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Autecology of Forbs on the Northern Mixed Grass Prairie

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

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

This report contains descriptions of the changes in growth and development during the annual growing season life history of 47 forbs, 17 cool season perennials, 19 warm season perennials, 6 biennials, 2 winter annuals, and 3 annuals, species living on Northern Mixed Grass Prairie ecosystems. These data were collected during 67 growing seasons of ecological studies at the NDSU Dickinson Research Extension Center over a time period from 1946 to 2012.

Forbs are broad-leaved, flowering herbaceous plants that do not develop permanent woody stems and the aerial parts die at the end of each growing season. During unfavorable conditions, biennial and perennial forbs persist by specialized subterranean caudexes that have vegetative buds from which the next growing season's aerial parts develop.

Companion reports of autecological studies provide quantitative descriptions of the growing season life history of grass and upland sedge species and of shrubs and subshrubs species living on the Northern Mixed Grass Prairie.

Autecology of Western Yarrow on the Northern Mixed Grass Prairie

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The autecology of Western yarrow, *Achillea millefolium*, 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 yarrow, *Achillea millefolium* L., is a member of the aster (sunflower) family, Asteraceae, syn.: *Achillea lanulosa* Nutt., and is a native, short lived perennial, dicot, herb that is drought tolerant and intolerant of dense shade. The first North Dakota record is Stevens 1954. Early aerial growth consists of a rosette of basal petioled leaves arising from the tip of a short rhizome where an enlarged crown has formed, some of these basal leaves may have persisted through winter from the previous growing season. Annual aerial growth arise from enlarged crowns at rhizome ends as single or loosely clustered stems 30-60 cm (11.8-23.6 in) tall with branched upper portions. Stem (cauline) leaves are alternate, lanceolate, deeply bipinnately dissected to be fern-like, sessile 3-15 cm (1.2-5.9 in) long, decreasing upwards. Soft hairs cover stems, basal leaves, and stem leaves giving a grayish hue. The root system has short taproots developing at enlarged crowns at rhizome ends with fine, short fibrous roots produced at crown ends and at rhizome nodes. Regeneration is by vegetative and sexual reproduction. Vegetative growth is by annual sprouts from the crown ends of rhizomes, sprouts do no appear to form at rhizome nodes. The numerous short weakly spreading rhizomes form colonies. Inflorescences are numerous terminal small heads in nearly flat topped compound corymbs. Flowers are perfect in small heads, ray corollas are white appearing during early June to mid July. Fruit is a one seeded achene with no pappus. Aerial parts are unpalatable to livestock. Fire kills aerial parts and may fragment the rhizomes. A cool April burn can increase percent frequency and cover, however, an August, or moderate and severe fire may decrease plant numbers for several years. This summary information on growth development and regeneration of Western yarrow are based on the works of Stevens 1963, Zaczkowski 1972, Great Plains Flora Association 1986, Aleksoff 1999, Stubbendieck et al. 2003, Hurteau 2006, Johnson and Larson 2007, and Stubbendieck et al. 2011.

Procedures

The 1955-1962 Study

Western yarrow 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 Western yarrow 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

Western yarrow 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 12 ungrazed specimens randomly selected on each of the 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 25 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 Western yarrow 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 Western yarrow 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

Western yarrow resumed vigorous growth in mid April as rosettes of basal leaves arising from a crown at the end of a rhizome. A few of the basal leaves may have persisted from the previous growing season through the winter. Single or clustered aerial stems develop from the rosettes. Composite flowers develop atop branches of the upper stems. On the fall

grazed pasture of the 1955-1962 study, the earliest first flowers appeared 11 June, the mean first flowers occurred on 19 June, and the flower period, from the 1969-1971 study, extended from early June to mid July (table 1) (Goetz 1963, Zaczkowski 1972). A mean mature height of 32.2 cm (12.7 in) with an annual variance in height from 20.0 cm (7.9 in) to 46.0 cm (18.1 in) was reached during July (table 2) (Goetz 1963). The reported normal mature plant height ranged from 30 cm to 60 cm (11.8 to 23.6 in), the mean mature height of 32.2 cm (12.7 in) from the 1955-1962 study was 107.3% and 53.7% of the reported normal range of heights. The mean height of Western yarrow on the 1955-1962 study was at the low end of the reported normal height. This lower height of Western yarrow on the 1955-1962 study was not caused directly by grazing effects but was caused by low quantities of available mineral nitrogen below the threshold levels of 100 lbs/ac in the soil.

