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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 Spiny Ironweed on the Northern Mixed Grass Prairie

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The autecology of Spiny ironweed, *Haplopappus spinulosus*, 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).

Spiny ironweed, *Haplopappus spinulosus* (Pursh) DC., is a member of the aster (sunflower) family, Asteraceae, syn.: *Aplopappus spinulosus* (Pursh) DC.; *Machaeranthera pinnatifida* (Hook.) Shinners, and is a native, perennial, warm season, dicot, herb, that is extremely drought tolerant. The first North Dakota record is Bergman 1911. Annual aerial growth has numerous erect or ascending stems 20-40 cm (7.9-15.7 in) tall, simple below, widely branched above arising from a woody, branching crown (caudex). Stem leaves are alternate, oblong to subspatulate, 1-3 cm (0.4-1.2 in) long, 2-10 mm wide, pinnately divided into linear lobes with spiny tips, sessile, reducing upwards. Stems and leaves are sparsely pubescent or sometimes densely covered with hairs. The root system has a strong woody taproot that develops from below the woody crown and can descend to 1.4-1.5 m (4.5-5.0 ft) deep. Numerous fibrous lateral roots with widely spreading branches arise from the top 91 cm (3 ft) of the taproot and extend horizontally with a radial spread of 46 cm (1.5 ft). This root system has little or no absorption in the top 30.5 cm (1 ft) of soil, however, has good absorption from the deeper soil. Regeneration is by vegetative and sexual reproduction. Vegetative growth is by annual sprouts from the woody crown and by offset shoots from crown branches. Inflorescence are solitary heads 1.5-2 cm (0.6-0.8 in) wide, terminal on a peduncle arising from leaf axils with several on each stem. Flowers with yellow ray florets appearing during late July to early September. Pollination is by insects. Fruit is a pubescent achene with pappus of yellowish brown bristles. Aerial parts are not eaten by livestock and are top killed by fire. Damage to aerial stems activates regrowth sprouts from the crown. This summary information on growth development and regeneration of spiny ironweed was based on works of Weaver 1958, Stevens 1963, Zaczkowski 1972, Great Plains Flora Association 1986, Stubbendieck et al. 2003, and Johnson and Larson 2007.

Procedures

The 1955-1962 Study

Spiny ironweed 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 Spiny ironweed 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 Spiny ironweed 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 Spiny ironweed 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 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 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

Spiny ironweed resumes annual aerial growth as numerous erect or ascending stems arising from a woody branching caudex. A woody taproot descends 1.4-1.5 m (4.5-5.0 ft) deep below the caudex. Numerous fibrous lateral roots with radially spreading horizontal branches extend 46 cm (1.5 ft). Several solitary composite heads with yellow ray florets develop terminal on peduncles that arise from leaf axils. On the fall grazed pastures of the 1955-1962 study, the earliest first flowers appeared 6 July, the mean first flowers occurred on 23 July, and the long six week flower period was observed during the 1969-1971 study to extend from late July to early September (table 1) (Goetz 1963, Zaczkowski 1972). A mean mature stem height of 17.3 cm (6.8 in) with an annual variance in height from 15.0 cm (5.9 in) to 20.0 cm (7.9 in) was reached during September (table 2) (Goetz 1963). The reported normal mature stem height in the Northern Plains ranged from 20 cm (7.9in) to 40 cm (15.7 in) tall. The mature stem heights measured during the 1955-1962 study were shorter than normal stem heights for the Northern Plains.

Plant species composition in rangeland ecosystems is variable during a growing season and dynamic among growing seasons. Spiny ironweed was found to have low abundance on sandy and silty

ecological sites. Patterns in the changes of individual plant species abundance was followed for 30 growing seasons during the 1983-2012 study on the shallow ecological sites of the long-term nongrazed, traditional seasonlong, and twice-over rotation management treatments (tables 3, 4, and 5).

On the shallow site of the nongrazed treatment, Spiny ironweed was present during 36.8% and 3.9% of the years that density and basal cover data were collected, with a mean 0.15 stems/m^2 density and a mean 0.001% basal cover during the total 30 year period, respectively. During the early period (1983-1992), Spiny ironweed was not present where basal cover data were collected and was present during 20.0% of the years with a mean 0.04 stems/m^2 density. During the later period (1998-2012), Spiny ironweed was present during 42.9% and 6.7% of the years with a mean 0.19 stems/m^2 density and a mean 0.002% basal cover, respectively. The percent present for density data and stem density increased (tables 3, 4, and 5). Spiny ironweed was not present with the basal cover data during the early period and all observations were made during the later period.

