Weed Science. 1993. Volume 41:434–440

Retreatment with Fall-Applied Herbicides for Canada Thistle (*Cirsium arvense*) Control[1]

WILLIAM W. DONALD[2]

Abstract. **This field research was designed to compare the long-term effectiveness of late-September applications of several herbicides for reducing Canada thistle shoot density on noncropped, untilled abandoned farmland when reapplied annually for 3 yr. Clopyralid at 560 and 840 g ae ha^{-1} or picloram at 280 and 560 g ae ha^{-1} reduced Canada thistle shoot density as well as either glyphosate[3] at 0.8 to 2.8 kg ae ha^{-1} or dicamba at 1.1 and 2.2 kg ae ha^{-1}. These treatments were much more effective than 2,4-D at 1.1 and 2.2 kg ae ha^{-1}, chlorsulfuron at 34 and 67 g ai ha^{-1}, and metsulfuron at 34 and 67 g ha^{-1} for progressively reducing Canada thistle shoot density over three annual fall applications. Picloram and clopyralid greatly reduced and delayed shoot emergence from adventitious root buds in spring after two fall-applied treatments compared with nontreated checks. Nomenclature: Chlorsulfuron, 2-chloro-*N*-[[(4-methoxy-6-methyl-1,3,5,-triazin-2-yl)amino]carbonyl]benzenesulfonamide; clopyralid, 3,6-dichloro-2-pyridinecarboxylic acid; dicamba, 3,6-dichloro-2-methoxybenzoic acid; glyphosate, *N*-(phosphonomethyl)glycine; metsulfuron, 2-[[[[(4-methoxy-6-methyl-1,3,5-triazin-2-yl)amino]carbonyl]amino]sulfonyl]benzoic acid; picloram, 4-amino-3,5,6-trichloro-2-pyridinecarboxylic acid; 2,4-D, (2,4-dichlorophenoxy)acetic acid; Canada thistle, *Cirsium arvense* (L.) Scop. #[4] CIRAR.**

Additional index words: **Perennial weed, chlorsulfuron, clopyralid, dicamba, glyphosate, metsulfuron, picloram, 2,4-D, CIRAR.**

INTRODUCTION

Management of Canada thistle on cropland must be a sustained effort over several years regardless of whether herbicides or tillage are used (7). Although several selective herbicides are registered for controlling Canada thistle in some large-acreage field crops, other small-acreage specialty or vegetable crops lack registered herbicides for controlling this competitive perennial weed. One approach for controlling Canada thistle for these crops is to apply nonselective herbicides in the fall before planting to prevent, reduce, and/or delay Canada thistle shoot emergence and growth the following spring (4, 7, 11, 12). However, there are few published reports on the relative effectiveness of herbicides applied in fall for more than 2 yr for controlling Canada thistle, as pointed out in a review on Canada thistle management (7).

Most long-term research (≥ 2 yr) involving annual herbicide retreatment for Canada thistle control involved herbicides such as atrazine (5), chlorsulfuron (8, 11, 13), dicamba (5), phenoxy herbicides (2, 5, 6, 15, 16, 17, 21, 22, 23), or picloram (1, 18, 26) reapplied in spring or early summer, not in fall. In these studies, herbicides were applied at excessively high rates and researchers did not compare many different herbicides within one study.

The first objective of this research was to determine the relative effectiveness of several herbicides (chlorsulfuron, clopyralid, dicamba, glyphosate, metsulfuron, picloram, and 2,4-D) for reducing Canada thistle shoot density when reapplied in fall for up to 3 yr on noncropped, untilled abandoned farmland. In this way, the residual effect of herbicides could be studied independently of crop competition. The second objective was to determine whether fall-applied herbicides delayed Canada thistle shoot emergence the summer following treatment.

MATERIALS AND METHODS

Treatments. The treatments were: a nontreated check; chlorsulfuron at 34 and 67 g ha^{-1} (Trials 1 and 2 only); clopyralid at 280, 560, and 840 g ha^{-1}; dicamba at 1.1 and 2.2 kg ha^{-1}; glyphosate at 0.8, 1.7, and 2.8 kg ha^{-1}; metsulfuron at 34 and 67 g ha^{-1} (Trials 1 and 2 only); picloram at 67, 280, and 560 g ha^{-1}; and 2,4-D at 1.1 and 2.2 kg ha^{-1} (Table 1). Nonionic surfactant[5] was added to chlorsulfuron, glyphosate, and metsulfuron at 0.5% (by vol) in Trial 1, and at 0.25% in Trials 2 and 3. Herbicides were applied POST in 70 to 115 L ha^{-1} with a single-tire bicycle sprayer equipped with flat-fan nozzles[6] spaced 50 cm apart on a 3.1-m boom and operated at 3.2 to 4.8 km h^{-1} and 140 to 170 kPa generated by pressurized air.