Changes in phenological growth stages from the 1984-1985 study are summarized on tables 3, 4, 5, and 6. A total of 3,091 Western yarrow stems were sampled during this study, with 594 stems (19.22%) from the sandy sites, 714 stems (23.10%) from the shallow sites, 1046 stems (33.84%) from the silty sites, and 737 stems (23.84%) from the clayey sites. Western yarrow can grow on the sandy, shallow, silty, and clayey ecological sites, however, a greater quantity of stems were located on the silty ecological sites. The mean mature height reached during July and percent of the reported lower normal height of 30 cm (11.8 in) was, 28.2 cm (94.0%) on the sandy sites, 26.1 cm (87.0%) on the shallow sites, 30.3 cm (101.0%) on the silty sites, and 27.5 cm (91.6%) on the clayey sites. The silty sites were the only ecological sites with mean mature stem heights during July greater than the reported low normal stem height of 30 cm. The reduced stem height of Western yarrow on the 1984-1985 study was caused by low quantities of available mineral nitrogen below the threshold levels of 100 lbs/ac that resulted from the traditional management practices conducted prior to the start of this study.

During the growing season, most of the western yarrow stems remained at early growth stages of vegetative and budding stages, 81.7% on the sandy sites, 83.3% on the shallow sites, 81.9% on the silty sites, and 81.8% on the clayey sites (tables 3, 4, 5, and 6).

Mean western yarrow stem weights were not significantly different on the four ecological sites. Stem weights were heaviest on the silty sites at 0.37 g, were lightest on the shallow sites at 0.24 g, and were in the middle on the sandy and clayey sites at 0.33 g and 0.31 g, respectively (tables 3, 4, 5, and 6).

Plant species composition in rangeland ecosystems is variable during a growing season and dynamic among growing seasons. The number of documented Western yarrow stems on the sandy and shallow ecological sites of the three management treatments, during the 1983-2012 study, was insufficient to describe abundance patterns and were not included in this report.

On the silty site of the nongrazed treatment, Western yarrow was present during 31.6% and 15.4% of the years that density and basal cover data were collected, with a mean 1.21 stems/m^2 density and a mean 0.01% basal cover during the total 30 year period, respectively. During the early period (1983-1992), Western yarrow was present during 0.0% and 0.0% of the years. During the later period (1998-2012), Western yarrow was present 42.9% and 26.7% of the years, with a mean 1.64 stems/m^2 density and a mean 0.01% basal cover, respectively. Both the stem density and basal cover increased on the nongrazed treatment over time (tables 7, 8, and 9).

On the silty sites of the seasonlong treatment, Western yarrow was present on the ungrazed silty site during 30.0% and 34.6% of the years, with a mean 0.24 stems/m^2 density and a mean 0.02% basal cover, and was present on the grazed silty site during 55.0% and 42.3% of the years that density and basal cover were collected, with a mean 0.38 stems/m^2 density and a mean 0.03% basal cover during the total 30 year period, respectively. During the early period (1983-1992), Western yarrow was present on the ungrazed silty site during 20.0% and 50.0% of the years, with a mean 0.54 stems/m^2 density and a mean 0.02% basal cover. During the later period (1998-2012), Western yarrow was present on the ungrazed silty site during 33.3% and 33.3% of the years, with a mean 0.14 stems/m^2 density and a mean 0.02% basal cover, respectively. The stem density decreased and the basal cover was low and unchanged on the ungrazed silty site of the seasonlong treatment over time. During the early period (1983-1992), Western yarrow was present on the grazed silty site during 40.0% and 80.0% of the years, with a mean 1.04 stems/m^2 density and a mean 0.12% basal cover. During the later period (1998-2012), Western yarrow was present on the grazed silty site during 60.0% and 46.7% of the years, with a mean 0.15 stems/m^2 density and a mean 0.02% basal cover, respectively. Both the stem density and basal cover decreased on the grazed silty site of the seasonlong treatment over time. During the early

period (1983-1992), stem density and basal cover of Western yarrow were greater on the grazed site than those on the ungrazed silty site. Stem density on the grazed and ungrazed sites and basal cover on the grazed site decreased during the low precipitation period of 1988 to 1992. During the late period (1998-2012), stem density and basal cover of Western yarrow were nearly the same on the grazed and ungrazed silty sites of the seasonlong treatment (tables 7, 8, and 9).

