Chemical Management of Western Snowberry

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Western snowberry colonies invade and spread rapidly by means of extensive rhizome systems in pastures managed by traditional grazing practices that weaken the competitive abilities of grass plants. The aerial stem canopy cover of healthy western snowberry colonies shades sunlight from the grass understory, reducing the forage biomass production in a pasture and decreasing the livestock carrying capacity. Chemical management with herbicide treatments can reduce or eliminate the shrubs from the grassland ecosystem and permit full sunlight to reach the grass. Two years after shrub removal by herbicide treatment, the grass biomass production can increase three to six times greater than the pretreatment production, depending on the previous density of the shrubs. After three years with shrub removal, the increase in grass biomass production can equal the weight of the shrubs on an untreated area. Chemical management of western snowberry uses herbicides that interfere with vital physiological processes within the plant. Herbicide active ingredients from different chemical groups affect various plant processes. Effective chemical management requires an understanding of the general properties and characteristics of the herbicides approved for woody plant control or suppression on grazingland.

Herbicide Classification

Herbicides are classified by their general route of entry and their method of activity in plants. The mode of entry is categorized as either foliage-active or soil-active. The type of activity is categorized as either nonselective, with chemical activity on contact of any plant, or selective, with chemical translocation from entry point to site of activity.

Foliage-active herbicides are applied directly to leaves and stems of plants by spraying or wiping and usually have limited residual activity in the soil. Contact foliage-active herbicides are nonselective and kill the plant tissue directly contacted by the chemical. Translocated foliage-active herbicides penetrate the leaves and stems of plants, move through the phloem vascular system, and are translocated to the roots and other organs some distance from the point of entry (Scifres 1980).

Soil-active herbicides are applied directly to the soil within the vicinity of the root zone of target plant species. Translocated soil-active herbicides must be moved into the soil by rainfall, absorbed by the plant roots, and then moved upward through the xylem vascular system, which consists of nonliving vessel cells (Scifres 1980). A few herbicides can be transported both downward through the phloem from the leaves and upward though the xylem from the roots. Nonselective soil-active herbicides are used in some industrial areas to remove all vegetation. This type of herbicide is not used on grazinglands.

Most of the herbicides labeled for rangelands and grasslands were developed for other markets first. Development of new herbicide active ingredients is expensive for chemical companies, and there is a low profit potential for herbicides specific for grazinglands. As a result, there are relatively few chemicals available for use as woody plant control on grazinglands. Some improvements in herbicide efficacy and reductions in application rates and in total costs per acre have resulted from the development of synergistic mixtures of existing herbicides. One new active ingredient (aminopyralid) was developed by Dow AgroSciences in 2005. The new herbicide, Milestone, is labeled for control of broadleaf herbaceous plants in rangelands, pasturelands, and noncroplands. This herbicide can be safely applied right up to water's edge or in areas with a high water table.

A list of herbicides and synergistic mixtures of herbicides used in western snowberry management is on table 1. The herbicides are sorted by the mechanisms of action; the chemical group, trade name, and production company name for each herbicide are also included on table 1.

Herbicide Toxicity

Herbicides are intended to be toxic to undesirable plants, but they also may have varying degrees of toxicity to humans and other organisms. The toxicity of herbicide chemicals is measured by the lethal dose (LD) or lethal concentration (LC) that kills 50% of the test animals, which are usually rats or rabbits (table 2). Toxic quantities that are ingested orally, exposed to the dermal layer of skin, and inhaled as vapor are measured separately. The oral and dermal lethal dosages are expressed as milligrams (mg) of toxicant per kilogram (kg) of body weight (mg/kg), and the inhaled lethal concentration is expressed as milligrams (mg) of toxicant per liter (l) of aerosol (mg/l).

Highly toxic herbicides have an LD_{50} of 50 to 500 mg/kg for a single oral dose and an LD_{50} of 200 to 1000 mg/kg for a single dermal dose. Moderately toxic herbicides have an LD_{50} of 500 to 5000 mg/kg for a single oral dose and an LD_{50} of 1000 to 2000 mg/kg for a single dermal dose. Slightly toxic herbicides have an LD_{50} of 5000 to 15000 mg/kg for a single oral dose and an LD_{50} of 2000 to 20000 mg/kg for a single dermal dose (Hamilton et al. 2004). None of the herbicides used in the chemical management of western snowberry are highly toxic. The herbicides are either moderately or slightly toxic to humans and other mammals, and generally a one-time exposure results in minimal irritation. Herbicide applicators need to wear appropriate personal protective equipment described on the respective product labels.

Beef Animal Restrictions

The grazing and haying restrictions for beef animals on grazinglands treated with herbicides used in western snowberry management are on table 3. These herbicides are either nontoxic or have low toxicity to domesticated animals and have no grazing restrictions at the application rates labeled for pasture use. Glyphosate (Roundup) that is applied by wiper technique at less than 3 quarts product per acre requires seven days without livestock grazing for maximum performance of the chemical, but the chemical does not pose any toxicity problems for the livestock. The restriction period between herbicide application and harvest of treated vegetation for hay ranges from zero days to one year (table 3). The restriction period required between slaughter of animals and their removal from herbicide treated pastures ranges from zero days to thirty days (table 3).

Table 1. Chemical name, chemical group, trade name, and company name of herbicides used in western snowberry management.

Mechanism of Action Herbicide Chemical Name	Chemical Group	Trade Name	Producer Company Name
Growth Regulates or Synthetic Auxins			
2,4-D low volatile ester	Phenoxy	2,4-D LVE	Several
2,4-D amine	Phenoxy	2,4-D A	Several
dicamba	Benzoic acid	Banvel	Micro Flo Co.
dicamba	Benzoic acid	Clarity	BASF
dicamba + 2,4-D	Benzoic acid + Phenoxy	Weedmaster	BASF
triclopyr	Pyridine	Garlon 3A	Dow AgroSciences
triclopyr + 2,4-D	Pyridine + Phenoxy	Crossbow	Dow AgroSciences
triclopyr + fluroxypyr	Pyridine + Pyridine	PastureGard	Dow AgroSciences
picloram	Picolinic acid	Tordon 22K	Dow AgroSciences
picloram + 2,4-D	Picolinic + Phenoxy	Grazon P+D	Dow AgroSciences
ALS Enzyme Inhibitors			
metsulfuron	Sulfonylurea	Ally XP	Dupont
metsulfuron	Sulfonylurea	Cimarron	Dupont
metsulfuron +chlorsulfuron	Sulfonylureas	Cimarron X-tra	Dupont
ALS Enzyme Inhibitor + Growth Regulators			
metsulfuron + dicamba + 2,4-D	Sulfonylurea + Benzoic acid + Phenoxy	Cimarron Max	Dupont
EPSP Synthase Inhibitor			
glyphosate	Aliphatic	Roundup	Monsanto
Photosystem II Inhibitor			
tebuthiuron	Amide	Spike 20P	Dow AgroSciences

Table 2. Toxicological test data of herbicides used in western snowberry management.

Trade Name	Chemical Name	Ingestion Oral LD_{50} (rat) (mg/kg)	Skin Dermal LD_{50} (rabbit) (mg/kg)	Inhalation Vapor LC_{50} (rat) (mg/L-4h)
2,4-D LVE	2,4-D low volatile ester	1161	>2000	N/E
2,4-D A	2,4-D amine	837-1492	2871	N/D
Banvel	dicamba	2629	>2000	>5.4
Clarity	dicamba	3512	>2000	>5.3
Weedmaster	dicamba + 2,4-D	1150	>2000	>20.3
Garlon 3A	triclopyr	1847-2574	>5000	N/E
Crossbow	triclopyr + 2,4-D	1000-2589	>5000	>5.0
PastureGard	triclopyr + fluroxypyr	2389-2675	>5000	>5.6
Tordon 22K	picloram	>5000	>5000	>8.11
Grazon P+D	picloram + 2,4-D	2598	>2000	N/E
Ally XP	metsulfuron	>5000	>2000	>5.3
Cimarron	metsulfuron	>5000	>2000	>5.3
Cimarron X-tra	metsulfuron + chlorsulfuron	>5000 >5000	>2000 >2000	>5.3 >5.9
Cimarron Max	metsulfuron (ptA) + dicamba + 2,4-D (ptB)	>5000 1497	>2000 >2000	>5.3 >2.07
Roundup	glyphosate	>5000	>5000	2.6
Spike 20P	tebuthiuron	>2000	>2000	N/A

Data from Material Safety Data Sheets

Table 3. Grazing and haying restrictions for beef animals on grazinglands treated with herbicides used in western snowberry management.

