Autecology of Curlycup gumweed on the Northern Mixed Grass Prairie

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The autecology of Curlycup gumweed, *Grindelia squarrosa*, 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).

Curlycup gumweed, *Grindelia squarrosa* (Parsh) Dunal, is a member of the aster (sunflower) family, Asteraceae, and is a native, biennial or short lived perennial, warm season, dicot, herb that is highly drought resistant and intolerant of dense vegetation. The first North Dakota record is Bergman 1911. First year aerial growth consists of a rosette of basal leaves along with the early development of the crown and taproot. Second year aerial growth has a solitary (rarely a few) erect whitish or straw colored stem 30-60 cm (11.8-23.6 in) tall much branched above. Stem (cauline) leaves are alternate, simple, narrowly oblong or ovate to oblanceolate, finely toothed, thick, stiff, 2-4 cm (0.8-1.6 in) long, 4-15 mm wide, sessile to clasping, and secrete a sticky resin from glands. The extensive root system has a taproot that can descend to 1.5-1.8 m (5-6 ft) deep with abundant lateral roots that have a radial spread of 70.1 cm (2.3 ft) horizontally before turning downward and developing multifold branches providing the capability of great absorption. A short vertical rhizome also develops from the crown. Regeneration is by limited vegetative and sexual reproduction. Vegetative growth is by sprouts from the rhizome after the aerial stem has been damaged prior to senescence. Inflorescence are several to numerous terminal heads on branches forming a loose corymb. Flowers are perfect, ray florets are yellow appearing during mid July to early September. The entire head is covered with a very gummy resin. Pollination is by bees and other insects. Fruit is a smooth, straw colored, one seeded achene with a pappus of bristles. Aerial parts are unpalatable to livestock and is top killed by fire. Sprouts from rhizome are activated after aerial stem is damaged by fire or mowing. This summary information on growth development and regeneration of Curlycup gumweed was based on the works of Weaver 1958, Stevens 1963, Zaczkowski 1972, Great Plains Flora Association 1986, Walsh 1993, Stubbendieck et al. 2003, Johnson and Larson 2007, and Stubbendieck et al. 2011.

Procedures

The 1955-1962 Study

Curlycup gumweed 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 Curlycup gumweed 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

Curlycup gumweed 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 11 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 Curlycup gumweed 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 Curlycup gumweed 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

Curlycup gumweed is a biennial; during the first growing season, after a seed germinates a crown, taproot, and rosette of basal leaves are produced. The rosette of leaves persists through winter. During the spring of the second growing season, an extensive root system that has great absorption capacity with a horizontal spread of 70.1 cm (2.3 ft) and a vertical depth of 1.5-1.8 m (5-6 ft) and a single stiff flower stalk develop from the crown of the rosette. The earliest first flowers appeared 25 July, the mean first flowers occurred on 8 August on the fall pasture of the 1955-1962 study, and the flower period, from 1969-1971 study, was from mid July to early September (table 1) (Goetz 1963, Zaczkowski 1972). A mean mature flower stalk height of 22.1cm (8.7 in) tall with an annual variance in height from 16.0 cm (6.3 in) to 30.0 cm (11.8 in) was reached in August (table 2) (Goetz 1963). The reported normal mature flower stalk height in the Northern Plains ranged from 30 cm to 60 cm (11.8-23.6 in). The range of measured mature flower stalk heights was 16.0-30.0 cm (6.3-11.8 in), which was shorter than the reported normal heights. These lower flower stalk heights of Curlycup gumweed on the 1955-1962 study were not caused directly by grazing effects but were caused by low levels of available mineral nitrogen below the threshold quantity 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 1,619 Curlycup gumweed stems were sampled during this study with, 220 stems (13.59%) from the sandy sites, 521 stems (32.18%) from the shallow sites, 491 stems (30.33%) from the silty sites, and 387 stems (23.90%) from the clayey sites. Curlycup gumweed can grow on the sandy, shallow, silty, and clayey ecological sites, however, it was more plentiful on the shallow and silty sites than on the clayey and sandy ecological sites. The mean mature flower stalk heights reached during August on the 1984-1985 study were, 25.4 cm on the sandy sites, 21.4 cm on the clayey sites, 20.9 cm on the silty sites, and 18.5 cm on the shallow sites. The flower stalk heights on the sandy sites were significantly taller than the others, and the stalk heights on the shallow sites, were significantly shorter than the others. All of the flower stalk heights were shorter than the reported normal stalk heights. The reduced stalk heights of Curlycup gumweed on the 1984-1985 study was caused by low available mineral nitrogen below the threshold quantity of 100 lbs/ac that resulted from the traditional management practices conducted prior to the start of this study.

