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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 Groundplum on the Northern Mixed Grass Prairie

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The autecology of Groundplum, *Astragalus crassicarpus*, 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).

Groundplum, *Astragalus crassicarpus* Nutt., is a member of the legume (bean) family, Fabaceae, syn.: *Astragalus caryocarpus* Ker., and is a native, perennial, dicot, herb. The first North Dakota record is Bergman 1912. Annual aerial growth has 7 to 30 coarse, stout, fleshy, decumbent stems 10-30 cm (3.9-11.8 in) long spreading widely in a radial manner, covering a circular area 61-91 cm (2-3 ft) in diameter and less than 20 cm (8 in) tall arising from a large crown (caudex). Stem leaves are alternate, odd pinnately compound, 4-13 cm (1.6-5.1 in) long with 13 to 27 leaflets, oblong to linear, 8-20 mm long. Leaves are pubescent below, glabrous above. The extensive root system has a stout prominent taproot descending from the woody branched caudex to 2.1 or 3.7 m (7-12 ft) deep in loose soil. Several main roots arise from the top 31 cm (12 in) of the taproot, with many branches spreading horizontally for 46 cm (1.5 ft) before turning downward and penetrating into the soil to depths of 1.8-2.4 m (6-8 ft). Numerous fibrous lateral roots develop from the main roots in the top 91 cm (3 ft) of soil with little or no absorption from the top 31 cm (12 in) of soil. Regeneration is by vegetative and sexual reproduction. Vegetative growth is by annual sprouts from the subterranian crown and sprouts from the crown branches. Inflorescence has 5 to 15 flowers in a dense cluster forming a raceme on top of leafless stalks arising from leaf axils. Flowers are perfect, pea shaped with 5 large purple to violet petals appearing during early May to early June. Pollination is by bees and butterflies. Fruit is a large, fleshy, plum like pod with two cells. The top turns red when exposed to the sun. They are eatable when young. Aerial parts are sometimes eaten by livestock and wildlife and are top killed by fire. Damage to aerial parts activates regrowth shoots from the crown. This summary information on growth development and regeneration of groundplum 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 1955-1962 Study

Groundplum 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 Groundplum 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 Groundplum 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 Groundplum 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

Groundplum resumes annual aerial growth as numerous stout, fleshy decumbent stems arising from a large caudex. The stems spread radially covering a wide circular area. The extensive root system has a stout taproot that can descend to 3.7 m (12 ft). Several main roots arise from the top portion of the taproot spreading horizontally for 46 cm (1.5 ft) then descending to 2.4 m (8 ft). Numerous lateral roots develop from the main roots. The expansive root system has little or no absorption in the top 31 cm (12 in) of soil and does not compete with other plants in the top portion of the soil. Several perfect, pea shaped flowers develop in dense clusters on top of leafless stalks arising from leaf axils. On the fall grazed pastures of the 1955-1962 study, the earliest first flowers appeared 12 May, the mean first flowers occurred on 16 May, with the 5 week flower period extending from early May through the first week of June was observed during the 1969-1971 study (table 1) (Goetz 1963, Zaczkowski 1972). The mean flower stalk height of 17.2 cm (6.8 in) with an annual variance in height from 14.0 cm (5.5 in) to 22.0 cm (8.7 in) was reached during June (table 2) (Goetz 1963). The fruit is large, fleshy, plum like pod that is eatable when young. The top of the fruit turns red when exposed to the sun.

Plant species composition in rangeland ecosystems is variable during a growing season and dynamic among growing seasons. Groundplum has been found to have low abundance on sandy ecological sites. Patterns in the changes in individual plant species abundance was followed for 30 growing seasons during the 1983-2012 study on the shallow and silty ecological sites of the long-term nongrazed, traditional seasonlong, and twice-over rotation management treatments.

On the shallow site of the nongrazed treatment, Groundplum was not present during the total 30 year period (tables 3, 4, and 5).

On the shallow site of the ungrazed seasonlong treatment, Groundplum was not present during the total 30 year period (tables 3, 4, and 5).

On the shallow site of the grazed seasonlong treatment, Groundplum was not present during the total 30 year period (tables 3, 4, and 5).