		Restrictions for beef animals		
Chemical Name	Trade Name	Period before grazing	Period before haying	Removal before slaughter
2,4-D low volatile ester	2,4-D LVE	0d	30d	3d
2,4-D amine	2,4-D A	0d	30d	3d
dicamba	Banvel	0d	7d	30d
dicamba	Clarity	0d	0d	30d
dicamba + 2,4-D	Weedmaster	0d	37d	30d
triclopyr	Garlon 3A	0d	14d	3d
triclopyr + 2,4-D	Crossbow	0d	14d	3d
triclopyr + fluroxypyr	PastureGard	0d	14d	3d
picloram	Tordon 22K	0d	14d	3d
picloram + 2,4-D	Grazon P+D	0d	30d	3d
metsulfuron	Ally XP	0d	4hr	0d
metsulfuron	Cimarron	0d	4hr	0d
metsulfuron + chlorsulfuron	Cimarron X-tra	0d	4hr	0d
metsulfuron + dicamba + 2,4-D	Cimarron Max	0d	37d	30d
glyphosate	Roundup	7d	7d	0d
tebuthiuron	Spike 20P	0d	1yr	0d

Data from product labels

Herbicide Properties and Characteristics

Phenoxy Herbicides

All of the numerous formulations of 2,4-D are phenoxy herbicides that are synthetically produced growth hormones similar to auxin. The ester forms of 2,4-D are more toxic per unit of acid equivalence for most plants and do not mix with water unless emulsified. The amine forms of 2,4-D are generally less toxic than the ester forms, but they have no volatility hazard and they are directly soluble in water. The exact mode of action is virtually impossible to ascertain because the physiological effects are so complex. The phenoxy herbicides cause changes in nitrogen metabolism, respiration, photosynthesis, and nucleic acid metabolism; they effect changes in the composition of carbohydrates, lipids, organic acids, ethylene alkaloids, steroids, aromatics, vitamins, pigments, minerals, hormones, nucleic acids, and enzymes; and they stimulate meristematic activity that results in abnormal morphological changes and twisting and curling of stems (Scifres 1980). Phenoxy herbicides are short lived in the environment and have limited mobility, with movement through soil to groundwater unlikely. Phenoxy herbicides are rapidly decomposed by soil microbes, sunlight, and plant metabolism (Hamilton et al. 2004).

2,4-D low volatile ester (LVE) is manufactured by several companies for control of annual, biennial, and perennial weeds and brush on pastures, rangeland, CRP acres, and noncropland. This herbicide is toxic to aquatic invertebrates and cannot be applied directly to water. This product contains 66.2% 2,4-D, with the acid equivalent (ae) of 3.8 lbs per gallon. Nonionic surfactants may be added to the spray mixture, and their use is recommended for application to woody plants on pasture and rangeland. The label rates for control or suppression of buckbrush on grazingland are 2.14 to 2.85 lb ae 2,4-D (2.25 to 3.0 qt product) per acre. Repeat treatments may be required (data from product label).

2,4-D amine is manufactured by several companies for control of annual, biennial, and perennial weeds and brush on pastures, rangeland, CRP acres, and noncropland. This herbicide is toxic to aquatic invertebrates and cannot be applied directly to water. This product contains 47.3% 2,4-D, with the acid equivalent (ae) of 3.8 lbs per gallon. Nonionic surfactants may be added to the spray mixture, and their use is recommended for application to woody plants on pasture and rangeland. The label rate for control or suppression of buckbrush on grazingland is 1.9 lb ae 2,4-D (2 qt product) per acre. Repeat treatments may be required (data from product label).

Benzoic Acid Herbicides

Dicamba is a broad spectrum benzoic acid herbicide. The exact mode of action has not been defined; however, the complex reactions in plants to benzoic acid phytotoxicity are similar to those caused by the phenoxy herbicides. Benzoic acid herbicides also disrupt the physiological processes of nucleic acid metabolism and photosynthesis (Scifres 1980). Dicamba is degraded by microbial activity and remains only a short time in the environment. In warm, moist soil, dicamba has a half-life of <14 days, and in native grasses and litter, the half-life is only 3 to 4 weeks (Hamilton et al. 2004).

Banvel is a water-soluble liquid manufactured for Micro Flo Co. for control of annual, biennial, and perennial broadleaf weeds and woody brush and vine species on pasture, hay, rangeland, noncropland, and CRP acres. This herbicide cannot be applied directly to water. This product contains 48.2% dicamba, with the acid equivalent (ae) of 4.0 lbs per gallon. Agriculturally approved adjuvants, emulsifiers, surfactants, wetting agents, drift control agents, and penetrants may be used for wetting, penetration, or drift control. The specific application rates of this herbicide that control western snowberry have not been determined through research. The label rates for control or suppression of woody species on grazingland are 0.5 to 1.0 lb ae dicamba (1 pt to 1 qt product) per acre broadcast applied and no more than 2.0 lb ae dicamba (2 qt product) per acre as a spot treatment. The amount of herbicide applied cannot exceed a total of 2.0 lb ae dicamba (2 qt product) per treated acre per growing season (data from product label).

Clarity is a water-soluble liquid manufactured by BASF for control of annual, biennial, and perennial broadleaf weeds and woody brush and vine species on CRP acres, noncropland, pasture, and rangeland. This herbicide cannot be applied directly to water. This product contains 56.8% dicamba, with the acid equivalent (ae) of 4.0 lbs per gallon. Agriculturally approved nonionic surfactants and crop oil concentrates may be added to spray mixtures. The specific application rates of this herbicide that control western snowberry have not been determined through research. The label rates for control or suppression of woody species on grazingland are 0.5 to 1.0 lb ae dicamba (1 pt to 1 qt product) per acre broadcast applied and no more than 2.0 lb ae dicamba (2 qt product) per acre as a spot treatment. The amount of herbicide applied cannot exceed a total of 2.0 lb ae dicamba (2 qt product) per treated acre during a growing season (data from product label).

Weedmaster is a selective postemergence mixture manufactured by BASF for control of annual, biennial, and perennial weeds and brush on CRP acres, noncropland, grass (hay or silage), pastures, and rangeland. This herbicide is toxic to aquatic invertebrates and cannot be applied directly to water. This product contains 12.4% dicamba and 35.7% 2,4-D, with the acid equivalents (ae) of 1.0 lb dicamba per gallon and 2.87 lb 2,4-D per gallon. Nonionic surfactants may be added to the spray mixture. The specific application rates of this herbicide that control western snowberry have not been determined through research. The label rates for control or suppression of woody species on grazingland are no more than 0.5 lb ae dicamba and 1.44 lb ae 2,4-D (2 qt product) per acre broadcast applied and 0.5 to 1.0 lb ae dicamba and 1.44 to 2.87 lb ae 2,4-D (2 to 4 qt product) per acre as a spot treatment. The amount of herbicide applied cannot exceed a total of 1.0 lb ae dicamba and 2.87 lb ae 2,4-D (4 qt product) per treated acre during a growing season (data from product label 2004).

Pyridine Herbicides

Triclopyr and fluroxypyr are pyridine herbicides. The complex reactions in plants to pyridine phototoxicity are similar to those caused by the phenoxy herbicides (Scifres 1980). Breakdown of pyridine herbicides occurs in soil by leaching, photodegradation, and microbial activity, with the rate of breakdown related to temperature. Movement through soil to groundwater is unlikely, and mobility in runoff water is limited (Hamilton et al. 2004).

Garlon 3A is a speciality herbicide manufactured by Dow AgroSciences for control of woody plants, broadleaf weeds, vines, and deciduous trees on noncropland and forests, including grazing areas. Use within production forests may include herbicide applications to control target vegetation in and around standing water sites if no more than one-third to one-half of the water area is in a single treatment. This product contains 44.4% triclopyr, with the acid equivalent (ae) of 3.0 lbs per gallon. Addition of an agriculturally labeled nonionic surfactant to the spray mixture is recommended for all foliar applications. The specific application rates of this herbicide that control western snowberry have not been determined through research. The label rates for treatment of woody plants on range and pasture sites where grazing is allowed are no more than 2.0 lb ae triclopyr (two-thirds gallon product) per acre per growing season. Spot treatments of problem plants in grazed areas may be conducted when the treated sites compose no more than 10% of the total grazable area (data from product label 2003).

Crossbow is a speciality herbicide mixture manufactured by Dow AgroSciences for control of trees and brush, and annual, biennial, and perennial broadleaf weeds on rangeland, permanent grass pastures, CRP acres, and noncropland. This product may not be applied to forage that is to be cut and sold for commercial purposes. This herbicide is toxic to fish and cannot be applied directly to water. This product contains 16.5% triclopyr BEE and 34.4% 2,4-D LVE, with the acid equivalents (ae) of 1.0 lb triclopyr per gallon and 2.0 lb 2,4-D per gallon. Continuous agitation of spray mixture is necessary because this herbicide forms an emulsion in water, not a solution, and separation may occur. The specific application rates of this herbicide that control western snowberry have not been determined through research. The label instructions and rates for suppression of buckbrush on grazingland are to use the 1.5% mixture (2.0 fl oz product per gallon of water) at 1.0 lb ae triclopyr and 2.0 lb ae 2,4-D (4 qt product) per acre. The amount of herbicide applied cannot exceed a total of 1.0 lb ae triclopyr and 2.0 lb ae 2,4-D (4 qt product) per acre per growing season. Hard to control species will require retreatment or a double rate application. Spot treatments of problem plants in grazed areas may be conducted when the treated sites compose no more than 10% of the total grazable area (data from product label 2005).