During the growing season, almost all of the Curlycup gumweed stems developed through the mature phenological growth stages and less than 2% remained at vegetative growth stages with, 1.5% on the sandy sites, 2.2% on the shallow sites, 2.4% on the silty sites, and 1.8% on the clayey sites (tables 3, 4, 5, and 6).

Mean Curlycup gumweed stem weights were not significantly different on the four ecological sites. Stem weights were heaviest on the sandy sites at 1.70 g, were lightest on the shallow sites at 1.24 g, and were in the middle on the silty and clayey sites at 1.52 g and 1.42 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. Patterns of the changes in individual plant species abundance was followed for 30 growing seasons during the 1983-2012 study. The number of documented Curlycup gumweed stems on the sandy ecological site of the three management treatments was insufficient to describe the changes in abundance patterns and were not included in this report.

On the shallow site of the nongrazed treatment, Curlycup gumweed was present during 10.5% and 7.7% of the years that density and basal cover data were collected, with a mean 0.08 stems/m^2 density and a mean 0.005% basal cover during the total 30 year period, respectively. During the early period (1983-1992), Curlycup gumweed was present during 20.0% and 16.7% of the years, with a mean 0.04 stems/m^2 density and a mean 0.02% basal cover. During the later period (1998-2012), Curlycup gumweed was present during 28.6% and 6.7% of the years, with a mean 0.10 stems/m^2 density and a mean 0.002% basal cover, respectively. Stem density increased and basal cover decreased on the shallow sites of the nongrazed treatment over time (tables 7, 8, and 9).

On the shallow sites of the seasonlong treatment, Curlycup gumweed was present on the ungrazed shallow site during 15.0% and 5.0% of the years, with a mean 0.04 stems/m^2 density and a mean 0.001% basal cover, and was present on the grazed shallow site during 20.0% and 10.0% of the years that density and basal cover data were collected, with a mean 0.04 stems/m^2 density and a mean 0.002% basal cover during the total 30 year period, respectively. During the early period (1983-1992), Curlycup gumweed was present on the ungrazed shallow site during 40.0% and 16.7 % of the years, with a mean 0.12 stems/m^2 density and a mean 0.005% basal cover. During the later period (1998-2012), Curlycup gumweed was present on the ungrazed shallow site during 6.7% and 0.0% of the years, with a mean 0.01 stems/m^2 density, respectively. Both the stem density and basal cover decreased on the ungrazed shallow site of the seasonlong treatment over time. During the early period (1983-1992), Curlycup gumweed was present on the grazed shallow site during 40.0% and 16.7% of the years, with a mean 0.12 stems/m^2 density and a mean 0.005% basal cover. During the later period (1998-2012), Curlycup gumweed was present on the grazed shallow site during 13.3% and 6.7% of the years, with a mean 0.01 stems/m^2 density and a mean 0.001% basal cover, respectively. Both the stem density and basal cover decreased on the grazed shallow site of the seasonlong treatment over time. During the early period (1983-1992) stem density and basal cover of Curlycup gumweed were similar on the ungrazed and grazed shallow site. Stem density and basal cover increased during the 1988 to 1992, the low precipitation period. During the later period (1998-2012), stem density and basal cover of Curly gumweed decreased on both the ungrazed and grazed shallow sites of the seasonlong treatment (tables 7, 8, and 9).

