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Absorption and translocation of foliar-applied sulfometuron in leafy spurge[1]

RODNEY G. LYM

Rodney G. Lym is an associate professor of the Crop and Weed Science Department, North Dakota State University, Fargo, N.D. 58105.

Abstract:

Optimum conditions for leafy spurge control with sulfometuron were determined. Absorption and translocation of ^{14}C-sulfometuron to roots in leafy spurge averaged 11 and 0.1% of applied herbicide, respectively, and were not affected by growth stage. Absorption and translocation increased to 40 and 4%, respectively, of applied ^{14}C-sulfometuron when the relative humidity remained at 90 and 95% for at least 72 hours after treatment. Absorption and translocation of ^{14}C-sulfometuron to the roots were similar at 18/14 and 24/20º C and when ^{14}C-sulfometuron was applied with picloram or 2,4-D. Absorption of ^{14}C-picloram was greater but ^{14}C-2,4-D absorption was less when applied with sulfometuron compared to picloram or 2,4-D applied alone. Sulfometuron plus picloram applied during the fall regrowth stage provided better leafy spurge control than either herbicide applied alone. The combination treatment would be useful especially in areas where grass injury was acceptable in order to extend the fall treatment season by 2 to 3 weeks compared to present practices. Nomenclature: Picloram, 4-amino-3,5,6-trichloro-2-pyridinecarboxylic acid; sulfometuron, 2-[[[[(4,6-dimethyl-2-pyrimidinyl)-amino]carbonyl]amino]sulfonyl]benzoic acid, 2,4-D (2,4-dichlorophenoxy) acetic acid; leafy spurge, *Euphorbia esula* L. #[2] EPHES.

Additional index words:

Picloram, range improvement, 2,4-D, EPHES.

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[2] Letters following this # symbol are a WSSA-approved computer code from Composite List of Weeds, Revised 1989. Available from WSSA, 309 West Clark Street, Champaign, IL 61820.

Introduction

Sulfometuron is a sulfonylurea herbicide registered for control of many grass and broadleaf weed species in noncropland areas (16). Sulfometuron is used for vegetation suppression on roadside rights-of-way and for weed control under trees (6). In preliminary research, sulfometuron selectively controlled leafy spurge but had to be applied at 140 g ai ha^{-1} or less to prevent grass injury (8). Leafy spurge control with sulfometuron was improved by adding picloram or dicamba (3,6-dichloro-2-methoxybenzoic acid) but not by adding 2,4-D.

Picloram is the most effective herbicide for leafy spurge control (7). However, picloram cannot be used near trees, surface water, or areas with sandy soil and a high water table because of its long soil residual and high leaching potential. Sulfometuron may be used for leafy spurge control under trees and has a shorter soil residual than picloram. Sulfometuron is degraded by hydrolysis and microorganisms in soil and has an average half-life of 4 weeks in acidic soil (1,4) but can persist over 12 mo. in high-pH soil (5, 12).

Sulfometuron may provide more economical and effective control of leafy spurge than herbicides presently used or may be useful in areas where auxin herbicides cannot be used. The purpose of this research was to evaluate absorption and translocation of sulfometuron in leafy spurge as affected by plant growth stage, environment, and application with picloram or 2,4-D in order to determine the optimum conditions for leafy spurge control with sulfometuron.

Materials and methods

Plant propagation

Leafy spurge plants were propagated from one accession (1984 ND 001)[3] that originally was obtained from a natural infestation near Fargo, ND. Stem tips about 3 cm long were cut from the parent clones, all but the upper three to four leaves were removed, and the basal stem end was dipped in a commercial mixture of 0.2% NAA (1-naphthaleneacetic acid). Each cutting was planted into a 4-cm-diam by 20-cm-long conical pot, which contained a growth medium of peat, perlite, and vermiculite[4]. Plants were grown in the greenhouse at 24 to 27º C, 40 to 60% relative humidity, and with supplemental light (400 $\mu E\ m^{-2}\ s^{-1}$ photosynthetic photon flux) when necessary for a 16-hour photoperiod.

