Burning Management of Western Snowberry

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Western snowberry is one of the few woody plants that can successfully invade grasslands by means of rhizomes that produce aerial stems in quantities sufficient to shade out grasses and permit expansion of the colonies (Pelton 1953). The invasion of western snowberry colonies into grassland habitat may have been facilitated by the widespread practice of suppressing grassland wildfires to protect valuable pasture forage. Unlike growth from frequently burned western snowberry colonies, growth from unburned colonies accumulates aboveground stem biomass and enlarges the total leaf area. With these increases of plant material, the unburned colonies can produce greater quantities of nonstructural carbohydrates, which can be used to support growth of more rhizome suckers. Western snowberry colonies in grasslands protected from fire increase progressively in density and size, and after several years can render major portions of pastures relatively useless for forage production (Pelton 1953). Encroachment of western snowberry colonies has become a serious pasture problem across most of the areas that suppress grassland wildfires and do not practice prescribed burning for woody plant control. Controlled fire can be used as an important tool in the management of western snowberry colony expansion. Effective use of prescribed burning requires an understanding of fire's effects on western snowberry.

Fire was historically a natural environmental factor on grasslands of North America (Wright and Bailey 1982), and, presumably, frequent fires helped check western snowberry encroachment (Pelton 1953). Historical fire frequency was not the same across all of the grassland regions. The fire return interval (Wright and Bailey 1982, Bragg 1995) was 3 to 4 years for tallgrass prairie, 5 to 10 years for moist mixed grass prairie, and around 25 years for dry mixed grass prairie. The seasonal period during which grassland fires occurred was interpreted by Higgins (1986) from historical information about Indian- and lightning-set fires. The Indian-set fires occurred primarily during two periods: March through May, with a peak in April, and July through early November, with a peak in October. The probable practice was burning the mixed grass prairie in late summer and fall and the tallgrass prairie in spring. Lightning-set fires occurred during summer and early fall, with 73% occurring in July and August. The historical frequency and seasonal period of Indian-set and lightning-set fires are considered to be natural forces that have influenced how western snowberry responds to prescribed burning.

Pelton (1953) compared burned and unburned treatments for two growing seasons after a mid April fire in Minnesota to assess the effect of fire on western snowberry colonies. The aerial stems were not completely consumed by the fire but were charred sufficiently to kill all stems to ground level. The sucker shoots grew rapidly from the stem bases at an average of 2.5 suckers for each killed stem. The number of vegetative shoots that develop following a fire is affected by the length of daylight during the time of the fire. Day lengths shorter than 14 hours prevent normal vegetative growth, and day lengths longer than 14 hours stimulate vegetative growth (Pelton 1953). The numerous vegetative sucker shoots grew to about half the height and diameter of the unburned stems during the first growing season. Most of the stronger sucker shoots reached three-fourths of the unburned stem height during the second growing season. During that growing season, the stem density on the burned treatment was greater than that on the unburned treatment; however, competition had reduced the stem density from that occurring during the first growing season.

Pelton (1953) found that the aerial stems of western snowberry are sensitive to fire and are easily killed. The rhizomes and stem bases are unharmed by fire, probably because of their depth in the soil, which ranges from 1 to 14 inches (2 to 35 cm). Recovery of aerial stems by vegetative development of lateral buds on rhizomes and stem bases is moderately rapid during the first and second growing seasons following a spring fire. The responses of the vegetation suggest that annual or very frequent fires are probably detrimental to western snowberry (Pelton 1953).

Anderson and Bailey (1979) evaluated the effects from two prescribed single spring burns conducted during May 1970 and May 1971 in western snowberry communities of central Alberta. The study analyzed frequency, canopy cover, and woody stem density data collected in August along landscape transects on both burned and unburned treatments and assessed the responses of western snowberry and of other vegetation categories.

Responses varied among vegetation categories. Single burns during May resulted in an increase in frequency and canopy cover for annual and perennial forbs (tables 1 and 2). Annual forbs were prominent only during the first year after the fire; their invasion was in response to increased nutrients, a favorable seedbed, and reduced competition. The perennial forb increase remained high for 3 years after burning. Perennial forbs responded to the temporary reduction in competition from shrubs, higher light intensity at the soil surface, warmer soil temperatures, a release of nutrients, and a favorable seedbed (Anderson and Bailey 1979). Frequency of grasses and sedges decreased (tables 1 and 2) after a single burn. Canopy cover increased (table 1) for grasses and sedges after the 1970 burn, but decreased after the 1971 burn (table 2). Shrub frequency and canopy cover (tables 1 and 2) increased after a single spring burn. Most of this increase was the result of a great increase in red raspberry density following the fire (Anderson and Bailey 1979).