On the shallow sites of the twice-over treatment, Curlycup gumweed was present on the ungrazed shallow site during 50.0% and 27.6% of the years, with a mean 0.20 stems/m^2 density and a mean 0.01% basal cover, and was present on the grazed shallow site during 95.5% and 60.0% of the years that density and basal cover data were collected, with a mean 0.50 stems/m^2 density and a mean 0.03% basal cover during the total 30 year period, respectively. During the early period (1983-1992), Curlycup gumweed was present on the ungrazed shallow site during 85.7% and 55.6% of the years, with a mean 0.61 stems/m^2 density and a mean 0.03% basal cover. During the later period (1998-2012), Curlycup gumweed was present on the ungrazed shallow site during 33.3% and 6.7% of the years, with a mean 0.03 stems/m^2 density and a mean 0.003% basal cover, respectively. Both stem density and basal cover decreased on the ungrazed shallow site of the twice-over treatments over time. During the early period (1983-1992), Curlycup gumweed was present on the grazed shallow site during 100.0% and 50.0% of the years, with a mean 0.51 stems/m^2 density and a mean 0.04% basal cover. During the later period (1998-2012), Curlycup gumweed was present on the grazed shallow site during 93.3% and 66.7% of the years, with a mean 0.56 stems/m^2 density and a mean 0.02% basal cover, respectively. Stem density increased slightly and basal cover decreased on the grazed shallow site of the twice-over treatment over time. Stem density and basal cover increased during the low precipitation period of 1988-1992 on both the ungrazed and grazed shallow sites. During the early period (1983-1992), Curlycup gumweed stem density was greater on the ungrazed site than that on the grazed shallow site and basal cover was slightly higher on the grazed site than that on the ungrazed shallow site. When growing season precipitation returned to normal after 1992, stem density and basal cover of Curlycup gumweed decreased on the ungrazed shallow site, and stem density increased slightly and basal cover decreased on the grazed shallow site of the twice-over treatment (tables 7, 8, and 9).

During the 30 year period of the 1983-2012 study, on the shallow sites, the greatest stem density of 0.50 stems/m^2 and the greatest basal cover of 0.03% were on the grazed site of the twice-over treatment.

On the silty site of the nongrazed treatment, Curlycup gumweed was present during 84.2% and 38.5% of the years that density and basal cover data were collected, with a mean 3.31 stems/m^2 density and a mean 0.006% basal cover during the total 30 year period, respectively. During the early period (1983-1992), Curlycup gumweed was present during 40.0% and 0.0% of the years, with a mean 0.40 stems/m^2 density. During the later period (1998-2012), Curlycup gumweed was present during 100.0% and 6.3% of the years, with a mean 4.34 stems/m^2 density and a mean 0.01% basal cover, respectively. Stem density increased remarkably and basal cover increased slightly on the silty sites of the nongrazed treatment over time (tables 7, 8, and 9).

On the silty sites of the seasonlong treatment, Curlycup gumweed was present on the ungrazed silty site during 70.0% and 11.5% of the years, with a mean 1.44 stems/m^2 density and a mean 0.004% basal cover, and was present on the grazed silty site during 75.0% and 15.4% of the years that density and basal cover data were collected, with a mean 1.07 stems/m^2 density and a mean 0.02% basal cover during the total 30 year period, respectively. During the early period (1983-1992), Curlycup gumweed was present on the ungrazed silty site during 40.0% and 16.7 % of the years, with a mean 0.68 stems/m^2 density and a mean 0.01% basal cover. During the later period (1998-2012), Curlycup gumweed was present on the ungrazed silty site during 80.0% and 6.7% of the years, with a mean 1.69 stems/m^2 density and a mean 0.002% basal cover, respectively. Stem density increased greatly and basal cover decreased on the ungrazed silty site of the seasonlong treatment over time. During the early period (1983-1992), Curlycup gumweed was present on the grazed silty site during 20.0% and 33.3% of the years, with a mean 1.22 stems/m^2 density and a mean 0.06% basal cover. During the later period (1998-2012), Curlycup gumweed was present on the grazed silty site during 93.3% and 6.7% of the years, with a mean 1.02 stems/m^2 density and a mean 0.003% 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 Curlycup gumweed were greater on the grazed silty sites than those on the ungrazed sites. Stem density and basal cover greatly increased during 1988, the drought year. During the later period (1998-2012), stem density and basal cover of Curlycup gumweed decreased on the grazed silty sites, and stem density increased and basal cover decreased on the ungrazed silty sites, resulting in slightly greater stem density values on the ungrazed silty site of the seasonlong treatment (tables 7, 8, and 9).

