Effect of Soil-Applied Chlorsulfuron on Canada Thistle (*Cirsium arvense*) Root and Root Bud Growth[1,2]

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Abstract. Chlorsulfuron [2-chloro-*N*-[[(4-methoxy-6-methyl-1,3,5-triazin-2-yl)-amino]carbonyl]benzene-sulfonamide], applied at 9 to 560 g ai/ha to the soil surface, stopped shoot elongation of well established Canada thistle [*Cirsium arvense* (L.) Scop. #[4] CIRAR] plants in the greenhouse. Root fresh weight decreased progressively as chlorsulfuron rate was increased when measured 1 month after treatment. In contrast, the number of visible root buds plus secondary shoots increased 1.9- to 2.3-fold between 9 and 67 g/ha chlorsulfuron 1 month after soil surface treatment. Despite more numerous root buds, the number of secondary shoots arising from adventitious root buds progressively decreased as chlorsulfuron rate was raised. Increases in the number of visible root buds were observed first between 3 and 4 weeks following soil application with 67 g/ha of chlorsulfuron, 2 weeks after shoot growth stopped.
Additional index words. Growth inhibitors, herbicide, growth stimulator, sulfonylurea, CIRAR.

INTRODUCTION

Chlorsulfuron is registered in the United States for selective control of broadleaf weeds and suppression of some grass weeds in cereals. While annual broadleaf weeds are controlled with the lowest registered rate of 9 g ai/ha, the highest recommended rate, 28 g/ha, is used for season-long control of Canada thistle. Canada thistle is a serious perennial weed which spreads vegetatively and forms new secondary shoots from adventitious root buds (5, 6, 7). Once they are formed, root buds can persist from one growing season to the next, although not all root buds formed give rise to new secondary shoots. Some buds either remain quiescent or become nonviable. Whether this quiescence is due to correlative inhibition or enforced dormancy is unknown (13). McAllister and Haderlie (11) present one line of evidence that Canada thistle root buds lack innate dormancy.

The objectives of this greenhouse research were to determine a) whether soil-applied chlorsulfuron influenced parent Canada thistle shoot growth, root biomass, numbers of visible adventitious root buds, and secondary shoot development from adventitious root buds; b) how quickly soil-applied chlorsulfuron increased the numbers of visible root buds; c) whether excised root buds responded to direct treatment with chlorsulfuron; and d) how the root biomass, visible root bud numbers, and secondary shoot numbers of decapitated plants responded to soil-applied chlorsulfuron.

MATERIALS AND METHODS

General methods. Donald (3) described greenhouse conditions, potting soil, Canada thistle propagation, plant age, selection for chlorsulfuron treatment, plant harvest, observations, and statistical methods. Canada thistle (var. 'integrifolium' Wimm. and Grab.) plants were started from 4- to 8-cm long root cuttings which were grown for 1.5 to 2 months in trays (21- by 30- by 8-cm) filled with fine vermiculite. The vermiculite was watered periodically with 1/3rd strength nutrient solution or tap water (3). Uniform plants were selected and transplanted to potting soil and were allowed to grow an additional 1.5 to 2 months before treatment. Plants in pots (16.5-cm diam by 18-cm, 2.8-L) of soil were watered with tap water as needed. The potting soil, amended with peat, was 73% sand, 19% silt, 8% clay, and 3.6% organic matter, at pH 7.9. Plants were fertilized with 6.3 g/pot slow-release granular fertilizer (N:P:K, 3:1:1) when transferred from vermiculite to soil.

Uniform plants were selected for herbicide treatment. Because the growth of Canada thistle changes throughout the year, uniform plants of comparable height and morphology were selected, rather than plants of the same chronological age. The plants

were treated with formulated chlorsulfuron (75% dry flowable). Plants were watered from above (4) after treatment, and care was taken in watering the soil-treated or sprayed plants to prevent cross-contamination between pots.

Roots were washed free of soil, were weighed, and were divided into 2.0- to 2.5-cm long segments at harvest. Roots were cut into segments to break correlative inhibition of root buds and to promote maximal secondary shoot sprouting. Segments were placed 1 cm deep in pots (12.0- by 16.5- by 5.5-cm, 1-L) with fine vermiculite as quickly as possible to prevent drying or bud death and were grown for 5 weeks. All roots were exposed to ambient light during handling. Secondary shoots from root buds were counted at 5 weeks after the roots were segmented. This methodology provides a measure of the vigor of secondary shoot emergence but may not adequately measure total root bud numbers, the proportion of viable buds, or bud death. No generally accepted way to measure bud death or dormancy exists.

