Autecology of Stiff 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 Stiff goldenrod *Solidago rigida,* 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).

Stiff goldenrod, *Solidago rigida* L., is a member of the aster (sunflower) family, Asteraceae, syn.: *Oligoneuron rigidum* (L.) Small, and is a native, perennial, warm season, dicot, herb that is drought resistant. The first North Dakota record is Bergman 1911. Aerial growth consists of a set of large basal leaves with some from the previous growing season that persisted through the winter and some from early current season growth. Annual aerial growth has a single or usually a group of 2 to 8 stiff, stout, unbranched stems 30-80 cm (11.8-31.5 in) tall arising from a stout branching crown (caudex). Stem (cauline) leaves are alternate, 1 nerved, thick, rigid, leathery, petioled below, sessile above, broadly oblong to elliptic, ovate, or lanceolate 5-15 cm (2.0-5.9 in) long, 2-10 cm (0.8-3.9 in) wide, progressively reduced upward. Stems and leaves are covered with fine white hairs a felty appearance. The root system has numerous main roots of about equal size arising from the crown spreading horizontally 30.5-45.7 cm (12-18 in) then descending vertically to 1.5-1.8 m (5-6 ft) in depth in loose soil. The deeper roots are silvery white. Numerous, mostly unbranched fibrous lateral roots about 1 mm in diameter are yellowish brown with a smooth cortex fill the area from immediately below the soil surface to a depth of about 61 cm (2 ft) with a radial spread of about 45.7 cm (18 in). This root system has the capacity for vigorous absorption of water and nutrients. A thick, stout, branched, woody rhizome system develops from the caudex. Regeneration is by vegetative and sexual reproduction. Vegetative growth is by annual sprouts from the subterranian crown, by sprouts from the rhizome system, and by ground level, prostrate offset shoots with large leaves developed from the branches on the caudex. Inflorescence has numerous, small heads about 1 cm wide, terminal on pedicels that arise from leaf axils forming a corymb, compounded by numerous other clustered corymbs developing on the upper portions of the stem appearing during late July to early September forming somewhat of a flat top 10-20 cm (3.9-7.9 in) wide. Flower corollas of disk and ray florets are yellow. Pollination is by bees, butterflies, and other insects. Fruit is a ribbed achene with pappus of small tufts of white and light brown bristles. Aerial parts Aerial parts are not usually eaten by livestock and are top killed by fire. Damage to aerial stems activates regrowth shoots from the rhizome system and offset shoots from the crown. This summary information on growth development and regeneration of stiff goldenrod was based on works of Weaver and Fitzpatrick 1934, Weaver 1954, 1958; Stevens 1963, Zaczkowski 1972, Great Plains Flora Association 1986, and Larson and Johnson 2007.

Procedures

The 1969-1971 Study

The range of flowering time of Stiff 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 Stiff 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 Stiff 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

Stiff goldenrod resumes annual aerial growth early with a set of large basal leaves, some persisted from the previous growing season and some from early current season growth, followed with the growth of a few stiff, stout, unbranched stems arising from a stout branching caudex. Stems and leaves are covered with fine white hairs. Numerous main roots arise from the caudex, spread horizontally, then descend vertically to 1.8 m (6 ft) in depth in loose soil. The deeper roots are silvery white. Numerous unbranched yellowish brown fibrous lateral roots occupy the top 61 cm (2 ft) of soil. All of the roots have the capacity for vigorous absorption of water and nutrients. An extensive stout, branched woody rhizome system extends horizontally from the caudex. Numerous small composite heads with yellow disk and ray florets develop terminal on pedicels arising from upper stem leaf axils forming a compound cluster of corymbs producing a flat top. A flower period of six weeks extends from late July to early September (table 1) (Zaczkowski 1972). The reported normal mature stem height in the Northern Plains ranged from 30.0 cm (11.8 in) to 80.0 cm (31.5 in) tall (Stevens 1963).