On the silty sites of the twice-over treatment, Curlycup gumweed was present on the ungrazed silty site during 36.4% and 13.8% of the years, with a mean 0.06 stems/m^2 density and a mean 0.01% basal cover, and was present on the grazed silty site during 50.0% and 40.0% of the years that density and basal cover data were collected, with a mean 0.17 stems/m^2 density and a mean 0.02% basal cover during the total 30 year period, respectively. During the early period (1983-1992), Curlycup gumweed was present on the ungrazed silty site during 42.9% and 22.2% of the years, with a mean 0.07 stems/m^2 density and a mean 0.02% basal cover. During the later period (1998-2012), Curlycup gumweed was present on the ungrazed silty site during 33.3% and 6.7% of the years, with a mean 0.14 stems/m^2 density and a mean 0.003% basal cover, respectively. Stem density increased slightly and basal cover decreased on the ungrazed silty site of the twice-over treatments over time. During the early period (1983-1992), Curlycup gumweed was present on the grazed silty site during 28.6% and 60.0% of the years, with a mean 0.11 stems/m^2 density and a mean 0.06% basal cover. During the later period (1998-2012), Curlycup gumweed was present on the grazed silty site during 60.0% and 40.0% of the years, with a mean 0.22 stems/m^2 density and a mean 0.01% basal cover, respectively. Stem density increased slightly and basal cover decreased on the grazed silty site of the twice-over treatment over time. Stem density and basal cover decreased during the low precipitation period of 1988 to 1992 on both the ungrazed and grazed silty sites. During the early period (1983-1992), Curlycup gumweed stem density and basal cover were greater on the grazed site than that on the ungrazed silty site. When growing season precipitation returned to normal after 1992, stem density and basal cover of Curlycup gumweed remained at low levels on both the ungrazed and grazed silty sites of the twice-over treatment (tables 7, 8, and 9).

During the 30 year period of the 1983-2012 study, on the silty sites, the greatest stem density of 3.31 stems/m^2 was on the nongrazed treatment.

Basal cover values were very low on the shallow and silty ecological sites of the three management treatments and followed a similar abundance pattern. During the early period (1983-1992), Curlycup gumweed basal cover ranged from 0.01% to 0.04% on the shallow sites and ranged from 0.01% to 0.06% on the silty sites. During the later period (1998-2012), basal cover decreased, and ranged from 0.001% to 0.02% on the shallow sites and ranged from 0.002% to 0.01% on the silty sites.

Stem density values were low on the shallow ecological sites of the three management treatments. During the early period (1983-1992), Curlycup gumweed stem density ranged from 0.04 to 0.61 stems/m^2. During the later period, stem density decreased on the ungrazed and grazed sites of the seasonlong treatment and on the ungrazed site of the twice-over treatment; stem density increased slightly on the grazed site of the twice-over treatment, and increased greater on the shallow site of the nongrazed treatment.

Stem density values were low on the silty ecological sites during the early period, 1983-1992, on the ungrazed and grazed sites of the twice-over treatment and increased slightly during the later period 1998-2012. Stem density of Curlycup gumweed was 1.2 stems/m^2 during the early period and decreased to 1.0 stems/m^2 during the later period on the grazed silty site of the seasonlong treatment. During the early period, stem density was 0.4 stems/m^2 and 0.7 stems/m^2 on the nongrazed treatment and the ungrazed site of the seasonlong treatment, respectively. During the later period stem density of Curlycup gumweed greatly increased to 1.7 stems/m^2 and 4.3 stems/m^2 on the ungrazed silty site of the seasonlong treatment and the silty site of the nongrazed treatment, respectively.

Discussion

Curlycup gumweed, *Grindelia squarrosa*, is an early succession forb that is present on degraded areas of mixed grass prairie plant communities, usually on the locations where livestock loiter for long periods of time, such as at a corner gate, or it can be present on abandoned wildlife earthen mounds and other highly disturbed areas. Curlycup gumweed can grow on small areas of sandy, shallow, silty, and clayey ecological sites, however, it does grow better on silty and shallow ecological sites, and it grows poorly on sandy ecological sites. First growing season aerial growth is a rosette of basal leaves that arise from a crown (caudex) with a taproot. Second growing season aerial growth is a flower stalk with a corymb inflorescence of numerous terminal heads on branches. The flower heads are covered with a gummy resin. The mean first flower date is 8 August (1955-1962 study), with a seven week flower period from mid July to early September (1969-1971 study). Erect aerial stems reached maximum mature flower stalk height during August. The mean mature flower stalk heights collected during the 1955-1962 study were 22.1 cm tall, and during the 1984-1985 study were 21.5 cm tall. These collected mean flower stalk heights were shorter than the reported range of normal Northern Plains mature stalk heights at 30 cm to 60 cm tall. These shorter stalk heights occurred because the soils of both studies had mineral nitrogen available at less than the threshold quantity of 100 lbs/ac which resulted from the detrimental effects caused by the traditional management practices on the ecosystem biogeochemical processes and soil microorganism biomass of the prairie plant communities. During the 1984-1985 study, a mean of about 98% of the second growing season rosettes produced a flower stalk that progressed through the phenological growth stages. Some (about 2.0%) Curlycup gumweed rosettes may live longer than two growing seasons. Aerial leaves and stems of Curlycup gumweed also have a gummy resin from glands causing it to be unpalatable and not eaten by livestock and thus the effects from partial defoliation by grazing do not directly cause annual changes in stem abundance. The extensive root system developed from one crown has the potential to occupy nearly 2.8 m^3 (100 ft^3) of soil, at the same location that the roots of most grasses occupy, however, Curlycup gumweed roots are not adversarial enough to compete against grass roots. Despite these limitations, Curlycup gumweed is not easy to kill; damage, such as mowing the aerial stems before second year fall senescence will activate sprout production from the short vertical rhizome arising from the crown. Management to thicken grass plant density through activated vegetative secondary tiller development from axillary buds will reduce Curlycup gumweed stems and prevent its return.