Growth stage

Approximately 6 weeks after planting, the topgrowth was removed at the soil surface, and one stem per pot was allowed to regrow for 30, 60, or 80 days to provide plants in the

[3] Registry of leafy spurge accessions maintained by David G. Davis, USDA Biosci. Res. Lab., Fargo, ND 58105.

[4] Sunshine Mix No. 1, patented formulation. Fisons Western Corp. Downers Grove, IL 60515.

vegetative, flowering, and postflowering growth stages, respectively. Cuttings were started periodically to obtain uniformly sized plants in each growth stage.

The leaf to be treated with ^{14}C-herbicide was midway on the stem of each plant and was enclosed with a paper envelope prior to herbicide treatment. Then, the rest of the plant was treated with sulfometuron at 140 g ha^{-1} applied with a moving-nozzle pot sprayer delivering 47 L ha^{-1} at 240kPa. Pots were covered at the base of the stem to prevent herbicide application to the soil. The protective envelope was removed and the leaf was treated with approximately 1700 Bq of uniformly pyrimidine-ring-labeled ^{14}C-sulfometuron methyl (specific activity 1.13 GBq $mmole^{-1}$) plus enough commercially formulated sulfometuron for a final concentration equivalent to 140 g ha^{-1}. The herbicide solution with 0.125% by volume nonionic surfactant[5] was applied in one 10-µl droplet over the entire leaf (approximately 1 cm^2).

Plants were returned to the greenhouse immediately and harvested 72 hours after treatment. Plants were separated into the treated leaf, stem and leaves above or below the treated leaf, and roots. Roots were washed with water to remove the potting medium and were sectioned into 0- to 4-, 4- to 8-, and 8- to 16-cm depths. The treated leaf was rapidly dipped 10 times into 15 ml of scintillation fluid 'A' {[toluene:ethanol 1:1, by volume, plus 5 g L^{-1} PPO (2,5-diphenyloxazole)] and 0.5 g L^{-1} dimethyl-POPOP [1,4-bis-2-(4-methyl-5-phenyloxazolyl)benzene]}. Preliminary experiments showed this leaf wash method effectively solubilized the ^{14}C-herbicides but did not excessively solubilize the cuticle waxes. The removed unabsorbed ^{14}C-herbicide was quantified using liquid scintillation spectrometry. Plant parts were dried at 60º C for 24 hours, and root and shoot sections were ground in a Wiley mill (No. 10 mesh) and weighed.

The treated leaf and two or more 120- to 150-mg root or shoot subsamples totaling at least 10% of the sample weight were each combusted in a biological tissue oxidizer[6]. The $^{14}CO_2$ was collected in 15 ml of scintillation fluid 'B' [toluene: 2-methoxyethanol:ethanolamine (10:7:3, by volume, plus 5.0 g L^{-1} PPO and 0.5 g L^{-1} dimethyl-POPOP)] and was assayed using liquid scintillation spectrometry. Oxidizer efficiency was determined using methyl-^{14}C-methacrylate, and liquid scintillation counting efficiency was determined using an external standards ratio and standard corrections. Percent ^{14}C recovery averaged 87% for all experiments.

Humidity

Leafy spurge plants were transferred from the greenhouse to growth chambers 48 hours before treatment with environmental conditions similar to the greenhouse. Growth chamber conditions following treatment were either high (90 to 95%) or low (20 to 30%) relative humidity at 30/18º C day/night temperatures with a 16-hour photoperiod from fluorescent and incandescent light (700 μm^{-2} s^{-1} photosynthetic photon flux).

Plants were sprayed and then treated with ^{14}C-sulfometuron as described previously and returned to the growth chambers immediately. Plants were transferred between

[5] Surfactant WK (dodecyl ether of polyethylene glycol). E. I. duPont de Nemours and Co., Wilmington, DE 19898.

