Evaluation of Western Snowberry Management Practices: A Study and Demonstration

Curtis J. Hullick and Llewellyn L. Manske PhD
Grazing Project Coordinator, Critical Wildlife Habitat Program, Shoal Lake, MB.
Range Scientist, North Dakota State University, Dickinson Research Extension Center, Dickinson, ND.

Western snowberry can successfully invade and expand on grasslands because the shrub's rhizomes and clusters of stem bases are persistent and produce numerous growing points of meristematic tissue that can vegetatively grow into additional aerial stems and rhizomes. By shading the native grass vegetation with taller aerial stems that have the competitive advantage for the aboveground resource of sunlight, the shrub can eliminate existing native grass community species and convert the area into brush habitat with a replacement understory community of Kentucky bluegrass.

The problem of western snowberry expansion on the grazinglands of Canada and the United States has been occurring for over one hundred years. The widespread practice of suppressing grassland wildfires and the implementation of traditional grazing practices that are antagonistic to the biological requirements of grass plants and to the biogeochemical processes in grassland ecosystems reduce the competitive abilities of native grass plants and facilitate the encroachment and enlargement of western snowberry colonies.

To improve native plant species biodiversity, the wildlife habitat, and the economic status of land owners on the mixed grass prairie of western Manitoba, the Critical Wildlife Habitat Program, has been conducting a prairie management project that instructs livestock producers about biologically effective grazing practices. This plant friendly grazing management improves the health and competitive abilities of the native grass plants but does not remove the aerial stems and reduce the size of the preexisting western snowberry colonies. Some additional type of management is needed to diminish western snowberry colonies on prairie. This prairie restoration study and demonstration project was conducted to gain understanding of management practices that land owners can use to reduce western snowberry aerial stems in their grazinglands.

Procedure

The western snowberry management study and demonstration was conducted on about 12 acres of grazingland located south of Cromer, between Virden and Melita, Manitoba, on NE 23-08-24-WPM and NW 24-08-24-WPM. The plant community was mixed grass prairie that had been overrun by western snowberry and Kentucky bluegrass. Rectangular treatment plots of approximately 2.25 acres were arranged in a strip block design with each randomly assigned treatment block consisting of 5 replications of about 0.45 acres. Four management treatments and a control of no treatment were conducted and evaluated as two separate trials.

Trial I was a chemical management study that evaluated spray application of dicamba plus 2,4-D and wick application of glyphosate. The herbicide spray-application treatment was conducted on 7 June 2001. A mixture of dicamba (Banvel) and 2,4-D was spray applied at the near maximum rate of 1.97 qt dicamba + 1.92 qt 2,4-D (2.0 lb ae dicamba + 1.8 lb ae 2,4-D) per acre with a quad ATV equipped with a tank and pump. The herbicide wick-application treatment was conducted on 5 June 2001. Glyphosate (Roundup) mixed at a 1:2 ratio in water was wick applied with a sixteen-foot wick applicator mounted on the front-end loader of a farm tractor. The application rate was difficult to calibrate and was estimated to be around the maximum rate of 3 qt glyphosate (2.25 lb ae glyphosate) per acre. The over-the-top wick method was used on this treatment to apply the nonselective herbicide to only the taller shrub leaves and to prevent the chemical from coming in contact with the understory vegetation.

Trial II evaluated burning and mechanical management practices. The prescribed burn management treatment was conducted on 2 May 2002. The fire was controlled with a mowed strip and a wet line. The fire was lighted a short distance from the wet line, the back fire was put out at the wet line, and the head fire formed a surround fire; all sides met in the middle of the plot. The mechanical management treatment was conducted on 31 May 2002. A five-foot flail mower pulled by a farm tractor was adjusted to cut the branches and leaves from the shrub stems at about 8 to 10 inches above the ground. Short, rigid stems can puncture the soles of the hooves of cattle walking through the mowed western snowberry colony areas. Relatively tall, flexible, bare aerial shrub stems and most of the understory vegetation remained on the plots following the completion of the mowing treatment.

Aboveground herbage biomass production was sampled by the clipping method. The understory herbaceous vegetation in five half-meter square frames was clipped to ground level. Shrub live stem density was determined by counting all living aerial stems rooted within five one-meter square frames. Pretreatment aboveground herbage biomass and live stem density data were collected from all plots 29-30 May 2001. Post treatment herbage biomass data were collected 17-21 June 2002. Visual estimates of positive or negative changes in living stems were made during the growing season following treatment. Post treatment live stem density data were collected from all plots 17 November 2004 and 30 August-1 September 2005. Differences between means were analyzed by a standard paired-plot t-test (Mosteller and Rourke 1973).