PastureGard is a herbicide mixture manufactured by Dow AgroSciences for control of broadleaf herbaceous and woody plants in rangeland, permanent pastures, and noncropland. This herbicide is toxic to fish and cannot be applied directly to water. This product contains 25.0% triclopyr and 8.6% fluroxypyr, with the acid equivalents (ae) of 1.5 lb triclopyr and 0.5 lb fluroxypyr per gallon. Using a nonionic surfactant may improve weed control. The specific application rates of this herbicide that control western snowberry have not been determined through research. The label rates for the control of woody plants on grazingland are 0.56 lb to 1.5 lb ae triclopyr and 0.19 lb to 0.5 lb ae fluroxypyr (3 pt to 8 pt product) per acre broadcast applied. The amount of herbicide applied cannot exceed a total of 1.5 lb ae triclopyr and 0.5 lb ae fluroxypyr (4 qt product) per treated acre per growing season (data from product label 2005).

Picolinic Acid Herbicides

Picloram is a picolinic acid herbicide that interferes with a multitude of vital processes and enzyme systems, disrupts nucleic acid metabolism, and stimulates abnormal meristematic activity that causes twisted stems and death of growing points (Scifres 1980). Picloram is an effective broad spectrum herbicide because it is readily absorbed both by upper and lower leaf surfaces and by the roots, and it can move through either the phloem or the xylem vascular systems. Picloram degrades rapidly by sunlight; however, degradation by soil microorganisms and plant metabolism is slow and may require 3 to 6 months, with the half-life depending on rainfall and soil temperature. The persistence is longer in cooler climates, and some of the chemical may leach to lower soil depths (Hamilton et al. 2004).

Tordon 22K is a restricted use pesticide manufactured by Dow AgroSciences for control of broadleaf weeds and woody plants and vines on rangeland, permanent grass pastures, CRP acres, and noncropland. This herbicide cannot be applied directly to water. This product contains 24.4% picloram, with the acid equivalent (ae) of 2.0 lbs per gallon. The addition of a surfactant may improve efficacy during drought conditions or when plant surfaces are dusty. The specific application rates of this herbicide that control western snowberry have not been determined through research. The label rates for the control of woody species on grazingland are 0.5 lb to 1.0 lb ae picloram (1 qt to 2 qt product) per acre broadcast applied and no more than 1.0 lb ae picloram (2 qt product) per acre as a spot treatment. The amount of herbicide applied cannot exceed a total of 1.0 lb ae picloram (2 qt product) per acre per growing season (data from product label 2005).

Grazon P+D is a restricted use pesticide mixture manufactured by Dow AgroSciences for control of annual and perennial broadleaf weeds and woody plants on CRP acres, rangeland, and permanent grass pastures. This herbicide cannot be applied directly to water. This product contains 10.2% picloram and 39.6% 2,4-D amine, with the acid equivalents (ae) of 0.54 lb picloram per gallon and 2.0 lbs 2,4-D per gallon. Grazon P+D is a water-soluble liquid, and a nonionic surfactant may be used to provide more complete wetting and coverage of the foliage. The specific application rates of this herbicide that control western snowberry have not been determined through research. The label rates for the control of woody species on grazingland are 0.14 lb to 0.54 lb ae picloram and 0.5 lb to 2.0 lb ae 2,4-D (1 qt to 4 qt product) per acre. The amount of herbicide applied cannot exceed a total of 0.54 lb ae picloram and 2.0 lb ae 2,4-D (4 qt product) per acre per growing season (data from product label 2002).

Sulfonylurea Herbicides

Metsulfuron and chlorsulfuron are sulfonylurea herbicides that disrupt enzyme systems, rapidly inhibiting growth; within 1 to 3 weeks the meristemetic tissue at the growing points dies (product label). Sulfonylurea herbicides are moderately persistent in soil, with a typical half-life of 30 days. Degradation by soil microbes is generally slow, with increased rates at high soil temperatures and high soil moisture. Nonmicrobial hydrolysis degrades the herbicides slowly at high pH and relatively rapidly at lower pH (Hamilton et al. 2004).

Ally XP is manufactured by DuPont for control of broadleaf weeds and woody species on pastures and rangeland. This herbicide cannot be applied directly to water. This dry flowable product contains 60% metsulfuron methyl. Use of a nonionic surfactant is recommended. The label rates for suppression of western snowberry are 0.2 to 0.3 oz product per acre broadcast applied and 1.0 oz product per 100 gallons of water as a spot treatment. The amount of herbicide applied cannot exceed a total of 0.75 oz product per acre (data from product label 2001).

Cimarron is manufactured by DuPont for control or suppression of broadleaf weeds and brush on pastures, rangeland, CRP, and noncropland. This herbicide cannot be applied directly to bodies of water. This dry flowable product contains 60% metsulfuron methyl. A nonionic surfactant should be used. The label rates for control or suppression of western snowberry are 0.12 oz to 0.60 oz metsulfuron (0.2 to 1.0 oz product) per acre broadcast applied and 0.60 oz metsulfuron (1.0 oz product) per 100 gallons of water as a spot treatment. The degree of suppression varies with the rate used, the size of the weeds, and the environmental conditions following treatment. The amount of herbicide applied cannot exceed a total of 1.0 oz metsulfuron (1.67 oz product) per acre per year (data from product label 2005).

Cimarron X-tra is a herbicide mixture manufactured by DuPont for control of weeds and brush on pastures, rangeland, CRP acres with established grasses, and noncropland. This herbicide cannot be applied directly to water. A 20-ounce unit pack of this product contains 30.0% metsulfuron and 37.5% chlorsulfuron in separate compartments. A nonionic surfactant must be used in the spray mixture. The specific application rates of this herbicide that control western snowberry have not been determined through research. The label instructions and rates for control or suppression of western snowberry on grazingland are to use Rate I–0.15 oz metsulfuron and 0.19 oz chlorsulfuron (0.5 oz product) per acre. The amount of herbicide applied cannot exceed a total of 1.0 oz chlorsulfuron (2.67 oz product) per acre and cannot exceed a total of 1.0 oz of metsulfuron (3.33 oz product) per acre per year (data from product label 2005).

Cimarron Max is a two-part product mixture manufactured by DuPont for control of weeds and brush on pastures, rangeland, CRP acres with established grasses, and noncropland. This herbicide is toxic to aquatic invertebrates and cannot be applied directly to water. Part A of this product contains 60% metsulfuron. Part B of this product contains 10.3% dicamba, with the acid equivalent (ae) of 1.0 lb per gallon and 29.6% 2,4-D, with the acid equivalent (ae) of 2.87 lb per gallon. A crop oil concentrate or a nonionic surfactant must be used in the spray mixture. The specific application rates of this herbicide that control western snowberry have not been determined through research. The label instructions and rates for control or suppression of western snowberry are to use Rate I–0.15 oz metsulfuron (0.25 oz part A) and 0.125 lb dicamba and 0.359 lb 2,4-D (1 pt part B) per acre. The amount of herbicide applied cannot exceed a total of 1.0 oz metsulfuron (1.67 oz part A) per acre per year (data from product label 2005).

Aliphatic Herbicides

Glyphosate is an aliphatic herbicide that is nonselective and it can kill in about 2 to 7 days from application all types of plants contacted by the chemical by inhibiting an enzyme essential for amino acid formulation (product label 2004). Glyphosate is strongly adsorbed to soil, so it is virtually biologically unavailable and immobile. The chemical is degraded by microbial activity (Hamilton et al. 2004).

Roundup is a nonselective broad spectrum systemic herbicide manufactured by Monsanto for control of annual and perennial weeds, woody brush, and trees on pastures, rangeland, CRP acres, and noncropland. Application of this product may be as spot treatments or over-the-top wiper treatments where the chemical does not come in contact with the desirable understory vegetation. Surfactants cannot be added to the herbicide solution when wiper applicators are used. This herbicide cannot be applied directly to water. This product contains 41.0% glyphosate, with the acid equivalent (ae) of 3.0 lb per gallon and 4.0 lb active ingredient (ai) per gallon. The specific application rates of this herbicide that control western snowberry have not been determined through research. The label rates for control or suppression of woody brush on grazingland are 2.0 to 3.0 lb ai glyphosate (2 to 3 qt product) per acre. The amount of herbicide applied onto pasture and rangeland cannot exceed a total of 3.0 lb ai glyphosate (3 qt product) per acre per year (data from product label 2004).