Sunlight was supplemented with fluorescent lighting in these glasshouse experiments to provide at least a 14-h photoperiod throughout the year. Flourescent lighting produced irradiance and photosynthetic photon flux density of between 20 and 68 W/m^2 and between 90 and 168 $\mu E \cdot m^{-2} \cdot s^{-1}$, respectively, at plant height, 40 to 75 cm below fluorescent bulbs. The temperature and relative humidity varied seasonally during the experiments. However, supplemental heating and cooling generally kept temperatures close to 25 and 20 C during the day and night, respectively. The extremes of day temperature ranged between 18 and 28 C, and the extremes of night temperature ranged between 15 and 20 C throughout the winter, when most glasshouse experiments were conducted. Relative humidity ranged between 28 and 75% depending upon the season.

All experiments employed a completely randomized design with 8 to 11 plants/treatment (3). Data were subjected to analysis of variance (ANOVA) and regression analysis, and means were separated by Duncan's multiple range test (P = 0.05) (3), where it was appropriate. Each experiment was repeated on one to two separate occasions, and results were combined where there were no significant interactions.

Effect of soil surface dose on intact plants. Chlorsulfuron was applied by pouring a 10 ml aqueous solution from a graduated cylinder on to the soil surface of intact, potted Canada thistle plants at 0, 9, 17, 33, 67, 280, and 560 g/ha. There were nine plants per treatment. The percentage of plants that were injured was determined 1 month following treatment for each of the following criteria: plants with chlorotic apices, dead apices, discolored stems, dead leaves on the lower half of the shoots, and leaves with damaged petioles that collapsed along the stem. The difference in plant height between the start and end of the experiment was measured. Also, root fresh weight and the total number of visible adventitious root buds plus secondary shoots derived from root buds were determined 1 month after treatment.

No generally accepted method for determining the total number of nascent unemerged, adventitious root buds of Canada thistle exists. The lactic acid clearing method for determining the total number of root buds described by McIntyre and Hunter (12) was unreliable in practice and highly subjective. Roots were cut into segments after making these measurements and were grown in fine vermiculite for 5 weeks in the greenhouse (3). Then the number of emerged secondary shoots derived from root buds was counted. The phenological observations, height changes, root fresh weight and secondary shoot numbers 5 weeks after cutting roots into segments were combined for the two trials in time (P ≤ 0.01 for treatment and trial, P = NS for the interaction of treatment by trial). The results for the numbers of visible adventitious root buds plus secondary shoots per plant are presented separately for each trial (P ≤ 0.01) for the interaction of treatment by trial).

Both repetitions of this experiment were conducted in the spring, 1983, with plants that had similar heights, 59 ± 8 and 59 ± 11 cm (mean ± standard deviation) for the first and second trials, respectively. The plants also had similar numbers of leaf nodes, 27 to 39 and 25 to 36 nodes, respectively. While plants from the first trial had not formed flower buds at treatment, 89% of the plants in the second trial had formed buds when they were treated.

Effect of treatment duration on intact plants. Chlorsulfuron at 0 or 67 g/ha was applied on the soil

of intact, potted Canada thistle plants. Nine plants per treatment were harvested at the time of treatment and 2, 3 or 4 weeks later for determination of root fresh weight and the number of visible adventitious buds plus secondary shoots.

The first trial was started in early October, 1984, whereas the second trial was initiated in mid-April, 1985. The shoot heights were 87 ± 5 and 74 ± 7 cm, respectively. The plants had 33 to 39 leaf nodes and 0 to 7 branches with flower buds in both repetitions.

Dose-response of excised root buds. Canada thistle roots were unearthed and were washed free of soil when plants had reached the late vegetative or flower bud stage. Thickened roots with visible root buds 1 mm or less in length were excised so that there was approximately 1 cm of root tissue on either side of the bud. Segments were 2 mm or more in diameter. Ten root buds were placed in each of three petri dishes containing 5 ml for each of the following treatment solutions: 0.01 nM, 1 nM, 10 nM, 100 nM, 0.001 mM, 0.01 mM, and 0.1 mM chlorsulfuron. The solutions were prepared by dissolving the analytical-grade herbicide in acetone and diluting the acetone with distilled, deionized water so that the final acetone concentration was 0.5% (v/v) for all treatments and a control. The petri dishes were covered with aluminum foil to exclude light and were placed in a dark incubator at 20 C and 100% relative humidity for 3 weeks. The percentage of buds which failed to elongate ("damaged") was determined and was averaged for each of the treatments. The combined results of three repetitions were subjected to regression analysis for log (chlorsulfuron in nM +1) (8).

