Autecology of Western Snowberry on the Northern Mixed Grass Prairie

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The autecology of Western Snowberry, *Symphoricarpos occidentalis*, 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).

Western snowberry, wolfberry, buckbrush, *Symphoricarpos occidentalis* Hook., is a member of the honeysuckle family, Caprifoliaceae, and is a native, perennial, deciduous, cool season shrub. Aerial growth has few to several erect flexible stems arising from a woody stem base 1-3 feet (0.3-1 m) tall. Branches develop on the top half of the main stem. Starting the second growing season, one new branch develops from the previous years branch, and a single new branch develops each consecutive growing season. The age of each stem can be determined by the number of branches on that stem. Leaves, flowers, and fruits develop only on current years branches. The root system has vertical roots at each stem base that descend 5 feet (1.5 m) deep, with lateral roots extending 30 inches (76 cm) outward. Several rhizomes develop from each stem base that are about 14 inches (36 cm) deep and extend about 3 feet (1 m) outward with little or no branches; one to several new stems develop at the rhizome ends during spring, followed by the development of a new stem base at that site. The distance between stem bases is about the effective distance of apical hormone control of meristematic buds. The rhizomes between stem bases have opposite paired buds at about 1 inch (2.5 cm) increments, with each bud having the potential to develop into a sprout after apical hormonal control is disrupted. Regeneration is by vegetative and sexual reproduction. Vegetative growth is sprouts from the rhizomes and stem bases. Aggressive development by rhizome and stem bases form dense low colonies that are 3-700 feet (1-200 m) in diameter. Sexual reproduction is from racemes developing from the ends of branches and from the axils of leaves with dense clusters of perfect bisexual flowers with both male and female organs that emerge during late June-August. Pollination is by insects. Fruit is a two nutlet drupe that matures during August-September and is persistent on the plant until eaten and dispersed by birds and small mammals. Seedling establishment is rare. Fire easily top kills aerial stems and activates vigorous sprout growth from the opposite paired buds on rhizomes and from the buds on stem bases. Mowing that cuts off the top half of the stems and heavy browsing removes the apical hormonal control and also activates sprout growth from the rhizomes and stem bases. This summary information on growth development and regeneration of western snowberry was based on the works of Stevens 1963, Great Plains Flora Association 1986, Stubbendieck et al. 2003, Manske 2006a, Hauser 2007, Johnson and Larson 2007, and Stubbendieck et al. 2011.

Procedures

The 1969-1971 Study

The range of flowering time of Western Snowberry 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.

Results

Western snowberry resumed growth during early spring. New stem branches develop from previous branches on aerial woody stems. Erect unbranched flexible aerial sucker stems arise from buds on woody stem bases, on long, 3.0 feet (91 cm), rhizomes, and on short, 1.0 foot (30.5 cm), rhizomes. Branches form on upright stems during the second growing season. Western snowberry grows in association with a great variety of plant communities and vegetation types on a wide variety of soils (Pelton 1953). This report is restricted to grassland plant communities of the mixed grass prairie and is a compendium of the findings by Manske (2006).

Manske (2006) described the annual growing season phenological development of western snowberry in the Northern mixed grass prairie (table 1). The buds swell during mid to late April after 14 hours of daylenght has been received, twig elongation occurs during mid April to early June, leaf opening begins during mid April to early May, sucker development from buds on the long and short rhizomes is slightly delayed and occurs during late April to early June, full leaf expansion of all the leaves occurs during mid May to late May, flower buds appear during late May to late June, initial flowers appear during mid June to late June, flower development period occurs during mid June to mid August, fruit development occurs during late July to mid August, fruits mature to white snowberries during August to September, and leaf senescence occurs during late August to October. Fruits persist attached to the plants through winter unless removed by bird or mammal.

The flowering period occurred from late June through late July during the 1969-1971 study (table 2) (Zaczkowski 1972).

Western snowberry encroachment into northern mixed grass prairie communities has been a serious problem since the early 1900's. When grassland ecosystems are managed with traditional grazing practices or managed to exclude grazing, the belowground resource uptake competitiveness in grasses is greatly reduced creating the opportunity for western snowberry invasion.