On the silty sites of the twice-over treatment, Western Yarrow was present on the ungrazed silty site during 95.5% and 90.0% of the years, with a mean 5.64 stems/m^2 density and a mean 0.24% basal cover, and was present on the grazed silty site during 86.4% and 80.0% of the years that density and basal cover data were collected, with a mean 4.52 stems/m^2 density and a mean 0.19% basal cover during the total 30 year period, respectively. During the early period (1983-1992), Western yarrow was present on the ungrazed silty site during 85.7% and 77.8% of the years, with a mean 1.99 stems/m^2 density and a mean 0.17% basal cover. During the later period (1998-2012), Western yarrow was present on the ungrazed silty site during 100.0% and 100.0% of the years, with a mean 7.35 stems/m^2 density and a mean 0.33% basal cover, respectively. Both the stem density and basal cover greatly increased on the ungrazed silty sites of the twice-over treatment over time. During the early period (1983-1992), Western yarrow was present on the grazed silty site during 71.4% and 80.0% of the years, with a mean 5.00 stems/m^2 density and a mean 0.28% basal cover. During the later period (1998-2012), Western yarrow was present on the grazed silty site during 93.3% and 86.7% of the years, with a mean 4.30 stems/m^2 density and a mean 0.17% basal cover, respectively. Both the stem density and basal cover decreased on the grazed silty site of the twice-over treatment over time. During the early period (1983-1992), stem density and basal cover of Western yarrow were greater on the grazed site than those on the ungrazed silty site. Stem density and basal cover on the grazed and ungrazed sites decreased during the low precipitation period of 1988 to 1992. During the later period (1998-2012), stem density and basal cover increased on the ungrazed silty site and stem density and basal cover decreased on the grazed silty site. During the later period, stem density and basal cover of Western yarrow were greater on the ungrazed site than those on the grazed silty site of the twice-over treatment (tables 7, 8, and 9).

The stem abundance of Western yarrow decreased during the low precipitation period of 1988-1992 on all management treatments. During the 30 year period of the 1983-2012 study, stem density and basal cover increased on the nongrazed treatment and on the ungrazed site of twice-over treatment and decreased on the grazed site of the seasonlong treatment and on the grazed site of the twice-over treatment (tables 7, 8, and 9).

Discussion

Western yarrow, *Achillea millefolium*, is a late succession forb that is commonly present but a minor component of healthy mixed grass prairie plant communities. Western yarrow can grow in sandy, shallow, silty, and clayey ecological sites but does better growing in silty ecological sites. Annual aerial growth resumes in early spring (April) from crowns (caudexes) that had developed at ends of short rhizomes. The flower period (anthesis) occurs during June and July. Erect aerial stems reach maximum mature height during July, however, fewer than 20% of the stems growing in grazed prairie develop to the anthesis and mature phenological growth stages. Western yarrow is unpalatable and not grazed by livestock and thus the effects from partial defoliation by grazing do not directly cause annual changes in stem abundance. Western yarrow is intolerant of dense shade and stem abundance would tend to decrease with the accumulation of litter and standing dead. The increase in stem abundance on the nongrazed treatment and the ungrazed site of the twice-over treatment would most likely be associated with increases in open spaces in the plant communities. The decreases in stem abundance on the grazed sites of the seasonlong and twice-over treatments would be associated with increases in grass density following the low precipitation period of 1988-1992. The normal mature stem height of Western yarrow in the Northern Plains is reported to be between 30 cm and 60 cm (12-24 in). The stem heights collected during the 1955-1962 study and the 1984-1985 study were at the short end of normal mature stem height because the soils of both studies had quantities of mineral nitrogen available at less than the threshold quantity of 100 lbs/ac which resulted from the detrimental effects caused by traditional management practices on the biogeochemical processes and the soil microbe biomass of the prairie plant communities.