Long-term effect of soil treatment on decapitated plants. Soil surface treatments of chlorsulfuron at 0 or 67 g/ha were applied to decapitated, potted Canada thistle plants. Plants were topped 20 cm above the soil surface just before treatment to simulate decapitation by a swather of Canada thistle shoots growing in spring wheat. Ten plants were harvested for either treatment at the time of chlorsulfuron application and 1, 2, 4, or 6 months later. Root fresh weight, the number of visible adventitious root buds plus secondary shoots, and the regrowth ability of adventitious root buds on segments of roots in fine vermiculite were determined at each harvest (3).

The first and second trials were started in early November, 1983, and late December, 1984, respectively. Plants were 104 ± 8 cm and 165 ± 13 cm tall, respectively, and had finished shedding seed. Even though the plants in either repetition had grown for 3 months, they had different heights and different numbers of leaf nodes (29 to 37 and 52 to 61 nodes, respectively). The plants in the second trial were more vigorous and had greater shoot and root biomass than did those in the first trial. There were highly significant effects due to trial, treatment, and time ($P < 0.01$) and significant interactions at $P < 0.05$ or less for the interactions of trial by treatment, trial by time, treatment by time, and trial by time by treatment. The results of the first and second trials of this experiment are presented separately.

RESULTS AND DISCUSSION

Effect of soil surface dose on intact plants. Chlorsulfuron between 9 and 560 g/ha, applied to the soil, stopped shoot elongation of well-established Canada thistle plants when measured 1 month after treatment ($P < 0.01$) (Table 1). Treated plants probably did not stop shoot elongation immediately after soil surface treatment as observations after 1 month showed a height increase from the start of 1- to 6-cm (Table 1).

Although soil-applied chlorsulfuron at 9 to 560 g/ha reduced shoot growth, foliar symptoms

Table 1. Shoot and root growth of Canada thistle one month following soil-applied chlorsulfuron treatment. The average of two trials are presented, unless otherwise indicated.

Chlorsulfuron rate	Shoot height increase 4 weeks after soil treatment[a]	Root fresh weight[a]	Visible root buds plus secondary shoots[a]		Emerged secondary shoots 5 weeks following root segmentation 4 weeks after treatment[a]
			Trial 1	Trial 2	
(g/ha)	(cm)	(g)		(no./plant)	
0	33 a	41 a	13 c	23 c	32 ab
9	6 b	43 a	20 ab	40 b	35 a
17	5 b	37 ab	20 ab	57 a	32 ab
33	3 b	36 ab	24 a	53 ab	26 b
67	3 b	34 ab	25 a	38 b	28 b
280	2 b	30 bc	13 c	60 a	14 c
560	1 b	24 c	5 d	45 ab	7 d

[a]Means in a column followed by the same letter were not different by Duncan's multiple range test at $P \leq 0.05$.
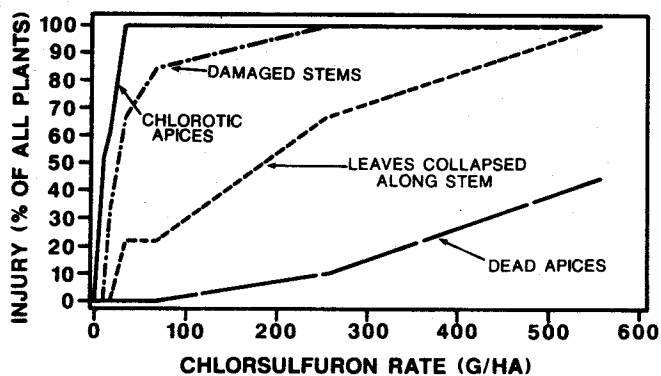
Figure 1. The influence of various rates of soil-applied chlorsulfuron on the percentage of damaged Canada thistle shoots 1 month following treatment. The results of two experiments were averaged.

differed depending upon dose (Figure 1). Apical chlorosis occurred in half of the population at doses as low as 17 g/ha, whereas all plants exhibited chlorosis at higher rates. Increasing rates of soil-applied chlorsulfuron were needed to cause progressive damage to the stems, collapse of older leaves along the stem, and both death and desiccation of the shoot apices. Only soil-applied chlorsulfuron at 280 and 560 g/ha caused apical death. In contrast, much lower rates of chlorsulfuron applied to foliage caused apical death (3). The current, maximum, registered rate of postemergence chlorsulfuron for use in wheat is 28 g/ha.