In the northern mixed grass prairie, western snowberry develops large colonies (table 3). The size of these colonies ranges in diameter from 1 to 82 yards (1-75 m) with the typical colonies having diameters of 22 to 55 yards (20-50 m). Canopy cover ranges from 12.3% to 93.1% with average cover between 24.0% to 44.9%. Some colonies become dense enough to completely shade out Kentucky bluegrass which is usually at the oldest portion near the center. Stem density varies within a colony with the greatest density of 49.5 stems/yd^2 (59.2/m^2) at the center and the lowest density of 28.1 stems/yd^2 (33.6/m^2) at the periphery. Average stem densities range from 38.5 to 61.8 stems/yd^2 (46.0-73.9/m^2). Stem height varies within a colony with the greatest height of 45 inches (115 cm) at the center and the shortest height of 16 inches (40 cm) at the periphery. Average stem height ranges from 17.0 to 29.5 inches (43.2-75 cm). Average mature stem age is 7.2 years with the maximum stem age at 13.0 years.

The successful survival of western snowberry in the Northern Plains is attributable to the persistence of the extensive rhizome system (table 3). Rhizomes possess pairs of meristematic nodes along the complete length at about one inch intervals that have the potential to produce both roots and new aerial stems. Basically, rhizomes develop at two distinct lengths. Long rhizomes are 3.0 feet (91 cm) long and grow from a stem base to the site of a new stem base that can produce several aerial stems. Short rhizomes are around 1.0 foot (30.5 cm) long and grow as a branch to produce one sucker stem.

The rhizome diameter ranges from 0.12 to 0.24 inches (3-6 mm) with an average of 0.16 inches (4 mm). At the junction of a rhizome and a rhizome branch, the diameter increases to 0.39 inches (1 cm) and at the junction of a rhizome and a stem base, the diameter increases to 0.79 inches (2 cm). Rhizomes are the primary underground organ of western snowberry and typically grow at 2 to 6 inches (5-15 cm) below the soil surface. This amount of soil provides good protection and rhizomes have been found to live for 40 years. Roots can develop at the meristematic nodes on the rhizomes usually as opposite pairs with one root larger than the other. The larger roots can descend to depths of 61 inches (155 cm). Mycorrhizal fungi form symbiotic relationships with the western snowberry roots. Aerial stems develop from the meristematic nodes on the rhizomes. Rhizome suckers can develop directly from a node or a short rhizome can grow one foot out from the rhizome then turn up and produce an aerial rhizome sucker. New stem bases are produced at the end of a long (3 foot (91 cm)) rhizome. Several aerial stems can develop at stem bases without rhizomes that are crown suckers. Pelton (1953) excavated a complete 10 year old colony and determined that the cumulative rhizome length was 4.4 times longer than the cumulative length of the aerial stems which clearly shows the relative importance of the rhizome system to a western snowberry colony.

Western snowberry produces great numbers of seeds but few seedlings (table 4). An average mature stem produces 160.3 flower buds, that develop into 119.6 mature fruits with 2 nutlets (239.2 nutlets) of which only 122.5 of the nutlets are filled resulting in 48.8% defective nutlets. The weight of 1000 filled nutlets ranges between 5.9 and 6.5 grams. The mature fruits persist on the stems during winter and usually fall to the ground in the spring. The density of nutlets in the soil is around 200/ft^2. The nutlet germination is a complex double-dormancy mechanism with a multiple stage afterripening process and on average only 1% of the nutlets are viable. The optimum temperature for spring germination ranges between 41° F to 59° F (5°-15° C). Seedlings have a high mortality rate at 86% because they have few defenses against insects, diseases, water stress, and competition from other plants. Despite the high rate of defective nutlets, the extremely low rate of viability of filled nutlets, the complexity of the germination process, the high rate of seedling mortality, and the low rate of seedling establishment, western snowberry is extremely successful in the grasslands of the Northern Plains because of the widespread use of naive antagonistic management practices.

After a western snowberry colony has become established in a grassland community it is difficult to remove. The aerial stems are relatively easy to kill with fire, mowing, and foliar herbicides. These treatments do not kill the rhizomes which usually produce more aerial stems post treatment than existed pretreatment. Reducing and killing western snowberry rhizomes can be accomplished through two mechanisms: 1) destroy all of the meristematic buds on the rhizomes and stem bases, or 2) deplete the nonstructural carbohydrate stores while preventing replenishment of the depleted carbohydrates. Successful treatment of western snowberry requires knowledge of the biology of burning, mechanical, and chemical management practices.