Amide Herbicides

Tebuthiuron is an amide-urea derivative herbicide that is soil activated and absorbed by plants through the roots. Tebuthiuron interferes with or inhibits the photosynthetic process, causing premature aging and shedding of the leaves. Several leaf defoliation cycles deplete stored nonstructural carbohydrates and result in death of the plant (Bjerregaard et al. 1978). Tebuthiuron may persist in soils for long periods. It is adsorbed to the organic matter and clay particles in the soil. Tebuthiuron resists photodecomposition and volatilization, and its breakdown by microbial activity is slow (Hamilton et al. 2004).

Spike 20P is a surface applied soil-active pelleted product manufactured by Dow AgroSciences for control of woody plants in rangeland, pastureland, and noncropland. This product is also available as a wettable powder. This herbicide is toxic to fish and cannot be applied directly to water or to areas with a shallow water table (5 feet or less). This product contains 20% tebuthiuron. The specific application rates of this herbicide that control western snowberry have not been determined through research. The label rates for control of woody brush on grazingland are a maximum of 1.0 lb ai tebuthiuron (5 lb product) per acre in regions that receive less than 20 inches annual precipitation and a maximum of 2.0 lb ai tebuthiuron (10 lb product) per acre in regions that receive greater than 20 inches annual precipitation. Rates greater than 0.8 lb ai tebuthiuron (4.0 lb product) per acre may cause injury to perennial grasses. The product cannot be applied to an area more than once per year. Hay for livestock feed cannot be cut for one year after treatment. Intact treated woody plants should not be disturbed by mowing or burning for two years after treatment because the plants go through several defoliation cycles before stored nonstructural carbohydrates are depleted and death occurs (data from product label 2003). At low rates of 0.25 lb ai tebuthiuron per acre, additional time for control may be required.

Period of Vulnerability

In order to kill belowground plant parts, foliage-applied herbicides must enter leaf tissue through the stomata openings or penetrate the cuticle on the outer layer of the leaf and then be translocated downward through the bidirectional phloem vascular system to metabolically active organs of the rhizome crown (Scifres 1980). Young leaf tissue has a thin cuticle layer and the cell walls have low levels of cellulose and lignin; this young tissue presents low resistance to foliage-active herbicide penetration. The cuticle thickens and the cell walls stiffen as leaves mature; this aging process increases the resistance to herbicide penetration and absorption. Surfactants (or adjuvants) increase herbicidal activity. Adding surfactants to herbicide spray mixtures improves penetration and absorption of foliage-active herbicides into maturing leaves. The quantity of herbicide translocated downward is related to the rate at which carbohydrates are used for plant growth (Scifres 1980) and whether the source of carbohydrates is derived from current photosynthate or stored reserves (Leopold and Kriedemann 1975). When the rate of photosynthesis is insufficient to meet demands of plant growth, stored nonstructural carbohydrates move upward from the storage site in the rhizome crown to the active growing points of the twigs and leaves. When photosynthetic rates exceed plant growth demands, nonstructural carbohydrates move downward from the leaves to the storage site in the rhizome crown (Coyne et al. 1995). Greater quantities of foliar-applied herbicides are translocated downward to belowground plant parts during replenishment periods, when carbohydrates are moving downward from leaves to the storage site, than during drawdown periods, when carbohydrates are moving upwards from the storage site to actively growing aerial parts (Adams and Bailey 1983). Changes in the amount of stored carbohydrates follow a typical pattern each growing season, with periods of drawdown and replenishment (Coyne et al. 1995).

Adams and Bailey (1983) conducted a study in Alberta to determine when drawdown and replenishment periods occur in western snowberry. Rhizome crowns were collected every ten days during the growing season and analyzed for nonstructural carbohydrate content. The resulting pattern of carbohydrate drawdown and replenishment indicates the time periods and plant growth stages when foliar application of herbicides would be expected to produce greater kill of belowground plant parts.

The major carbohydrate drawdown period occurs during the rapid growth of early spring, starting in mid April and continuing until early June, shortly after full leaf stage and about the time the sucker stems have elongated to two-thirds of full length. Two other periods of carbohydrate drawdown occur, one during fruit fill, from mid July to early August, and the other during fall growth, from early September to late October (Adams and Bailey 1983). Herbicides applied during the early drawdown period would likely penetrate the young foliage and cause high rates of top kill (Adams and Bailey 1983). However, only small amounts of herbicide would reach the roots because the upward flow of carbohydrates during this period interferes with the downward movement of herbicides; the result is low levels of kill of belowground plant parts.

The main carbohydrate replenishment period occurs from early June to mid July, starting during the final stages of sucker stem elongation and continuing through the flower bud stage into the early stages of flower development. A second carbohydrate replenishment period occurs between mid August and early September (Adams and Bailey 1983). Much of the herbicide applied during the early replenishment period would be expected to be carried downward to the rhizome crowns, with the downward flow of carbohydrates moving from the leaves to the belowground storage sites; the result would be kill of both aboveground and belowground plant parts (Adams and Bailey 1983). Herbicides applied during the earlier portions of the first replenishment period would possibly have greater kill levels than herbicides applied during the latter portions because herbicide penetration into leaf tissue tends to decrease as the leaves mature (Scifres 1980).

Chemical Management Research

Pelton (1953) projected that chemical herbicide use would increase as a method to control western snowberry and indicated that 2,4-D was the most promising herbicide, even though western snowberry was one of the more resistant shrubs to this chemical.

McCarty (1967) conducted three experiments in southern Nebraska that compared one, two, or three repeated annual applications of chemical herbicides to replicated western snowberry colonies on different dates in May, June, and July and estimated percent control of aerial stems one year after final treatment.

McCarty (1967) considered the timeliness of herbicide application to be important for good western snowberry control. The phenological growth of western snowberry in Nebraska is similar to that of western snowberry colonies across North America. Most of the growth occurs during May. New shoots are 4 to 8 inches (10-20 cm) long, with the first four to six leaves full size in early May, and by late May the plants have completed full foliar development (McCarty 1967). The results of the herbicide experiment indicated that herbicide application during early to mid May was more effective for western snowberry aerial stem control than herbicide application in late May and that herbicide application during late June or mid July was much less effective than the May applications (McCarty 1967). The June and July application treatments were discontinued during the second and third experiments.

Favorable moisture conditions and multiple retreatments appeared to improve western snowberry control (McCarty 1967). Three applications of 2,4-D HV ester on the 14 and 21 May treatment dates gave excellent control of aerial stems (table 4). Three applications of 2,4-D HV ester on the late June and mid July treatment dates were much less effective at aerial stem control than the May application dates (table 4). Herbicide penetration into mature leaf tissue is much less than herbicide penetration into young leaf tissue (Scifres 1980). The low levels of aerial stem control during the late June and mid July treatment dates may reflect low herbicide penetration into mature leaf tissue. The greater levels of aerial stem control during the May treatment dates may reflect high herbicide penetration into young leaf tissue.

The 2,4-D ester treatment was consistently more effective than the 2,4-D amine treatment on all application dates (table 4). The 2,4-D amine did not kill a large portion of the aerial stems. These surviving stems were able to reinfest the area quickly by respouting during subsequent growing seasons (McCarty 1967).

Two applications of 2,4-D HV ester at both the 1.0 lb/ac and 2.0 lb/ac rates gave excellent control of western snowberry aerial stems on all three treatment dates in May (table 4). Percent control of aerial stems with two applications of 2,4-D LV ester at both the 1.0 lb/ac and 2.0 lb/ac rates was only slightly lower than the percent control of aerial stems from 2,4-D HV ester at the respective rates (table 4).

One application of 2,4-D HV ester at the 2.0 lb/ac rate resulted in greater percent control of aerial stems than one application at the 1.0 lb/ac rate on all three treatment dates in May (table 4). Treatments with one application of herbicide had lower percent control of western snowberry aerial stems than treatments with multiple annual applications of herbicide.

The high percent control of aerial stems during the three May application dates indicates high levels of herbicide penetration and effective top kill. However, the increase in the presence of living western snowberry stems on study plots during the second growing season after the final treatment indicates that only low levels of control of the belowground plant parts had been achieved. McCarty (1967) concluded that because western snowberry can quickly reinfest an area, the use of 2,4-D every second or third year will be necessary for long-term pasture management.

Ferrel (1986, 1992a, 1992b) and Ferrel and Whitson (1987) conducted four experiments to evaluate various formulations of herbicides for the control of western snowberry. Research was conducted near Aladdin, Wyoming, on an unimproved pasture that had a heavy infestation of western snowberry. Experimental plots of around 10 by 20 ft. (3 X 6 m) were arranged in a randomized complete block design with three replications. Liquid herbicide treatments were broadcast applied with a CO_2 pressurized six-nozzle knapsack spray unit. Granular formulations were applied by hand. Percent control of aerial stems was evaluated by visual estimates one year following treatment (Ferrel 1986, 1992a, 1992b; Ferrel and Whitson 1987).