Western snowberry frequency and canopy cover were about the same in burned and unburned treatments three months following the spring burns (tables 1 and 2). Western snowberry vegetative suckers were visible two weeks after the fire and grew rapidly, maintaining dominance in the stand. The rhizomes of western snowberry are resistant to spring fires. The lateral buds on rhizomes are hormonally controlled from active growth by apical dominance of the stems. The fire consumed the aerial stems and removed the growth-inhibiting hormone control, releasing rhizome bud development into vegetative sucker shoots (Anderson and Bailey 1979). Western snowberry stem density per m^2 increased 174.4% and 363.6% during the first year after a May burn in 1970 and 1971, respectively. Stem density decreased during the second and third growing seasons after burning (Anderson and Bailey 1979).

Bailey and Anderson (1980) conducted a study to determine the range in temperatures reached during prescribed burning grassland communities of rough fescue-western porcupine grass and shrubland communities of western snowberry in the central Alberta aspen parkland. Commercial temperature pellets that melt at specific temperatures were placed on asbestos cards attached at different heights to metal posts randomly located within the grassland and shrubland communities. Spring burns were conducted in 1971 and 1972, with areas of each community type burned by both backfires and headfires (Bailey and Anderson 1980).

The grasslands burned rapidly but at comparatively low temperatures ranging from 199.4° F to 800.6° F (93° C - 427° C) (table 3). Temperatures of grassland backfires were lower than temperatures of grassland headfires. The temperature at the soil surface was 278.6° F (137° C) for the backfires and 402.8° F (206° C) for the headfires. The hottest temperature of grassland backfires was 449.6° F (232° C), at a height of 2 inches (5 cm) above the soil surface (table 3). The hottest temperature of grassland headfires was 800.6° F (427° C), at a height of 6 inches (15 cm) above the soil surface (table 3).

The shrublands burned at higher temperatures than the grasslands, with a range of temperatures from 399.2° F to 1299.2° F (204° C - 704° C) (table 3). Temperatures of shrubland backfires were lower than temperatures of shrubland headfires. The temperature at the soil surface was 617° F (325° C) for the backfires and 815° F (435° C) for the headfires. The hottest temperature of shrubland backfires was 800.6° F (427° C), at a height of 3.2 inches (8 cm) above the soil surface (table 3). The hottest temperature of shrubland headfires was 1299.2° F (704° C), at a height of 3.2 to 7.9 inches (8-20 cm) above the soil surface (table 3).

Microrelief, type of fire, weather conditions before and during burning, and the kind, quantity and spatial distribution of fuels influence fire temperatures. The hottest fire temperatures are not at the soil surface. Woody fuels burn hotter than grass fuels. The temperature of fire increases with the density of western snowberry stems (Bailey and Anderson 1980).

All of the temperatures measured at or above the soil surface were greater than the lethal temperature for leaf tissue, which is approximately 140° F (60° C). Green grass shoots became conspicuous on burned grassland about a week after the fire (Bailey and Anderson 1980), and western snowberry shoots became visible on burned shrubland about two weeks after the fire (Anderson and Bailey 1979). The wet soil prevented penetration of lethal temperatures to the depth of perennial plant meristematic buds or growing points. Wet soils apparently dissipate heat more effectively than do dry soils (Bailey and Anderson 1980).

Western snowberry lateral buds on stem bases and rhizomes would not be expected to be damaged by lethal temperatures during prescribed burns conducted under wet soil conditions. However, near the center of western snowberry colonies, where the stem density and total fuels are greater, long periods of high fire temperatures would be experienced, and under dry soil conditions, lethal temperatures could be expected to cause considerable mortality to the growing points on the shallower rhizomes and stem bases (Bailey and Anderson 1980).

Romo et al. (1993) evaluated the effects from prescribed single spring burns and fall burns conducted from fall 1986 to spring 1988 in western snowberry communities of a relict rough fescue prairie in central Saskatchewan that had not been burned, mowed, or grazed for about 20 years. The study analyzed stem densities per m^2 data collected during four successive years on permanent plots in both burned and unburned treatments.

Single burns during early spring and early fall resulted in increases in western snowberry stem density (table 4). The majority of the new shoots developed from crowns or stem bases, and some shoots arose from rhizomes. The increase in stem density on the spring burn (221%) was greater than that on the fall burn (90%) during the first growing season. Stem density during the second growing season was greater on the burned treatments than on the unburned treatments (table 4); however, density-dependent mortality had reduced stem density on the burned treatments from the density occurring during the first growing season. After the first year, the spring burns had a greater rate of stem mortality than the fall burns. Stem densities on the spring burns and fall burns were similar to those on the unburned reference controls during the third and fourth growing seasons after burning (table 4) (Romo et al. 1993).