Western snowberry aerial stems are sensitive to fire, and even if they are not completely consumed by the fire, the stems usually die to ground level. Because of the protection provided by soil, the belowground rhizomes and stem bases are usually not damaged by fire. These belowground parts have large quantities of buds that have the potential to develop into new aerial sucker stems. Vegetative reproduction of sucker stems from meristematic buds is regulated by apical dominance by an aerial stem through the production of inhibitory hormones that block or suppress the activity of growth hormones. When the aerial stem is killed or damaged, the production of inhibitory hormones is reduced or stopped, and the growth hormones activate the meristematic tissue in the rhizome and stem base buds. Spring burns result in great quantities of sucker stems. The new plant material can completely replenish the carbohydrate stores in one growing season. Spring burns do not decrease stem frequency and in little time the stem densities on the burn treatments are similar or greater than the stem densities on the unburned areas. August fires remove all or most of the top growth and result in fewer sucker shoots the following year than spring burns. Four burns are required to reduce western snowberry aboveground biomass production and stem frequency. However, even after 24 years, annually repeated prescribed burns cannot remove western snowberry from the northern mixed grass prairie.

Mechanical mowing treatments can effectively reduce western snowberry stem densities by causing depletion of stored nonstructural carbohydrate energy through repeated cutting of aerial stems at the times when the carbohydrate reserves are low. Energy reserves are reduced when vegetative sucker regrowth is produced. Repeat cutting is required to prevent replenishment of reserves when the replacement suckers produce greater quantities of carbohydrates than they use for growth. Plant growth requirements cause carbohydrate drawdown during rapid spring growth, from mid April to early June; during fruit fill, from mid July to early August; and during pre-winter root growth and bud development, from early September to late October.

The mowing height of western snowberry colonies in grazed pastures should not be close to the ground, at the height that hay is cut, but the mowing height should be raised to about 8 or 9 inches above the ground where the branches on the stems develop. The cutting height should be set so most of the leaves and branches on the typical stems are removed and a relatively tall, flexible, bare stem remains. Intact mature stems are flexible and can be bent to the ground without breakage. Stems cut short are very rigid and do not bend when stepped on. Short, rigid, sharp stems can be serious problems for cattle walking through closely mowed western snowberry colony areas. The stiff stems can puncture the sole of the hoof, causing an injury open to infection that can possibly result in hoof rot.

Single annual mowing treatments do not reduce stem numbers, because the regrowth of sucker stems can replenish the carbohydrate reserves during one growing season. Double mowing treatments can be effective at reducing stem numbers when mowing periods are conducted for maximum carbohydrate depletion. The seasonal low carbohydrate reserves for western snowberry occur from the period of rapid growth until near the start of flowering, between May and mid June. The first mowing treatment conducted during the last week in May through the third week in June should cause considerable depletion of stored carbohydrates. Growth of sucker shoots should continue to deplete carbohydrate reserves for nearly six weeks, until the new sucker stems develop about ten leaf pairs. A second mowing treatment conducted sometime during late July through August is needed to prevent full carbohydrate replenishment. Mowing in late July or August also cause a substantial amount of winter injury to late-season lateral bud sprouts on the stem bases. Double mowing treatments will need to be repeated for several years to completely deplete the carbohydrate stores. A few short sucker stems have developed on several treatment sites during the fourth growing season after the start of double mowing management practices.

Chemical management treatments of

western snowberry are separated into two categories based on the herbicides mode of entry which is either foliage-active or soil-active. The successfulness of a chemical treatment depends on sufficient quantities of the herbicide reaching the site or sites of activity which requires the manager to know the strengths and weaknesses of the plant and the mechanism of action of the chemical.

Foliage-active herbicides are applied directly to leaves and stems of the plant. The herbicides must penetrate the cuticle layer, enter the leaves, be absorbed through leaf tissue by diffusion, move to the phloem vascular system, and be translocated down to the rhizomes and stem bases, locate the meristematic buds, then terminate the regenerative capabilities of the colony. Western snowberry leaves mature rapidly, developing a thick waxy cuticle layer and dense cell walls. A good commercial surfactant must be added in order for the herbicide to penetrate the cuticle. Diesel fuel does not work well enough on western snowberry leaf wax. During the period of rapid twig elongation, from mid April to early June, nonstructural carbohydrates move from the storage sites in the rhizomes and stem bases upward through the phloem vascular system to the active growing points. The upward movement of carbohydrates through the phloem prevents downward movement of herbicides. Sometime between early June and mid June, the carbohydrate production by leaf photosynthesis exceeds the demands from growth, and the surplus carbohydrates are moved downward through the phloem for storage in the rhizomes and stem bases. This change in direction of carbohydrate flow permits the translocation of herbicides from the leaves downward to the belowground plant parts. At this stage, the leaf cuticle is becoming thicker, increasing the resistance to herbicide and surfactant penetration and absorption. During only a brief vulnerable stage, from about 10 June until 20 June, when herbicide penetration into leaf tissue is decreasing and herbicide translocation downward is increasing, can foliage-active herbicides be successful at reaching and killing the meristematic buds on the rhizomes and stem bases. It is highly probable that multiple annual applications of foliage-active herbicides will be necessary to kill all of the active meristematic buds on the belowground parts.