[6] Model OX100. R. J. Harvey Instrument Corp., Hillsdale, NJ 07642.

growth chambers to achieve the following post-treatment humidity regimes: 72 hours at low humidity, 1 hour at high followed by 71 hours at low humidity, 6 hours at high followed by 66 hours at low humidity, 24 hours at high followed by 48 hours at low humidity, 48 hours at high followed by 24 hours at low humidity, 24 hours at low followed by 48 hours at high humidity, 6 hours at low followed by 66 hours at high humidity, and 72 hours at high humidity. The humidity regimes chosen simulate the often high but rapidly fluctuating humidity conditions found in eastern North Dakota and the relatively low humidity conditions in western North Dakota. Plants were harvested 72 hours after treatment and analyzed as previously described.

Temperature

Plants in the late-vegetative growth stage were transferred from the greenhouse to growth chambers 48 hours prior to treatment. Growth chamber conditions were either high (24/20º C day/night) or low (18/14º C day/night) temperatures with a 16-hour photoperiod and 50 to 60% relative humidity. Plants were treated, harvested 24, 48, 96, and 168 hours after treatment, and analyzed as previously described.

Herbicide combinations

The effect of picloram and 2,4-D on sulfometuron absorption and translocation was evaluated. Picloram potassium salt, 2,4-D alkanolamine salt, or sulfometuron methyl were applied alone or in various combinations to leafy spurge plants in the late-vegetative growth stage. Approximately 1700 Bq of uniformly pyridyl-ring-labeled ^{14}C-picloram (specific activity 623 MBq mmole^{-1}) or 1700 Bq of uniformly phenol-ring-labeled ^{14}C-2,4-D (specific activity 2035 MBq mmole^{-1}) was applied alone or with sulfometuron as previously described. Treatments were: ^{14}C-sulfometuron, ^{14}C-sulfometuron plus picloram, ^{14}C-sulfometuron plus 2,4-D, ^{14}C-picloram plus sulfometuron, ^{14}C-2,4-D plus sulfometuron, ^{14}C-picloram, and ^{14}C-2,4-D. The labeled herbicides were combined with unlabeled herbicide plus 0.125% by volume nonionic surfactant[5] in 10 µl for a broadcast application rate equivalent to sulfometuron at 70 g ha^{-1}, picloram at 560 g ae ha^{-1}, and 2,4-D at 1100 g ae ha^{-1}. Plants were harvested 72 hours after treatment and ^{14}C absorption and translocation were determined as previously described.

Field experiment

An experiment to evaluate the optimum leafy spurge growth stage for control using sulfometuron alone or applied with picloram was established near Chaffee, ND, in 1987 and near Fargo, ND, in 1988. Plots were 3.1 by 9.1 m and replicated four times in a randomized complete block design at both locations. Herbicides were applied with a tractor-mounted sprayer delivering 75 L ha^{-1} at 240 kPa.

Treatments were sulfometuron at 70 g ha^{-1} applied alone or with picloram at 560 g ha^{-1} or picloram alone at 1100 g ha^{-1}. Treatments were applied when leafy spurge was in the vegetative to stem elongation, bract, true-flower, seed-fill, seed dispersal, summer dormancy, fall-, or late-fall regrowth growth stages for a total of eight treatment dates.

Percent leafy spurge control was evaluated 12 months after each treatment date based on visual estimates of the reduction of leafy spurge stems compared to the untreated control.

Statistical analysis

The laboratory experiments were conducted three times and had similar variance, so the combined data are presented. There was no difference in ^{14}C-sulfometuron concentration by root depth so data were combined for all experiments. The field experiment was conducted twice and the combined data are presented since the variance was similar. The experimental design for all studies was a randomized complete block with four replicates per treatment with the exception of the laboratory temperature experiment, which had a factorial arrangement of temperature and time after treatment. Data were subjected to analysis of variance and means were separated using a protected LSD test.