Romo et al. (1993) presented a direct and an indirect possible explanation for the difference in the quantity of sucker sprouts developing after the spring burns compared to the fall burns. The possible direct explanation is related to the difference in the fire temperature. The fuels on the fall burned treatments were loose and fine, with oxygen pockets throughout; the fall fire would be hotter than a fire consuming the compacted fine fuels on the spring burned treatments. The hotter temperatures of fall burns may cause damage to meristematic tissue on crowns and a resulting reduction in the number of new shoots that develop the following growing season. The possible indirect explanation is related to modification of the microenvironment. The fall fire consumed the aerial stems that would have trapped insulating snow; during the winter the unprotected crowns would be exposed to temperature extremes that might cause damage to meristematic tissue and a resulting reduction in the number of new shoots that develop the following growing season.

A single burn during spring or fall should not be expected to reduce stem density of western snowberry colonies. Aerial stem dominance is rapidly reestablished because of prolific sucker sprouting in combination with increased productivity following burning (Romo et al. 1993).

Anderson and Bailey (1980) evaluated the effects from annual early spring burning conducted during April for 24 years in aspen parkland of east central Alberta. The study analyzed frequency, canopy cover, and woody stem density data collected in August of 1976 along landscape transects on both burned and unburned treatments.

Annual early spring burning resulted in a considerable expansion of grassland habitat and a reduction in the proportion of aspen groves. Annual burning for 24 years resulted in increased frequency and canopy cover of grasses, sedges, and perennial forbs (table 5). Competition for sunlight was temporarily reduced after each annual fire consumed the aerial stems of western snowberry. Annual burning caused an increase in the number of grass, sedge, and forb species, with a change towards plants adapted for more arid regions. Fringed sage increased in frequency (133.3%) and in canopy cover (50.0%) on the burned treatments. The early spring fires were deleterious to cool-season grasses. Rough fescue and western porcupine grass increased in frequency but decreased in canopy cover. The annually burned areas had lower soil moisture than the unburned areas; this condition resulted from reduced infiltration rates and greater evaporation loss. Water stress in grasses and sedges on the burned areas caused a reduction of leaf blade length (43.8%) and herbage biomass production (48.9%). Annual burning prevented litter accumulation; the greater area of exposed soil surface in burned areas resulted in a more favorable seedbed. Organic matter was greater in the top 6 inches (15 cm) of soil on the burned areas than on the unburned areas. Total mineral nitrogen (NH_4-NO_3) and other nutrients were not different on the burned and unburned areas (Anderson and Bailey 1980).

Annual burning during April for 24 years resulted in an increase in shrub frequency (64.7%)

(table 5); however, burning reduced shrub canopy cover (56.3%) (table 5), shrub height, and shrub herbage biomass (94.6%). Because of the vast quantity of vegetative suckers produced by shrubs after fire, annual early spring burning did not eliminate any woody species from the plant community. The stem density of shrubs was 245.5% greater on the burned areas than on the unburned areas. Annual burning during early spring for 24 years resulted in a grassland with a high frequency of small shrubs (Anderson and Bailey 1980).

Annual early spring burning resulted in a small decrease in frequency (7.1%) and a large decrease in canopy cover (93.5%) for western snowberry (table 5). Western snowberry stem density was 28.8% lower on the burned areas than on the unburned areas. The annual burning killed many aerial stems each year, but the rhizome systems were not killed. The rhizome system made western snowberry resistant to early spring fires (Anderson and Bailey 1980).

Manske (1992) evaluated the effects from the every-other-year burning strategy developed by refuge manager Karen A. Smith. During the thirteen-year period from 1978 to 1990, burning was conducted during early spring (mid-late April), spring (May-mid June), early summer (mid June-July), and mid summer (early-mid August), with burning repeated one, two, three, and four times on mixed grass prairie invaded by western snowberry in northwestern North Dakota (figure 1). The study analyzed shoot frequency and current year's live biomass production data collected in 1990 along landscape transects on both burned and unburned treatments.

The total current year's production of aboveground biomass was not different after one, two, three, and four repeated prescribed burns compared to the biomass of the unburned treatment (table 6). However, the composition of the aboveground biomass changed remarkably. The contribution of grasses to the total biomass changed from 24.2% on treatments with no burns to 65.6% after four burns (table 6), an increase of 171.1%. Grass biomass decreased 24.7% after one burn and increased 109.3% after four burns (table 6). The contribution from sedges changed from 13.2% on treatments with no burns to 11.1% after four burns. Sedge biomass increased 61.6% after one burn and decreased 35.1% after four burns (table 6). The contribution from forbs changed from 15.0% on treatments with no burns to 20.3% after four burns. After one burn, the forb contribution to total aboveground biomass was 139.7% greater than that on the unburned treatments. After two and three burns, the weedy forbs decreased and the ecological status of perennial forbs improved. The forb contribution to the total biomass production after four burns was 35.3% greater than that on the unburned treatments. Forb biomass increased 78.0% after one burn and increased 4.4% after four burns (table 6). The biomass contribution from shrubs changed from 47.5% on treatments with no burns to only 3.0% after four burns (table 6), a 93.7% decrease. Shrub biomass decreased 83.1% after one burn and decreased 95.1% after four burns (table 6).