Enough chlorsulfuron or phytotoxic metabolite(s) moved from the roots to the shoots to stop meristematic growth (Figure 1 and Table 1) . Also, radiolabel from ^{14}C-chlorsulfuron moved to a limited extent from the roots to the shoots of young Canada thistle in hydroponic culture over 2 days (14). Apparently, soil-applied chlorsulfuron was absorbed by the root system and was transported in the transpiration stream to the developing apex where it inhibited further stem elongation.

Whereas shoot height (Table 1) and foliar damage (Figure 1) were relatively sensitive to soil-applied chlorsulfuron, root fresh weight was relatively insensitive to this herbicide (P< 0.01) (Table 1). Chlorsulfuron at or below 67 g/ha had little effect on root fresh weight, although at rates as high as 560 g/ha it reduced fresh weight by approximately 41% relative to the untreated check 1 month after treatment. In addition, the roots appeared as white and healthy as the control at all chlorsulfuron rates.

The number of visible root buds plus secondary shoots per plant were 1.5- to 2.5-fold greater than the controls at chlorsulfuron rates between 9 and 67 g/ha for both trials (P< 0.01 and P< 0.02 for the first and second trials, respectively) (Table 1). While ANOVA demonstrated that the root fresh weight data could be combined between trials of this experiment, the response of the root buds to chlorsulfuron could not be combined because it was more variable between trials. Even though the two trials of this experiment were started in the greenhouse within 3 weeks of each other and plants were preselected for uniform shoot growth before treatment, control root bud numbers were 1.8-fold greater in the second trial relative to the first trial. The greenhouse environment over the course of the two experiments was relatively constant. Despite differences between control root bud numbers, chlorsulfuron at 9 to 67 g/ha increased root bud numbers by 1.5- to 1.9-fold and 1.7- to 2.5-fold in the first and second trials, respectively. This stimulation of root bud outgrowth may be due to a loss of either shoot or root correlative inhibition. More research is needed to determine whether rates of 280 and 560 g/ha chlorsulfuron decrease or increase root bud numbers.

The ability of the root system to form new secondary shoots once it was removed from the treated soil and segmented was not decreased by chlorsulfuron at or below 67 g/ha even though there were more visible root buds than in the controls 1 month following soil application of chlorsulfuron (Table 1). The ability of the root system to form secondary shoots decreased at herbicide doses greater than 67 g/ha. Those secondary shoots that emerged in vermiculite 5 weeks after root segmentation were normal in appearance. In earlier experiments, soil treatment with 67 g/ha chlorsulfuron inhibited later secondary shoots outgrowth in vermiculite less than did either foliar or foliar plus soil treatment (3).

Why the secondary shoot outgrowth at 9 to 67 g/ha chlorsulfuron was not greatly increased even though root bud numbers were greater than the controls over this dose range is unknown. In order to determine secondary shoot outgrowth, roots were segmented, releasing them from correlative inhibition. Perhaps, the first emerging secondary shoots on root segments reimposed correlative

inhibition on more slowly growing root buds, a possibility to be examined.

The decreases in root fresh weight and secondary shoot emergence with increasing chlorsulfuron rates were related to each other (Table 1). However, new secondary shoot emergence was more sensitive to the herbicide than root fresh weight. At 560 g/ha chlorsulfuron, the fresh weight and emerged secondary shoots were 58% and 21% of the control values, respectively. When these dependent variables were subjected to regression analysis for both trials, where X is chlorsulfuron rate in g/ha as the independent variable, the following equations were derived:

For root fresh weight ($\hat{Y}$) in g/plant:

$$\hat{Y} = 38.9 - 0.0283\,X \qquad r^2 = 0.23$$

For secondary shoots per plant ($\hat{Y}$):

$$\hat{Y} = 32.7 - 0.0913\,X + (8.13 \times 10^{-5})X^2 \quad r^2 = 0.5$$

These regression equations were derived by a stepwise selection process with a variable entry level for significance (α) of 0.05. All coefficients and intercepts were significantly different from zero ($P < 0.01$). The coefficients of determination (r^2) were relatively low despite the high significance of the overall regression analysis ($P < 0.01$). The low coefficients of determination indicate that the independent variable, herbicide rate, accounted for only 23% and 50% of the variation in the regression equation, respectively.