The phenological growth of western snowberry in Wyoming is similar to that of western snowberry colonies across North America. Most of the growth occurs during May, and by late May the stems are 6 to 20 inches (15-51 cm) tall and near full leaf development. Stems are at full leaf stage and 12 to 20 inches (31-52 cm) tall in early June and at bud to full bloom growth stages and 12 to 20 inches (31-51 cm) tall in early July. In mid September, stems are 15 to 36 inches (38-91 cm) tall, and leaves are beginning to drop (Ferrel 1986, 1992a, 1992b; Ferrel and Whitson 1987).

The objective of these four experiments was to perform a rapid screening of herbicides and identify chemicals that showed promise for the control of western snowberry. Most of the chemicals or chemical mixtures were evaluated at more than one application rate.

Spring application of triclopyr, fluroxypyr, fluroxypyr + triclopyr, tebuthiuron, and fosamine at 6.0 lb ai/ac, and summer application of triclopyr, Dowco 290 + 2,4-D A, Dowco 290 + picloram, metsulfuron, and metsulfuron + 2,4-D LVE did not show promise for controlling western snowberry aerial stems at the rates and application dates evaluated (table 5). Spring application of 2,4-D LVE and summer application of picloram provided 70% and 73% control of aerial stems at 2.0 lb ai/ac, respectively (table 5). Spring application of fosamine at 12.0 lb and 24.0 lb ai/ac, and glyphosate at 1.125 lb ai/ac provided 82%, 96%, and 95% control of aerial stems, respectively (table 5). Spring application of chlorsulfuron, metsulfuron, and metsulfuron + 2,4-D LVE provided 100% control of aerial stems at the rates evaluated, respectively (table 5), and showed considerable promise for western snowberry control.

Experiment #4 evaluated two herbicide application dates; one date was successful, and the other date was not successful. The differences in the percent control of western snowberry aerial stems between the two herbicide application dates are most likely related to differences in the quantities of herbicide penetration into the leaves and differences in the quantities of herbicide translocated to belowground plant parts. Greater quantities of herbicide penetrate young leaves than penetrate mature leaves, and greater quantities of foliar-applied herbicide are translocated downward during carbohydrate replenishment periods than during drawdown periods. On the early June application date, western snowberry has fully developed young leaves and is just starting the first carbohydrate replenishment period. On the mid September application date, western snowberry has mature leaves near senescence and is in a late season carbohydrate drawdown period. The early June herbicide application date resulted in 100% control of aerial stems, and the mid September application date resulted in 50% control of aerial stems one year after treatment (table 5).

Bowes (1991) conducted two chemical management experiments northeast of Regina, Saskatchewan, to evaluate the effects of herbicide mixtures on reducing western snowberry regrowth suckers in the aspen parkland vegetation zone following bulldozer treatments that sheared aspen poplar trees at the surface of frozen soil. Herbicide treatments of dicamba plus 2,4-D LVE (ester) and plus 2,4-D A (amine) applied at the rates of 1.34 + 1.96 lb ai/acre (1.5 + 2.2 kg/ha) in experiment #1 and 1.34 + 1.78 lb ai/acre (1.5 + 2.0 kg/ha) in experiment #2 were applied with a hand-held compressed-air sprayer one, two, and three times every year or every-other-year on 6 June 1981, 16 June 1982, and 16 June 1983 in experiment #1 and on 16 June 1983, 19 June 1984, and 27 June 1985 in experiment #2. The study analyzed data for percent canopy cover of western snowberry collected during mid August for nine years and data for aboveground herbage biomass of grasses and forbs collected during late June to mid July for eight years from plots replicated four times.

Bowes (1991) considered western snowberry effectively controlled when the canopy cover was reduced to less than 1%. Herbicide mixtures of dicamba + 2,4-D LVE and dicamba + 2,4-D A had similar effects in reducing canopy cover of western snowberry (Bowes 1991); however, sucker regrowth was greater five years after final treatment on the dicamba + 2,4-D A plots than on the dicamba + 2,4-D LVE plots (table 6). Dicamba + 2,4-D LVE and dicamba + 2,4-D A applied two and three times during early to mid June were more effective at reducing western snowberry canopy cover than dicamba + 2,4-D LVE and dicamba + 2,4-D A applied one time during early June (table 6). No differences in canopy cover one year or five years after final treatment were found between treatments with herbicide mixtures applied two times every year or every-other-year (table 6). Dicamba + 2,4-D LVE applied two times during mid to late June was more effective than dicamba + 2,4-D LVE applied two times during early to mid June (table 6). Dicamba + 2,4-D LVE applied one time during mid June was more effective than dicamba + 2,4-D LVE applied one time during early June (table 6).

Grass biomass production was greater on the herbicide treated plots than on the untreated control plots (Bowes 1991) (table 7). Herbicide mixtures of dicamba + 2,4-D LVE and dicamba + 2,4-D A had similar effects on grass biomass production; however, five years after final treatment, grass biomass production was greater on the dicamba + 2,4-D LVE plots than on the dicamba + 2,4-D A plots (table 7). Dicamba + 2,4-D LVE and dicamba + 2,4-D A applied two and three times were more effective at increasing grass biomass production than dicamba + 2,4-D LVE and dicamba + 2,4-D A applied one time (table 7). No differences in grass biomass production one year or five years after final treatment were found between treatments with herbicide mixtures applied two times every year or every-other-year (table 7). Dicamba + 2,4-D LVE applied two times during mid to late June was more effective at increasing grass biomass production than dicamba + 2,4-D LVE applied two times during early to mid June (table 7).

Both dicamba + 2,4-D LVE and dicamba + 2,4-D A herbicide mixtures reduced forb biomass production. Two and three applications of the herbicide mixtures reduced forb biomass production more than a single application of the herbicide mixtures (Bowes 1991).

Western snowberry was not completely eradicated by the herbicide mixtures of dicamba and 2,4-D tested (Bowes 1991). Dicamba + 2,4-D LVE and dicamba + 2,4-D A have similar effects on western snowberry canopy cover and grass and forb herbage biomass production one year after final treatment; however, five years after final treatment, the effects from dicamba + 2,4-D A had diminished further than those from dicamba + 2,4-D LVE. Two and three applications of herbicide mixtures are more effective than a single application. Multiple applications every year or every-other-year have similar effects following the final treatment. Herbicide mixtures applied during mid to late June are more effective than mixtures applied during early to mid June.

Bowes and Spurr (1995) conducted two chemical management experiments southeast of Regina, Saskatchewan, to evaluate the effects from herbicide treatments on reducing western snowberry in mixed grass prairie that had not been grazed for ten years. Single herbicide treatments of metsulfuron, metsulfuron + 2,4-D LVE (ester), and 2,4-D LVE alone were applied with a hand-held compressed-air sprayer when western snowberry sucker stems were at or near full expansion growth stage on 16 June 1986 in experiment #1 and on 12 June 1987 in experiment #2. The study analyzed data for percent canopy cover of western snowberry collected during mid August for six years and data for aboveground biomass of western snowberry aerial stems and aboveground herbage biomass of grasses collected between mid June and mid July each year of the study from plots replicated four times.

Bowes (1991) considered western snowberry effectively controlled when the canopy cover was reduced to less than 1%. All herbicide treatments applied 16 June in experiment #1 and all treatments applied 12 June in experiment #2, with the exception of one treatment, resulted in 95% or better reduction of western snowberry canopy cover during the year of treatment. The low rate with 0.04 oz/acre (3 g/ha) of metsulfuron + 2,4-D LVE treatment in experiment #2 resulted in only 85% reduction in canopy cover (table 8).

All herbicide treatments applied 16 June in experiment #1, with the exception of one treatment, resulted in 95% or better reduction of canopy cover five years after treatment. The 2,4-D LVE alone treatment resulted in only 86% reduction in canopy cover five years after treatment (table 8). Two treatments applied 12 June in experiment #2 resulted in 95% or better reduction of canopy cover five years after treatment. The treatments with the 0.21 oz/acre (15 g/ha) rate of metsulfuron alone and the 0.21 oz/acre (15 g/ha) rate of metsulfuron + 2,4-D LVE resulted in 95% or better reduction in canopy cover five years after treatment (table 8). The treatments with lower rates of 0.11, 0.07, and 0.04 oz/acre (7.5, 5, and 3 g/ha) metsulfuron alone and metsulfuron + 2,4-D LVE, and with 2,4-D LVE alone applied 12 June in experiment #2 resulted in western snowberry canopy cover reductions of less than 95% five years after treatment (table 8). Percent canopy cover reductions were similar among the high rates of 0.21, 0.43, and 0.86 oz/acre (15, 30, and 60 g/ha) metsulfuron alone and metsulfuron + 2,4-D LVE one year and five years after treatment. Metsulfuron applied at the 0.43 and 0.86 oz/acre (30 and 60 g/ha) rates was no more effective than metsulfuron applied at the 0.21 oz/acre (15 g/ha) rate.

All herbicide treatments applied 16 June in experiment #1 resulted in 95% or better reduction of western snowberry aboveground biomass one year after treatment (table 9). All treatments applied 12 June in experiment #2, with the exception of two treatments, resulted in 95% or better reduction of western snowberry aboveground biomass one year after treatment. The treatments with the low rate of 0.04 oz/acre (3 g/ha) metsulfuron + 2,4-D LVE and with 2,4-D LVE alone resulted in aerial stem biomass reductions of less than 95% one year after treatment (table 9).