Herbicides were applied annually in late September to the same plots for 3 yr. Herbicides were applied in late

---

[1] Received for publication November 12, 1992, and in revised form March 27, 1993. Published with the approval of the Director, Agric. Exp. Stn., North Dakota State Univ. as J. Art. No. 2076.

[2] Res. Agron., Agric. Res. Serv., U. S. Dep. Agric., Bioscience Res. Lab., Fargo, ND 58105. Current address: U. S. Dep. Agric., Cropping Systems and Water Quality Res. Unit, 244 Agric. Engineering Bldg., UMC, Columbia, MO 65211.

[3] Mention of a trademark or proprietary product does not constitute a guarantee of the product by the U.S. Department of Agriculture and does not imply its approval to the exclusion of other products that also may be suitable.

[4] 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.

[5] Ortho X-77 [alkylarylpolyoxyethylene glycols, free fatty acids, and isopropanol (90%)], produced by Chevron Chem. Co., Agric. Chem. Div., 6001 Bollinger Canyon Rd., San Ramon, CA 94583. X-77 is now produced by Valent U.S.A. Corp., 1333 N. California Blvd., Walnut Creek, CA 94596.

[6] TeeJet 8001 or 8002 flat-fan nozzles. Spraying Systems Co., North Ave., Wheaton, IL 60188.

Table 1. Herbicide application and observation dates.

Treatment or measurement	Year	Date Trial 1	Trial 2	Trial 3
Herbicides applied in fall to regrowth rosettes 1.5 to 2 mo after mowing	1	9/29/1983	9/29/1984	9/24/1985
	2	9/29/1984	9/25/1985	9/30/1986
	3	9/24/1985	9/30/1986	9/30/1987
Fall rosette shoot density and dry weight determined in nontreated checks	1	9/29/1983	10/03/1984	9/24/1985
	2	10/02/1984	9/25/1985	10/01/1986
	3	9/24/1985	10/01/1986	9/30/1987
Canada thistle shoot density determined every 2 wk in summer after fall herbicide treatment	1	4/10/1984-7/31/1984	4/16/1985-8/02/1985	4/22/1986-8/05/1986
	2	4/15/1985-8/01/1985	4/22/1986-8/05/1986	4/20/1987-7/28/1987
	3	4/22/1986-8/05/1986	4/20/1987-7/28/1987	4/21/1988-7/26/1988
Mature Canada thistle shoot density and dry weight determined for all treatments	1	8/01/1984	8/02/1985	8/08/1986
	2	8/01/1985	8/12/1986	7/28/1987
	3	8/05/1986	7/28/1987	7/26/1988
Mature Canada thistle shoots mowed 1.5 to 2 mo before fall herbicide treatment	1	8/03/1984	8/06/1985	8/13/1986
	2	8/06/1985	8/14/1986	8/11/1987
	3	8/13/1986	8/11/1987	8/01/1988

September to Canada thistle rosettes that had emerged between 1.5 to 2 mo after mowing mature plants in early August (Table 2). Trial 1 was conducted from late September 1983 to early August 1986, Trial 2 was conducted from late September 1984 to early August 1987, and Trial 3 was conducted from September 1985 to early August 1988.

Experimental design. A randomized complete block design with three blocks was used on three adjacent sites. Blocking was based on initial Canada thistle shoot density in late September of year 1 for each trial (Table 2). These Canada thistle densities were chosen to represent a "worst-case" situation and were greater than those typically found in surveys of weeds of commercial cereal farms in the northern Great Plains (7). The Canada thistle subspecies *arvense* (Wimm. and Grab.) was present (20). Individual plots measured 1.8 by 7.6 m in all trials. Even though the plots were relatively narrow, Canada thistle root encroachment from neighboring plots was unlikely because of the observed sharp demarkation between plots over each 3-yr-long trial and the lack of tillage.