Results

In the Melita, Manitoba, area, the long-term mean (LTM) annual temperature is 37.4° F (3.0° C) (table 1). January is the coldest month, with a mean temperature of 2.1° F (-16.6° C). July and August are the warmest months, with mean temperatures of 66.5° F (19.1° C) and 65.0° F (18.3° C), respectively. Plants experience temperature stress during months with mean monthly temperatures below 32.0° F (0.0° C). From November through March each year, plants in western Manitoba cannot conduct active growth because mean temperatures are below 32.0° F (0.0° C) (table 1).

The long-term annual precipitation in the Melita, Manitoba, area is 16.71 inches (424.5 mm) (table 1). The growing season precipitation (April through October) is 12.94 inches (317.0 mm), 77.44% of the annual precipitation. The seasonal period during which the greatest amount of precipitation occurs is spring, April, May, and June, with 6.60 inches (161.7 mm), 39.50% of the annual precipitation. June has the greatest monthly precipitation, 3.29 inches (80.6 mm). The precipitation received during the 3-month period of May, June, and July accounts for 48.06% of the annual precipitation (8.03 inches, or 196.7 mm). The combined amount of precipitation received during the 5-month period of November through March averages 3.77 inches, (92.4 mm), 22.56% of annual precipitation. The seasonal period during which the least precipitation occurs is winter, January, February, and March, with 2.08 inches (51.0 mm), 12.45% of the annual precipitation.

A technique reported by Emberger et al. (1963) was used to identify water deficiency months from temperature and precipitation data. This method graphs the mean monthly temperature (°C) and monthly precipitation (mm) on the same axis, with the scale of the precipitation data at twice that of the temperature data. The temperature and precipitation data are plotted against an axis of time. The resulting ombrothermic diagram shows general monthly trends and indicates the months with water deficiency conditions, unfavorable periods during which perennial plants experience water stress. Water deficiency exists during months when the precipitation data bar drops below the temperature data curve. Plants are under temperature stress when the temperature curve drops below the freezing mark (0° C).

The long-term ombrothermic graph for the Melita area (figure 1) shows that August and September typically have near water deficiency conditions. In the long term, August and September have had water deficiency conditions during 60.0% and 50.0% of the years, respectively. The ombrothermic diagram (figure 2) for the years of the study period shows that August and September 2001, July and August 2003, and August and September 2005 had water deficiency conditions that caused water stress in plants growing near the vicinity of Melita, Manitoba.

Annual precipitation during the study period averaged 17.23 inches (437.6 mm), 103.1% of LTM, and growing season precipitation, April through October, averaged 13.76 inches (349.5 mm), 106.3% of LTM. The annual precipitation and growing season precipitation were greater than the long-term means during 2000, 2002, 2004, and 2005, and lower than the long-term means during 2001 and 2003 (table 2). The growing season precipitation during 2001 and 2003 was 71.5% and 54.6% of the long-term mean, respectively, and the total annual precipitation was 69.4% and 57.6% of the long-term mean, respectively (table 2). The water deficiencies during 2001 and 2003 caused water stress in perennial plants and restricted herbage biomass production in the region.

Mastel (1983) found that low precipitation during April and May, the period of growth initiation and rapid twig elongation of western snowberry, was important in determining the quantity of total annual growth even if the remainder of the growing season received near normal precipitation. The precipitation that occurred in the study area during April and May of 2002 and 2003 was only 43.2% and 62.8% of the long-term mean, respectively (table 2). These two-month water deficiency periods caused severe water stress in western snowberry during the critical early spring rapid growth stage and greatly restricted the quantity of twig growth. During 2001, the April-May precipitation was 3.47 inches (88.1 mm), 103.3% of LTM, and normal early spring growth occurred. However, the June-July-August precipitation was only 5.22 inches (132.6 mm), 69.7% of LTM (table 2). The growing season water deficiency that occurred during 2001 placed western snowberry colonies under water stress that resulted in restriction of vegetative stem development, and no new sucker stems were produced on the untreated plots.