Soil-active herbicides are applied directly to the soil within the root zone of a western snowberry colony. Translocated soil-active herbicides must be moved into the soil by rain water, absorbed by the plant roots, and then moved upward through the nonliving vessel cells of the xylem vascular system to the leaves. Tebuthiuron is a soil applied amide-urea derivative herbicide that interferes with the leaf photosynthetic process, reducing the production of carbohydrates, and causing premature aging and shedding of the leaves. Several leaf defoliation cycles causes drawdown of the nonstructural carbohydrate reserves, and when these stores are depleted, the plant dies. Tebuthiuron resists photodecomposition and volatilization, and biological breakdown through microbial activity is slow. Several years of leaf defoliation cycles may be required for complete depletion of stored nonstructural carbohydrates and plant death. Tebuthiuron (Spike 20P) applied at 0.50 lb ai/ac causes noticeably rapid topgrowth deterioration during the first growing season and a high percentage of the aboveground stems are dead during the first three years. The rate of plant deterioration slows during the fourth growing season, presumably the herbicide effects continue at progressively slower rates until the effects from tebuthiuron completely cease during year 6 to 8 after application. If new sucker stems develop during the fifth growing season, a second application at 0.25 lb ai/ac should be made before the end of the sixth growing season.

Western snowberry cannot be killed with one application of one treatment. Western snowberry has several biological mechanisms and processes that provide the shrub with strong capabilities to survive natural and human caused detrimental conditions. However, it does have a few weaknesses and periods of vulnerability that can be used effectively to reduce and kill western snowberry colonies on the northern mixed grass prairie.

Discussion

Western snowberry, *Symphoricarpos occidentalis*, is a common shrub capable of producing large colonies on numerous ecological sites in mixed grass prairie plant communities where the belowground resource uptake competitiveness of the grasses has been reduced by naive antagonistic management practices. Each year western snowberry resumes stem growth during early spring after 14 hours of day length has been received around mid April. Stem branches develop from the previous years branches, and a single new branch develops each consecutive growing season. The age of each aerial woody stem can be determined by the number of branches on that stem. Leaves, flowers, and fruits develop only on current years branches. Sucker stems development from buds on the long and short rhizomes and stem bases is slightly delayed and occurs during late April to early June. Flower buds appear during late May to late June. The flower (anthesis) period occurs during mid June to mid August. Fruits develop during late July to mid August and mature during August to September. Fruits remain attached to the plants through winter and drop to the ground the following spring. The typical colony diameter ranges around 22 to 55 yards (20-50 m). Average canopy cover ranges between 24% to 45%. Average stem density ranges between 39 stems to 62 stems/yd^2 (46-74/m^2). Average stem height is around 30 inches (75 cm) and the average mature stem lives for 7.2 years. The successful survival of western snowberry in the northern mixed grass prairie is because of the extensive rhizome system. The total length of a rhizome system is 4.4 times longer than the total aerial stem length. The persistent rhizomes with numerous meristematic buds that are capable of producing roots and aerial stems are the primary reason western snowberry is difficult to reduce or kill.

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Table 1. Phenological development of Symphoricarpos occidentalis, Western snowberry.

Phenological Stages	Time Period
Bud Swell	April, 14 hours of day length
Twig Elongation	mid April to early June
Leaf Opening	mid April to early May
Sucker Development	late April to early June
Full Leaf, with all fully expanded	mid May to late May
Flower Buds Appear	late May to late June
Initial Flowering (Anthesis)	mid June to late June
Flower Development	mid June to mid August
Fruit Development	late July to mid August
Fruit Mature (white)	August to September
Leaf Senescence	late August to October

Data from Manske 2006.