Native grass shoot frequency increased significantly as a result of repeated burning. The average increase after one, two, and three burns was 79.6%, and after four burns native grass shoot frequency increased 94.7% (table 7). Sedge shoot frequency increased an average of 58.4% after repeated burning. Introduced grass shoot frequency decreased an average of 49.4% after one, two, and three burns and decreased 65.1% after four burns. Four burns were required to reduce introduced grasses significantly (table 7). Kentucky bluegrass shoot frequency decreased an average of 36.2% after one, two, three, and four burns. Quackgrass shoot frequency decreased an average of 84.0% after one and two burns and decreased an average of 90.9% after three and four burns. Smooth bromegrass shoot frequency decreased an average of 90.0% after one and two burns and decreased an average of 96.7% after three and four burns.

Perennial forb shoot frequency increased 39.3% after one burn (table 7) and increased an average of 7.5% after additional repeated burns of two, three, and four times. Early succession and weedy forb shoot frequency increased 8.2% after one burn, decreased an average of 7.5% after two and three burns, and decreased 50.9% after four burns (table 7). Four burns were required to reduce weedy forbs significantly (table 7).

Shrub shoot frequency decreased 36.4% after one burn, decreased an average of 46.1% after two and three burns, and decreased 58.2% after four burns (table 7). Four burns were required to reduce shrubs significantly (table 7).

Western snowberry shoot frequency decreased 62.7% after one burn, decreased an average of 55.8% after two and three burns, and decreased 64.0% after four burns. Shoot frequency of western snowberry changed little from repeated burning after the first burn. However, the aboveground biomass produced by the shrubs was greatly reduced after the third and fourth burns.

All burns cause some damage to plants, but the seasonal period that prescribed burns are conducted affects the biomass production and shoot frequency of plant biotypes differently. Effective prescribed burns are conducted during appropriate seasonal periods so that the greatest reduction to the undesirable plants is caused and the damage to the desirable plants is minimized.

Grass biomass greatly increased after spring (May-mid June) and mid summer (early-mid August) burns but decreased after early summer (mid June-July) burns (table 8). Grass shoot frequency increased significantly after burns conducted during all seasonal periods. The greatest increases occurred after spring (May-mid June) and mid summer (early-mid August) burns (table 9). Shoot frequency of native cool-season grasses increased significantly after burns conducted during all seasonal periods (table 10). Shoot frequency of western wheatgrass increased significantly after early spring (mid-late April) burns and decreased after spring (May-mid June) burns (table 10). Shoot frequency of native warm-season grasses increased significantly after burns conducted during spring (May-mid June) (table 10). Blue grama shoot frequency increased significantly after spring (May-mid June) burns (table 10). Shoot frequency of introduced grasses decreased significantly after spring (May-mid June) burns (table 9). Kentucky bluegrass shoot frequency decreased significantly after spring (May-mid June) burns (table 10) and increased after early spring (mid-late April) burns (table 10). Smooth bromegrass and quackgrass shoot frequency decreased after burns conducted during all seasonal periods. Smooth bromegrass shoot frequency decreased most after early spring (mid-late April) burns (table 10). Quackgrass shoot frequency decreased most after spring (May-mid June) burns (table 10).

Sedge biomass increased after burns conducted during early spring (mid-late April) and early summer (mid June-July) and decreased after spring (May-mid June) and mid summer (early-mid August) burns (table 8). Shoot frequency of sedges increased significantly after spring (May-mid June) burns (table 9).

Forb biomass increased after burns conducted during all seasonal periods. The greatest increases occurred after early spring (mid-late April) and spring (May-mid June) burns (table 8). Shoot frequency of perennial forbs increased after early spring (mid-late April) and early summer (mid June-July) burns and decreased slightly after spring (May-mid June) burns (table 9). Shoot frequency of weedy forbs increased significantly after early spring (mid-late April) burns and decreased after spring (May-mid June), early summer (mid June-July), and mid summer (early-mid August) burns (table 9).

Shrub biomass decreased after burns conducted during all seasonal periods. The greatest decreases occurred after early spring (mid-late April), spring (May-mid June), and mid summer (early-mid August) burns (table 8). Shoot frequency of shrubs decreased significantly after early spring (mid-late April), spring (May-mid June), and mid summer (early-mid August) burns (table 9). Shrub shoot frequency did not decrease significantly after early summer (mid June-July) burns (table 9). Silverberry shoot frequency decreased significantly after early spring (mid-late April) and mid summer (early-mid August) burns (table 11). Western rose shoot frequency decreased significantly after early spring (mid-late April) and spring (May-mid June) burns (table 11) and increased slightly after early summer (mid June-July) and mid summer (early-mid August) burns. Shoot frequency of western snowberry decreased significantly after early spring (mid-late April), spring (May-mid June), and mid summer (early-mid August) burns (table 11). Western snowberry shoot frequency did not decrease significantly after early summer (mid June-July) burns (table 11).