Land for the trials had not been cropped or tilled for at least 4, 5, or 6 yr before starting Trials 1, 2, or 3, respectively, although it had been mowed periodically. Plots were not tilled during the experiment but were mowed once each year in early August at least 6 wk before the late-September treatment (Table 2). Mowing in August corresponded to the normal time of Canada thistle seed dispersal, spring cereal harvest, and forage harvest and allowed enough time for numerous Canada thistle adventitious shoots to emerge from the perennial root system and form rosettes (Table 2). The Canada thistle regrowth would permit good spray interception by plant foliage. The impact of mowing on herbicide transport from the foliage to Canada thistle's perennial root system has not been studied in the field (7). However, mowing once a year is insufficient to prevent the increase of Canada thistle infestations (7). All trials were conducted on the North Dakota State University Experimental Farm at Fargo. The soil was a Fargo silty clay (fine, montmorillonitic, frigid Vertic Haplaquolls) with 2% sand, 47% silt, 51% clay, 3.9% organic matter, and a pH of 7.7. Dates of significant field events are presented in Table 2.

Measurements. Rosette density and shoot dry weight in nontreated check plots were measured at the time of herbicide application in three randomly placed 0.5 m^2 square quadrats (Table 2). Live shoots were cut at the soil surface, washed free of soil, and oven dried at 70 C for at least 3 d before being weighed. Approximately 10 mo after each fall herbicide treatment in each of the 3 yr, shoot density and dry weight of Canada thistle were determined from three randomly placed circular quadrats (0.2 m^2 in area) in each plot for all treatments (Table 1). Shoot dry weight data are not presented because conclusions based on these data are similar to those for shoot density m^{-2}.

Table 2. Canada thistle rosette density and dry weight per plant in nontreated check plots at the time of herbicide application in September approximately 1.5 to 2 mo after mowing mature Canada thistle shoots at Fargo.

Trial	Year	Shoot density[a]	Shoot dry weight per plant
		no. m^{-2}	g $plant^{-1}$
1	1983	34 ± 7 a	0.63 ± 0.06 a
	1984	22 ± 10 a	0.55 ± 0.02 a
	1985	41 ± 14 a	0.77 ± 0.14 a
2	1984	10 ± 2 a	0.72 ± 0.07 a
	1985	35 ± 5 a	0.85 ± 0.03 a
	1986	30 ± 10 a	0.24 ± 0.04 b
3	1985	40 ± 7 a	2.44 ± 0.34 a
	1986	21 ± 4 b	0.24 ± 0.02 b
	1987	6 ± 2 b	0.05 ± 0.02 b

[a] Means ± standard errors are presented. Means within a trial followed by the same letter are not different from one another by the LSD test at $P \leq 0.05$.