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

On the sandy site of the nongrazed treatment, Stiff goldenrod was not present where density data were collected and was present during 8.0% of the years that basal cover data were collected with a mean 0.04% basal cover during the total 30 year period. During the early period (1983-1992), Stiff goldenrod was present during 20.0% of the years with a mean 0.001% basal cover. During the later period (1998-2012), Stiff goldenrod percent present decreased to 0.0% basal cover. Stiff goldenrod was not present where density data were collected. The percent present for basal cover data and basal cover decreased to zero on the sandy site of the nongrazed treatment over time (table 3).

On the sandy site of the ungrazed seasonlong treatment, Stiff goldenrod was present during 47.4% and 32.0% of the years that density and basal cover data were collected with a mean 1.77 stems/m^2 density and a mean 0.03% basal cover during the total 30 year period, respectively. During the early period (1983-1992), Stiff goldenrod was not present on the sandy site of the ungrazed seasonlong treatment. During the later period (1998-2012), Stiff goldenrod was present during 60.0% and 53.3% of the years with a mean 2.25 stems/m^2 density and a mean 0.05% basal cover, respectively. Stiff goldenrod was not present during the early period and all observations were made during the later period.

On the sandy site of the grazed seasonlong treatment, Stiff goldenrod was present during 84.2% and 32.0% of the years that density and basal cover data were collected with a mean 1.26 stems/m^2 density and a mean 0.03% basal cover during the total 30 year period, respectively. During the early period (1983-1992), Stiff goldenrod was present during 75.0% and 40.0% of the years with a mean 0.52 stems/m^2 density and a mean 0.10% basal cover, respectively. During the later period (1998-2012), Stiff goldenrod was present during 86.7% and 40.0% of the years with a mean 1.43 stems/m^2 density and a mean 0.02% basal cover, respectively. The percent present for density data and stem density increased, percent present for basal cover data remained the same, and basal cover decreased on the sandy site of the grazed seasonlong treatment over time (tables 2, 3, and 4). The percent present for density data was greater, stem density was lower, and percent present for basal cover data and basal cover were fairly similar on the sandy site of the grazed seasonlong treatment than those on the sandy site of the ungrazed seasonlong treatment.

On the sandy site of the ungrazed twice-over treatment, Stiff goldenrod was present during 76.2% and 6.0% of the years that density and basal cover data were collected with a mean 2.11 stems/m^2 density and a mean 0.09% basal cover during the total 30 year period, respectively. During the early period (1983-1992), Stiff goldenrod was present during 66.7% and 62.5% of the years with a mean 0.26 stems/m^2 density and a mean 0.05% basal cover, respectively. During the later period (1998-2012), Stiff goldenrod was present during 80.0% and 86.7% of the years with a mean 2.83 stems/m^2 density and a mean 0.13% basal cover, respectively. The percent present, stem density, and basal cover all increased on the sandy site of the ungrazed twice-over treatment over time (tables 2, 3, and 4).

On the sandy site of the grazed twice-over treatment, Stiff goldenrod was present during 66.7% and 34.5% of the years that density and basal cover data were collected with a mean 0.37 stems/m^2 density and a mean 0.02% basal cover during the total 30 year period, respectively. During the early period (1983-1992), Stiff goldenrod was present during 50.0% and 44.4% of the years with a mean 0.19 stems/m^2 density and a mean 0.04% basal cover, respectively. During the later period (1998-2012), Stiff goldenrod was present during 73.3% and 33.3% of the years with a mean 0.43 stems/m^2 density and a mean 0.009% basal cover, respectively. The percent present for density data and stem density increased and percent present for basal cover data and basal cover decreased on the sandy site of the grazed twice-over treatment over time (tables 2, 3, and 4). The percent present, stem density, and basal cover were all greater on the sandy site of the ungrazed twice-over treatment than those on the sandy site of the grazed twice-over treatment.

On the sandy site, Stiff goldenrod was present during 54.9% and 35.1% of the years with a mean 1.10 stems/m^2 density and a mean 0.05% basal cover.

