Autecology of Soft Goldenrod on the Northern Mixed Grass Prairie

Llewellyn L. Manske PhD
Research Professor of Range Science
North Dakota State University
Dickinson Research Extension Center
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The autecology of Soft goldenrod, *Solidago mollis,* 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).

Soft goldenrod, *Solidago mollis* Bartlett, is a member of the aster (sunflower) family, Asteraceae, and is a native, perennial, warm season, dicot, herb. The first North Dakota record is Hanson 1933. Aerial growth has a single or loose cluster of erect stems 30-60 cm (11.8-23.6 in) tall arising from a perennating crown (caudex). Stem (cauline) leaves are alternate, 3 nerved, ovate to obovate, or elliptic, 3-6 cm (1.2-2.4 in) long, 1-3 cm (0.4-1.2 in) wide, with lower leaves larger, irregular toothed and early deciduous. Stems and leaves are covered by dense hair giving a soft, gray velvety appearance. The root system has numerous main roots of about equal size arising from the crown spreading horizontally then descending vertically to 2.1 or 2.4 m (7-8 ft) deep in loose soil. Lateral roots spreading from the main roots have extensive development in the top 30.5-61.0 cm (1-2 ft) of soil. This root system has capacity for vigorous absorption. An extensive system of creeping horizontal rhizomes develops from the crown that can form large colonies. Regeneration is by vegetative and sexual reproduction. Vegetative growth is by annual sprouts from the subterranian crown and by sprouts from the extensive rhizome system. Inflorescence is a dense, rather elongated panicle, in a compact pyramidal shape, with the lower branches often recurved. Flowers have yellow ray florets appearing during early August to early September. Fruit is an achene covered with stiff flattened hairs. Aerial parts are not eaten by livestock and are top killed by fire. Damage to aerial stems activates sprouts from extensive rhizome system. This summary information on growth development and regeneration of soft goldenrod was based on works of Weaver 1958, Stevens 1963, Zaczkowski 1972, Great Plains Flora Association 1986, and Larson and Johnson 2007.

Procedures

The 1955-1962 Study

Soft goldenrod 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 Soft goldenrod 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 Soft goldenrod 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 Soft goldenrod 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

Soft goldenrod resumes annual aerial growth with a single or a few erect stems arising from a perennating caudex. An extensive creeping horizontal rhizome system that can form large colonies develops from the caudex. Numerous, about equal size, main roots arise from the caudex, spread horizontally, then turn downward and descend vertically to 2.4 m (8 ft) deep in loose soil. Lateral roots with vigorous absorption capacity develop from the main roots extensively in the top 61.0 cm (2 ft) of the soil. Numerous flowers with yellow ray florets develop densely on an elongated panicle forming a compact pyramid shape. On the fall grazed pastures of the 1955-1962 study, the earliest first flowers appeared 22 June, the mean first flowers occurred on 15 July, with an observed flower period during the 1969-1971 study extending from early August through the first week of September. With a 10 week combined flower period from late June to early September (table 1) (Goetz 1963, Zaczkowski 1972). A mean mature stem height of 26.0 cm (10.2 in) with an annual variance in height from 15.0 cm (5.9 in) to 35.0 cm (13.8 in) was reached during August (table 2) (Goetz 1963). The reported normal mature stem height in the Northern Plains ranged from 30.0 cm (11.8 in) to 60.0 cm (23.6 in) tall. The mature stem heights measured during the 1955-1962 study were within the short end or shorter than the normal mature stem height for the Northern Plains.

Plant species composition in rangeland ecosystems is variable during a growing season and dynamic among growing seasons. Soft goldenrod was found to have low abundance on 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 sandy and shallow ecological sites of the long-term nongrazed, traditional seasonlong, and twice-over rotation management treatments (tables 3, 4, and 5).

On the sandy site of the nongrazed treatment, Soft goldenrod was not present during the total 30 year period.

On the sandy site of the ungrazed seasonlong treatment, Soft goldenrod was not present where basal cover data were collected and was present during 10.5% of the years that density data were collected with a mean 0.13 stems/m^2 density during the total 30 year period. During the early period (1983-1992), Soft goldenrod was not present on the sandy site of the ungrazed seasonlong treatment. During the later period (1998-2012), Soft goldenrod was present during 13.3% of the years with a mean 0.16 stems/m^2 density. Soft goldenrod was not present during the early period and all density observations were made during the later period indicated low abundance.