Results and discussion

Growth stage

Absorption and translocation of ^{14}C-sulfometuron in leafy spurge were low and were similar regardless of growth stage (Table 1). An average of 11% of the applied ^{14}C-sulfometuron was absorbed in leafy spurge and approximately 90% of the absorbed herbicide remained in the treated leaf. Relatively poor absorption of imazethapyr {(±)-2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1*H*-imidazol-2-yl]-5-ethyl-3-pyridinecarboxylic acid} which has a similar mode of action as sulfometuron also has been observed in leafy spurge and averaged 15% or less under conditions similar to these experiments (14). In contrast, 2,4-D absorption averaged 35 to 45% of applied (11).

Table 1. Influence of growth stage on ^{14}C-sulfometuron absorption and translocation in leafy spurge 72 hours after treatment.

		^{14}C detected in each plant section			
Growth stage	^{14}C absorbed	Treated leaf	Above treated leaf	Below treated leaf	Root
	% of applied				
Vegetative	13	12	0.2	0.2	0 2
Flowering	11	10	0.5	0.2	0.1
Post flowering	9	8	0.2	0.2	0.1
LSD (0.05)	NS	NS	NS	NS	NS

Only an average of 0.3 and 0.13% of the ^{14}C-sulfometuron applied to leafy spurge translocated to the shoot and roots, respectively, regardless of the growth stage at application (Table 1). In contrast, picloram translocation to leafy spurge roots was greatest during the flowering and late seed-set growth stages and averaged 2% of applied herbicide

(11). Also, an average of 3.4% of absorbed imazethapyr was translocated to leafy spurge roots (14). Thus, it appears that translocation of sulfometuron is less than that of other herbicides presently used for control, which implies that sulfometuron would have to be more phytotoxic than imazethapyr and picloram to obtain similar leafy spurge control.

Humidity

Absorption of ^{14}C-sulfometuron increased as duration of posttreatment high humidity increased (Table 2). Absorption was 12% of applied herbicide when the relative humidity was low for 72 hours after treatment but increased to 40% when the relative humidity was high for 72 hours after treatment. Translocation of ^{14}C-sulfometuron was generally independent of posttreatment humidity except when humidity remained high 72 hours after treatment. Translocation of ^{14}C-sulfometuron to roots increased to 4% of applied herbicide following 72 hours at high humidity compared to 0.2% following 72 hours posttreatment low humidity.

Table 2. Influence of posttreatment relative humidity on ^{14}C-sulfometuron absorption and translocation in leafy spurge 72 hours after treatment[a].

Length of post treatment relative humidity conditions[b]				^{14}C detected in each plant section			
High RH	Low RH	High RH	^{14}C absorbed	Treated leaf	Above treated leaf	Below treated leaf	Root
h			% of applied				
-	72	0	12	11	0.4	0.2	0.2
1	71	-	17	15	0.8	0.4	0.5
6	66	-	21	18	1.3	0.8	1
24	48	-	23	21	0.5	0.5	0.7
48	24	-	21	17	0.9	1.7	1.5
-	24	48	29	26	0.6	1.1	1.2
	6	66	22	19	0.4	1.3	0.8
	0	72	40	31	2.6	2.2	4
LSD (0.05)			8	12	1	1	1.7

[a]Plants were preconditioned at 30/18º C day/night temperatures and high (90 to 95%) or low (20 to 30%) relative humidity 24 hours before treatment.
[b]RH = relative humidity.

Although relative humidity is important in determining optimum absorption and translocation of sulfometuron in leafy spurge, scheduling applications for periods of high humidity is not practical. Most leafy spurge infestations occur in the Northern Great Plains and Rocky Mountain regions of the United States (3). Since the relative humidity is generally low in most of the region during the growing season it is not practical to anticipate a time when the humidity will be 90 to 95% for at least 3 days. Perhaps use of spray additives would increase sulfometuron absorption and subsequent translocation in leafy spurge. However, general use of spray additives may not be possible because grass injury increases when a spray additive is applied with sulfometuron (6, 16).