The pretreatment herbage biomass produced on the spray-applied and wick-applied herbicide treatments of trial I was not significantly different (P<0.05) from the pretreatment herbage biomass produced on the control treatment (table 3). The herbage biomass produced one year post treatment was significantly greater (P<0.05) than the pretreatment herbage biomass on the spray-applied herbicide treatment and the control treatment (table 3). The heavy rate of dicamba plus 2,4-D of the spray-applied treatment damaged some of the grass understory during the treatment year but apparently did not alter herbage biomass production during the first growing season following herbicide treatment. The post treatment herbage biomass produced on the spray-applied herbicide treatment and biomass produced on the control treatment were not significantly different (P<0.05) (table 3). The herbage biomass produced one year post treatment was not significantly different (P<0.05) from the pretreatment herbage biomass on the wick-applied herbicide treatment (table 3). The wick-applied herbicide was wiped onto the western snowberry leaves by a wick applicator in front of a farm tractor. The tires of the tractor came in contact with the herbicide on the leaves and transferred the chemical to the understory vegetation; the considerable damage the grasses and forbs sustained from the herbicide resulted in a reduction in herbage biomass production the following growing season.

The pretreatment live stem densities of western snowberry on the spray-applied and on the wick-applied herbicide treatments of trial I were not significantly different (P<0.05) (table 4). The pretreatment live stem density on the spray-applied herbicide treatment was not significantly different (P<0.05) from that on the control treatment (table 4). The pretreatment stem density on the wick-applied herbicide treatment was significantly greater (P<0.05) than the pretreatment stem density on the control treatment (table 4). Stem density is not uniform throughout large western snowberry colonies. Both the spray-applied herbicide treatment with the maximum rate of dicamba plus 2,4-D and the wick-applied herbicide treatment with the maximum rate of glyphosate effectively killed all of the aerial stems. There were no live aerial stems on the spray-applied and wick-applied herbicide treatments about a month after the herbicide application. The visual estimate method for evaluation of stem density detected no change from the pretreatment densities in the quantity of live aerial stems on the untreated plots during the 2001 growing season (table 4). The western snowberry plants recovered from the chemical management treatments during the first and second years following herbicide application. During the third and fourth growing seasons post treatment, the live stem densities on the spray-applied and wick- applied herbicide treatments were not significantly different (P<0.05) from the live stem density on the untreated control treatment (table 4).

The pretreatment herbage biomass production on the burn management and the mow management treatments of trial II was not significantly different (P<0.05) (table 5). The pretreatment herbage biomass production on the mow management treatment was not significantly different (P<0.05) from that on the control treatment (table 5). The pretreatment herbage biomass on the burn management treatment was significantly greater (P<0.05) than the pretreatment herbage biomass on the control treatment (table 5). The herbage biomass produced one year post treatment was significantly greater (P<0.05) than the pretreatment herbage biomass on the control treatment (table 5). The herbage biomass produced seven weeks post treatment on the burn management treatment was not significantly different (P<0.05) from that produced on the control with no treatment (table 5). The herbage biomass produced three weeks post treatment on the mow management treatment was significantly less (P<0.05) than that produced seven weeks post treatment on the burn treatment but not significantly different (P<0.05) from the herbage biomass produced one year post treatment on the control treatment (table 5).

The pretreatment live stem densities of western snowberry on the burn management treatment and on the mow management treatment of trial II were not significantly different (P<0.05) from the pretreatment stem density on the control treatment (table 6). Both the burn management and the mow management treatments effectively killed all of the aerial stems. There were no live aerial stems on the burn management and mow management plots following application of treatments. Numerous sucker stems were visually observed on the mowing management plots during the middle and latter portions of the treatment growing season. Several sucker stems grew on the burn management plots during the latter portions of the treatment growing season. At 2.5 years post treatment, the live stem density on the mow management treatment was not significantly different (P<0.05) from the stem density on the control treatment (table 6). The live stem density on the burn management treatment was significantly less (P<0.05) than the stem density on the control treatment 2.5 years post treatment (table 6). The live stem density on the burn management and that on the mow management treatments were not significantly different (P<0.05) from the stem density on the control treatment during the third year post treatment (table 6).

The spray-applied dicamba plus 2,4-D herbicide treatment, the wick-applied glyphosate herbicide treatment, the burn management treatment, and the mow management treatment were effective at completely killing the aerial stems of western snowberry. The belowground plant parts received little, if any, damage from these four management treatments. The rhizomes and the stem base clusters on the crowns recovered from one application of the respective treatments and by the third growing season post treatment had produced sucker stems equal to the density of the aerial stems on areas that received no treatment.

Effective Management Practices

Development of successful management practices for the reduction of western snowberry in grazinglands requires an understanding of how the shrub grows, when phenological growth stages occur, and when the shrub has vulnerable periods in its life cycle.