Effect of treatment duration on intact plants. The numbers of visible root buds plus secondary shoots were unchanged for both the control- and chlorsulfuron-treated plants 2 weeks after herbicide application (Table 2). A highly significant ($P < 0.01$ for both trials) increase in root bud numbers was noted at 4 weeks for both trials of the chlorsulfuron treatment. A 3.6- and 3.7-fold increase in root bud numbers were observed 4 weeks after chlorsulfuron treatment in the first and second trials. More experimentation would be needed to determine whether the increase also occurred at 3 weeks. Those root buds on treated plants that elongated and became visible were as white and healthy in appearance as the controls. Because it took a relatively long time for root bud outgrowth to be distinguished from the controls, stimulation of root bud outgrowth may be an indirect effect of release of correlative inhibition of adventitious

root bud growth, rather than breaking of innate root bud dormancy. Seasonal patterns or cycles in the numbers of root buds were not observed in field studies of undisturbed patches of Canada thistle in Nebraska (11).

When the dependent variable, visible root bud plus secondary shoot number per plant ($\hat{Y}$) for only the chlorsulfuron treatment, was subjected to regression analysis where X is time in weeks as the independent variable, the following equations were derived:

For trial 1: $\hat{Y} = 20.64 + 4.78\,X^2 \qquad r^2 = 0.54$
For trial 2: $\hat{Y} = 20.71 - 7.25\,X + 3.33\,X^2 \quad r^2 = 0.32$

Separate but qualitatively similar regression equations are presented because the trials could not be combined. The selection criteria for the best regression equation and significance level were the same as previously described. All coefficients and intercepts were significantly different from zero ($P < 0.01$). The coefficients of determination (r^2) were relatively low despite the high significance of the over-all regression analysis ($P < 0.01$) because of variability in the measured parameter. Only 50% and 32% of the variability in root bud number in the regression equations for the first and second trials could be attributed to the independent variable, time following chlorsulfuron treatment. There were no changes in control root bud plus secondary shoot numbers by 1 month after treatment, and the overall regression analysis of this

Table 2. Number of visible root buds plus secondary shoots of Canada thistle at various times after treatment with soil-applied chlorsulfuron at 67 g/ha.

Treatment	Time	Visible root buds plus secondary shoots[a]	
		Trial 1	Trial 2
	(weeks)	—— (no./plant)——	
Control	0	14 b	30 c
	2	23 b	29 c
	3	13 b	32 c
	4	19 b	35 c
Chlorsulfuron at 67 g/ha	0	14 b	30 c
	2	20 b	25 c
	3	18 b	68 b
	4	51 a	98 a

[a]Means in a column followed by the same letter were not different by Duncan's multiple range test at $P < 0.05$.

parameter versus time was nonsignificant (P≤ 0.69 and P≤ 0.26 for trials 1 and 2, respectively).

Dose-response of excised buds. Approximately 12.4 ± 6.7% (mean ± s.d.) of the root buds in the controls failed to grow. This value may be due to nonviability or the inability to visually distinguish root buds in about 12% of the population that was sampled. Alternatively, the buds may have been immature. The percentage of buds which grew decreased as dose was increased when newly developed root buds were incubated directly in analytical-grade chlorsulfuron (Figure 2). No dose which enhanced root bud outgrowth relative to the controls was found over a wide concentration range. Consequently, it seems unlikely that direct interaction between buds and chlorsulfuron in the soil solution is responsible for the stimulation of root bud outgrowth in the first two experiments. Root buds were white and healthy in appearance at the end of the 3-week incubation period. The coefficient of determination (r^2) indicated that roughly 71% of the variability in the regression equation can be attributed to chlorsulfuron concentration.

Long-term effect of soil treatment with chlorsulfuron on decapitated plants. There was little change in control root fresh weight for the first month following shoot decapitation (Figure 3). Differences be-

tween treatments were first observed 2 months following treatment and thereafter. At that time, control root fresh weight exceeded that of the chlorsulfuron-treated plants. There was almost complete loss of root fresh weight for chlorsulfuron-treated plants by 6 months following application. Perhaps, the controls formed enough shoot photosynthate to support further root fresh weight increases whereas chlorsulfuron-treated plants did not. The leaves remaining on the decapitated shoots of herbicide-treated plants died by 4 months after treatment.