Stiff goldenrod on the sandy site of the nongrazed treatment was present during 0.0% and 8.0% of the years with a mean 0.0 stems/m^2 density and a mean 0.04% basal cover. Stiff goldenrod on the sandy site of the seasonlong treatment was present during 65.8% and 32.0% of the years with a mean

1.52 stems/m^2 density and a mean 0.03% basal cover. Stiff goldenrod on the sandy site of the twice-over treatment was present during 71.4% and 51.7% of the years with a mean 1.24 stems/m^2 density and a mean 0.05% basal cover. The percent present for density data, percent present for basal cover data and basal cover were greater on the sandy site of the twice-over treatment and stem density was greater on the sandy site of the seasonlong treatment.

Discussion

Stiff goldenrod, *Solidago rigida*, 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. Stiff goldenrod grows best on sandy ecological site. Annual aerial growth consists of a set of large basal leaves followed by a few stiff unbranched stems arising from a stout branching perennating caudex. Stems and leaves are covered with fine white hairs. An extensive woody rhizome system extends from the caudex. Numerous deep main roots descent to 1.8 m (6 ft) in depth while numerous yellowish brown fibrous lateral roots occupy the top 61 cm (2 ft) of soil. Numerous flowers with yellow disk and ray florets develop on pedicels forming a compound cluster of corymbs with a flat top. A flower period of 6 weeks extends from late July to early September (1969-1971 study). The mean mature stem height for the Northern Plains ranged from 30-80 cm (11.8-31.5 in) (Stevens 1963). Stiff goldenrod had very low abundance on the nongrazed treatment, had moderate abundance on the seasonlong treatment, and slightly greater abundance on the twice-over treatment.

The perennating stout caudex, the thick branching rhizome system, the shallow lateral fibrous roots, and the deep main roots help Stiff goldenrod to persist through the harsh conditions of the Northern Mixed Grass Prairie.

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Table 1. Flower period of Solidago rigida, stiff goldenrod.

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

Flower Period Data from Zaczkowski 1972.

Table 2. Autecology of Solidago rigida, Stiff 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	8.96	2.15	1.92
1988-1992	0.00	0.00	2.70	1.93	1.29
1993-1998	0.00	0.00	0.00	0.00	0.00
1999-2003	0.00	1.64	4.64	12.43	4.05
2004-2009	0.00	6.00	4.95	14.25	2.08
2010-2012	0.00	16.20	7.24	5.83	1.65
Shallow					
1983-1987	Few Plants Present				
1988-1992					
1993-1998					
1999-2003					
2004-2009					
2010-2012					
Silty					
1983-1987	Few Plants Present				
1988-1992					
1993-1998					
1999-2003					
2004-2009					
2010-2012					

Table 3. Autecology of Solidago rigida, Stiff goldenrod, 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	0.00	0.00	0.00	0.20	0.11
1988-1992	0.10	0.00	1.07	0.73	0.55
1993-1998	1.15	0.00	0.00	0.13	0.11
1999-2003	0.00	0.07	0.11	1.72	0.13
2004-2009	0.00	0.94	0.24	1.67	0.08
2010-2012	0.00	0.71	0.05	0.23	0.00
Shallow					
1983-1987	Few Plants Present				
1988-1992					
1993-1998					
1999-2003					
2004-2009					
2010-2012					
Silty					
1983-1987	Few Plants Present				
1988-1992					
1993-1998					
1999-2003					
2004-2009					
2010-2012					

Table 4. Autecology of Solidago rigida, Stiff 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	0.12	0.03	0.02
1988-1992	0.00	0.00	0.04	0.03	0.02
1993-1998	0.00	0.00	0.00	0.00	0.00
1999-2003	0.00	0.06	0.14	0.29	0.08
2004-2009	0.00	0.23	0.17	0.42	0.03
2010-2012	0.00	0.57	0.13	0.09	0.03
Shallow					
1983-1987	Few Plants Present				
1988-1992					
1993-1998					
1999-2003					
2004-2009					
2010-2012					
Silty					
1983-1987	Few Plants Present				
1988-1992					
1993-1998					
1999-2003					
2004-2009					
2010-2012					

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