Aspects of Applied Biology 58, 2000
Vegetation management in changing landscapes

Herbicide programmes for the control of creeping thistle *Cirsium arvense* in farm woodland

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Summary

Herbicide treatments of potential use in farm woodland establishment were applied in spring and summer 1997 and 1998 to field plots of established *Cirsium arvense* cultivated the previous winter. The best long-term control was given by a sequential treatment of clopyralid applied to extending shoots in May or early June and repeated 3 weeks later. This was more effective than the recommended application timing for the product, which is to treat weeds at the rosette stage, followed by a further (May or early June) treatment after 3 weeks. Application of a single dose of clopyralid generally gave poorer control than sequential treatments, except in 1998 where a single application made in late June to established plants gave the best control. Pre-emergence treatment with atrazine + cyanazine gave little suppression of *C. arvense* and spring treatments with amitrole or glyphosate gave only short-term control. Tribenuron-methyl applied in summer gave significant growth suppression. The late single application of clopyralid and a mixture of paraquat + atrazine + cyanazine followed by two applications of clopyralid were the most successful treatments to reduce shoot growth the following season.

Key words: *Cirsium arvense*, clopyralid, farm woodland

Introduction

Cirsium arvense (L) Scop. (creeping thistle) can be a serious problem in the establishment of farm woodland, often resulting in severe reductions in tree growth or survival through competition for moisture and nutrients, or by physical smothering. It is also listed as an injurious species under the U.K. Weeds Act 1959 with occupiers of land being responsible for its control (MAFF, 1999). It establishes initially from seed, but then spreads vegetatively through underground roots which produce adventitious shoots; it regenerates readily from buried root fragments (Clapham *et al.*, 1987). It can rapidly spread and dominates many new woodland plantings on better quality land within 2-3 years of establishment. Non-chemical methods of control are generally not effective – cutting encourages more vigorous growth, and ploughing increases its spread. The use of mulches will not be effective against plants arising from roots or cuttings, and closer initial spacing of trees will not be wholly effective and is very expensive. Clopyralid is generally considered to be the best herbicide treatment for the control of *C. arvense* in farm woodland situations where non-selective treatments such as glyphosate are unsuitable (Willoughby & Clay, 1996); however efficacy is variable, often with no long-term control. A number of factors could be responsible for this variability in efficacy of clopyralid, including clonal variations in response, climate and stage of growth at the time of application. There is evidence from North America of clonal variations in the response of *C. arvense* to clopyralid (Frank & Tworkoski, 1994). Efficacy also appears to be affected by the weather at the time of application, with clopyralid being more active in humid conditions (O'Sullivan & Kossatz, 1984). Activity may also be enhanced by uptake from soil; greater efficacy of clopyralid has been reported where the soil was wet at spraying or where precipitation followed soon afterwards (Hall *et al.*, 1985). Clopyralid is reported as being more effective applied as a single dose on *C. arvense* at shoot extension (20 – 40 cm) rather than at the rosette stage or later (Lake, 1980). However sequential application at the rosette stage and three weeks later was the most effective treatment (Lake, 1980).

Because the primary method of regeneration and spread once *C. arvense* is established is not from seed, conventional soil-acting herbicides are unlikely to have a great effect. Indeed, of the soil-acting herbicides commonly used in farm woodlands, none are listed as giving pre-emergence control (Willoughby & Clay, 1996). Nevertheless soil-acting herbicides are likely to be used in any event in new woodlands on better quality land to give pre-emergent control of the wide range of annual and perennial grass and herbaceous weed species that may establish. It would be advantageous to determine which, if any, of these commonly used herbicides might offer extra control of *C. arvense* arising from root fragments in addition to their primary use in controlling other weed species. Atrazine + cyanazine gives effective control of most annual weed species; simazine + metazachlor are used for pre-emergence weed control. Glufosinate, glyphosate and paraquat may also be used as shielded sprays around young trees. There is a need to know if applications of clopyralid following these treatments are effective. Tribenuron-methyl has some activity on *C. arvense* (Donald, 1992) and the potential of a mixture with clopyralid needs investigation.

The two experiments described in this paper were designed to investigate the efficacy of clopyralid applied alone and in sequence at various stages of growth. Efficacy of several potential pre-emergence, and early post-emergence herbicides alone and with clopyralid as a sequential treatment were also tested.

Materials and Methods

Both experiments were situated at Failand, near Bristol on an area of *C. arvense* that had originally been established in 1992. In both years the area was surveyed during the early autumn prior to it being ploughed and cultivated during the winter (January 97 and February 98) to select the best areas for the experiments. Actual sprayed plots were 2.5 x 2.5 m square in both years with four replicates of each treatment in 1997 and three in 1998; the central 2 m square was used for assessments.