The numbers of visible root buds plus secondary shoots followed a strikingly different pattern (Figure 4). Again, chlorsulfuron did not affect the number of visible buds present at 1 month following treatment, although by 2 months there was a 3.1- and 2.6-fold increase in visible root bud number in
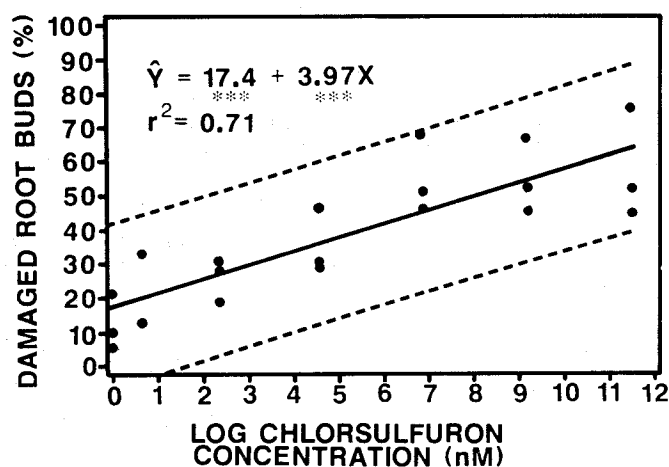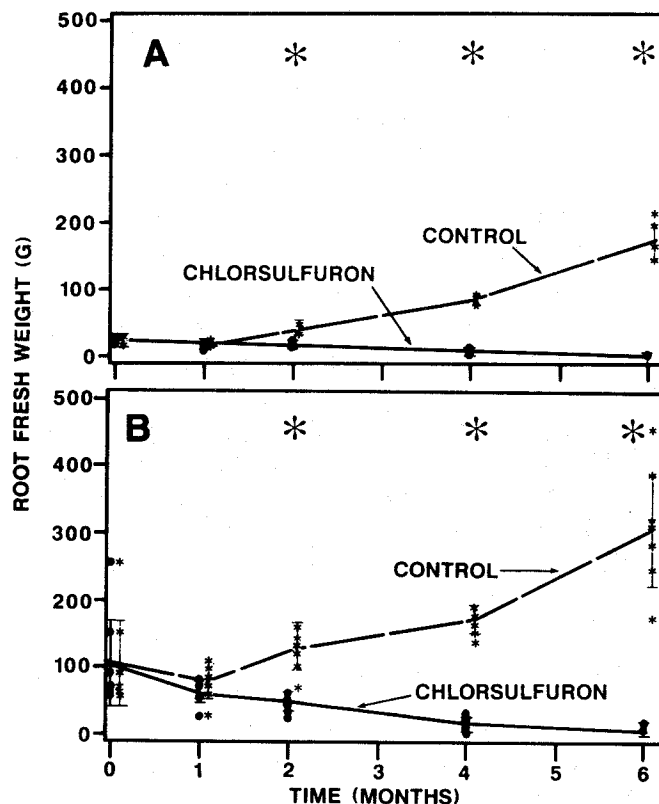

Figure 2. The effect of direct incubation for 3 weeks in various concentrations of chlorsulfuron on the proportion of excised Canada thistle root segments with root buds that did not grow ("damaged"). The combined regression analysis (P≤0.01) of three repeated trials is presented with 95% confidence intervals. The slope and intercept were significantly different from zero (P≤0.01)(***).

$\hat{Y} = 17.4 + 3.97X$
*** ***
$r^2 = 0.71$

Figure 3. The influence of soil-applied chlorsulfuron at 67 g/ha on root fresh weight of decapitated Canada thistle plants over time. Means and standard deviation bars as well as data points (* = control; • = chlorsulfuron) are presented. T tests demonstrated significant differences at P≤0.05 (*). Separate results of two repeated trials are presented (A and B).
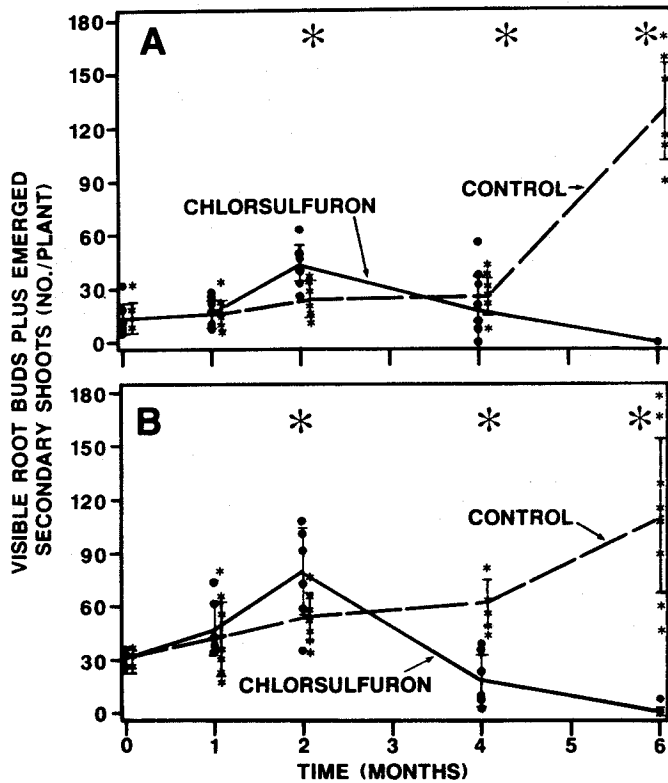
Figure 4. The influence of soil-applied chlorsulfuron at 67 g/ha on the number of visible adventitious root buds plus secondary shoots of decapitated Canada thistle plants over time. Means and standard deviation bars as well as data points (* = control; ● = chlorsulfuron) are presented. T tests demonstrated significant differences at P≤0.05 (*). Separate results of two repeated trials are presented (A and B).