On the sandy site of the grazed seasonlong treatment, Soft goldenrod was not present where basal cover data were collected and was present during 15.8% of the years that density data were collected with a mean 0.24 stems/m^2 density during the total 30 year period, respectively. During the early period (1983-1992), Soft goldenrod was not present on the sandy site of the grazed seasonlong treatment. During the later period (1998-2012), Soft goldenrod was present during 20.0% of the years with a mean 0.31 stems/m^2 density. Soft goldenrod was not present during the early period and all density observations were made during the later period that indicated low abundance.

On the sandy site of the ungrazed twice-over treatment, Soft goldenrod was present during 4.8% and 10.3% of the years that density and basal cover data were collected with a mean 0.72 stems/m^2 density and a mean 0.05% basal cover during the total 30 year period, respectively. During the early period (1983-1992), Soft goldenrod was not present on the sandy site of the ungrazed twice-over treatment. During the later period (1998-2012), Soft goldenrod was present during 6.7% and 6.7% of the years with a mean 1.01 stems/m^2 density and a mean 0.003% basal cover, respectively. Soft goldenrod was not present during the early period and all observations were made during the later period that indicated low abundance.

On the sandy site of the grazed twice-over treatment, Soft goldenrod was present during 4.8% and 3.5% of the years that density and basal cover data were collected with a mean 0.32 stems/m^2 density and a mean 0.005% basal cover during the total 30 year period, respectively. During the early period (1983-1992), Soft goldenrod was not present on the sandy site of the grazed twice-over treatment. During the later period (1998-2012), Soft goldenrod was not present where basal cover data were collected and was present during 6.7% of the years with a mean 0.32 stems/m^2 density. Soft goldenrod was not present during the early period and all density observations were made during the later period that indicated low abundance.

On the shallow site of the nongrazed treatment, Soft goldenrod was not present during the total 30 year period.

On the shallow site of the ungrazed seasonlong treatment, Soft goldenrod was not present during the total 30 year period.

On the shallow site of the grazed seasonlong treatment, Soft goldenrod was not present where density data were collected and was present during 7.7% of the years that basal cover data were collected with a mean 0.006% basal cover during the total 30 year period. During the early period (1983-1992), Soft goldenrod was not present on the shallow site of the grazed seasonlong treatment. During the later period (1998-2012), Soft goldenrod was present during 6.7% of the years with a mean 0.003% basal cover. Soft goldenrod was not present where density data were collected and was not present with basal cover data during the early period and all observations were made during the later period that indicated low abundance.

On the shallow site of the ungrazed twice-over treatment, Soft goldenrod was not present where density data were collected and was present during 6.9% of the years with a mean 0.21% basal cover. Soft goldenrod was not present during the early and later periods and was present during the middle period (1993-1997), that indicated low abundance.

On the shallow site of the grazed twice-over treatment, Soft goldenrod was not present where basal cover data were collected and was present during 9.1% of the years that density data were collected with a mean 0.04 stems/m^2 density during the total 30 year period. During the early period (1983-1992), Soft goldenrod was present during 14.3% of the years with a mean 0.06 stems/m^2

density. During the later period (1998-2012), Soft goldenrod was present during 6.7% of the years with a mean 0.03 stems/m^2 density. Soft goldenrod was not present where basal cover data were collected. The percent present for density data and stem density decreased on the shallow site of the grazed twice-over treatment that indicated low abundance.

On the sandy site, Soft goldenrod was present during 7.2% and 2.8% of the years with a mean 0.28 stems/m^2 density and a mean 0.01% basal cover. On the shallow site, Soft goldenrod was present during 1.8% and 2.9% of the years with a mean 0.01 stems/m^2 density and a mean 0.05% basal cover. The percent present for density data, percent present for basal cover data, and stem density were greater on the sandy site and basal cover was greater on the shallow site.

Soft goldenrod was not present on the sandy site of the nongrazed trreatment. Soft goldenrod on the sandy site of the seasonlong treatment was not present where basal cover data were collected and was present during 13.2% of the years with a mean 0.18 stems/m^2 density. Soft goldenrod on the sandy site of the twice-over treatment was present during 4.8% and 6.9% of the years with a mean 0.52 stems/m^2 density and a mean 0.03% basal cover. The percent present for density data was greater on the sandy site of the seasonlong treatment. The percent present for basal cover data, stem density, and basal cover were greater on the sandy site of the twice-over treatment.

