Autecology of Peppergrass on the Northern Mixed Grass Prairie

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The autecology of Peppergrass, *Lepidium densiflorum,* 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).

Peppergrass, *Lepidium densiflorum* Schrader, is a member of the mustard family, Brassicaceae, and is a native, annual, winter annual, or biennial, dicot, herb. The first North Dakota record is Stevens 1941. First year aerial growth consists of a basal rosette of oblanceolate leaves 4-7 cm (1.6-2.8 in) long, with short petioles, coarse teeth, pinnately lobed, and early deciduous during the second year before fruit, along with the early development of the crown and taproot. Second year aerial growth has a solitary, erect, stem 10-40 cm (3.9-15.7 in) tall, unbranched below, widely branched at inflorescence, arising from a crown (caudex). Stem (cauline) leaves are alternate, entire, simple, narrowly oblanceolate to linear 2-4 cm (0.8-1.6 in) long, with very short petioles below, sessile above, reducing upwards. The root system has a taproot with numerous fibrous lateral roots. Regeneration is by limited vegetative and sexual reproduction. Vegetative growth is by sprouts from the crown. Inflorescence is numerous tiny flowers along a terminating branch 5-10 cm (2.0-3.9 in) long, arising from leaf axils of the upper portions of the stem, forming a raceme, compounded with several racemes per stem. Flowers have 4 greenish sapals and no petals, 0.8 mm long, appearing during early June to late July. Fruit is a dry, dehiscent, silicle with 2 seeds that are flat and narrowly winged. Aerial parts are not usually eaten by livestock and are top killed by fire. Damage to aerial parts prior to senescence activates regrowth shoots from the crown. This summary information on growth development and regeneration of peppergrass was based on works of Stevens 1963, Zaczkowski 1972, Great Plains Flora Association 1986, Stubbendieck et al. 2003, and Larson and Johnson 2007.

Procedures

The 1955-1962 Study

Peppergrass 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 Peppergrass 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

Peppergrass 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 42 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 13 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 Peppergrass 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 Peppergrass 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

Peppergrass develops a crown, taproot, and a basal rosette of short leaves during the first growing season. During the second growing season, a stem develops that is unbranched below and widely branched above with each forming a terminal raceme of numerous tiny flowers of 4 green sepals and no petals. The basal rosette leaves senesce at the time of flowers and fruits. On the fall grazed pastures of the 1955-1962 study, the earliest first flowers appeared 10 June, the mean first flowers occurred on 19 June, and a seven week flower period, from the 1969-1971

study, extended from early June to the end of July (table 1) (Goetz 1963, Zaczkowski 1972). A mean mature stem height of 23.5 cm (9.3 in) with an annual variance in height from 16.0 cm (6.3 in) to 28.0 cm (11.0 in) was reached during July (table 2) (Goetz 1963). The stem heights from the 1955-1962 study occurred within the reported normal mature stem height in the Northern Plains which ranged from 10 cm to 40 cm (3.9-15.7 in) tall.

Changes in phenological growth stages from the 1984-1985 study are summarized on tables 3, 4, 5, and 6. A total of 2,635 Peppergrass stems were sampled during this study with 742 stems (28.2%) from the sandy sites, 627 stems (23.8%) from the shallow sites, 734 stems (27.9%) from the silty sites, and 532 stems (20.2%) from the clayey sites. Peppergrass can grow on sandy, shallow, silty, and clayey ecological sites, The mean mature stem height reached during July was 10.6 cm (4.2 in) on the sandy sites, 10.6 cm (4.2 in) on the shallow sites, 10.7 cm (4.2 in) on the silty sites, and 10.6 cm (4.2 in) on the clayey sites. All at nearly the same mean mature stem height and all just above the short end of the range of mature stem height in the Northern Plains at 10.0 cm (3.9 in) tall.

During the growing season, the percentage of Peppergrass stems that had passed through the anthesis phenological growth stages was 52.8% during early June, 55.7% during late June, 95.4% during early July, and 99.7% during late July (tables 3, 4, 5, and 6).

Mean Peppergrass stem weights were not significantly different on the four ecological sites. Mean stem weights were 0.10 g on the sandy sites, 0.06 g on the shallow sites, 0.06 g on the silty sites, and 0.04 g on the clayey sites (tables 3, 4, 5, and 6).