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Table 1. First flower and flower period of Grindelia squarrosa, Curlycup gumweed.

	Apr	May	Jun	Jul	Aug	Sep
First Flower						
1955-1962						
Earliest				25		
Mean					8	
Flower Period						
1969-1971				XX	XX XX	X

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

Table 2. Autecology of Grindelia squarrosa, Curlycup gumweed, 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	30.0	22.1		51.2	68.5	92.6	100.0	

Data from Goetz 1963.

Table 3. Phenological growth stage changes during the growing season for, Grindelia squarrosa, Curlycup gumweed, 1984-1985.

Site Sandy	8 Jun	23 Jun	8 Jul	23 Jul	8 Aug	23 Aug
% Population						
Veg	92.9	100.0	60.9	92.3		2.9
Bud	7.1		34.8		78.8	35.3
Anth					21.2	38.2
Seed Dev			4.3	7.7		23.5
Seed Shed						
Mat						
Mean Height (cm)						
Veg	9.0	11.2	10.8	18.3		6.3
Bud	8.4		14.2		20.4	18.2
Anth					24.4	29.1
Seed Dev			24.1	25.1		22.6
Seed Shed						
Mat						
% Dryness						
Veg	0.6	1.0	28.8	35.6		1.0
Bud	0.0		37.5		27.9	28.3
Anth					41.0	58.1
Seed Dev			25.0	50.0		34.4
Seed Shed						
Mat						
Mean Weight (g)	-	0.98	0.35	0.90	3.52	2.74

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, Grindelia squarrosa, Curlycup gumweed, 1984-1985.

Site Shallow	8 Jun	23 Jun	8 Jul	23 Jul	8 Aug	23 Aug
% Population						
Veg	100.0	100.0	50.9	3.1	2.5	0.9
Bud			49.1	95.3	79.2	13.3
Anth				1.6	14.2	55.8
Seed Dev					4.2	30.1
Seed Shed						
Mat						
Mean Height (cm)						
Veg	11.1	14.2	13.9	9.5	12.4	3.2
Bud			16.4	12.2	17.9	15.5
Anth				13.4	18.3	18.9
Seed Dev					17.8	18.9
Seed Shed						
Mat						
% Dryness						
Veg	2.8	6.7	24.5	25.0	2.0	0.0
Bud			25.5	30.6	32.1	30.4
Anth				25.0	29.0	33.4
Seed Dev					30.0	36.8
Seed Shed						
Mat						
Mean Weight (g)	0.92	0.96	0.21	1.51	2.02	1.82

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, Grindelia squarrosa, Curlycup gumweed, 1984-1985.

Site Silty	8 Jun	23 Jun	8 Jul	23 Jul	8 Aug	23 Aug
% Population						
Veg	96.4	100.0	81.8	5.5	0.9	0.9
Bud	3.6		18.2	92.7	82.5	14.7
Anth				1.8	15.8	53.2
Seed Dev					0.9	31.2
Seed Shed						
Mat						
Mean Height (cm)						
Veg	11.2	14.0	11.5	16.0	5.7	6.6
Bud	18.9		19.2	13.0	19.4	16.7
Anth				22.9	19.3	20.4
Seed Dev					13.1	22.9
Seed Shed						
Mat						
% Dryness						
Veg	2.6	8.3	22.6	50.0	2.0	2.0
Bud	0.0		31.5	36.4	28.6	22.6
Anth				25.0	27.9	43.3
Seed Dev					25.0	37.6
Seed Shed						
Mat						
Mean Weight (g)	0.53	0.66	1.08	1.24	2.93	2.67

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, Grindelia squarrosa, Curlycup gumweed, 1984-1985.