Soft goldenrod was not present on the shallow site of the nongrazed treatmnet. Soft goldenrod on the shallow site of the seasonlong treatment was not present where density data were collected and was present during 3.9% of the years with a mean 0.003 basal cover. Soft goldenrod on the shallow site of the twice-over treatment was present during 4.6% and 3.5% of the years with a mean 0.02 stems/m^2 density and a mean 0.11% basal cover. The percent present for basal cover data was greater on the shallow site of the seasonlong treatment. The percent present for density data, stem density, and basal cover were greater on the shallow site of the twice-over treatment.

Soft goldenrod had no abundance on the sandy and shallow sites of the nongrazed treatment. Soft goldenrod had low abundance on the sandy and shallow sites of the seasonlong treatment. Soft goldenrod had slightly greater abundance on the sandy and shallow site of the twice-over treatment.

Discussion

Soft goldenrod, *Solidago mollis*, 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. Soft goldenrod can grow on sandy and shallow ecological sites. It grows better on shallow site and grows best on shallow sites managed with the twice-over treatment. Annual aerial growth consists of a single or a few erect stems arising from a perennating caudex. Large colonies can develop from the extensive creeping rhizome system. Numerous main roots with lateral roots spread horizontally before descending to 2.4 m (8 ft) deep in loose soil. Numerous flowers with yellow ray florets form a compact pyramid shape panicle. The mean first flowers occurred on 15 July (1955-1962 study), with an observed 5 week flower period from early August to early September (1969-1971 study), and a combined 10 week flower period from late June to early September. A mean mature stem height of 26.0 cm (10.2 in) was reached during August (1955-1962 study). Soft goldenrod had no abundance on the nongrazed treatment, low abundance on the seasonlong treatment, and slightly greater abundance on the twice-over treatment.

The perennating caudex, the extensive creeping rhizome system, and the deep vigorously absorbent root system help Soft goldenrod to persist through the harsh conditions of the Northern Mixed Grass Prairie.

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Table 1. First flower and flower period of Solidago mollis, soft goldenrod.

	Apr	May	Jun	Jul	Aug	Sep
First Flower						
1955-1962						
Earliest			22			
Mean				15		
Flower Period						
1969-1971					XX XX X	

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

Table 2. Autecology of Solidago mollis, soft goldenrod, 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	35.0	26.0		27.9	55.7	73.1	100.0	

Data from Goetz 1963.

Table 3. Autecology of, Solidago mollis, Soft goldenrod, 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	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	16.54	100.44	36.86
1999-2003	0.00	0.00	0.00	0.00	0.00
2004-2009	0.00	0.00	0.24	0.00	0.00
2010-2012	0.00	3.09	0.96	0.00	0.00
Shallow					
1983-1987	0.00	0.00	0.00	0.00	0.55
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	0.00	0.00	0.00	0.00	0.35
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 4. Autecology of, Solidago mollis, Soft goldenrod, 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	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	2.10	0.20
1999-2003	0.00	0.00	0.00	0.00	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
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	0.12	8.31	0.00
1999-2003	0.00	0.00	0.15	0.00	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	Few Plants Present				
1988-1992					
1993-1998					
1999-2003					
2004-2009					
2010-2012					

Table 5. Autecology of, Solidago mollis, Soft goldenrod, with growing season changes in density, 1983-2012.					
Ecological Site Year Period	Nongrazed	Seasonlong		Twice-over	
		Ungrazed	Grazed	Ungrazed	Grazed
Sandy					
1983-1987	0.00	0.00	0.00	0.00	0.00
1988-1992	0.00	0.00	0.00	0.00	0.00
1993-1998	0.00	0.00	0.38	1.52	0.48
1999-2003	0.00	0.00	0.00	0.00	0.00
2004-2009	0.00	0.00	0.01	0.00	0.00
2010-2012	0.00	0.08	0.01	0.00	0.00
Shallow					
1983-1987	0.00	0.00	0.00	0.00	0.01
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	0.00	0.00	0.00	0.00	0.01
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					

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