Western snowberry has an extensive interconnected rhizome system with clusters of stem bases that are protected by 1 to 14 inches of soil. Each of the numerous nodes along the rhizomes produces a pair of buds or growing points that have the potential to grow vegetatively into new rhizomes and aerial stems. Growth of the rhizome buds is regulated by a complex hormone system controlled by a dominant stem. When a lead aerial stem is killed or damaged by unfavorable environmental conditions or management treatments, the production of inhibitory hormones is reduced or stopped, and growth hormones activate the rhizome buds to develop several new rhizomes and sucker stems (Manske 2005a).

Western snowberry starts growing in mid to late April, when there are at least 14 hours of daylight. Rapid twig elongation and leaf growth and expansion occur at the same time and continue until late May or early June, when pinkish flower buds appear at the twig tips. By early June, the twigs are about 75% of full growth and the leaves are near full expansion. Twigs continue growing at a slower rate, and by mid June they have completed about 95% of their annual growth. Flower buds continue to appear in the leaf axils until about late June. The first flowers begin opening at the twig tips around mid June, and subsequent new flowers open at lower leaf axils through July and sometimes into mid August. After fertilization, the fruits fill and ripen during mid July to late August. Most of the fruits remain attached to the stems all winter. Leaf senescence usually occurs during late August to October (Manske 2005a).

The quantity of stored nonstructural carbohydrates is related to plant growth and reproduction, with the cycles of drawdown and replenishment following a typical pattern each growing season. A sharp drawdown in carbohydrate reserves occurs during the rapid growth of early spring, from mid April to early June. Rapid replenishment occurs during the flowering stage, from early June to mid July. A second drawdown period occurs during fruit fill, between mid July and early August. A second replenishment period occurs between mid August and early September. A gradual third drawdown occurs during pre-winter root growth and bud development, from early September to late October (Manske 2005a).

Management of prairie with traditional grazing practices that are antagonistic to the biological requirements of grass plants and the biogeochemical processes in the grassland ecosystem reduces the health status of grass plants and weakens their competitive abilities to acquire soil water and mineral nitrogen. Grass plants in diminishing condition relinquish greater quantities of ecosystem natural resources that become available for western snowberry colony expansion and increase in stem density. The aerial stems have the competitive advantage over the grass understory for the sunlight resource. The quantity of light reaching the grass plants is below the light saturation point of most native grassland species, and the shading reduces grass biomass production severely, causing reduction in pasture carrying capacity (Manske 2005a).

Healthy grass plants are superior competitors for belowground resources of soil water and mineral nitrogen and can suppress western snowberry encroachment (Kochy 1999, Kochy and Wilson 2000, Peltzer and Kochy 2001). Implementation of grazing management practices that meet the biological requirements of plants and enhance the biogeochemical processes in grassland ecosystems increases vegetative tillering and rhizosphere organism activity. The result is a healthy, dense, productive grass population that is highly competitive for belowground resources and creates the strongest possible biological barriers to western snowberry encroachment (Manske 2005b).

Livestock and wild ungulate browsing has only a relatively small direct effect on aerial stems of western snowberry and the size and densities of the colonies. Some additional types of management practices that use burning, mechanical, or chemical methods are required to reduce existing western snowberry colonies on grazinglands.

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. The belowground rhizomes and rhizome crowns with clusters of aerial stems are usually not damaged by fire. The belowground parts have large quantities of buds that have the potential to develop into new aerial sucker stems. Stem density on burn treatments recovers and is similar to the density of stems on the unburned reference areas during the third growing season following burning (Pelton 1953, Romo et al. 1993).

Prescribed burning can be used to remove western snowberry aerial stems, and four every-other-year burns can reduce shrub stem frequency. Prescribed fires during August cause the least damage to native cool- and warm-season grasses and perennial forbs. August fires remove all or most of the top growth of western snowberry and result in fewer sucker shoots the following year than spring burns. Prescribed burning alone, however, will not remove western snowberry from the northern mixed grass prairie (Manske 2005c).

Mechanical mowing treatments can effectively reduce western snowberry stem densities by causing depletion of stored nonstructural carbohydrate energy from 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 (Adams and Bailey 1983).

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 should be raised to about 8 or 9 inches above the ground. The cutting height should be set so most of the leaves and branches on the typical stems are removed and relatively tall, flexible, bare stems remain. 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 the mowed western snowberry colonies. The stiff stems can puncture the sole of the hoof, causing an injury that is 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 during 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 causes a substantial amount of winter injury to late-season lateral bud sprouts on the stem bases. Double mowing treatments will need to be repeated two, three, or more seasons, depending on the quantity of stored carbohydrates of the western snowberry colonies at the start of the mowing treatments (Manske 2005d).