Temperature

Absorption of ^{14}C-sulfometuron was similar for the 18/14º C and 24/20º C temperature regimes and averaged 20 and 22% of applied ^{14}C, respectively (Table 3). Most of the ^{14}C absorbed remained in the treated leaf regardless of temperature. The ^{14}C concentration in the above- and below-treated leaf sections was two-fold greater at 24/20º C than at 18/14º C, but translocation to the root was not affected by temperature and averaged 0.8% of applied.

Absorption of ^{14}C-sulfometuron increased slightly from 20 to 24% of ^{14}C applied between 96 and 168 hours after treatment (Table 3). Maximum ^{14}C-sulfometuron translocation to the shoot occurred within 48 hours after treatment and averaged 1.9 and 0.9% of ^{14}C applied in the above- and below-treated leaf sections, respectively. Translocation to roots was about 1% of applied and did not change over time.

Table 3. Influence of temperature and time after treatment on ^{14}C-sulfometuron absorption and translocation in leafy spurge at four times after treatment.

		^{14}C detected in each plant section			
Treatment	^{14}C absorbed	Treated leaf	Above treated leaf	Below treated leaf	Root
	% of applied				
Temperature (C):					
18	20	18	0.9	0.5	0.8
24	22	18	2.3	1.0	0.8
LSD (0.05)	NS	NS	0.6	0.2	NS
Time (h)					
24	21	19	0.8	0.5	1.0
48	21	17	2.0	0.8	0.8
96	20	16	1.8	0.8	0.9
168	24	20	1.8	1.0	0.9
LSD (0.05)	2	NS	0.8	0.3	NS
LSD (0.05) Temperature x time NS.					

Sulfometuron apparently can be applied in the field in a variety of air temperatures without loss of activity. In contrast, absorption of ^{14}C-picloram increased 1% for each 1º C increase in temperature from 12 to 30º C, but translocation to the leafy spurge root system declined (9). Occasional poor leafy spurge control may be due to application during periods of temperature fluctuation adverse to picloram absorption and translocation.

Since temperature does not appear to affect sulfometuron absorption and translocation, using a mixture of sulfometuron plus picloram may provide better leafy spurge control than using picloram alone if the temperature is less than 12º C.

Herbicide combinations

Absorption and translocation of ^{14}C-sulfometuron in leafy spurge were unaffected by the addition of picloram or 2,4-D (Table 4). Absorption of ^{14}C-picloram was greater when applied with sulfometuron, but translocation from the treated leaf was not influenced by sulfometuron. In contrast, ^{14}C-2,4-D absorption and translocation to the below-treated leaf and root sections was reduced when applied with sulfometuron compared to ^{14}C-2,4-D applied alone. Translocation of ^{14}C-2,4-D to the root declined by 20% (from 2.4 to 1.9%) when applied with sulfometuron.

Table 4. Absorption and translocation of ^{14}C-sulfometuron, ^{14}C-picloram, and ^{14}C-2,4-D in leafy spurge 72 hours after treatment when applied alone or in various combinations.

Treatment	^{14}C absorbed	^{14}C detected in each plant section: Treated leaf	Above treated leaf	Below treated leaf	Root
	% of applied				
^{14}C-Sulfometuron	10	7	1	0.8	0.7
^{14}C-sulfometuron plus picloram	8	5	1.7	0.5	0.3
^{14}C-sulfometuron plus 2,4-D	10	7	2.0	0.7	0.4
^{14}C-picloram	9	6	1.5	0.5	1.5
^{14}C-picloram plus sulfometuron	14	11	1.5	0.5	1.5
^{14}C-2,4-D	46	40	1.2	2.1	2.4
^{14}C-2,4-D plus sulfometuron	30	27	1.1	1.3	1.9
LSD (0.05)	5	5	NS	0.5	0.5

Field experiment

Sulfometuron applied alone provided similar leafy spurge control of about 10% 12 months after treatment regardless of application date (Figure 1). This agrees with the ^{14}C data, which show similar foliar absorption and translocation regardless of leafy spurge growth stage (Table 1) at time of application. Picloram alone provided 85% leafy spurge control when applied during the true-flower and seed-fill growth stages (Figure 1). These are the optimum growth stages for picloram translocation to leafy spurge roots and subsequent long-term control (10).