the first and second trials, respectively. At 4 and 6 months, the number of root buds of controls increased whereas those of chlorsulfuron-treated plants decreased below the number in the controls. Root bud number (Figure 4) and root fresh weight (Figure 3) decreased in response to soil-applied chlorsulfuron in a similar fashion in the latter half of the experiment.

The secondary shoot outgrowth of the control and treated plants differed by 1 month following treatment in one trial and by 2 months in the second trial (Figure 5). The chlorsulfuron-treated plants exhibited further reductions in secondary shoot number and an almost total loss of secondary shoot regrowth potential between 4 and 6 months following treatment in both trials. Nevertheless, decapitated parent shoots took a relatively long time to die and were still green and viable 2 months following soil applications. Regrowth from the

root system at the end of the experiment occurred for a few isolated plants treated with chlorsulfuron. However, the plants were not vigorous and did not grow well, although they appeared normal.

Decreases in root fresh weight following chlorsulfuron treatment were similar to decreases in the growth potential of secondary shoots (Figures 3 and 5). The results also demonstrate that Canada thistle shoots were not needed for increases in visible root bud numbers in response to soil-applied chlorsulfuron. Root death appeared to be an extremely slow process, and took much longer than shoot death. Shoots were severely moribund by 2 months after treatment and died between 2 and 4 months. Root died between 4 and 6 months after treatment.

This is the first report that a sulfonylurea herbicide, chlorsulfuron, can stimulate adventitious root bud outgrowth of a perennial weed, Canada
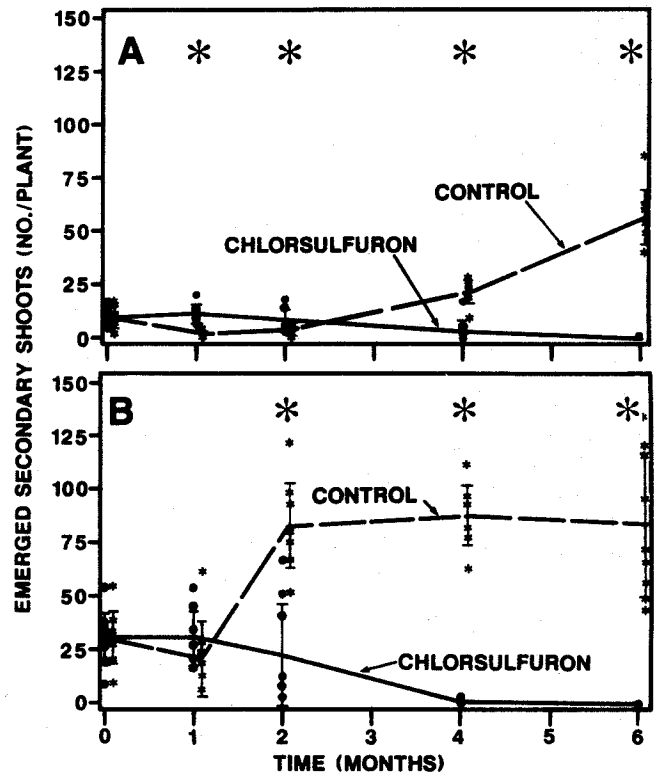

Figure 5. The influence of soil-applied chlorsulfuron at 67 g/ha on the number of secondary shoots per Canada thistle plant 5 weeks following root segmentation at various times after treatment. Means and standard deviation bars as well as data points (* = control; ● = chlorsulfuron) are presented. T tests demonstrated significant differences at P≤0.05 (*). Separate results of two repeated trials are presented (A and B).

thistle. Depending upon rate of application and time of observation, increases in root bud numbers of 1.5- to 3.1-fold were noted for intact, well-established plants (Tables 1 and 2). Chlorsulfuron at 67 g/ha increased the number of visible root buds whether plants were intact (Tables 1 and 2) or decapitated (Figure 4), although other rates may be effective (Table 1). Soil treatment stimulated root bud growth, but shoot treatment did not (3).