Successful chemical management of western snowberry depends on terminating the regenerative capabilities of the rhizomes and the cluster of stem bases on the crowns. Two critical factors must occur in order for sufficient quantities of foliage-active herbicides to reach the site of activity in the belowground plant parts and interfere with their physiological processes. First, the herbicides must enter the leaf tissue through the stomata openings or penetrate the outer cuticle layer, be absorbed through leaf tissue by diffusion, and be moved to the vascular system within the leaf. Second, the herbicides must be translocated from the leaves downward through the phloem vascular system to the metabolically active sites of the crowns and rhizomes. During spring rapid twig elongation, from mid April to early June, nonstructural carbohydrates move from the storage site in the rhizomes and the crowns upward through the phloem vascular system to the active growing points. The upward movement of carbohydrates through the phloem prevents downward movement of herbicides. Herbicides can readily penetrate young western snowberry leaves during May and early June but cannot be translocated downward. Sometime between early June and mid June, the carbohydrate production by leaf photosynthesis exceeds the carbohydrate demands from growth, and the surplus carbohydrates are moved downward through the phloem for storage in the rhizomes and crowns. This change in direction of carbohydrate flow permits the translocation of herbicides from the leaves downward to the belowground plant parts. The leaves have continued to mature, developing a thicker cuticle layer and denser cell walls; the result is an increased resistance to herbicide penetration and absorption. The two critical factors for successful chemical management of western snowberry occur coincidentally 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. Leaf penetration by herbicides is improved with wetting agents, and these surfactants should be added to all foliage-active herbicide spray mixtures (Manske 2006).

Western snowberry has biological mechanisms and processes that provide the shrub with the capabilities to survive the loss of the aerial stems. By the third growing season following removal of aerial stems by unfavorable environmental factors or management practices, the aerial stem density and biomass are completely restored. Management practices that effectively reduce western snowberry colony size and stem density deplete the nonstructural carbohydrate reserves and damage the capabilities for vegetative replacement of lost aerial stems.

Acknowledgment

The authors thank the Kelly Toews family for providing the grazingland on which this study was conducted. We thank Roy Bullion of the Manitoba Habitat Heritage Corporation for assistance with the burning treatments. We thank Kelly Toews for assistance with the wick-application treatments. We thank West Souris River Conservation District for providing the tractor and flail mower used to perform the mowing treatments. We are grateful to Kathy Murray and Marilena Kowalchuk for assistance with field data collection. We are grateful to Sheri Schneider for assistance in production of this manuscript and for development of the tables and figures. We are grateful to Amy M. Kraus for assistance in preparation of this manuscript. We thank Peggy Westhorpe, Critical Wildlife Habitat Program, for support of the Prairie Restoration Project. The authors thank the following agencies for their participation in the Prairie Restoration Project: Environment Canada, Canadian Wildlife Service, Critical Wildlife Habitat Program, Manitoba Habitat Heritage Corporation, Manitoba Conservation, Ducks Unlimited Canada, Manitoba Agriculture and Food and Rural Initiatives, Upper Assiniboine Conservation District, West Souris River Conservation District, and Manitoba Cattle Producers Association.

Table 1. Long-term (1996-2005) mean monthly temperature and monthly precipitation at Melita, Manitoba.

	° F	**° C**	**in.**	**mm**
Jan	2.14	-16.59	0.78	19.9
Feb	12.00	-11.11	0.50	12.8
Mar	19.99	-6.67	0.80	20.2
Apr	40.08	4.49	0.93	23.5
May	50.92	10.51	2.38	60.4
Jun	60.62	15.90	3.29	83.6
Jul	66.45	19.14	2.36	60.1
Aug	64.96	18.31	1.84	46.8
Sep	55.27	12.93	1.01	25.7
Oct	40.57	4.76	1.13	28.6
Nov	23.94	-4.48	0.77	19.5
Dec	11.62	-11.32	0.92	23.4
	MEAN		**TOTAL**	
	37.38	**2.99**	**16.71**	**424.5**