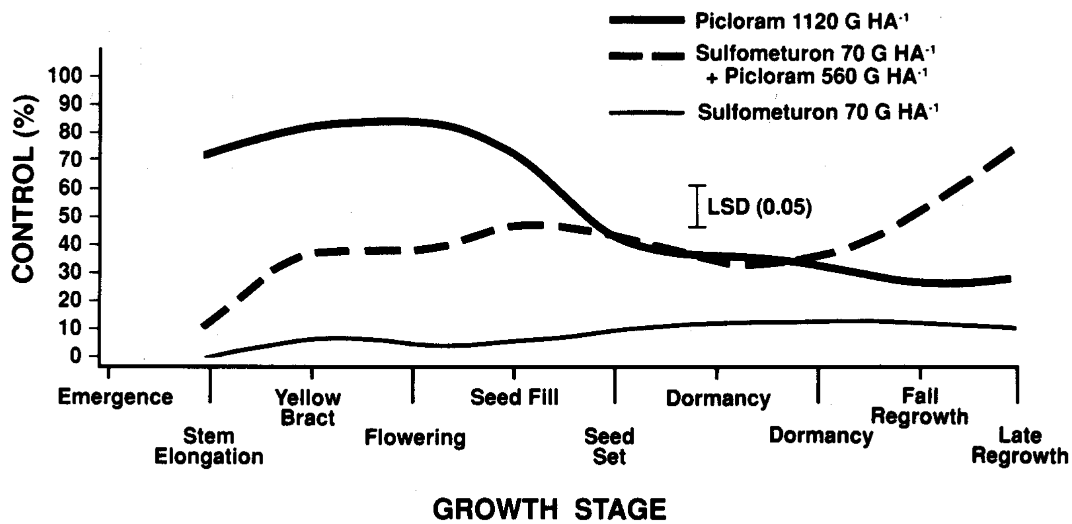

Figure 1. Leafy spurge control 12 months after treatment with sulfometuron and picloram, applied alone or in combination at eight growth stages. Data were averaged over two locations.

Sulfometuron plus picloram at 70 plus 560 g ha^{-1} applied during the fall regrowth stages provided better leafy spurge control than picloram at 1120 g ha^{-1} alone (Figure 1). Control increased from 10% with sulfometuron and 30% with picloram to > 70% when the herbicides were applied together in the late-fall regrowth stage. The reason for synergism of the fall-applied sulfometuron plus picloram combination is not known. Absorption of ^{14}C-picloram increased when applied with sulfometuron compared to picloram applied alone (Table 4), but this probably is not the sole reason for improved control because leafy spurge control was improved in the field only during the last part of the growing season.

Increased control may be due to the different modes of action of the two herbicides. Sulfometuron inhibits acetolactate synthase activity and inhibits cell division in the growing tips of roots and shoots (2, 15), while picloram interferes with nucleic acid metabolism (13).

Most leafy spurge is presently treated with picloram plus 2,4-D during the true-flower growth stage in June. Although picloram can be fall applied, late-season treatment is less desirable because the picloram rate must be doubled to achieve control similar to treatments applied in June (7). Often, the flower and seed-set growth stages are too short for county weed officers and other land managers to treat all leafy spurge infested land. Thus, a relatively inexpensive fall-applied treatment of sulfometuron plus picloram would be useful in a leafy spurge management program. However, sulfometuron has sometimes resulted in grass injury when fall applied, especially in dry years (8). Therefore, the most likely use of sulfometuron plus picloram would be for total vegetation control along railroad rights-of-way and industrial sites or for leafy spurge control during fall growing seasons with average or above precipitation when unacceptable grass injury is less likely to occur.

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