Site Clayey	8 Jun	23 Jun	8 Jul	23 Jul	8 Aug	23 Aug
% Population						
Veg	100.0	100.0	66.0		4.1	1.2
Bud			34.0	100.0	87.8	25.6
Anth					8.2	40.7
Seed Dev						32.6
Seed Shed						
Mat						
Mean Height (cm)						
Veg	11.9	12.1	15.0		15.0	2.8
Bud			20.8	14.2	18.6	18.2
Anth					20.0	22.3
Seed Dev						21.9
Seed Shed						
Mat						
% Dryness						
Veg	3.4	16.2	27.2		19.8	0.0
Bud			22.2	30.1	24.6	35.9
Anth					31.3	33.7
Seed Dev						34.9
Seed Shed						
Mat						
Mean Weight (g)	0.50	0.43	1.30	0.31	2.69	3.28

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

Table 7. Autecology of Grindelia squarrosa, Curlycup gumweed, 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	0.28	0.70
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	0.11
2004-2009	0.00	0.00	0.09	0.00	0.00
2010-2012	0.00	0.00	0.00	0.00	0.00
Shallow					
1983-1987	1.00	0.00	0.00	3.92	2.46
1988-1992	0.00	0.00	1.53	2.56	7.33
1993-1998	0.00	0.00	0.00	0.00	3.40
1999-2003	0.00	0.15	0.00	0.22	2.56
2004-2009	0.93	0.00	0.40	0.19	3.29
2010-2012	1.51	0.00	0.00	0.00	1.45
Silty					
1983-1987	6.77	1.97	0.00	0.64	0.83
1988-1992	2.10	4.82	10.30	0.00	0.00
1993-1998	41.72	7.92	4.69	0.00	0.88
1999-2003	26.83	10.47	6.36	0.69	3.56
2004-2009	4.37	2.28	1.89	0.36	0.12
2010-2012	4.67	3.83	5.43	0.00	1.07

Table 8. Autecology of Grindelia squarrosa, Curlycup gumweed, 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	1.23	0.00	0.00	0.00	0.04
1988-1992	0.13	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	0.00
2010-2012	0.00	0.00	0.00	0.00	0.00
Shallow					
1983-1987	0.00	0.00	0.00	0.22	0.08
1988-1992	0.17	0.07	0.07	0.25	0.55
1993-1998	0.00	0.00	0.00	0.04	0.20
1999-2003	0.00	0.00	0.00	0.01	0.20
2004-2009	0.00	0.00	0.00	0.00	0.18
2010-2012	0.07	0.00	0.04	0.00	0.06
Silty					
1983-1987	0.00	0.00	0.00	0.28	0.39
1988-1992	0.00	0.10	0.67	0.00	0.53
1993-1998	0.16	0.02	0.04	0.02	0.00
1999-2003	0.00	0.00	0.03	0.00	0.13
2004-2009	0.00	0.00	0.00	0.05	0.04
2010-2012	0.00	0.04	0.00	0.00	0.02

Table 9. Autecology of Grindelia squarrosa, Curlycup gumweed, 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	0.28	0.00
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	0.00
2010-2012	0.00	0.00	0.00	0.00	0.00
Shallow					
1983-1987	0.02	0.00	0.00	0.08	0.03
1988-1992	0.00	0.01	0.02	0.03	0.06
1993-1998	0.00	0.00	0.00	0.00	0.05
1999-2003	0.00	0.002	0.00	0.004	0.07
2004-2009	0.01	0.00	0.01	0.01	0.07
2010-2012	0.03	0.00	0.00	0.00	0.02
Silty					
1983-1987	0.12	0.05	0.00	0.01	0.02
1988-1992	0.02	0.07	0.15	0.00	0.00
1993-1998	1.40	0.24	0.07	0.00	0.01
1999-2003	1.00	0.36	0.20	0.01	0.05
2004-2009	2.50	0.05	0.05	0.01	0.01
2010-2012	0.07	0.06	0.06	0.00	0.02

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