The effects of every-other-year burning treatments on mycorrhizal fungi infection were evaluated from roots of three plants of western snowberry, smooth bromegrass, western wheatgrass, and blue grama collected at each replicated site and analyzed individually. The number of repeated burns and the seasonal period of burns did not significantly change the level of fungal infection (tables 12 and 13).

The effects of every-other-year burning treatments on the quantity of available mineral (inorganic) nitrogen (NH_4-NO_3) were evaluated. The number of repeated burns and the seasonal period of burns did not significantly change the level of mineral nitrogen (tables 12 and 13).

The average quantity of soil water during the growing season was not significantly different on the unburned and burned treatments (Manske 1992).

Prior to the initiation of the every-other-year prescribed burn strategy in 1978 by refuge manager

Karen Smith, the Lostwood National Wildlife Refuge had not been burned in over 80 years (Smith 1985b). Western snowberry invasion had progressed unchecked in the absence of fire, and the expanded colonies covered over 50% of the upland landscape. Kentucky bluegrass was the dominant grass associated with western snowberry colonies. Native grasses and forbs were still present but greatly suppressed. Large portions of the western snowberry colonies were extremely dense and had no herbaceous understory. Decadent centers of old western snowberry colonies had been invaded by smooth bromegrass, quackgrass (Smith 1985a), and Canada thistle (Smith 1985b). The management strategy designed to reduce the invading western snowberry and exotic grasses and renovate the prairie ecosystem was a regime of burning on alternate years. Annual burns were not possible because of insufficient production of plant biomass for fuel (Smith 1985a).

Four burns conducted every other year were required to significantly reduce the undesirable plants of introduced grasses, early succession and weedy forbs, and shrubs from mixed grass prairie habitat. Native grasses, sedges, and perennial forbs were not reduced by repeated burning and benefitted from the reduction in competition for sunlight from the taller shrubs. The long period of native species suppression by western snowberry colonies had greatly diminished plant numbers. The quantity of basal area for native species was not well developed even after four burns. Grazing management based on the twice-over rotation system was implemented to stimulate vegetative tillering and activity of rhizosphere organisms to increase native species stem density (Smith 1997).

The prescribed burns conducted during early spring (mid-late April), spring (May-mid June), and mid summer (early-mid August) resulted in decreased western snowberry shoot frequency and shrub biomass production. These burns coincided with the first two carbohydrate drawdown periods of western snowberry. The first carbohydrate drawdown period occurs during early spring, from mid April to early June (9 June), when the plants are in rapid growth to full leaf expansion stages. The second carbohydrate drawdown period occurs during the major portion of fruit fill stage, from mid July to mid August.

The prescribed burns conducted during early summer (mid June-July) caused the least reduction in western snowberry shoot frequency and shrub biomass production. These burns coincided with western snowberry's major carbohydrate replenishment period, which occurs from full leaf expansion stage through most of the flowering stage, from early June to mid July. Burns conducted during carbohydrate drawdown periods had greater success at western snowberry reduction than burns conducted during carbohydrate replenishment periods.

Management Implications

Western snowberry aerial stems are sensitive to fire, and even if they are not completely consumed by the fire, they 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.

Historically, fire has been an environmental factor on mixed grass prairie, with an estimated fire return interval of 5 to 10 years on the moist portions and around 25 years on the dry portions. Most lightning-set fires occurred in July and August, and a large portion of the Indian-set fires occurred between July and early November. The Northern Plains has probably had considerably more late season fires, occurring after mid July, than spring or early summer fires.

A prescribed fire during August causes the least damage to native cool- and warm-season grasses and perennial forbs. An August fire removes all or most of the top growth of western snowberry and results in fewer sucker shoots the following year than a spring burn. August burns can be nearly nondetrimental to desirable plants when the soil is not dry, and August burns can cause considerable damage to the undesirable woody plants.

June and early July burns are usually detrimental to native grass plants and hurt western snowberry plants only a little. Spring burns during late April or May are severely detrimental to native cool-season grasses because of the removal of the valuable growth of the fall tillers and overwintering secondary tillers. Kentucky bluegrass is increased by earlier burns and decreased by later spring burns. Weedy forbs are increased greatly by spring burns. Western snowberry top growth is usually removed completely if sufficient fine fuel is present; however, spring burns result in great quantities of sucker stems, which become visible about two weeks following the burn, and because carbohydrates stores can be completely replenished by the new plant material in one growing season, spring burns do not decrease stem frequency even after 24 years. Late April and May prescribed burns are less likely to escape control measures compared to August burns; however, the growth pattern and biological requirements of the herbaceous vegetation in the mixed grass prairie match the August burns more closely. Prescribed burning can be used to remove western snowberry aerial stems, and four every-other-year burns can reduce shrub stem frequency, but fire alone will not remove western snowberry from the northern mixed grass prairie.