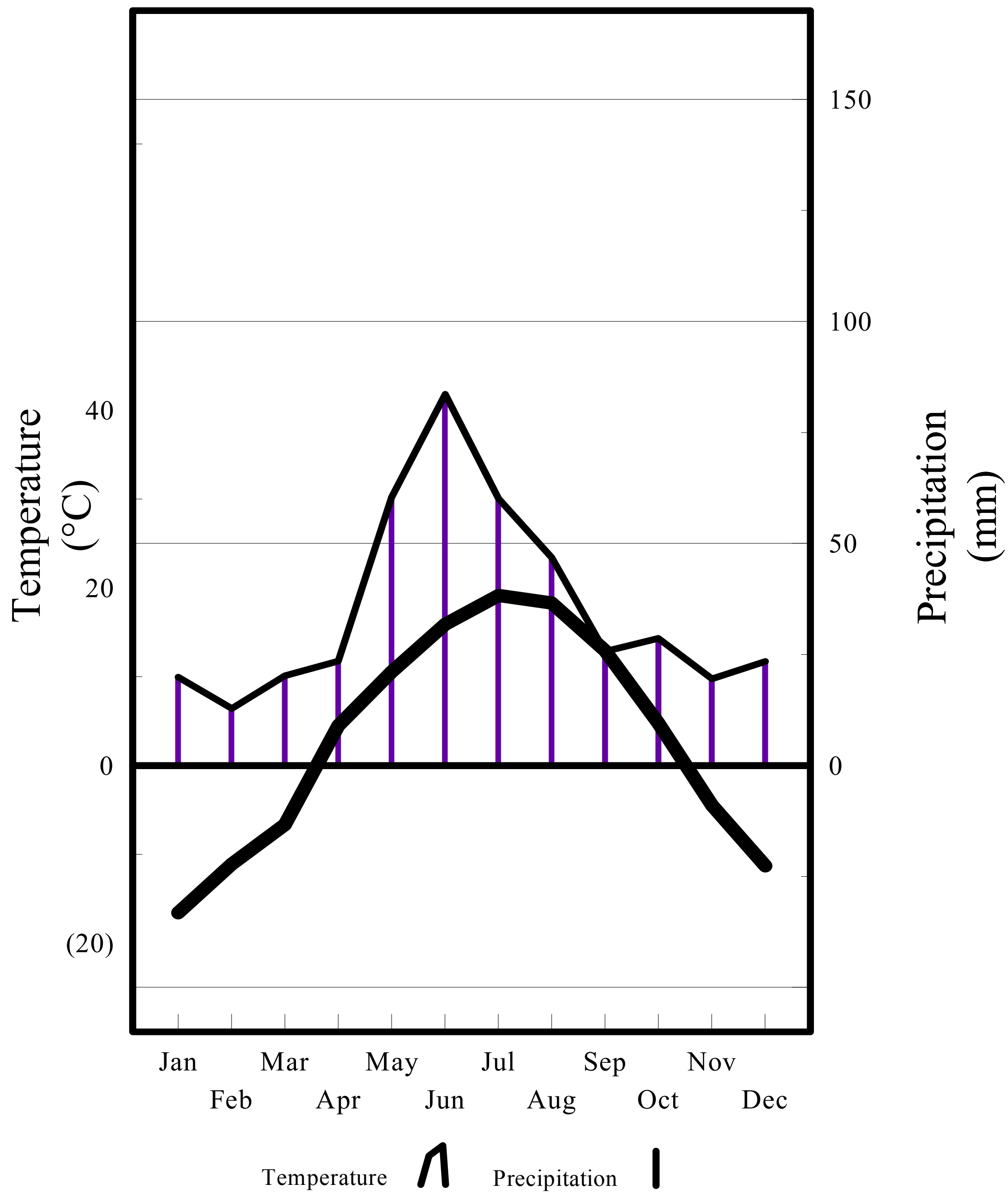

Fig. 1. Ombrothermic diagram of long-term (1996-2005) mean monthly temperature and monthly precipitation at Melita, Manitoba.