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Table 1. First flower and flower period of Achillea millefolium, Western Yarrow.

	Apr	May	Jun		Jul	Aug	Sep
First Flower							
1955-1962							
Earliest			11				
Mean				19			
Flower Period							
1969-1971			XX	XX	XX		

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

Table 2. Autecology of Achillea millefolium, Western Yarrow, 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	20.0	46.0	32.2	14.5	38.6	85.0	100.0		

Data from Goetz 1963.

Table 3. Phenological growth stage changes during the growing season for, Achillea millefolium, Western Yarrow, 1984-1985.

Site Sandy	8 Jun	23 Jun	8 Jul	23 Jul	8 Aug	23 Aug
% Population						
Veg	95.3	83.3	78.6	72.6	81.4	71.9
Bud	4.7	1.4	0.9			
Anth		8.3	4.3	0.9		
Seed Dev			13.7	14.2	3.5	
Seed Shed		6.9	2.6	11.3	15.1	24.6
Mat				0.9		3.5
Mean Height (cm)						
Veg	7.5	5.2	5.4	8.2	7.5	5.9
Bud	24.1	20.3	18.6			
Anth		32.5	26.3	23.2		
Seed Dev			28.9	28.2	30.0	
Seed Shed		23.9	28.8	30.6	33.3	26.1
27.2Mat				31.6		
% Dryness						
Veg	4.3	20.5	26.6	30.0	49.2	33.7
Bud	1.0	25.0	0.0			
Anth		29.8	5.8	2.0		
Seed Dev			25.8	40.4	75.0	
Seed Shed		0.4	98.7	81.3	79.1	96.3
Mat				50.0		100.0
Mean Weight (g)	0.23	0.35	0.31	0.43	0.33	0.30

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, Achillea millefolium, Western Yarrow, 1984-1985.

Site Shallow	8 Jun	23 Jun	8 Jul	23 Jul	8 Aug	23 Aug
% Population						
Veg	79.2	84.3	81.7	75.2	81.1	80.5
Bud	13.2	3.5	0.8			
Anth	7.5	6.1	1.7			
Seed Dev		5.2	11.7	6.0		
Seed Shed		0.9	4.2	18.8	18.9	12.6
Mat						6.9
Mean Height (cm)						
Veg	7.5	4.0	5.8	5.6	5.4	4.8
Bud	16.7	16.9	17.1			
Anth	29.5	23.4	32.3			
Seed Dev		28.3	22.2	24.3		
Seed Shed		17.1	27.6	24.3	24.3	25.8
Mat						22.1
% Dryness						
Veg	4.2	22.1	30.6	42.4	37.0	44.8
Bud	4.4	19.3	25.0			
Anth	7.3	22.0	2.0			
Seed Dev		54.5	14.6	46.2		
Seed Shed		0.0	70.0	95.3	93.7	100.0
Mat						91.3
Mean Weight (g)	0.16	0.23	0.27	0.30	0.26	0.19

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, Achillea millefolium, Western Yarrow, 1984-1985.

Site Silty	8 Jun	23 Jun	8 Jul	23 Jul	8 Aug	23 Aug
% Population						
Veg	88.4	79.3	83.7	73.2	76.0	-
Bud	5.8	2.7	0.5			
Anth	5.8	17.0	3.3	2.7		
Seed Dev		1.1	10.3	12.8		
Seed Shed			2.2	11.4	22.0	
Mat					2.0	
Mean Height (cm)						
Veg	6.7	6.0	5.7	7.1	6.2	-
Bud	19.2	16.7	30.5			
Anth	33.8	29.0	28.6	31.1		
Seed Dev		32.3	33.5	29.3		
Seed Shed			28.5	31.2	27.9	
Mat					46.3	
% Dryness						
Veg	6.9	13.2	31.7	38.2	30.8	-
Bud	0.8	6.2	25.0			
Anth	2.0	11.1	1.3	44.3		
Seed Dev		13.5	28.6	47.4		
Seed Shed			86.5	91.0	86.0	
Mat					100.0	
Mean Weight (g)	0.34	0.17	0.43	0.70	0.32	0.23

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, Achillea millefolium, Western Yarrow, 1984-1985.