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Table 1. Frequency % and canopy cover % of vegetation in unburned and burned western snowberry colonies from a single May 1970 burn treatment.

	Frequency %						Canopy Cover %					
	Unburned			Burned			Unburned			Burned		
	1970	1971	1972	1970	1971	1972	1970	1971	1972	1970	1971	1972
Annual Forbs	0	0	0	61	29	4	0	0	0	15	4	4
Perennial Forbs	26	26	30	96	68	82	5	2	9	29	31	30
Grass and Sedge	57	78	83	64	57	75	19	19	34	42	60	64
Shrubs	56	80	70	72	90	90	2	17	7	8	16	13
Western snowberry	100	100	100	100	100	100	95	90	89	95	90	89

Data from Anderson and Bailey 1979

Table 2. Frequency % and canopy cover % of vegetation in unburned and burned western snowberry colonies from a single May 1971 burn treatment.

	Frequency %		Canopy Cover %	
	Unburned	Burned	Unburned	Burned
	1971	1971	1971	1971
Annual Forbs	5	14	<1	2
Perennial Forbs	36	94	4	41
Grass and Sedge	46	8	7	<1
Shrubs	35	106	7	35
Western snowberry	99	100	87	78

Data from Anderson and Bailey 1979

Table 3. Range in temperatures reached during prescribed burning of grassland and shrubland habitats.

	Grassland Habitat		Shrubland Habitat	
Backfire				
Soil surface Temperature	278.6° F	(137° C)	617° F	(325° C)
Range of fire Temperatures	199.4°-449.6° F	(93°-232° C)	399.2°-800.6° F	(204°-427° C)
Height of hottest Temperature	2 inches	(5 cm)	3.2 inches	(8 cm)
Headfire				
Soil surface Temperature	402.8° F	(206° C)	815° F	(435° C)
Range of fire Temperatures	199.4°-800.6° F	(93°-427° C)	449.6°-1299.2° F	(232°-704° C)
Height of hottest Temperature	6 inches	(15 cm)	3.2-7.9 inches	(8-20 cm)

Data from Bailey and Anderson 1980

Table 4. Stem density (stems/m^2) for western snowberry on spring and fall burn treatments during four years following burning and percent change from preburn control.

		No Burns 2 reps	Early Spring (late Apr-early May) 4 reps	Early Fall (mid Oct) 4 reps
Preburn	(stems/m^2)	38a	38a	38a
Year 1	(stems/m^2)	39b	122c	72bc
% change	(%)	2.6	221.1	89.5
Year 2	(stems/m^2)	43d	111e	67de
% change	(%)	13.2	192.1	76.3
Year 3	(stems/m^2)	46f	95f	62f
% change	(%)	21.1	150.0	63.2
Year 4	(stems/m^2)	46g	51g	57g
% change	(%)	21.1	34.2	50.0

Data from Romo et al. 1993

Means in the same row and followed by the same letter are not significantly different ($P<0.05$).

Table 5. Frequency % and canopy cover % of vegetation in unburned and burned western snowberry colonies from 24 years of annual April burn treatment.

	Frequency %		Canopy Cover %	
	Unburned	Burned	Unburned	Burned
	1976	1976	1976	1976
Annual Forbs	0	0	0	0
Perennial Forbs	204	348	13.1	49.9
Grass and Sedge	207	437	67.4	109.8
Shrubs	68	112	16	7
Western snowberry	56	52	31	2

Data from Anderson and Bailey 1980

Table 6. Live biomass production of plant biotypes on every-other-year burn treatments and percent change from nonburned control.

Plant Biotypes		No Burns 6 reps	One Burn 4 reps	Two Burns 4 reps	Three Burns 4 reps	Four Burns 3 reps
Grass Biomass	(lbs/ac)	411.61a	310.12a	762.75a	512.87a	861.51a
% change	(%)		-24.7	85.3	24.6	109.3
Sedge Biomass	(lbs/ac)	224.59b	362.93b	74.34b	238.58b	145.81b
% change	(%)		61.6	-66.9	6.2	-35.1
Forb Biomass	(lbs/ac)	255.33c	454.35c	445.14c	587.41c	266.49c
% change	(%)		78.0	74.3	130.1	4.4
Shrub Biomass	(lbs/ac)	806.83d	136.00d	237.09d	52.00d	39.57d
% change	(%)		-83.1	-70.6	-93.6	-95.1
Total Live Biomass	(lbs/ac)	1698.36e	1263.39e	1519.19e	1390.87e	1313.38e
% change	(%)		-25.6	-10.6	-18.1	-22.7

Data from Manske 1992

Means in the same row and followed by the same letter are not significantly different ($P<0.05$).

Table 7. Shoot frequency of plant biotypes on every-other-year burn treatments and percent change from nonburned control.