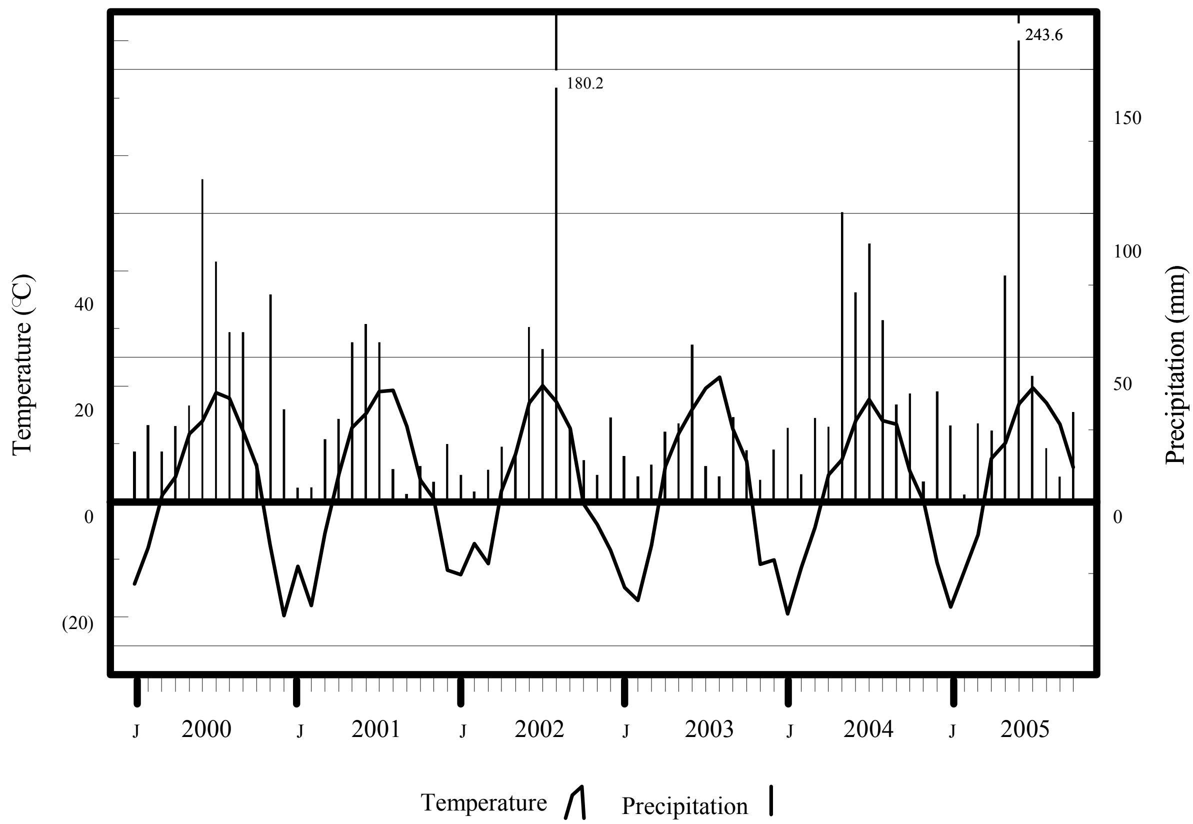

Fig. 2. Ombrothermic diagram of 2000-2005 mean monthly temperature and monthly precipitation at Melita, Manitoba.

Table 2. Precipitation in inches for growing season months and the annual total precipitation for 2000-2005, Melita, Manitoba.

	Apr	May	Jun	Jul	Aug	Sep	Oct	Growing Season	Annual Total
Long-term mean	0.93	2.38	3.29	2.36	1.84	1.01	1.13	12.94	16.71
2000	1.07	1.36	4.56	3.40	2.39	2.39	0.53	15.70	22.42
% of LTM	115.0	56.9	138.7	143.9	130.0	236.8	47.3	121.3	134.1
2001	1.17	2.25	2.51	2.25	0.46	0.11	0.50	9.25	11.60
% of LTM	125.5	94.7	76.4	95.5	24.8	5.8	44.1	71.5	69.4
2002	0.77	0.66	2.47	2.16	7.36	1.01	0.58	15.01	17.52
% of LTM	82.9	27.8	75.2	91.3	399.7	100.2	51.3	116.0	104.8
2003	0.98	1.10	2.22	0.50	0.36	1.19	0.72	7.07	9.63
% of LTM	105.8	46.2	67.5	21.1	19.5	118.0	63.9	54.6	57.6
2004	1.06	4.09	2.96	3.66	2.56	1.37	1.53	17.23	21.66
% of LTM	113.7	172.0	89.8	155.0	139.3	135.8	135.1	133.2	129.6
2005	1.00	3.20	9.94	1.78	0.75	0.35	1.27	18.29	20.56
% of LTM	108.0	134.5	302.2	75.4	40.8	34.8	112.0	141.3	123.1

Table 3. Herbage biomass of understory vegetation on chemical management trial I and percent change from pretreatment.

		No Treatment Control	Spray-Applied Herbicide	Wick-Applied Herbicide
Pretreatment				
2001	(lbs/ac)	174.87a	271.64a	203.97a
Treatment				
2001				
Post treatment				
2002	(lbs/ac)	644.97ab	729.24a	438.86b
% change	(%)	+268.8*	+168.5*	+115.2

Means in the same row and followed by the same letter are not significantly different (P<0.05).
*Percent change from pretreatment is significantly different (P<0.05).

Table 4. Stem density (stem/m^2) for western snowberry on chemical management trial I during four years following treatment and percent change from pretreatment.