Plant species composition in rangeland ecosystems is variable during a growing season and dynamic among growing seasons. All of the plant communities on all management treatments greatly improved in species composition and plant density in a few years after the start of the studies in 1983. The presence of Peppergrass greatly decreased on the sandy and silty sites. Patterns in the changes in Peppergrass abundance was followed for 30 growing seasons during the 1983-2012 study only on the shallow ecological sites of the long-term nongrazed, traditional seasonlong, and twice-over rotation management treatments.

On the shallow site of the nongrazed treatment, Peppergrass was present during 10.5% of the years that density data were collected and was not present where basal cover data were collected, with a mean 0.06 stems/m^2 density during the total 30 year period, respectively. During the early period (1983-1992), Peppergrass was not present where density and basal cover data were collected. During the later period (1998-2012), Peppergrass was present during 14.3% of the years that density were collected, with a mean 0.09 stems/m^2 density. The percent present for the density data and stem density increased slightly on the shallow site of the nongrazed treatment over time (tables 7, 8, and 9).

On the shallow site of the ungrazed seasonlong treatment, Peppergrass was present during 20.0% and 3.9% of the years that density and basal cover data were collected, with a mean 0.34 stems/m^2 density and a mean 0.001% basal cover during the total 30 year period, respectively. During the early period (1983-1992), Peppergrass was not present where density and basal cover data were collected. During the later period (1998-2012), Peppergrass was present during 26.7% and 6.7% of the years that density and basal cover data were collected, with a mean 0.45 stems/m^2 density and a mean 0.002% basal cover, respectively. The percent present, stem density, and basal cover all increased slightly 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, Peppergrass was present during 45.0% and 19.2% of the years that density and basal cover data were collected, with a mean 1.47 stems/m^2 density and a mean 0.007% basal cover during the 30 year period, respectively. During the early period (1983-1992), Peppergrass was present during 40.0% and 16.7% of the years, with a mean 1.52 stems/m^2 density and with a mean 0.005% basal cover, respectively. During the later period (1998-2012), Peppergrass was present during 46.7% and 20.0% of the years, with a mean 1.45 stems/m^2 density and a mean 0.005% basal cover, respectively. The percent present increased slightly, the stem density decreased slightly, and the basal cover remained the same 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 greater on the grazed seasonlong than that on the ungrazed seasonlong treatment.

On the shallow site of the ungrazed twice-over treatment, Peppergrass was present during 50.0% and 17.2% of the years that density and basal cover data were collected, with a mean 0.44 stems/m^2 density and a mean 0.02% basal cover during the total

30 year period, respectively. During the early period (1983-1992), Peppergrass was present during 57.1% and 22.2% of the years, with a mean 0.59 stems/m^2 density and a mean 0.01% basal cover, respectively. During the later period (1998-2012), Peppergrass was present during 46.7% and 13.3% of the years, with a mean 0.37 stems/m^2 density and a mean 0.003% basal cover, respectively. The percent present, stem density, and basal cover all decreased slightly 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, Peppergrass was present during 68.2% and 23.3% of the years that density and basal cover data were collected, with a mean 1.13 stems/m^2 density and a mean 0.02% basal cover during the total 30 year period, respectively. During the early period (1983-1992), Peppergrass was present during 71.4% and 30.0% of the years, with a mean 0.81 stems/m^2 density and a mean 0.01% basal cover, respectively. During the later period (1998-2012), Peppergrass was present during 66.7% and 20.0% of the years, with a mean 1.27 stems/m^2 density and a mean 0.003% basal cover, respectively. The percent present decreased, stem density increased, and basal cover decreased on the shallow site of the grazed twice-over treatment over time (tables 7, 8, and 9).

During the 30 year period of the 1983-2012 study, on the shallow sites, Peppergrass percent present was greatest on the grazed twice-over treatment, stem density was greatest on the grazed seasonlong treatment and lowest on the nongrazed treatment, basal cover was very low on every treatment and lowest on the nongrazed treatment. It appears that Peppergrass must have some problem with shading during the early stage development.