Table 2. Flower period of Symphoricarpos occidentalis, Western snowberry.

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

Flower Period Data from Zaczkowski 1972.

Table 3. Quantitative dimensions of Symphoricarpos occidentalis, Western snowberry colonies.

Component Part	Measurement	Key: Data Source (A, B, C, D, E)
Colony Size		
Diameter range 1.1 to 2.2 yards (1-2 m) to 55 to 82 yards (50-75 m) (A)		
Diameter typically 22 to 55 yards (20-50 m) (B & C)		
Canopy Cover		
Cover average of 15 colonies 44.9%, range 17.6% to 93.1% (C)		
Cover average of 15 colonies 24.0%, range 12.3% to 47.3% (B)		
Cover average of 8 colonies 32.6%, range 14.7% to 46.8% (D)		
Cover of 20 colonies, half were dense enough to completely shade out Kentucky bluegrass (A)		
Stem Density		
Density varies within a colony, the greatest at center, the lowest at periphery		
Density at center 49.5 stems/sq. yard ($59.2/m^2$), at edge 28.1 stems/sq. yard ($33.6/m^2$) (B)		
Average density 38.5 stems/sq. yard ($46.0/m^2$) (A)		
Average density 40.7 stems/sq. yard ($48.7/m^2$) (B)		
Average density 61.8 stems/sq. yard ($73.9/m^2$) (C)		
Stem Height		
Height varies within a colony, the greatest at center, the lowest at periphery		
Height average 29.5 inches (75 cm), range 16 to 45 inches (40-115 cm) (A)		
Height mature average 17.0 inches (43.2 cm) (B)		
Peak annual height determined by Apr-May precipitation (D)		
Stem Age		
Average mature stem age 7.2 years, maximum age 13.0 years (A)		

Table 3 cont. Quantitative dimensions of Symphoricarpos occidentalis, Western snowberry colonies.

Component Part	Measurement	Key: Data Source (A, B, C, D, E)
Rhizome Length		
Long Rhizome, between stem bases, 3.0 feet (91 cm) (E)		
Short Rhizome, branch to sucker stem, 1.0 feet (30.5 cm) (E)		
Rhizome Diameter		
Diameter average 0.16 inches (4 mm), range 0.12 to 0.24 inches (3-6 mm) (E)		
Diameter at junction with rhizome branch 0.39 inches (1 cm) (E)		
Diameter at junction with stem base 0.79 inches (2 cm) (E)		
Rhizome Depth		
Typical depth below soil surface 2 to 6 inches (5-15 cm) (A)		
Root Depth		
Roots can extend down to 61 inches (155 cm) in depth (A)		
Rhizome Age		
Rhizome age to 40 years old (A)		
Stem Types from Rhizome Buds		
Stem bases develop at end of long rhizomes, 3.0 feet (91 cm) long (E)		
Rhizome suckers develop at end of short rhizomes, 1.0 feet (30.5 cm) long (E)		
Crown suckers develop at stem bases, no rhizomes (E)		
Total Rhizome Length vs Total Aerial Stem Length		
10 year old colony, cumulative rhizome length 4.4 times longer than cumulative aerial stem length (A)		

Data Sources (A) Pelton 1953 Minnesota
(B) Roel 1983 south central North Dakota
(C) Ransom-Nelson 1985 south central North Dakota
(D) Mastel 1983 western North Dakota
(E) Manske 2006 western North Dakota

Table 4. Quantitative Seed Production of Symphoricarpos occidentalis, Western snowberry.

Component Part	Measurement	Key: Data Source (A, F)
Seed Production		
Average mature stem production:	160.3 flower buds	
	119.6 mature fruits with 2 nutlets	
	122.5 filled nutlets	
	48.8% defective nutlets (A)	
Filled Nutlet Weight		
1000 filled nutlets	6.53 grams (A) Minnesota	
1000 filled nutlets	5.85 grams (F) North Dakota	
Viability of Nutlet Bank in Soil		
Sample area 1 sq foot, Replicated 10 times		
	200 nutlets/ft^2	
	1% viable (A)	
Nutlet Germination Type		
Complex double-dormancy mechanism with a multiple stage afterripening process (A)		
Spring Germination		
Optimum temperature range 41° F to 59° F (5°-15° C) (A)		
Seedling Mortality		
Mortality rate 86% (A)		

Data Sources (A) Pelton 1953 Minnesota
(F) Stevens 1932 North Dakota

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