collected					
1984						
1985	No Densities Collected					
1986						
1987						
1988						
1989						
1990						
1991	No Densities Collected					
1992						
1993	No Densities Collected					
1994	No Densities Collected					
1995	No Densities Collected					
1996	No Densities Collected					
1997	No Densities Collected					
1998						
1999						
2000						
2001						
2002		0.08	1.61	4.00	2.08	3.70
2003		0.04	1.09	4.00	2.63	3.72
2004		0.04	1.14	4.00	2.27	3.41
2005		0.12	4.48	8.00	6.45	10.93
2006						
2007						
2008						
2009						
2010						
2011		0.08	1.80	8.00	3.64	5.44
2012						

Table 6.	Density analysis for native range on the twice-over rotation grazing system at the Dickinson Research Extension Center.					
System:	West/East					
Pasture:	NR-1-6				Relative	
Site:	Silty, grazed		Relative	Percent	Percent	Importance
Species:	Ceratoides lanata	Density	Density	Frequency	Frequency	Value
1983		No Densities Collected				
1984						
1985		No Densities Collected				
1986						
1987						
1988						
1989						
1990						
1991		No Densities Collected				
1992						
1993		No Densities Collected				
1994		No Densities Collected				
1995		No Densities Collected				
1996		No Densities Collected				
1997		No Densities Collected				
1998		0.04	1.69	4.00	3.57	5.27
1999						
2000		0.04	0.92	4.00	2.27	3.19
2001		0.04	0.56	4.00	1.56	2.12
2002		0.04	0.71	4.00	2.63	3.34
2003		0.08	3.64	8.00	9.52	13.16
2004						
2005		0.20	7.58	12.00	6.67	14.24
2006		0.12	3.57	8.00	3.77	7.35
2007		0.12	8.11	8.00	7.14	15.25
2008		0.12	15.00	12.00	15.00	30.00
2009		0.08	1.24	4.00	1.75	3.00
2010						
2011						
2012		0.04	3.23	4.00	4.17	7.39

Table 7.	Points analysis for native range on the 4.5 month seasonlong grazing system at the Dickinson Research Extension Center.						
System:	West/East/North						
Pasture:	NR-9-12		Relative		Relative		
Site:	Silty, grazed	Basal	Basal	Percent	Percent	Importance	
Species:	Ceratoides lanata	Cover	Cover	Frequency	Frequency	Value	
1983		No Data					
1984		No Data					
1985		No Data					
1986		No Data					
1987							
1988							
1989		0.40	1.42	4.00	2.20	3.62	
1990							
1991							
1992							
1993							
1994							
1995							
1996							
1997							
1998							
1999							
2000							
2001							
2002							
2003							
2004							
2005							
2006							
2007							
2008							
2009							
2010							
2011							
2012							

Table 8.	Points analysis for native range on the twice-over rotation grazing system at the Dickinson Research Extension Center.						
System:	West/East						
Pasture:	NR-1-6		Relative		Relative		
Site:	Silty, ungrazed	Basal	Basal	Percent	Percent	Importance	
Species:	Ceratoides lanata	Cover	Cover	Frequency	Frequency	Value	
1983							
1984							
1985							
1986							
1987							
1988							
1989		0.50	2.15	4.00	2.65	4.79	
1990							
1991							
1992							
1993							
1994							
1995							
1996							
1997							
1998							
1999		0.10	0.27	1.00	0.44	0.71	
2000							
2001							
2002							
2003		0.15	1.22	1.00	1.16	2.38	
2004							
2005							
2006							
2007		0.05	0.27	0.50	0.38	0.65	
2008		0.05	0.38	0.50	0.45	0.84	
2009							
2010		0.20	1.01	0.50	0.40	1.41	
2011		0.05	0.25	0.50	0.40	0.65	
2012		0.10	0.46	0.50	0.35	0.81	

Table 9.	Points analysis for native range on the twice-over rotation grazing system at the Dickinson Research Extension Center.					
System:	West/East					
Pasture:	NR-1-6		Relative		Relative	
Site:	Silty, grazed	Basal	Basal	Percent	Percent	Importance
Species:	Ceratoides lanata	Cover	Cover	Frequency	Frequency	Value
1983		0.10	0.15	1.00	0.34	0.49
1984		0.11	0.27	1.07	0.49	0.76
1985		0.11	0.37	1.07	0.64	1.01
1986						
1987						
1988						
1989		0.11	0.52	1.09	0.70	1.23
1990						
1991						
1992						
1993						
1994						
1995						
1996						
1997						
1998						
1999						
2000						
2001						
2002						
2003						
2004		0.05	0.14	0.50	0.22	0.35
2005		0.10	0.29	1.00	0.46	0.74
2006		0.05	0.15	0.50	0.24	0.39
2007						
2008						
2009						
2010						
2011						
2012						