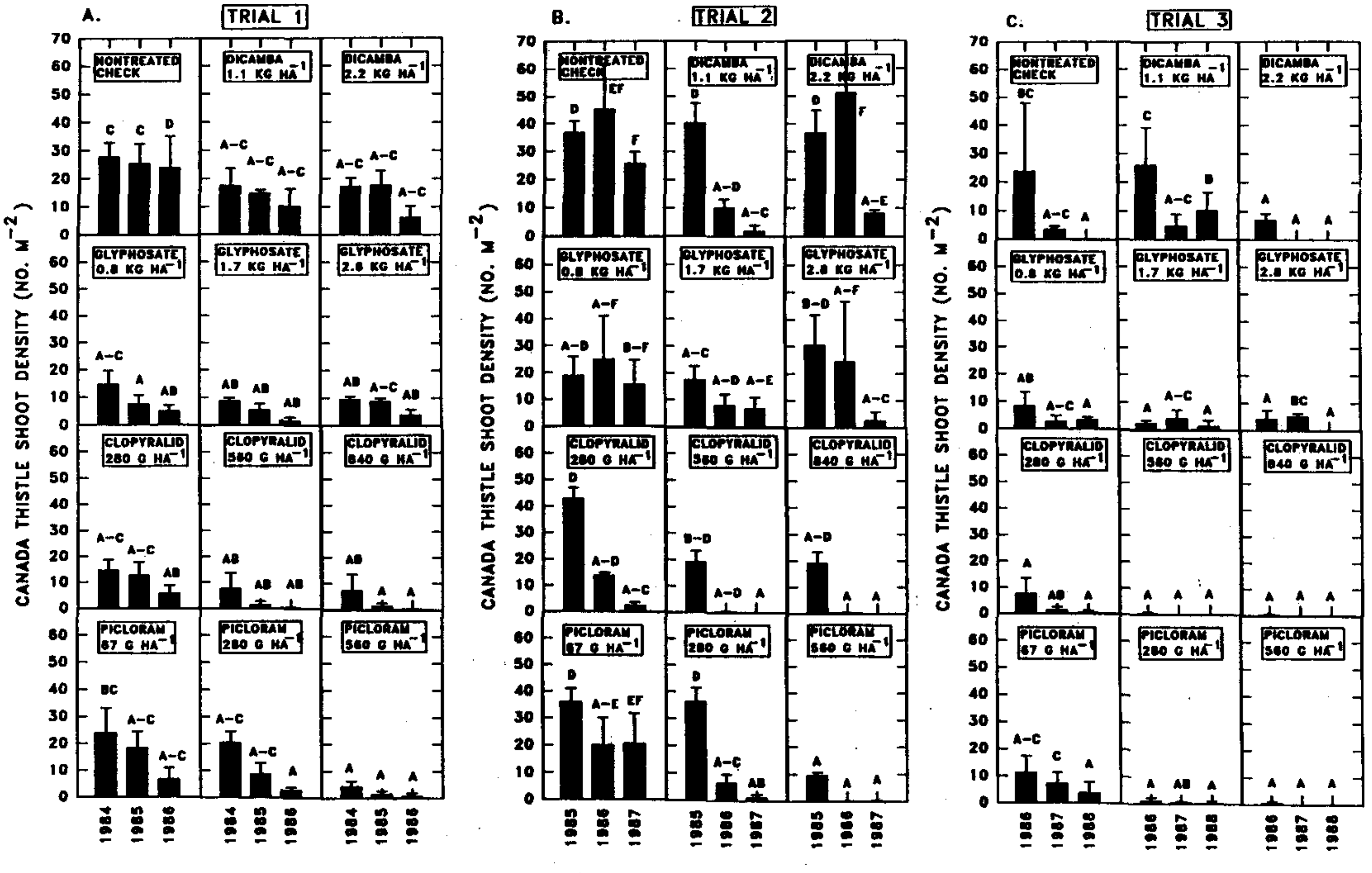

Figure 1. Effect of herbicide treatments applied in fall for each of 3 consecutive years on long-term Canada thistle shoot density in late July or early August of the following year for Trial 1 (Figure 1A), Trial 2 (Figure 1B), and Trial 3 (Figure 1C). Means ± standard error bars are presented. Means followed by the same letters within a year were not different at P ≤ 0.05 by the LSD test.

Canada thistle shoot emergence was determined in three randomly placed 0.2 m^2 circular quadrats per plot at various times throughout the growing season following each fall treatment (Table 1). Summer observations were ended before mowing mature shoots in early to mid-August. Quadrats for measuring emergence were repositioned each spring and observations were made on the same quadrats during the growing season following each fall treatment. Canada thistle seedlings were not counted because there were rare.

Statistical analysis. Analyses of variance (ANOVA) were conducted (24, 25), and means and either log or arcsin square root-transformed means were separated using Fisher's LSD Test ($P \leq 0.05$) if overall ANOVAs were significant. Data were not combined over years because year by treatment effects were significantly different.

RESULTS AND DISCUSSION

Nontreated checks. Canada thistle shoot density m^{-2} in late July or early August in nontreated check plots remained greater than 20 shoots m^{-2} for 3 yr in Trials 1 and 2 (Figure 1A and 1B). These trials experienced normal or above-normal rainfall during the second and third growing seasons after the trials were started (i.e., 1985 and 1986 in Trial 1, respectively, and 1986 and 1987 in Trial 2, respectively) (Figure 2). In contrast, Canada thistle shoot density decreased over three growing seasons in the nontreated check in Trial 3 (Figure 1C), although initial shoot density in early August in year 1 (1986) was similar to the initial densities in year 1 of the other two trials. Growing season drought during 1987 and 1988 of Trial 3 reduced subsequent Canada thistle shoot emergence, probably by killing the perennial root system (4, 7, 8).

Data were not combined over trials or over years because rainfall varied dramatically both within and between growing seasons, giving each 3-yr-long trial a unique environmental history (Figure 2). Trials 1 and 3 were started after a growing season of normal cumulative rainfall whereas Trial 2 was started after a summer drought. The ANOVA assumption of independence of observations ignores the possibility that several years of drought may influence perennial weed growth and response to herbicides, as previously observed (4, 7, 11, 12). Also, environment during the growing season preceding the start of the three trials may have influenced results.