On the shallow site of the ungrazed seasonlong treatment, Spiny ironweed was present during 20.0% and 19.2% of the years that density and basal cover data were collected with a mean 0.09 stems/m^2 density and a mean 0.005% basal cover during the total 30 year period, respectively. During the early period (1983-1992), Spiny ironweed was not present on the shallow site of the ungrazed seasonlong treatment. During the later period (1998-2012), Spiny ironweed was present during 26.7% and 33.3% of the years with a mean 0.12 stems/m^2 density and a mean 0.009% basal cover, respectively. Spiny ironweed was not present during the early period and all observations were made during the later period that indicated low abundance.

On the shallow site of the grazed seasonlong treatment, Spiny ironweed was present during 75.0% and 30.8% of the years that density and basal cover data were collected with a mean 0.28 stems/m^2 density and a mean 0.019% basal cover during the total 30 year period, respectively. During the early period (1983-1992), Spiny ironweed was present during 80.0% and 66.7% of the years with a mean 0.40 stems/m^2 density and a mean 0.06% basal cover, respectively. During the later period (1998-2012), Spiny ironweed was present during 73.3% and 26.7% of the years with a mean 0.23 stems/m^2 density and a mean 0.009% basal cover, respectively. The percent present, stem density and basal cover all decreased on the shallow site of the grazed seasonlong treatment over time (tables 3, 4, and 5). The percent present, stem density, and basal cover were greater on the shallow site of the grazed seasonlong treatment than those on the shallow site of the ungrazed seasonlong treatment.

On the shallow site of the ungrazed twice-over treatment, Spiny ironweed was present during 95.5% and 55.2% of the years that density and basal cover data were collected with a mean 0.47 stems/m^2 density and a mean 0.02% basal cover during the total 30 year period, respectively. During the early period (1983-1992), Spiny ironweed was present during 85.7% and 77.8% of the years with a mean 0.46 stems/m^2 density and a mean 0.04% basal cover, respectively. During the later period (1998-2012), Spiny ironweed was present during 100.0% and 46.7% of the years with a mean 0.47 stems/m^2 density and a mean 0.01% basal cover, respectively. The percent present for density data and stem density increased slightly and percent present for basal cover data and basal cover decreased slightly on the shallow site of the ungrazed twice-over treatment over time (tables 3, 4, and 5).

On the shallow site of the grazed twice-over treatment, Spiny ironweed was present during 95.5% and 50.0% of the years that density and basal cover data were collected with a mean 0.39 stems/m^2 density and a mean 0.02% basal cover during the total 30 year period, respectively. During the early period (1983-1992), Spiny ironweed was present during 85.7% and 50.0% of the years with a mean 0.50 stems/m^2 density and a mean 0.03% basal cover, respectively. During the later period (1998-2012), Spiny ironweed was present during 100.0% and 66.7% of the years with a mean 0.33 stems/m^2 density and a mean 0.014% basal cover, respectively. The percent present for density data and percent present for basal cover data increased and stem density and basal cover decreased slightly on the shallow site of the grazed twice-over treatment over time (tables 3, 4, and 5). The percent present for density data and percent present for basal cover data, stem density, and basal cover were fairly similar on the shallow site of the ungrazed and grazed twice-over treatments.

On the shallow sites, Spiny ironweed was present during 64.5% and 31.8% of the years with a mean 0.27 stems/m^2 density and a mean 0.013% basal cover which is at a fairly low abundance.

Spiny ironweed on the shallow site of the nongrazed treatment was present during 36.8% and 3.9% of the years with a mean 0.15 stems/m^2 density

and a mean 0.001% basal cover. Spiny ironweed on the shallow site of the seasonlong treatment was present during 47.5% and 25.0% of the years with a mean 0.18 stems/m^2 density and a mean 0.012% basal cover. Spiny ironweed on the shallow site of the twice-over treatment was present during 95.5% and 52.6% of the years with a mean 0.43 stems/m^2 density and a mean 0.02% basal cover. The percent present for density data, percent present for basal cover data, stem density and basal cover were greater on the shallow site of the twice-over treatment.