All herbicide treatments applied 16 June in experiment #1, with the exception of one treatment, resulted in 95% or better reduction of western snowberry aerial stem biomass five years after treatment. The 2,4-D LVE alone treatment resulted in aerial stem biomass reduction of only 89% five years after treatment (table 9). Two treatments applied 12 June in experiment #2 resulted in high reductions of aerial stem biomass five years after treatment. These two treatments were the 0.21 oz/acre (15 g/ha) rate of metsulfuron alone and the 0.21 oz/acre (15 g/ha) rate of metsulfuron + 2,4-D LVE (table 9). The herbicide treatments with the low rates of 0.04, 0.07, and 0.11 oz/acre (3, 5, and 7.5 g/ha) metsulfuron alone and metsulfuron + 2,4-D LVE, and with 2,4-D LVE alone applied 12 June in experiment #2 had considerable western snowberry aerial stem biomass production from regrowth of rhizome suckers, crown suckers, and new growth on existing stems five years after treatment, and these treatments were considered not to be successful long-term control of western snowberry (Bowes and Spurr 1995).

All treatments with herbicide applied 16 June in experiment #1 had greater grass production than the untreated control plots one year and five years after treatment (table 10). Grass biomass production on the treatments with herbicide applied 12 June in experiment #2 was not much different from grass production on the untreated control plots one year after treatment. However, all treatments with herbicide applied 12 June in experiment #2 had greater grass production than the untreated control plots five years after treatment (table 10). Reduction of western snowberry canopy cover resulted in greater quantities of sunlight reaching the herbaceous layer and caused an increase in grass herbage biomass production.

The time of herbicide application is important (Bowes and Spurr 1995). Foliar-applied herbicides are translocated through the phloem vascular system when materials are moving downward. The carbohydrate reserves in the crowns of western snowberry are drawn down during the rapid growth of early spring and are at the lowest level about the time the sucker stems have elongated to two-thirds of full length, during the ten days prior to 9 June (Adams and Bailey 1983). From early June to mid July, the energy reserves in the crowns are replenished with surplus carbohydrates produced in the leaves and moved down into belowground plant parts. That the herbicide treatments applied 16 June were more effective than the treatments applied 12 June indicates that greater quantities of herbicide were translocated to the crowns on the later application date.

Western snowberry was not eradicated by the metsulfuron and 2,4-D treatments tested (Bowes and Spurr 1995). Metsulfuron was more effective at killing western snowberry crowns than 2,4-D because a greater percent of the metsulfuron than of the 2,4-D was translocated through the phloem (Bowes and Spurr 1995). The addition of 2,4-D to metsulfuron did not improve the effectiveness. At the low chemical rates, metsulfuron was more effective alone than when 2,4-D was present in the mixture. Bowes and Spurr (1995) concluded that the effective herbicide treatment for the control of western snowberry through the fifth year after treatment was metsulfuron applied alone at the rate of 0.21 oz ai/acre (15 g/ha) during mid June.

Bowes and Spurr (1996) conducted two chemical management experiments northeast of Regina, Saskatchewan, to evaluate the effects of herbicide treatments on reducing western snowberry regrowth suckers in the aspen parkland vegetation zone following bulldozer treatments that sheared aspen poplar trees at the surface of frozen soil. Single herbicide treatments of metsulfuron, metsulfuron + 2,4-D LVE (ester), and 2,4-D LVE alone were applied with a hand-held compressed-air sprayer on 19 June 1985 in experiment #1 and on 10 June 1986 in experiment #2. The study analyzed data for percent canopy cover of western snowberry collected during mid August for seven years and data for aboveground herbage biomass of grasses and forbs collected during late June to mid July for five years from plots replicated four times.

All herbicide treatments applied 19 June in experiment #1 and 10 June in experiment #2 reduced western snowberry canopy cover to less than 1% during the year of treatment (table 11). Bowes (1991) considered western snowberry effectively controlled when the canopy cover was reduced to less than 1%. Percent canopy cover changed very little on the untreated and treated areas of both experiments six years after treatment (Bowes and Spurr 1996).

All treatments with herbicide applied 19 June in experiment #1 and 10 June in experiment #2 had greater five year mean grass biomass production than the untreated controls (table 12). Treatments with metsulfuron applied at 0.21, 0.43, and 0.86 oz/acre (15, 30, and 60 g/ha) rates on 19 June in experiment #1 and 10 June in experiment #2 had lower five year mean forb biomass production than the untreated controls. The addition of 2,4-D LVE to metsulfuron resulted in greater reductions in the five year mean forb biomass production for the three rates of metsulfuron, respectively (table 12). Treatments with application of 2,4-D LVE alone on 19 June in experiment #1 had greater five year mean forb biomass production than the untreated controls. Treatments with application of 2,4-D LVE alone on 10 June in experiment #2 had lower five year mean forb biomass production than the untreated controls (table 12).

Western snowberry was not completely eradicated by the metsulfuron and 2,4-D LVE treatments tested (Bowes and Spurr 1996). Metsulfuron applied at the high rates of 0.21, 0.43, and 0.86 oz/acre (15, 30, and 60 g/ha) effectively killed western snowberry crowns and controlled rhizome sucker canopy cover at less than 1% six years after treatment. Application of 2,4-D LVE alone at the 1.78 lb/acre (2 kg/ha) rate effectively killed western snowberry and controlled canopy cover at 1% six years after treatment. The addition of 2,4-D LVE to metsulfuron did not improve the effectiveness. Differences from the application dates were not found between respective herbicide treatments of metsulfuron and metsulfuron + 2,4-D LVE. Metsulfuron applied at 0.43 and 0.86 oz/acre (30 and 60 g/ha) was no more effective than the 0.21 oz/acre (15 g/ha) rate. Metsulfuron applied alone at the rate of 0.21 oz/acre (15 g/ha) during mid June is an effective herbicide treatment for the control of western snowberry.

Management Implications

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 respective specific 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 though the phloem vascular system to the metabolically active sites of the crowns and rhizomes. The vulnerable stage when the leaf tissue absorbs herbicides and the phloem system translocates herbicides downward is remarkably narrow, during mid June.

Spring growth of western snowberry starts in mid to late April, with rapid twig elongation and leaf growth and expansion occurring simultaneously until late May or early June, when the appearance of flower buds at the twig tips ends both rapid twig growth and the possibility for additional new leaves. Nonstructural carbohydrates move from the storage site in the rhizomes and the crowns upward through the phloem vascular system to the active growing points during the spring growth period of mid April to early June. By early June, the twigs have completed about 75% of their growth and the leaves are near full expansion. Herbicides can readily penetrate young western snowberry leaves during May and early June. However, when western snowberry colonies are at that stage of growth, carbohydrate movement upward through the phloem prevents downward movement of herbicides. The twigs continue to grow at a slower rate, and by mid June the twigs have reached about 95% of their annual growth. Sometime between early June and mid June, processes within the plant shift from using stored carbohydrates at the growing points to using the carbohydrates produced by leaf photosynthesis. As the rate of growth slows and leaf photosynthesis increases, a surplus of carbohydrates is produced and must be 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. Meanwhile, maturation of the leaves has been continuing with development of a thicker cuticle layer and denser cell walls; the result is an increasing resistance to herbicide penetration and absorption. The two critical factors required 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. Greater quantities of herbicide are translocated downward during mid to late June than during early to mid June. Leaf penetration by herbicides is improved with wetting agents, and these surfactants should be added to all foliage-active herbicide spray mixtures.

Soil-active herbicides have a relatively wide window of opportunity for treatment and require only that application be ahead of a rainy period. The herbicides move into the roots anytime the roots are absorbing water. Movement upward in the xylem vascular system is not as complex as movement within the phloem system. Plants have few resistance mechanisms to restrict activity of soil-applied herbicides. Usually lower rates are quite effective, but a longer period of time may be required to produce the desired results.

Comparisons and evaluations of the herbicide costs for chemical management of western snowberry should include the treatment cost per acre and the frequency of retreatment. None of the herbicides approved for control of woody plants on grazingland are known to eradicate western snowberry from grassland ecosystems. Retreatment will be required. Unfortunately, the frequency rate of retreatment for the various herbicides is currently not known.

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Table 4. Percent reduction of western snowberry live aerial stems from chemical herbicides estimated one year after final treatment.

Number of Repeated Annual Applications	Rate lbs ai/ac	Treatment Dates 12-15 May	19-22 May	26-29 May	28 Jun	16 Jul
3 Applications						
2,4-D HVE	na	97	96	82	65	26
2,4-D A	na	65	61	45	45	20
2 Applications						
2,4-D HVE	1.0 lb	99	100	99		
2,4-D HVE	2.0 lb	100	100	100		
2,4-D LVE	1.0 lb	90	92	87		
2,4-D LVE	2.0 lb	94	97	85		
1 Application						
2,4-D HVE	1.0 lb	62	24	84		
2,4-D HVE	2.0 lb	87	71	85		

Data from McCarty 1967

Table 5. Percent control of western snowberry live aerial stems from chemical herbicides estimated visually one year following final treatment.