Herbicide treatments. In the first two trials, clopyralid at ≥ 560 g ha^{-1}, glyphosate at ≥ 1.7 kg ha^{-1}, and picloram at ≥ 280 g ha^{-1} were generally equally effective for progressively reducing Canada thistle shoot density over time after two to three annual fall applications (Figure 1A and 1B). Fewer fall-applied treatments with clopyralid or picloram at ≥ 280 g ha^{-1} were required to reduce Canada thistle shoot density below 2 shoots m^{-2} than for glyphosate or dicamba, regardless of application rate. Clopyralid at 840 g ha^{-1} or picloram at 560 g ha^{-1} applied annually in three consecutive falls prevented or almost prevented Canada thistle shoot emergence in the third growing season, but dicamba and glyphosate did not, although differences between means could not be distinguished between these treatments based on the LSD test.

Previous research showed that Canada thistle shoot density m^{-2} in June could be predicted from shoot densities measured in late July or early August of the previous year using empirically derived regression equations (9). When these equations (9) are combined with regression equations relating percent spring wheat yield loss to Canada thistle shoot density m^{-2} in June (10), it was estimated that if 2 shoots m^{-2} were observed in late August then 4.6 shoots m^{-2} would emerge by early June of the following year causing an estimated 4.2% yield loss for chisel-plowed spring wheat and nearly twice this much loss for no-till spring wheat. Thus, 2 shoots m^{-2} is a reasonable goal to which Canada thistle shoot densities should be reduced to minimize crop yield loss the following growing season.

These comparative observations on noncropped, untilled abandoned farmland confirm earlier research on cropped, tilled farmland for fall-applied glyphosate (4) and dicamba (8, 11) applied in separate experiments. Glyphosate at 1.7 kg ha^{-1} applied for 1 or 2 yr in fall did not prevent subsequent Canada thistle shoot regrowth from adventitious root buds (4). Canada thistle growing in continuous spring wheat (*Triticum aestivum* L.) in a fall chisel-plowed system recovered after the second summer following the second fall-applied glyphosate treatment. Even though glyphosate applied for two consecutive falls decreased Canada thistle shoot density and root biomass (4), enough roots remained to allow Canada thistle shoots to emerge after two additional growing seasons unless annual in-crop treatments were applied. Similar observations were made for fall-applied dicamba at 1.7 or 2.2 kg ha^{-1} for each of 2 yr in continuous spring wheat (11, 12). Crop competition probably contributed to the greater residual level of Canada thistle shoot density reduction achieved with fall-applied glyphosate or dicamba in these previously published reports.

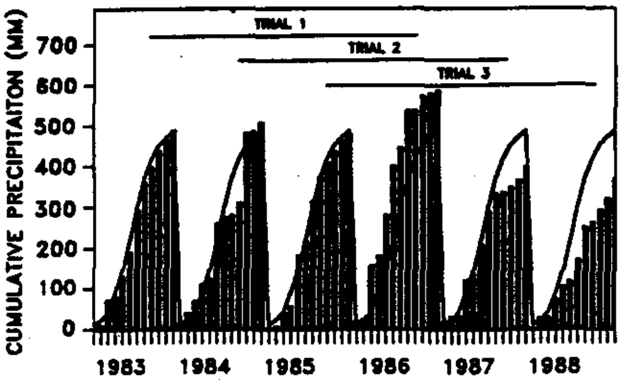

Figure 2. Monthly cumulative precipitation (solid vertical bars) over the 5 yr of Trials 1 to 3 and the 30-yr average cumulative precipitation (cubic splined line). Weather data were gathered at Hector International Airport, Fargo, approximately 1 km north of the experimental sites.