On the shallow site of the ungrazed twice-over treatment, Groundplum was present during 13.6% and 3.5% of the years that density and basal cover data were collected with a mean 0.06 stems/m^2 density and a mean 0.002% basal cover during the total 30 year period, respectively. During the early period (1983-1992), Groundplum was not present on the shallow site of the ungrazed twice-over treatment. During the later period (1998-2012), Groundplum was present during 20.0% and 6.7% of the years with a mean 0.08 stems/m^2 density and a mean 0.003% basal cover, respectively. The percent present, stem density, and basal cover all increased 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, Groundplum was present during 22.7% and 6.7% of the years that density and basal cover data were collected with a mean 0.13 stems/m^2 density and a mean 0.005% basal cover during the total 30 year period, respectively. During the early period (1983-1992), Groundplum was not present where basal cover data were collected and was present during 14.3% of the years with a mean 0.06 stems/m^2 density. During the later period (1998-2012), Groundplum was present during 26.7% and 6.7% of the years with a mean 0.16 stems/m^2 density and a mean 0.003% basal cover, respectively. The percent present, stem density, and basal cover all increased on the shallow site of the grazed twice-over treatment over time (tables 3, 4, and 5). The percent present, stem density, and basal cover were slightly greater on the shallow site of the grazed twice-over treatment than those on the shallow site of the ungrazed twice-over treatment.

On the silty site of the nongrazed treatment, Groundplum was not present during the total 30 year period (tables 3, 4, and 5).

On the silty site of the ungrazed seasonlong treatment, Groundplum was present during 5.0% and 3.9% of the years that density and basal cover data were collected with a mean 0.02 stems/m^2 density and a mean 0.002% basal cover during the total 30 year period, respectively. During the early period (1983-1992), Groundplum was not present on the silty site of the ungrazed seasonlong treatment. During the later period (1998-2012), Groundplum was present during 6.7% and 6.7% of the years with a mean 0.03 stems/m^2 density and a mean 0.003% basal cover, respectively. The percent present, stem density, and basal cover increased slightly on the silty site of the ungrazed seasonlong treatment over time (tables 3, 4, and 5)..

On the silty site of the grazed seasonlong treatment, Groundplum was not present where basal cover data were collected and was present during 10.0% of the years that density data were collected with a mean 0.08 stems/m^2 density during the total 30 year period. During the early period (1983-1992), Groundplum was not present on the silty site of the grazed seasonlong treatment. During the later period (1998-2012), Groundplum was present during 13.3% of the years with a mean 0.11 stems/m^2 density. The percent present for the density data and the stem density increased slightly on the silty site of the grazed seasonlong treatment over time (tables 3, 4, and 5). The percent present for the density data and the stem density were slightly greater on the silty site of the grazed seasonlong treatment than those on the silty site of the ungrazed seasonlong treatment. The percent present for the basal cover data and the basal cover were slightly greater on the silty site of the ungrazed seasonlong treatment than those on the silty site of the grazed seasonlong treatment.

On the silty site of the ungrazed twice-over treatment, Groundplum was not present during the total 30 year period (tables 3, 4, and 5).

On the silty site of the grazed twice-over treatment, Groundplum was present during 4.6% and 3.3% of the years that density and basal cover data were collected with a mean 0.06 stems/m^2 density and a mean 0.005% basal cover during the total 30 year period, respectively. During the early period (1983-

1992), Groundplum was present during 14.3% and 10.0% of the years with a mean 0.17 stems/m^2 density and a mean 0.01% basal cover, respectively. During the later period (1998-2012), Groundplum was not present on the silty site of the grazed twice-over treatment. The percent present, stem density, and basal cover decreased slightly on the silty site of the grazed twice-over treatment over time (tables 3, 4, and 5). The percent present, stem density, and basal cover were slightly greater on the silty site of the grazed twice-over treatment than those on the silty site of the ungrazed twice-over treatment.

On the shallow sites, Groundplum was present during 7.3% and 2.0% of the years that density and basal cover data were collected with a mean 0.04 stems/m^2 density and a mean 0.001% basal cover, respectively. On the silty sites, Groundplum was present during 3.9% and 1.4% of the years that density and basal cover data were collected with a mean 0.03 stems/m^2 density and a mean 0.001% basal cover. The percent present and stem density were slightly greater on the shallow sites, and basal cover was the same on the shallow and silty sites.

Groundplum was not present on the shallow sites of the nongrazed and seasonlong treatments during the total 30 year period. Groundplum was present on the shallow sites of the twice-over treatments during 18.2% and 5.1% of the years that density and basal cover were collected with a mean 0.09 stems/m^2 density and a mean 0.004% basal cover. Groundplum was not present on the silty site of the nongrazed treatment during the total 30 year period. Groundplum was present on the silty sites of the seasonlong treatments during 7.5% and 1.9% of the years that density and basal cover were collected with a mean 0.05 stems/m^2 density and a mean 0.001% basal cover. Groundplum was present on the silty sites of the twice-over treatments during 2.3% and 1.7% of the years that density and basal cover were collected with a mean 0.03 stems/m^2 density and a mean 0.003% basal cover.