During the drought year of 1988, Peppergrass was not present on any of the management treatments. The following growing season, 1989, Peppergrass was present at relatively high stem densities of the seasonlong and twice-over treatments, with the highest stem density of 7.5 stems/m^2 on the grazed seasonlong treatment.

Discussion

Peppergrass, *Lepidium densiflorum*, is a early succession winter annual or biennial native forb of the mustard family that is usually present at low densities for less than half of the growing seasons on healthy mixed grass prairie plant communities. Peppergrass can grow on sandy, shallow, silty, and clayey ecological sites if a few bare spaces are available, otherwise, it is usually on the shallow sites. During the first growing season, Peppergrass develops a basal rosette of leaves less than 3 inches long, a crown and taproot when soil moisture is adequate, usually during the fall. During the second growing season, a single stem unbranched below with numerous branches above containing a raceme of many tiny flowers on each branch. Each flower has 4 greenish sepals and no petals during early June to late July. A fruit with 2 flat winged seeds develops at each flower. When the seeds are ripe the dehiscent fruit shoots the seeds a short distance from the stem. The seeds are ready to germinate when conditions are favorable. The seeds do not appear to have any additional mode of distribution, however, this plant is common and widely spread across North America.

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Table 1. First flower and flower period of Lepidium densiflorum, Peppergrass.

	Apr	May	Jun		Jul		Aug	Sep
First Flower								
1955-1962								
Earliest			10					
Mean				19				
Flower Period								
1969-1971			X	XX	XX	XX		

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

Table 2. Autecology of Lepidium densiflorum, Peppergrass, 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	16.0	28.0	23.5		50.0	90.5	100.0		

Data from Goetz 1963.

Table 3. Phenological growth stage changes during the growing season for Lepidium densiflorum, Peppergrass, 1984-1985.

Site Sandy	8 Jun	23 Jun	8 Jul	23 Jul	8 Aug	23 Sep
% Population						
Veg	2.3	18.4	4.4			
Bud	48.8	16.8	1.5			
Anth		8.0	0.7		0.9	
Seed Dev	48.8	46.4	45.2	25.6	2.8	3.8
Seed Shed		9.6	39.3	58.1	45.3	15.4
Mat		0.8	8.9	16.3	50.9	80.8
Mean Height (cm)						
Veg	11.1	8.5	5.0			
Bud	13.1	6.4	9.6			
Anth		4.9	4.8		14.2	
Seed Dev	14.8	11.1	9.3	13.9	14.0	14.9
Seed Shed		12.4	10.7	8.6	12.3	11.4
Mat		5.8	9.8	12.7	12.0	14.5
% Dryness						
Veg	0.0	0.0	8.7			
Bud	2.8	0.2	1.0			
Anth		0.0	2.0		50.0	
Seed Dev	6.8	9.0	22.1	83.4	100.0	58.3
Seed Shed		79.1	58.1	91.2	99.8	71.4
Mat		100.0	97.9	100.0	96.9	100.0
Mean Weight (g)	0.31	0.05	0.06	0.07	0.06	0.05

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 Lepidium densiflorum, Peppergrass, 1984-1985.

Site Shallow	8 Jun	23 Jun	8 Jul	23 Jul	8 Aug	23 Sep
% Population						
Veg	2.0	16.2				
Bud	45.1	18.8	0.8			
Anth		8.5				
Seed Dev	52.9	39.3	56.0	34.4	10.1	
Seed Shed		12.0	36.0	41.9	54.4	4.2
Mat		5.1	7.2	23.7	35.4	95.8
Mean Height (cm)						
Veg	7.9	3.2				
Bud	11.7	6.1	3.4			
Anth		4.3				
Seed Dev	14.6	7.1	8.1	12.9	13.4	
Seed Shed		8.0	11.5	9.9	10.8	13.7
Mat		7.4	9.6	15.8	12.7	14.7
% Dryness						
Veg	0.0	0.0				
Bud	10.4	0.5	2.0			
Anth		0.0				
Seed Dev	11.7	18.1	24.6	84.5	87.0	
Seed Shed		71.6	62.4	94.2	100.0	100.0
Mat		100.0	99.9	97.7	98.3	97.8
Mean Weight (g)	0.10	-	0.05	0.03	0.06	-

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 Lepidium densiflorum, Peppergrass, 1984-1985.