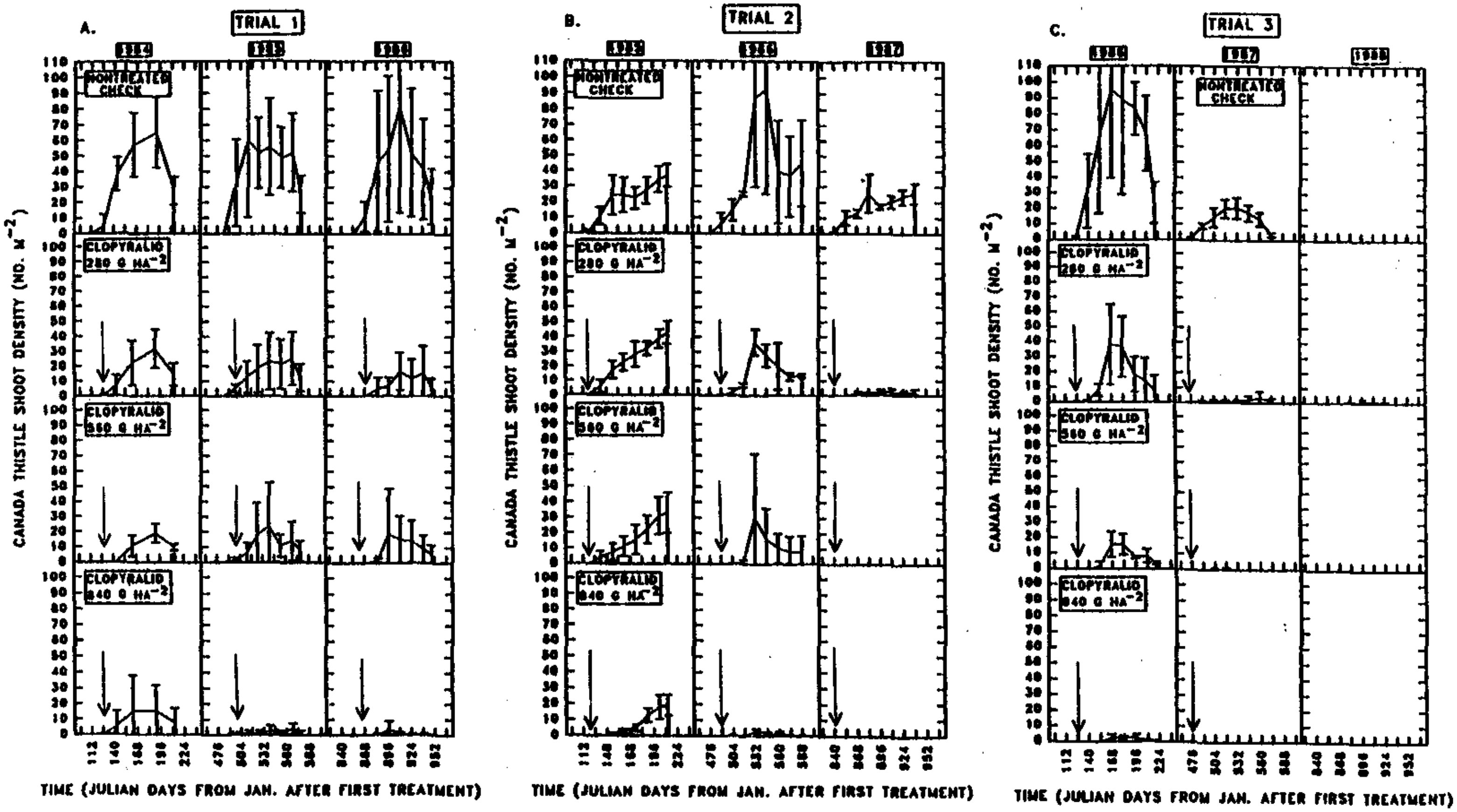

Figure 3. Effect of clopyralid applied in fall for each of 3 consecutive years on Canada thistle shoot emergence during the following growing season for Trial 1 (1984 to 1986) (Figure 3A), Trial 2 (1985 to 1987) (Figure 3B), and Trial 3 (1986 to 1988) (Figure 3C). Means ± standard deviation bars are presented. Arrows denote when Canada thistle shoots first emerged in the nontreated check.

None of the herbicides applied for only one fall reduced Canada thistle shoot density below 2 shoots m^{-2} in Trials 1 and 2 by late July or early August after treatment the previous fall (Figures 1A and 1B). In the first two trials, at least 2 yr of fall-applied treatments were required to reduce Canada thistle shoot density below 2 shoots m^{-2} for clopyralid at $\geq$ 560 g ha^{-1} or picloram at $\geq$ 280 g ha^{-1}. In contrast, one fall-applied treatment of clopyralid at $\geq$ 560 g ha^{-1} or picloram at $\geq$ 280 g ha^{-1} in Trial 3 prevented almost all Canada thistle shoot emergence the following growing season (Figure 1C). As noted above, 3 yr of summer drought reduced Canada thistle shoot density by early August in Trial 3, but not in Trials 1 or 2. In previous research, drought enhanced the efficacy of repeated annual fall-applied herbicides for Canada thistle control by reducing the size of Canada thistle root system independent of herbicide treatment (4, 8, 11, 12). Because progressively fewer Canada thistle shoots emerged in the nontreated check over time (Figure 1C), one cannot draw conclusions about the long-term effectiveness of 3 yr of repeated fall-applied herbicide on Canada thistle shoot density m^{-2} in year 3 of trial 3.