Groundplum had low abundance on the shallow sites of the twice-over treatment: it was present during the early period for one growing season; during the middle period for one growing season; and during the later period for seven growing seasons. Groundplum had low abundance on the silty sites of the twice-over treatment: it was present during the early period for one growing season; during the middle period for one growing season; and during the later period it was not present. Groundplum had low abundance on the silty sites of the seasonlong treatment: it was present during the later period for three growing season. Groundplum was not present on any ecological sites of any management treatment during the period of 1985-1993.

Discussion

Groundplum, *Astragalus crassicarpus*, is a native, late succession, perennial, dicot, forb of the legume family that is commonly present on healthy mixed grass prairie plant communities. Groundplum can grow on shallow and silty ecological sites at low abundance. Annual aerial growth resumes as several decumbent stems arising from a large caudex that has a deep taproot and an extensive root system. The purple to violet perfect, pea shaped flowers develop in clusters on top of leafless stalks. The mean first flower date is 16 May (1955-1962 study), with a five week flower period from early May through the first week of June (1969-1971 study). The mean flower stalk height of 17.2 cm (6.8 in) was reached during June (1955-1962 study). Groundplum has low abundance on the shallow and silty sites of the twice-over treatment and on the silty site of the seasonlong treatment. Groundplum was not present on the shallow and silty sites of the nongrazed treatment and on the shallow site of the seasonlong treatment. Groundplum was not present during the low precipitation period of 1987-1992.

The large caudex, deep taproot, and extensive root system help Groundplum to persist through the harsh conditions of the Northern Mixed Grass Prairie.

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Table 1. First flower and flower period of Astragalus crassicarpus, Groundplum.

	Apr	May	Jun	Jul	Aug	Sep
First Flower						
1955-1962						
Earliest		12				
Mean		16				
Flower Period						
1969-1971		XX XX	X			

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

Table 2. Autecology of Astragalus crassicarpus, Groundplum, 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	14.0	22.0	17.2		97.6	100.0			

Data from Goetz 1963.

Table 3. Autecology of Astragalus crassicarpus, Ground plum, with growing season changes in density importance value, 1983-2012.					
Ecological Site Year Period	Nongrazed	Seasonlong		Twice-over	
		Ungrazed	Grazed	Ungrazed	Grazed
Sandy					
1983-1987	Few Plants Present				
1988-1992					
1993-1998					
1999-2003					
2004-2009					
2010-2012					
Shallow					
1983-1987	0.00	0.00	0.00	0.00	0.90
1988-1992	0.00	0.00	0.00	0.00	0.00
1993-1998	0.00	0.00	0.00	2.94	1.79
1999-2003	0.00	0.00	0.00	0.23	0.50
2004-2009	0.00	0.00	0.00	0.00	0.44
2010-2012	0.00	0.00	0.00	0.53	0.00
Silty					
1983-1987	0.00	0.00	0.00	0.00	1.87
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	0.37	0.00	0.00
2004-2009	0.00	0.23	0.32	0.00	0.00
2010-2012	0.00	0.00	0.00	0.00	0.00

Table 4. Autecology of Astragalus crassicarpus, Ground plum, 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	Few Plants Present				
1988-1992					
1993-1998					
1999-2003					
2004-2009					
2010-2012					
Shallow					
1983-1987	0.00	0.00	0.00	0.00	0.00
1988-1992	0.00	0.00	0.00	0.00	0.00
1993-1998	0.00	0.00	0.00	0.00	0.26
1999-2003	0.00	0.00	0.00	0.09	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	0.00	0.00	0.00	0.00	0.13
1988-1992	0.00	0.00	0.00	0.00	0.00
1993-1998	0.00	0.00	0.00	0.00	0.12
1999-2003	0.00	0.00	0.00	0.00	0.00
2004-2009	0.00	0.07	0.00	0.00	0.00
2010-2012	0.00	0.00	0.00	0.00	0.00

Table 5. Autecology of Astragalus crassicarpus, Ground plum, with growing season changes in density, 1983-2012.					
Ecological Site Year Period	Nongrazed	Seasonlong		Twice-over	
		Ungrazed	Grazed	Ungrazed	Grazed
Sandy					
1983-1987	Few Plants Present				
1988-1992					
1993-1998					
1999-2003					
2004-2009					
2010-2012					
Shallow					
1983-1987	0.00	0.00	0.00	0.00	0.01
1988-1992	0.00	0.00	0.00	0.00	0.00
1993-1998	0.00	0.00	0.00	0.04	0.04
1999-2003	0.00	0.00	0.00	0.01	0.02
2004-2009	0.00	0.00	0.00	0.00	0.02
2010-2012	0.00	0.00	0.00	0.01	0
Silty					
1983-1987	0.00	0.00	0.00	0.00	0.04
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	0.02	0.00	0.00
2004-2009	0.00	0.01	0.01	0.00	0.00
2010-2012	0.00	0.00	0.00	0.00	0.00

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