Other herbicides have stimulated root bud outgrowth on perennial weeds, usually after direct treatment of isolated tubers, bulbs, or rhizomes. However, most reports deal with lateral or axillary buds, or tiller buds of shoots, rather than true root buds (13). There are few examples of systemic, translocated herbicides applied to the shoots which stimulate root bud outgrowth. For example, foliar treatments of leafy spurge (*Euphorbia esula* L. # EPHES) with glyphosate [*N*-(phosphonomethyl) glycine] (10) or 2,4-D [(2,4-dichlorophenoxy)acetic acid] (2) at herbicidal rates stimulated root bud outgrowth in the field and greenhouse, respectively. More commonly, plant growth regulators have been used to break correlative inhibition of root buds of perennial weeds (1, 9, 12). By stimulating root bud outgrowth, the sink activity of root buds and root systems of perennial weeds for other foliar, systemic herbicides may be enhanced. Translocation of herbicides in the phloem to root buds and root systems may be increased by stimulating root bud growth, thus increasing control of Canada thistle. This possibility remains to be explored.

LITERATURE CITED

1. Baradari, M. R., L. C. Haderlie, and R. G. Wilson. 1980. Chlorflurenol effects on absorption and translocation of dicamba in Canada thistle (*Cirsium arvense*). Weed Sci. 28:197–200.
2. Chow, P.N.P. 1984. Control of leafy spurge in pastures using dicamba and 2,4-D. J. Range Manage. 37:159–162.
3. Donald, W. W. 1984. Chlorsulfuron effects on shoot growth and root buds of Canada thistle (*Cirsium arvense*). Weed Sci. 32:42–50.
4. Hall, J. C., H. D. Bestman, M. D. Devine, and W. H. Vanden Born. 1985. Contribution of soil spray deposit from postemergence herbicide applications to control of Canada thistle (*Cirsium arvense*). Weed Sci. 33:836–839.
5. Hamdoun, A. M. 1970. The anatomy of subterranean structures of *Cirsium arvense* (L.) Scop. Weed Res. 10:284–287.
6. Hamdoun, A. M. 1972. Regenerative capacity of root fragments of *Cirsium arvense* (L.) Scop. Weed Res. 12:128–136.
7. Henson, I. E. 1969. Studies on the regeneration of perennial weeds in the glasshouse. I. Temperate species. Weed Res. Org. Agric. Res. Council Tech. Bull. 12:1–23.
8. Kleinbaum, D. G., and L. L. Kuper. 1978. Applied Regression Analysis and Other Multivariate Methods. Durbury Press, North Scituate, MA.
9. Lym, R. G., and N. E. Humburg. 1979. Effect of various growth regulators on field bindweed (*Convolvulus arvensis* L.). Abstr. Weed Sci. Soc. Am., p. 59–60.
10. Maxwell, B. D., M. E. Foley, and P. K. Fay. 1984. Distribution of ^{14}C-glyphosate in leafy spurge (*Euphorbia escula* L.) roots under field conditions. Abstr. Weed Sci. Soc. Am., p. 83–84.
11. McAllister, R. S., and L. C. Haderlie. 1985. Seasonal variations in Canada thistle (*Cirsium arvense*) root bud growth and root carbohydrate reserves. Weed Sci. 33:44–49.
12. McIntyre, G. I., and J. H. Hunter. 1975. Some effects of the nitrogen supply on growth and development of *Cirsium arvense*. Can. J. Bot. 53:3012–3021.
13. Parker, C. 1976. Effects on the dormancy of plant organs. Pages 165–190 *in* J. L. Audus, ed. Herbicides, Physiology, Biochemistry, Ecology. Vol. 1, 2nd ed., Academic Press, New York.
14. Peterson, P. J., and B. A. Swisher. 1985. Absorption, translocation, and metabolism of ^{14}C-chlorsulfuron in Canada thistle (*Cirsium arvense*). Weed Sci. 33:7–11.