Site Silty	8 Jun	23 Jun	8 Jul	23 Jul	8 Aug	23 Sep
% Population						
Veg	1.7	18.6	3.1	1.1		
Bud	48.3	12.4	3.1			
Anth	13.8	1.8				
Seed Dev	36.2	60.2	56.2	44.0	1.3	4.9
Seed Shed			26.2	35.2	60.0	
Mat			11.5	19.8	38.7	95.1
Mean Height (cm)						
Veg	4.8	5.7	10.0	2.6		
Bud	12.7	7.1	11.4			
Anth	11.4	7.6				
Seed Dev	18.3	10.0	8.4	11.4	12.1	13.0
Seed Shed		8.7	12.6	10.5	16.1	
Mat		5.8	8.5	23.2	15.0	14.7
% Dryness						
Veg	2.0	0.3	0.5	50.0		
Bud	8.7	2.4	24.5			
Anth	3.9	0.0				
Seed Dev	8.0	10.0	17.4	75.3	50.0	33.0
Seed Shed		60.7	74.2	92.3	97.5	
Mat		50.0	99.9	100.0	96.5	98.7
Mean Weight (g)	0.13	0.01	0.08	0.03	0.08	0.05

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 Lepidium densiflorum, Peppergrass, 1984-1985.

Site Clayey	8 Jun	23 Jun	8 Jul	23 Jul	8 Aug	23 Sep
% Population						
Veg		12.3	3.0			
Bud	26.7	13.6	2.0			
Anth		24.7				
Seed Dev	73.3	44.4	37.0	9.6	9.2	
Seed Shed		4.9	42.0	36.5	47.7	5.4
Mat			16.0	53.8	43.1	94.6
Mean Height (cm)						
Veg		5.6	4.8			
Bud	8.5	4.2	5.0			
Anth		9.9				
Seed Dev	9.5	7.5	10.4	13.9	13.2	
Seed Shed		9.9	10.9	7.4	10.0	10.4
Mat			9.8	13.0	11.9	14.6
% Dryness						
Veg		0.0	0.0			
Bud	7.1	0.5	2.0			
Anth		37.3				
Seed Dev	11.0	5.6	26.0	79.2	67.0	
Seed Shed		19.8	59.9	97.2	99.7	100.0
Mat			98.3	100.0	100.0	100.0
Mean Weight (g)	0.004	0.05	0.05	0.04	0.03	0.05

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

Table 7. Autecology of Lepidium densiflorum, Peppergrass, 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	1.21	1.29	2.11
1988-1992	0.00	0.00	6.51	4.54	6.66
1993-1998	0.00	0.00	0.00	0.49	0.00
1999-2003	0.00	0.00	1.85	3.11	2.48
2004-2009	0.94	4.97	11.24	2.01	8.06
2010-2012	0.00	0.68	4.40	0.34	0.87
Silty					
1983-1987	Few Plants Present				
1988-1992					
1993-1998					
1999-2003					
2004-2009					
2010-2012					

Table 8. Autecology of Lepidium densiflorum, Peppergrass, 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	0.04
1988-1992	0.00	0.00	0.48	0.20	0.18
1993-1998	0.00	0.00	0.15	0.49	0.81
1999-2003	0.00	0.00	0.00	0.02	0.03
2004-2009	0.00	0.04	0.09	0.04	0.04
2010-2012	0.00	0.00	0.00	0.00	0.00
Silty					
1983-1987	Few Plants Present				
1988-1992					
1993-1998					
1999-2003					
2004-2009					
2010-2012					

Table 9. Autecology of Lepidium densiflorum, Peppergrass, 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	0.00	0.00	0.01	0.03	0.05
1988-1992	0.00	0.00	0.19	0.08	0.11
1993-1998	0.00	0.00	0.00	0.01	0.00
1999-2003	0.00	0.00	0.02	0.04	0.04
2004-2009	0.02	0.11	0.28	0.06	0.27
2010-2012	0.00	0.01	0.12	0.01	0.03
Silty					
1983-1987	Few Plants Present				
1988-1992					
1993-1998					
1999-2003					
2004-2009					
2010-2012					

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