		No Treatment Control	Spray-Applied Herbicide	Wick-Applied Herbicide
Pretreatment				
2001	(stems/m^2)	33.0a	37.0ab	43.2b
Treatment				
2001	(stems/m^2)	No Change	0.0	0.0
% change	(%)		-100.0*	-100.0*
Year 1				
2002	(stems/m^2)			
% change	(%)			
Year 2				
2003	(stems/m^2)			
% change	(%)			
Year 3				
2004	(stems/m^2)	46.3a	27.7a	44.6a
% change	(%)	+40.4*	-25.2	+3.2
Year 4				
2005	(stems/m^2)	32.0a	20.7a	32.6a
% change	(%)	-3.0	-44.1	-24.5

Means in the same row and followed by the same letter are not significantly different (P<0.05).
*Percent change from pretreatment is significantly different (P<0.05).

Table 5. Herbage biomass of understory vegetation on burn and mow management trial II and percent change from pretreatment.

		No Treatment Control	Burn Management	Mow Management
Pretreatment				
2001	(lbs/ac)	174.87a	404.79b	310.02ab
Treatment				
2002				
Post treatment				
2002	(lbs/ac)	644.97ab	668.76a	456.31b
% change	(%)	+268.8*	+65.2*	+47.2

Means in the same row and followed by the same letter are not significantly different (P<0.05).
*Percent change from pretreatment is significantly different (P<0.05).

Table 6. Stem density (stem/m^2) for western snowberry on burn and mow management trial II during three years following treatment and percent change from pretreatment.

		No Treatment Control	Burn Management	Mow Management
Pretreatment				
2001	(stems/m^2)	33.0a	32.2a	38.8a
Treatment				
2002	(stems/m^2)		0.0	0.0
% change	(%)		-100.0*	-100.0*
Year 1				
2003	(stems/m^2)			
% change	(%)			
Year 2				
2004	(stems/m^2)	46.3a	21.5b	32.4ab
% change	(%)	+40.4*	-33.3	-16.5
Year 3				
2005	(stems/m^2)	32.0a	24.5a	18.2a
% change	(%)	-3.0	-23.9	-53.1*

Means in the same row and followed by the same letter are not significantly different (P<0.05).
*Percent change from pretreatment is significantly different (P<0.05).

Literature Cited

Adams, B.W., and A.W. Bailey. 1983. Effect of mowing on energy reserves of western snowberry. Agriculture and Forestry Bulletin (Special Issue). p. 72-75.

Emberger, C., H. Gaussen, M. Kassas, and A. dePhilippis. 1963. Bioclimatic map of the Mediterranean Zone, explanatory notes. UNESCO-FAO. Paris. 58p.

Kochy, M. 1999. Grass-tree interactions in western Canada. Ph.D. Dissertation. University of Regina. Regina, Saskatchewan, Canada.

Kochy, M., and S.D. Wilson. 2000. Competitive effects of shrubs and grasses in prairie. Oikos 91:385-395.

Manske, L.L. 2005a. Western snowberry biology. NDSU Dickinson Research Extension Center. Range Management Report DREC 05-1059. Dickinson, ND. 29p.

Manske, L.L. 2005b. Biological management of western snowberry. NDSU Dickinson Research Extension Center. Range Management Report DREC 05-1060. Dickinson, ND. 12p.

Manske, L.L. 2005c. Burning management of western snowberry. NDSU Dickinson Research Extension Center. Range Management Report DREC 05-1061. Dickinson, ND. 20p.

Manske, L.L. 2005d. Mechanical management of western snowberry. NDSU Dickinson Research Extension Center. Range Management Report DREC 05-1062. Dickinson, ND. 6p.

Manske, L.L. 2006. Chemical management of western snowberry. NDSU Dickinson Research Extension Center. Range Management Report DREC 06-1063. Dickinson, ND. 32p.

Mastel, J.A. 1983. Growth, production, utilization, and phytosociology of western snowberry (*Symphoricarpos occidentalis* Hook.) in the North Dakota badlands. M.S. Thesis. North Dakota State University. Fargo, ND.

Mosteller, F., and R.E.K. Rourke. 1973. Sturdy Statistics. Addison-Wesley Publishing Co., MA. 395p.

Pelton, J. 1953. Studies on the life-history of *Symphoricarpos occidentalis* Hook., in Minnesota. Ecological Monographs 23:17-39.

Peltzer, D.A., and M. Kochy. 2001. Competitive effects of grasses and woody plants in mixed grass prairie. Journal of Ecology 89:519-527.

Romo, J.T., P.L. Grilz, R.E. Redmann, and E.A. Driver. 1993. Standing crop, biomass allocation patterns and soil-plant water relations in *Symphoricarpos occidentalis* Hook. following autumn or spring burning. The American Midland Naturalist 130:106-115.