Herbicide Treatment	% Aerial Stem Control Spring Application	 Summer Application
Experiment #1, 4 Jul 84		
Triclopyr		
1.0 lb ai/ac		0
2.0 lb ai/ac		0
Dowco 290 + 2,4-D A		
0.25 + 1.0 lb ai/ac		10
0.38 +1.5 lb ai/ac		20
Dowco 290 + picloram		
0.25 + 2.25 lb ai/ac		20
Picloram		
2.0 lb ai/ac		73
Experiment #2, 30 May 85		
Triclopyr		
1.0 lb ai/ac	0	
2.0 lb ai/ac	0	
Fluroxypyr		
2.0 lb ai/ac	0	
3.0 lb ai/ac	0	
Fluroxypyr + Triclopyr		
1.0 + 1.0 lb ai/ac	0	
1.5 + 1.5 lb ai/ac	0	
Tebuthiuron		
0.25 lb ai/ac	0	
0.50 lb ai/ac	0	
0.75 lb ai/ac	0	
1.0 lb ai/ac	0	
2,4-D LVE		
2.0 lb ai/ac	70	

Table 5. (Cont.). Percent control of western snowberry live aerial stems from chemical herbicides estimated visually one year following final treatment.

Herbicide Treatment	% Aerial Stem Control	
	Spring Application	Summer Application
Experiment #3, 7 Jun 89		
Glyphosate		
1.125 lb ai/ac	95	
Fosamine		
6.0 lb ai/ac	13	
12.0 lb ai/ac	82	
24.0 lb ai/ac	96	
Metsulfuron		
0.3 oz ai/ac	100	
0.6 oz ai/ac	100	
1.2 oz ai/ac	100	
Chlorsulfuron		
0.4 oz ai/ac	100	
0.8 oz ai/ac	100	
2.2 oz ai/ac	100	
Experiment #4, 7 Jun 90, 13 Sep 90		
Metsulfuron		
0.2 oz ai/ac	100	50
0.3 oz ai/ac	100	50
0.4 oz ai/ac	100	50
Metsulfuron + 2,4-D LVE		
0.2 oz + 1.0 lb ai/ac	100	50
0.3 oz + 1.0 lb ai/ac	100	50
0.4 oz + 1.0 lb ai/ac	100	50

Data from Ferrell 1986, 1992a, 1992b, and Ferrell and Whitson 1987

Table 6. Percent canopy cover of western snowberry and percent change from control treatment resulting from herbicide treatments evaluated one year and five years after final treatment.

Herbicide Treatment	one year after final treatment		five years after final treatment	
	canopy cover %	% change from control	canopy cover %	% change from control
Experiment #1, 1981-1989				
No Herbicide				
Control	6		6	
Dicamba + 2,4-D LVE 1.34 + 1.96 lb ai/ac				
3 applications 6 Jun 81, 16 Jun 82, 16 Jun 83	0	-100.0	<1	>-83.3
2 applications 6 Jun 81, 16 Jun 82	<1	>-83.3	1	-83.3
6 Jun 81, 16 Jun 83	<1	>-83.3	<1	>-83.3
1 application 6 Jun 81	2	-66.7	5	-16.7
Dicamba + 2,4-D A 1.34 + 1.96 lb ai/ac				
3 applications 6 Jun 81, 16 Jun 82, 16 Jun 83	<1	>-83.3	2	-66.7
2 applications 6 Jun 81, 16 Jun 82	<1	>-83.3	3	-50.0
6 Jun 81, 16 Jun 83	<1	>-83.3	3	-50.0
1 application 6 Jun 81	2	-66.7	6	0.0

Table 6. (Cont.). Percent canopy cover of western snowberry and percent change from control treatment resulting from herbicide treatments evaluated one year and five years after final treatment.

	one year after final treatment		five years after final treatment	
Herbicide Treatment	canopy cover %	% change from control	canopy cover %	% change from control
Experiment #2, 1983-1989				
No herbicide				
Control	3		3	
Dicamba + 2,4-D LVE 1.34 + 1.78 lb ai/ac				
2 applications 16 Jun 83, 19 Jun 84	0	-100.0	<1	>-66.7
16 Jun 83, 27 Jun 85	0	-100.0	<1	>-66.7
1 application 16 Jun 83	0	-100.0	1	-66.7

Data from Bowes 1991

Table 7. Grass biomass production and percent change from control treatment resulting from herbicide treatments evaluated one year and five years after final treatment.

Herbicide Treatment	one year after final treatment Grass Biomass Production lbs/ac	 % change from control	five years after final treatment Grass Biomass Production lbs/ac	 % change from control
Experiment #1, 1981-1989				
No Herbicide				
Control	276.52		276.52	
Dicamba + 2,4-D LVE 1.34 + 1.96 lb ai/ac				
3 applications 6 Jun 81, 16 Jun 82, 16 Jun 83	1195.28	332.3	927.68	235.5
2 applications 6 Jun 81, 16 Jun 82	1079.32	290.3	749.28	171.0
6 Jun 81, 16 Jun 83	1141.76	312.9	749.28	171.0
1 application 6 Jun 81	838.48	203.2	526.28	90.3
Dicamba + 2,4-D A 1.34 + 1.96 lb ai/ac				
3 applications 6 Jun 81, 16 Jun 82, 16 Jun 83	1266.64	358.1	695.76	151.6
2 applications 6 Jun 81, 16 Jun 82	936.60	238.7	561.96	103.2
6 Jun 81, 16 Jun 83	1239.88	348.4	660.08	138.7
1 application 6 Jun 81	544.12	96.8	517.36	87.1

Table 7. (Cont.). Grass biomass production and percent change from control treatment resulting from herbicide treatments evaluated one year and five years after final treatment.

	one year after final treatment		five years after final treatment	
Herbicide Treatment	Grass Biomass Production lbs/ac	% change from control	Grass Biomass Production lbs/ac	% change from control
Experiment #2, 1983-1989				
No herbicide				
Control	338.96		338.96	
Dicamba + 2,4-D LVE 1.34 + 1.78 lb ai/ac				
2 applications 16 Jun 83, 19 Jun 84	1355.84	300.0	1284.48	278.9
16 Jun 83, 27 Jun 85	1257.72	271.1	1382.60	307.9
1 application 16 Jun 83	722.52	113.2	660.08	94.7

Data from Bowes 1991

Table 8. Percent canopy cover of western snowberry and percent change from control treatment resulting from herbicide treatments evaluated two months and five years after treatment.

	two months after treatment		five years after treatment	
Herbicide Treatment	Canopy cover %	% change from control	Canopy cover %	% change from control
Experiment #1, 1986-1989 16 June 1986				
No Herbicide				
Control	32.1		72.2	
Metsulfuron				
0.11 oz/ac	0.1	-99.7	0.7	-99.0
0.21 oz/ac	<0.1	>-99.7	<0.1	>-99.9
0.43 oz/ac	<0.1	>-99.7	0.5	-99.3
0.86 oz/ac	<0.1	>-99.7	<0.1	>-99.9
Metsulfuron + 2,4-D LVE				
0.11 oz/ac +1.78 lb/ac	<0.1	>-99.7	0.5	-99.3
0.21 oz/ac +1.78 lb/ac	<0.1	>-99.7	0.4	-99.4
0.43 oz/ac +1.78 lb/ac	<0.1	>-99.7	0.3	-99.6
0.86 oz/ac +1.78 lb/ac	<0.1	>-99.7	<0.1	>-99.9
2,4-D LVE 1.78 lb/ac	1.1	-96.6	9.0	-87.5

Table 8. (Cont.). Percent canopy cover of western snowberry and percent change from control treatment resulting from herbicide treatments evaluated two months and five years after treatment.

	two months after treatment		five years after treatment	
Herbicide Treatment	Canopy cover %	% change from control	Canopy cover %	% change from control
Experiment #2, 1987-1992 12 June 1987				
No Herbicide				
Control	32.2		76.4	
Metsulfuron				
0.04 oz/ac	0.2	-99.4	19.9	-74.0
0.07 oz/ac	0.2	-99.4	7.6	-90.1
0.11 oz/ac	<0.1	>-99.7	8.1	-89.4
0.21 oz/ac	<0.1	>-99.7	2.1	-97.3
Metsulfuron + 2,4-D LVE				
0.04 oz/ac +1.78 lb/ac	4.8	-85.1	31.3	-59.0
0.07 oz/ac +1.78 lb/ac	1.1	-96.6	7.9	-89.7
0.11 oz/ac +1.78 lb/ac	0.1	-99.7	4.7	-93.8
0.21 oz/ac +1.78 lb/ac	0.1	-99.7	0.3	-99.6
2,4-D LVE 1.78 lb/ac	0.3	-99.1	49.1	-35.7