Fall-applied 2,4-D, chlorsulfuron, and metsulfuron were ineffective for reducing Canada thistle shoot densities below 2 shoots m^{-2} by late July or early August after treatment in the previous fall, even when these herbicides were reapplied annually for three consecutive falls in Trials 1 and 2 (data not shown). In fact, shoot densities for these treatments were $\geq$ the nontreated check most years in all trials.

When data were pooled across treatments for each year for each trial, pooled shoot dry weight m^{-2} was positively correlated with pooled shoot density m^{-2}. Pearson product-moment correlation coefficients (R) were 0.85 (N = 66), 0.79 (N = 66), and 0.80 (N = 65) for years 1 to 3 of Trial 1, 0.56 (N = 62), 0.46 (N = 41), and 0.71 (N = 27) for years 1 to 3 of Trial 2, and 0.69 (N = 16) for the first year of Trial 3. Apparently, treatments that reduced Canada thistle shoot density also reduced shoot dry matter accumulation (i.e., the vigor of growth) (data not shown).

Clopyralid delayed and reduced Canada thistle shoot emergence from adventitious root buds in the summer following fall-applied treatment (Figure 3A–C). All rates of clopyralid both delayed and decreased Canada thistle shoot emergence in a rate-dependent response in the first year of each trial. Fall-applied clopyralid at 840 g ha^{-1} reduced shoot emergence more than lower rates. Shoot emergence in clopyralid-treated plots was delayed about 2 wk compared to the nontreated checks in the first year of all trials. In the second year of treatment, emergence was delayed in clopyralid-treated plots in two of three trials. In year 3, emergence in clopyralid-treated plots was delayed in the two trials in which shoots emerged (Trials 1 and 2). Canada thistle responded to fall-applied picloram in a similar fashion (data not presented).

This research provides weed scientists with information on the limitations of multiple-year strategies for controlling Canada thistle. Repeated fall-applied treatments with 2,4-D, chlorsulfuron, and metsulfuron for up to 3 yr were much less effective than glyphosate, dicamba, clopyralid, or picloram for reducing Canada thistle shoot density over time. Fall-applied treatments also reduced and/or delayed Canada thistle shoot emergence from adventitious root buds (Figure 3). Delayed weed emergence would allow crop establishment in spring resulting in more effective crop competition. This possibility needs to be confirmed and its usefulness may depend on vigorous crop growth early in the growing season.

Profitability of fall-applied herbicides for controlling Canada thistle is problematic (11) and break-even analysis depends on year-to-year input costs (herbicide plus application costs) and crop value. A strategy for controlling Canada thistle that requires repeated fall-applied treatments of relatively expensive herbicides over several years for lasting control likely will be useful only for high-value vegetable or specialty crops, not low-value field crops, such as spring wheat (4, 11, 12).

Because phytotoxic residues of some fall-applied herbicides persist into the following spring, use of fall-applied herbicides may be limited to crops that are not damaged by herbicides with persistent residues. Residues of clopyralid, dicamba, and picloram, but not glyphosate, are most likely to limit rotational crop options, according to their registration labels by the United States Environmental Protection Agency. However, published information on the susceptibility of specialty or horticultural crops to carryover residues of many of these herbicides is limited. Most published research on carryover damage from clopyralid (14), dicamba (3, 19), and picloram (14) relates only to field crops. More research is required to resolve this issue before commercial use of fall-applied clopyralid, dicamba, or picloram can be recommended.

ACKNOWLEDGMENTS

I thank R. Hoerauf and numerous student helpers for their technical assistance. I also thank Drs. C. Messersmith, A. Ogg, K. Renner, and R. Zimdahl for their critical review of an earlier draft of this manuscript.