Plant Biotypes		No Burns 6 reps	One Burn 4 reps	Two Burns 4 reps	Three Burns 4 reps	Four Burns 3 reps
Native Grass						
Shoot frequency	(%)	107.0a	194.3b	183.3ab	198.8b	208.3b
% change	(%)		81.6	71.3	85.8	94.7
Sedge						
Shoot frequency	(%)	56.7c	95.5d	97.0d	77.8cd	89.0cd
% change	(%)		68.4	71.1	37.2	57.0
Introduced Grass						
Shoot frequency	(%)	86.7e	46.3ef	31.8ef	53.5ef	30.3f
% change	(%)		-46.6	-63.3	-38.3	-65.1
Perennial Forbs						
Shoot frequency	(%)	120.5g	167.8h	125.5gh	137.5gh	125.7gh
% change	(%)		39.3	4.1	14.1	4.3
Weedy Forbs						
Shoot frequency	(%)	85.5i	92.5i	80.3ij	78.0ij	42.0j
% change	(%)		8.2	-6.1	-8.8	-50.9
Shrubs						
Shoot frequency	(%)	111.7k	71.0kl	58.5kl	62.0kl	46.7l
% change	(%)		-36.4	-47.6	-44.5	-58.2

Data from Manske 1992

Means in the same row and followed by the same letter are not significantly different (P<0.05).

Table 8. Live biomass production of plant biotypes on the seasonal period of every-other-year burn treatments and percent change from nonburned control.

Plant Biotypes		No Burns 6 reps	Early Spring (mid-late Apr) 1 rep	Spring (May-mid Jun) 3 reps	Early Summer (mid Jun-Jul) 7 reps	Mid Summer (early-mid Aug) 4 reps
Grass						
Biomass	(lbs/ac)	411.61a	571.59a	748.93a	347.88a	918.49a
% change	(%)		38.9	82.0	-15.5	123.1
Sedge						
Biomass	(lbs/ac)	224.59b	366.79b	48.88b	316.29b	103.33b
% change	(%)		63.3	-78.2	40.8	-54.0
Forb						
Biomass	(lbs/ac)	255.33c	771.40c	587.21c	451.17c	263.97c
% change	(%)		202.1	130.0	76.7	3.4
Shrub						
Biomass	(lbs/ac)	806.83d	0.0d	0.0d	226.43d	58.52d
% change	(%)		-100.0	-100.0	-71.9	-92.8
Total Live						
Biomass	(lbs/ac)	1698.36e	1709.78e	1385.02e	1341.77e	1344.18e
% change	(%)		0.7	-18.5	-21.0	-20.9

Data from Manske 1992

Means in the same row and followed by the same letter are not significantly different ($P<0.05$).

Table 9. Shoot frequency of plant biotypes on the seasonal period of every-other-year burn treatments and percent change from nonburned control.

Plant Biotypes		No Burns 6 reps	Early Spring (mid-late Apr) 1 rep	Spring (May-mid Jun) 3 reps	Early Summer (mid Jun-Jul) 7 reps	Mid Summer (early-mid Aug) 4 reps
Native Grass						
Shoot frequency	(%)	107.0a	189.0b	219.7b	182.9b	200.5b
% change	(%)		76.6	105.3	70.9	87.4
Sedge						
Shoot frequency	(%)	56.7c	39.0c	97.3d	93.4cd	90.8cd
% change	(%)		-31.2	71.6	64.7	60.1
Introduced Grass						
Shoot frequency	(%)	86.7e	73.0e	23.7f	43.4ef	42.3ef
% change	(%)		-15.8	-72.7	-49.9	-51.2
Perennial Forbs						
Shoot frequency	(%)	120.5g	157.0g	116.7g	154.6g	127.8g
% change	(%)		30.3	-3.2	28.3	6.1
Weedy Forbs						
Shoot frequency	(%)	85.5h	129.0i	43.3h	79.3h	78.8h
% change	(%)		50.9	-49.4	-7.3	-7.8
Shrubs						
Shoot frequency	(%)	111.7j	15.0l	22.0l	81.7jk	63.3k
% change	(%)		-86.6	-80.3	-26.9	-43.3

Data from Manske 1992

Means in the same row and followed by the same letter are not significantly different (P<0.05).

Table 10. Shoot frequency of grasses on the seasonal period of every-other-year burn treatments and percent change from nonburned control.