During the drought growing season of 1988; Spiny ironweed was present on the nongrazed treatment at no time for an index of 0.0%; Spiny ironweed was present on the seasonlong treatment 2 times out of a possible 4 for an index of 50.0%; and Spiny ironweed was present on the twice-over treatment 3 times out of a possible 4 for an index of 75.0%. Spiny ironweed appears to have fairly good drought tolerance on the seasonlong and twice-over treatments.

Discussion

Spiny ironweed, *Haplopappus spinulosus*, is a native, late succession, perennial, warm season, dicot, forb of the aster family that is commonly present on healthy mixed grass prairie plant communities. Spiny ironweed grows better on the shallow ecological sites. Spiny ironweed resumes annual aerial growth with numerous erect or ascending stems arising from a perennating woody branching caudex. A persistent taproot descends from below the caudex to 1.4-1.5 m (4.5-5.0 ft) in depth. Numerous fibrous lateral branching roots arise from the taproot spreading radially extending 46 cm (1.5 ft) horizontally. Several solitary composite heads with yellow ray florets develop terminal on peduncles that arise from leaf axils of the upper portions of the stems. The mean first flowers occurred on 23 July (1955-1962 study), with a six week long flower period extending from late July to early September (1969-1971 study). A mean mature stem height of 17.3 cm (6.8 in) is reached during September (1955-1962 study). The percent present, stem density, and basal cover data were all greater on the shallow site of the twice-over treatment than those on the shallow site of the nongrazed and seasonlong treatments. Spiny ironweed was present during the drought growing season of 1988 on the shallow sites of the seasonlong and twice-over treatments and appears to have fairly good drought tolerance.

The branching woody caudex, the deep persistent woody taproot, and the numerous fibrous lateral roots that spread radially help Spiny ironweed to persist through the harsh conditions of the Northern Mixed Grass Prairie.

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Table 1. First flower and flower period of Haplopappus spinulosus, Spiny ironweed.

	Apr	May	Jun	Jul	Aug	Sep
First Flower						
1955-1962						
Earliest			6			
Mean				23		
Flower Period						
1969-1971				X	XX XX	X

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

Table 2. Autecology of Haplopappus spinulosus, Spiny ironweed, 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	15.0	20.0	17.3		36.3	71.2	92.0	97.1	100.0

Data from Goetz 1963.

Table 3. Autecology of Haplopappus spinulosus, Spiny ironweed or Cutleaf ironplant, 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	1.00	0.00	5.44	1.63	4.18
1988-1992	0.00	0.00	3.63	6.61	3.57
1993-1998	0.00	0.00	4.98	0.91	1.45
1999-2003	0.00	1.27	2.09	2.08	3.20
2004-2009	2.84	0.26	1.52	1.66	1.68
2010-2012	1.81	1.24	1.47	2.57	2.54
Silty					
1983-1987	Few Plants Present				
1988-1992					
1993-1998					
1999-2003					
2004-2009					
2010-2012					

Table 4. Autecology of Haplopappus spinulosus, Spiny ironweed or Cutleaf ironplant, 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	0.28	0.35	0.21
1988-1992	0.00	0.00	0.61	0.35	0.43
1993-1998	0.00	0.00	0.00	0.10	0.02
1999-2003	0.00	0.08	0.17	0.18	0.10
2004-2009	0.05	0.07	0.05	0.08	0.15
2010-2012	0.00	0.04	0.00	0.00	0.02
Silty					
1983-1987	Few Plants Present				
1988-1992					
1993-1998					
1999-2003					
2004-2009					
2010-2012					

Table 5. Autecology of Haplopappus spinulosus, Spiny ironweed or Cutleaf ironplant, 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	0.02	0.00	0.02	0.02	0.05
1988-1992	0.00	0.00	0.03	0.05	0.03
1993-1998	0.00	0.00	0.05	0.02	0.01
1999-2003	0.00	0.05	0.02	0.08	0.05
2004-2009	0.03	0.00	0.02	0.03	0.02
2010-2012	0.03	0.02	0.02	0.04	0.03
Silty					
1983-1987	Few Plants Present				
1988-1992					
1993-1998					
1999-2003					
2004-2009					
2010-2012					

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