LITERATURE CITED

1. Alley, H. P. 1984. Longevity of Canada thistle shoot control in a crested wheatgrass pasture. Pages 11–12 *in* Res. Prog. Rep. West. Soc. Weed Sci.
2. Amor, R. L. and R. V. Harris. 1977. Control of *Cirsium arvense* (L.) Scop. by herbicides and mowing. Weed Res. 17:303–309.
3. Auch, D. E. and W. E. Arnold. 1978. Dicamba use and injury on soybeans (*Glycine max*) in South Dakota. Weed Sci. 26:471–475.
4. Carlson, S. J. and W. W. Donald. 1988. Fall-applied glyphosate for Canada thistle (*Cirsium arvense*) control in spring wheat (*Triticum aestivum*). Weed Technol. 2:445–455.
5. Carson, A. G. and J. D. Bandeen. 1975. Chemical control of Canada thistle. Weed Sci. 23:116–118.
6. Derscheid, L. A., R. L. Nash, and G. A. Wicks. 1961. Thistle control with cultivation, cropping, and chemicals. Weeds 9:90–102.
7. Donald, W. W. 1990. Management and control of Canada thistle (*Cirsium arvense*). Rev. Weed Sci. 5:193–250.
8. Donald, W. W. 1992. Fall-applied herbicides for Canada thistle (*Cirsium arvense*) root and root bud control in reduced-till spring wheat. Weed Technol. 6:252–261.
9. Donald, W. W. 1993. Root versus shoot measurements to evaluate

recovery of Canada thistle (*Cirsium arvense*) after several years of control treatments. Can. J. Plant Sci. 73 (in press).

10. Donald. W. W. and M. Khan. 1992. Yield loss assessment for spring wheat (*Triticum aestivum*) infested with Canada thistle (*Cirsium arvense*). Weed Sci. 40:590–598.
11. Donald. W. W. and T. Prato. 1992. Effectiveness and economics of repeated sequences of herbicides for Canada thistle (*Cirsium arvense*) control in reduced-till spring wheat (*Triticum aestivum*). Can. J. Plant Sci. 72:599–618.
12. Donald. W. W. and T. Prato. 1992. Efficacy and economics of herbicides for Canada thistle (*Cirsium arvense*) control in no-till spring wheat (*Triticum aestivum*). Weed Sci. 40:233–240.
13. Fay. P. K. and E. S. Davis. 1985. The effect of repeated application of chlorsulfuron on Canada thistle plant density. Pages 160–161 *in* Summary of 1985 Weed Control Trials. Montana State Univ., Bozeman.
14. Gillespie. G. R. 1990. Chapter 22. Picloram and clopyralid. Pages 477–487 *in* W. W. Donald, ed. Systems of Weed Control in Wheat in North America. Weed Sci. Soc. Am., Champaign, IL.
15. Hodgson, J. M. 1958. Canada thistle (*Cirsium arvense* Scop.) control with cultivation, cropping, and chemical sprays. Weeds 6:1–11.
16. Hodgson, J. M. 1968. The nature, ecology, and control of Canada thistle. U. S. Dep. Agric. Tech. Bul. 1386. 32 pp.
17. Hodgson, J. M. 1970. The response of Canada thistle ecotypes to 2,4-D, amitrole, and intensive cultivation. Weed Sci. 18:253–255.
18. Lanning, E. R., Jr. 1963. Tordon .. for the control of deep-rooted perennial herbaceous weeds in the western states. Down Earth 19(1): 3–5.
19. Magnusson, M. U. and D. L. Wyse. 1987. Tolerance of soybean (*Glycine max*) and sunflower (*Helianthus annuus*) to fall-applied dicamba. Weed Sci. 35:846–852.
20. Moore, R. J. and D. Frankton. 1974. The Thistle of Canada. Can. Dep. Agric. Monogr. 10.
21. Peterson, S. C. and J. V. Parochetti. 1978. Canada thistle (*Cirsium arvense*) control in timothy (*Phleum pratense*) and red clover (*Trifolium pratense*). Weed Sci. 26:215–220.
22. Rasmussen, L. W. 1956. The effects of 2,4-D and 2,4,5-T applications on the stand density of Canada thistle (*Cirsium arvense* Scop.). Weeds 4:343–348.
23. Schreiber, M. M. 1967. Effect of density and control of Canada thistle on production and utilization of alfalfa pasture. Weeds 15:138–142.
24. SPSS, Inc. 1990. SPSS/PC$^+$ 4.0 Base Manual for the IBM PC/XT/AT and PS/2. Marija J. Norusis/SPSS, Inc., Chicago, IL.
25. SPSS, Inc. 1990. SPSS/PC$^+$ 4.0 Statistics Manual for the IBM PC/XT/AT and PS/2. Marija J. Norusis/SPSS, Inc., Chicago, IL.
26. Warden, R. L. 1964. Tordon .... for the control of field bindweed and Canada thistle in the North Central United States. Down Earth 20(2): 6–10.