Plant Biotypes		No Burns 6 reps	Early Spring (mid-late Apr) 1 rep	Spring (May-mid Jun) 3 reps	Early Summer (mid Jun-Jul) 7 reps	Mid Summer (early-mid Aug) 4 reps
Native Grass						
Cool Season Grass						
Shoot frequency	(%)	89.2a	177.0b	166.0b	168.9b	169.0b
% change	(%)		98.4	86.1	89.3	89.5
Warm Season Grass						
Shoot frequency	(%)	17.8c	12.0c	53.7d	14.0c	31.5cd
% change	(%)		-32.7	201.0	-21.5	76.7
Western wheatgrass						
Shoot frequency	(%)	15.5e	42.0c	13.7e	16.4e	19.5e
% change	(%)		170.1	-11.8	6.0	25.8
Blue grama						
Shoot frequency	(%)	8.0f	4.0f	39.3g	7.4f	14.8fg
% change	(%)		-50.0	391.6	-7.1	84.4
Introduced Grass						
Smooth bromegrass						
Shoot frequency	(%)	17.5h	0.0h	2.3h	0.3h	2.3h
% change	(%)		-100.0	-86.7	-98.3	-87.1
Quackgrass						
Shoot frequency	(%)	7.8i	1.0i	0.0i	0.4i	2.8i
% change	(%)		-87.2	-100.0	-94.5	-64.7
Kentucky bluegrass						
Shoot frequency	(%)	59.5j	72.0j	21.3k	42.0j	37.3jk
% change	(%)		21.0	-64.2	-29.4	-37.3

Data from Manske 1992

Means in the same row and followed by the same letter are not significantly different ($P<0.05$).

Table 11. Shoot frequency of shrubs on the seasonal period of every-other-year burn treatments and percent change from nonburned control.

Plant Biotypes		No Burns 6 reps	Early Spring (mid-late Apr) 1 rep	Spring (May-mid Jun) 3 reps	Early Summer (mid Jun-Jul) 7 reps	Mid Summer (early-mid Aug) 4 reps
Western snowberry						
Shoot frequency	(%)	58.3a	5.0b	10.3b	33.4ab	21.5b
% change	(%)		-91.4	-82.3	-42.7	-63.1
Western rose						
Shoot frequency	(%)	35.8c	8.0d	4.3d	41.7c	41.3c
% change	(%)		-77.7	-87.9	16.4	15.1
Silverberry						
Shoot frequency	(%)	17.3e	2.0f	7.3e	6.6e	0.5f
% change	(%)		-88.5	-57.7	-62.1	-97.1

Data from Manske 1992

Means in the same row and followed by the same letter are not significantly different ($P<0.05$).

Table 12. Mycorrhizal fungi infection of plant roots and soil mineral nitrogen (NH_4-NO_3) on every-other-year burn treatments and percent change from nonburned control.

Plant Biotypes		No Burns 6 reps	One Burn 4 reps	Two Burns 4 reps	Three Burns 4 reps	Four Burns 3 reps
Western snowberry						
Fungi infection	(%)	93.8a	84.7a	84.3a	85.2a	85.9a
% change	(%)		-9.7	-10.7	-9.2	-8.4
Smooth bromegrass						
Fungi infection	(%)	32.3b	55.0b	50.0b	31.4b	40.1b
% change	(%)		70.3	54.8	-2.8	24.1
Western wheatgrass						
Fungi infection	(%)	66.0c	67.0c	61.3c	76.8c	63.8c
% change	(%)		1.5	-7.1	16.4	-3.3
Blue grama						
Fungi infection	(%)	78.8d	77.1d	84.9d	79.9d	73.5d
% change	(%)		-2.2	7.7	1.4	-6.7
Mineral Nitrogen						
NH_4-NO_3	(ppm)	9.56e	9.65e	9.41e	5.54e	8.36e
% change	(%)		0.9	-1.6	-42.1	-12.6

Data from Manske 1992

Means in the same row and followed by the same letter are not significantly different ($P<0.05$).

Table 13. Mycorrhizal fungi infection of plant roots and soil mineral nitrogen (NH_4-NO_3) on the seasonal period of every-other-year burn treatments and percent change from nonburned control.

Plant Biotypes		No Burns 6 reps	Early Spring (mid-late Apr) 1 rep	Spring (May-mid Jun) 3 reps	Early Summer (mid Jun-Jul) 7 reps	Mid Summer (early-mid Aug) 4 reps
Western snowberry						
Fungi infection	(%)	93.8a	92.3a	85.5a	82.7a	86.6a
% change	(%)		1.6	-8.8	-11.8	-7.7
Smooth bromegrass						
Fungi infection	(%)	32.3b	33.7b	40.0b	37.2b	65.7b
% change	(%)		4.3	23.8	15.2	103.4
Western wheatgrass						
Fungi infection	(%)	66.0c	74.7c	48.0c	73.7c	69.5c
% change	(%)		13.2	-27.3	11.7	5.3
Blue grama						
Fungi infection	(%)	78.8d	70.7d	79.6d	82.0d	76.2d
% change	(%)		-10.3	1.0	4.1	-3.3
Mineral Nitrogen						
NH_4-NO_3	(ppm)	9.56e	3.64e	8.47e	9.42e	7.09e
% change	(%)		-61.9	-11.4	-1.5	-25.8

Data from Manske 1992

Means in the same row and followed by the same letter are not significantly different ($P<0.05$).

Fig. 1. Western snowberry colony before (left) and after (right) four every-other-year prescribed burns during mid summer (August).

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