Data from Bowes and Spurr 1995

Table 9. Western snowberry aboveground biomass and percent change from control treatment resulting from herbicide treatments evaluated one year and five years after treatment.

	one year after treatment		five years after treatment	
Herbicide Treatment	Western snowberry aboveground biomass lbs/ac	% change from control	Western snowberry aboveground biomass lbs/ac	% change from control
Experiment #1, 1986-1989 16 June 1986				
No Herbicide				
Control	1873.11		2470.48	
Metsulfuron				
0.11 oz/ac	0.09	-99.9	<0.09	>-99.9
0.21 oz/ac	<0.09	>-99.9	<0.09	>-99.9
0.43 oz/ac	<0.09	>-99.9	<0.09	>-99.9
0.86 oz/ac	<0.09	>-99.9	<0.09	>-99.9
Metsulfuron + 2,4-D LVE				
0.11 oz/ac +1.78 lb/ac	<0.09	>-99.9	<0.09	>-99.9
0.21 oz/ac +1.78 lb/ac	0.09	-99.9	19.09	-99.2
0.43 oz/ac +1.78 lb/ac	3.03	-99.8	1.34	-99.9
0.86 oz/ac +1.78 lb/ac	3.03	-99.8	<0.09	>-99.9
2,4-D LVE 1.78 lb/ac	2.23	-99.9	267.60	-89.2

Table 9. (Cont.). Western snowberry aboveground biomass and percent change from control treatment resulting from herbicide treatments evaluated one year and five years after treatment.

	one year after treatment		five years after treatment	
Herbicide Treatment	Western snowberry aboveground biomass lbs/ac	% change from control	Western snowberry aboveground biomass lbs/ac	% change from control
Experiment #2, 1987-1992 12 June 1987				
No Herbicide				
Control	1071.02		3597.44	
Metsulfuron				
0.04 oz/ac	50.13	-95.3	354.03	-90.2
0.07 oz/ac	6.33	-99.4	125.06	-96.5
0.11 oz/ac	21.76	-98.0	349.84	-90.3
0.21 oz/ac	1.34	-99.9	20.43	-99.4
Metsulfuron + 2,4-D LVE				
0.04 oz/ac +1.78 lb/ac	99.01	-90.8	794.95	-77.9
0.07 oz/ac +1.78 lb/ac	44.96	-95.8	281.34	-92.2
0.11 oz/ac +1.78 lb/ac	3.84	-99.6	222.02	-93.8
0.21 oz/ac +1.78 lb/ac	3.84	-99.6	8.83	-99.8
2,4-D LVE 1.78 lb/ac	260.55	-75.7	1672.59	-53.5

Data from Bowes and Spurr 1995

Table 10. Grass biomass production and percent change from control treatment resulting from herbicide treatments evaluated one year and five years after treatment.

Herbicide Treatment	one year after treatment: Grass Biomass Production lbs/ac	one year after treatment: % change from control	five years after treatment: Grass Biomass Production lbs/ac	five years after treatment: % change from control
Experiment #1, 1986-1989 16 June 1986				
No Herbicide				
Control	359.48		643.13	
Metsulfuron				
0.04 oz/ac	759.98	+111.4	1740.29	+170.6
0.07 oz/ac	536.98	+49.4	1486.07	+131.1
0.11 oz/ac	591.40	+64.5	1567.24	+143.7
0.21 oz/ac	733.22	+104.0	1744.75	+171.3
Metsulfuron + 2,4-D LVE				
0.04 oz/ac +1.78 lb/ac	753.74	+109.7	1581.52	+145.9
0.07 oz/ac +1.78 lb/ac	732.33	+103.7	1659.12	+158.0
0.11 oz/ac +1.78 lb/ac	619.05	+72.2	1660.90	+158.3
0.21 oz/ac +1.78 lb/ac	759.98	+111.4	1424.52	+121.5
2,4-D LVE 1.78 lb/ac	765.34	+112.9	1678.74	+161.0

Table 10. (Cont.). Grass biomass production and percent change from control treatment resulting from herbicide treatments evaluated one year and five years after treatment.

	one year after treatment		five years after treatment	
Herbicide Treatment	Grass Biomass Production lbs/ac	% change from control	Grass Biomass Production lbs/ac	% change from control
Experiment #2, 1987-1992 12 June 1987				
No Herbicide				
Control	317.55		1577.06	
Metsulfuron				
0.04 oz/ac	397.83	+25.3	2580.56	+63.6
0.07 oz/ac	424.59	+33.7	2370.04	+50.3
0.11 oz/ac	340.74	+7.3	2630.51	+66.8
0.21 oz/ac	333.61	+5.1	2567.18	+62.8
Metsulfuron + 2,4-D LVE				
0.04 oz/ac +1.78 lb/ac	322.01	+1.4	2231.78	+41.5
0.07 oz/ac +1.78 lb/ac	302.39	-4.8	2799.99	+77.5
0.11 oz/ac +1.78 lb/ac	382.67	+20.5	2180.05	+38.2
0.21 oz/ac +1.78 lb/ac	390.70	+23.0	2326.34	+47.5
2,4-D LVE 1.78 lb/ac	338.07	+6.5	2167.56	+37.4

Data from Bowes and Spurr 1995

Table 11. Percent canopy cover of western snowberry and percent change from control treatment resulting from herbicide treatments evaluated two months and six years after treatment.

	two months after treatment		six years after treatment	
Herbicide Treatment	Canopy cover %	% change from control	Canopy cover %	% change from control
Experiment #1, 1985-1991 19 June 1985				
No Herbicide				
Control	9		9	
Metsulfuron				
0.21 oz/ac	<1	>-88.9	2	-77.8
0.43 oz/ac	<1	>-88.9	<1	>-88.9
0.86 oz/ac	<1	>-88.9	<1	>-88.9
Metsulfuron + 2,4-D LVE				
0.21 oz/ac +1.78 lb/ac	<1	>-88.9	<1	>-88.9
0.43 oz/ac +1.78 lb/ac	<1	>-88.9	<1	>-88.9
0.86 oz/ac +1.78 lb/ac	<1	>-88.9	<1	>-88.9
2,4-D LVE 1.78 lb/ac	<1	>-88.9	1	-88.9
Experiment #2, 1986-1992 10 June 1986				
No Herbicide				
Control	8		8	
Metsulfuron				
0.21 oz/ac	<1	>-87.5	<1	>-87.5
0.43 oz/ac	<1	>-87.5	<1	>-87.5
0.86 oz/ac	<1	>-87.5	<1	>-87.5
Metsulfuron + 2,4-D LVE				
0.21 oz/ac +1.78 lb/ac	<1	>-87.5	<1	>-87.5
0.43 oz/ac +1.78 lb/ac	<1	>-87.5	1	-87.5
0.86 oz/ac +1.78 lb/ac	<1	>-87.5	1	-87.5
2,4-D LVE 1.78 lb/ac	<1	>-87.5	1	-87.5

Data from Bowes and Spurr 1996

Table 12. Grass and forb biomass production and percent change from control treatment resulting from herbicide treatments evaluated as five year means.

Herbicide Treatment	Five year mean Grass Biomass Production lbs/ac	Five year mean % change from control	Five year mean Forb Biomass Production lbs/ac	Five year mean % change from control
Experiment #1, 1985-1991 19 June 1985				
No Herbicide				
Control	634.21		245.30	
Metsulfuron				
0.21 oz/ac	966.93	+52.5	227.46	-7.3
0.43 oz/ac	1342.46	+111.7	110.61	-54.9
0.86 oz/ac	1400.44	+120.8	33.00	-86.5
Metsulfuron + 2,4-D LVE				
0.21 oz/ac +1.78 lb/ac	1089.13	+71.7	92.77	-62.2
0.43 oz/ac +1.78 lb/ac	1144.44	+80.5	37.46	-84.7
0.86 oz/ac +1.78 lb/ac	1377.25	+117.2	29.44	-88.0
2,4-D LVE 1.78 lb/ac	891.11	+40.5	298.82	+21.8
Experiment #2, 1986-1992 10 June 1986				
No Herbicide				
Control	379.99		565.53	
Metsulfuron				
0.21 oz/ac	1012.42	+166.4	225.68	-60.1
0.43 oz/ac	940.17	+147.4	279.20	-50.6
0.86 oz/ac	1263.96	+232.6	190.00	-66.4
Metsulfuron + 2,4-D LVE				
0.21 oz/ac +1.78 lb/ac	1286.26	+238.5	198.92	-64.8
0.43 oz/ac +1.78 lb/ac	1129.27	+197.2	148.96	-73.7
0.86 oz/ac +1.78 lb/ac	1275.56	+235.7	151.64	-73.2
2,4-D LVE 1.78 lb/ac	758.20	+99.5	460.27	-18.6

Data from Bowes and Spurr 1996

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