Site Clayey	8 Jun	23 Jun	8 Jul	23 Jul	8 Aug	23 Aug
% Population						
Veg	86.7	83.5	79.2	74.7	69.7	77.7
Bud	8.3	9.4	1.6			
Anth	5.0	7.1	4.8			
Seed Dev			10.4	7.1	2.0	
Seed Shed			4.0	17.2	27.3	10.6
Mat				1.0	1.0	11.7
Mean Height (cm)						
Veg	8.4	4.6	5.5	7.0	6.0	5.0
Bud	14.7	27.6	24.7			
Anth	26.7	22.3	29.0			
Seed Dev			29.9	28.8	13.6	
Seed Shed			25.9	22.3	27.5	27.4
Mat				29.3	11.2	25.9
% Dryness						
Veg	5.0	9.9	30.9	36.4	34.0	41.1
Bud	2.0	15.4	1.0			
Anth	2.0	9.2	9.7			
Seed Dev			40.7	36.0	62.5	
Seed Shed			79.6	89.5	96.9	92.5
Mat				100.0	50.0	99.8
Mean Weight (g)	0.25	0.35	0.36	0.42	0.25	0.20

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

Table 7. Autecology of Achillea millefolium, Western yarrow, 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	Few Plants Present				
1988-1992					
1993-1998					
1999-2003					
2004-2009					
2010-2012					
Silty					
1983-1987	0.00	0.00	8.90	11.52	19.61
1988-1992	0.00	2.36	0.74	4.49	1.18
1993-1998	0.00	0.00	0.00	35.50	31.82
1999-2003	0.00	0.30	0.53	37.56	21.03
2004-2009	8.60	0.93	0.72	40.54	12.84
2010-2012	9.00	0.00	0.81	36.90	22.73

Table 8. Autecology of Achillea millefolium, Western yarrow, with growing season changes in basal cover importance value, 1983-2012.					
Ecological Site Ten 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	Few Plants Present				
1988-1992					
1993-1998					
1999-2003					
2004-2009					
2010-2012					
Silty					
1983-1987	0.00	0.00	2.30	2.15	2.86
1988-1992	0.00	0.21	0.45	0.79	1.46
1993-1998	0.00	0.02	0.00	1.39	1.09
1999-2003	0.00	0.19	0.08	4.77	1.62
2004-2009	0.17	0.17	0.24	4.36	1.49
2010-2012	0.22	0.00	0.00	1.31	0.41

Table 9. Autecology of Achillea millefolium, Western yarrow, with growing season changes in density, 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	Few Plants Present				
1988-1992					
1993-1998					
1999-2003					
2004-2009					
2010-2012					
Silty					
1983-1987	0.00	0.00	0.47	0.38	1.16
1988-1992	0.00	0.07	0.01	0.06	0.01
1993-1998	0.00	0.00	0.00	0.61	0.62
1999-2003	0.00	0.00	0.02	1.01	0.57
2004-2009	0.32	0.03	0.02	0.76	0.35
2010-2012	0.13	0.00	0.01	0.27	0.29

Literature Cited

Aleksoff, K.C. 1999. Achillea millefolium. Fire Effects Information System. USDA. Forest Service. http://www.fs.fed.us/database/feis

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.

Hurteau, M.D. 2006. Achillea millefolium L. Plants Database. USDA. Natural Resources Conservation Service. http://plants.usda.gov/

Johnson, J.R., and G.E. Larson. 2007. Grassland plants of South Dakota and the Northern Great Plains. South Dakota State 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.

Stubbendieck, J., M.J. Coffin, and L.M. Landholt. 2003. Weeds of the Great Plains. Nebraska Department of Agriculture. Lincoln, NE.

Stubbendieck, J., S.L. Hatch, and N.M. Bryan. 2011. North American wildland plants. 2nd Ed. University of Nrbraska Press. Lincoln, NE.

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.