Treatments of amitrole (Weedazol-TL; 225 g litre^{-1} a.i., a.c.; Bayer plc.), atrazine (Gesaprim 500 SC, 500 g litre^{-1} a.i., s.c.; Ciba Agriculture), clopyralid (Dow Shield; 200 g litre^{-1} a.i., a.c.; Dow AgroSciences), cyanazine (Fortrol; 500 g litre^{-1} a.i., s.c.; Cyanamid Agriculture Ltd.), glufosinate-ammonium (Challenge; 150 g litre^{-1} a.i., a.c.; AgrEvo UK Ltd.), glyphosate (Roundup; 360 g litre^{-1} a.e., a.c.; Monsanto plc.), metazachlor (Butisan S; 500 g litre^{-1} a.i., s.c.; BASF plc.), paraquat (Gramoxone 100; 200g litre^{-1} a.i., a.c.; Zeneca Crop Protection), tribenuron-methyl (Quantum; 50%w/w tablet; DuPont (UK) Ltd.) were sprayed at a range of stages of growth; pre-emergence (2 April 97 and 31 March 98), small rosettes up to 15 cm diameter (30 April 97, 8 May 98), shoots 20 to 40 cm tall (24 May 97, 4 June 98) and established plants with shoots up to 50cm tall (17 June 97 and 25 June 98). All the follow up clopyralid applications were made to distorted shoots. The wetter used with the clopyralid treatment was a non-ionic surfactant (Agral; Zeneca Crop Protection). Herbicide doses and dates of application are presented in Table 1.

Table 1. *Application details*

Herbicide treatments	Dose (kg a.i. ha^{-1})	Application date Expt 1	Expt 2
atrazine + cyanazine	2.0 + 2.0	2 April 97	31 March 98
atrazine + cyanazine	2.0 + 2.0	2 April 97	31 March 98
+ clopyralid	0.2	24 May 97	4 June 98
atrazine + cyanazine	2.0 + 2.0	2 April 97	
+ tribenuron	0.015	24 May 97	
atrazine + cyanazine	2.0 + 2.0	2 April 97	
+ glyphosate	1.8	17 June 97	
paraquat + atrazine + cyanazine	1.0 + 2.0 + 2.0		8 May 98
paraquat + atrazine + cyanazine	1.0 + 2.0 + 2.0		8 May 98
+ clopyralid	0.1		25 June 98
+ clopyralid	0.2		25 July 98
paraquat + atrazine + cyanazine	1.0 + 2.0 + 2.0		8 May 98
+ clopyralid	0.2		25 June 98
simazine	1.1	2 April 97	
+ clopyralid	0.2	24 May 97	
simazine + metazachlor	1.1 + 1.25		31 March 98
simazine + metazachlor	1.1 + 1.25	2 April 97	31 March 98
+ clopyralid	0.2	24 May 97	4 June 98
simazine + metazachlor	1.1 + 1.25		31 March 98
+ clopyralid	0.1		4 June 98
+ clopyralid	0.2		25 June 98
amitrole + atrazine	4.5 + 2.0	30 April 97	
glufosinate + atrazine	0.75 + 2.0	30 April 97	
glyphosate + atrazine	1.8 + 2.0	30 April 97	
clopyralid	0.2	30 April 97	8 May 98
clopyralid	0.1	30 April 97	8 May 98
+ clopyralid	0.2	24 May 97	4 June 98
clopyralid	0.2	24 May 97	4 June 98
clopyralid	0.1	24 May 97	4 June 98
+ clopyralid	0.2	17 June 97	25 June 98
clopyralid	0.2	17 June 97	25 June 98
clopyralid + tribenuron	0.2 + 0.015	24 May 97	
clopyralid + wetter	0.2 + 0.1%	24 May 97	
clopyralid + tribenuron-methyl	0.2 + 0.015	17 June 97	
tribenuron-methyl	0.015	24 May 97	

All treatments were applied with an Oxford Precision Sprayer fitted with five LP 11002 nozzles at a pressure of 110 kPa and in a spray volume of 240 litres per hectare. There were two untreated control plots in each replicate.

Live green growth of plants was assessed at intervals throughout the growing season and any damage recorded. With the second experiment the amount of regrowth the following spring was also assessed.

Results

Expt 1

The assessments in May and June showed that most of the treatments that been applied at least 3 weeks previously caused statistically significant ($P = 0.05$) reductions in growth. Long-term, none of the treatments completely killed *C. arvense* but there were many which reduced growth considerably (< 20% ground cover at the end of the summer) (Table 2).

Treatments with atrazine + cyanazine caused significant reductions in growth initially, however where there was no follow up treatment the plants re-grew strongly, and by September there was 80% ground cover of relatively healthy flowering plants. The most successful follow up treatment was glyphosate applied in June resulting in approximately 7% cover of very stunted shoots in September. With the other three mixtures of foliar-acting herbicides with atrazine, control was inadequate, and extensive ground cover developed later.

Treatments with clopyralid caused very significant reductions in growth. With the exception of the single application in April, ground cover was reduced to 15% or less by September with all plants being severely stunted. The most effective treatment was the half dose in May followed by a full dose three weeks later in June where only 1% ground cover of severely stunted plants remained in September.

The applications of simazine did not appear to reduce the emergence of *C. arvense* in the spring; the subsequent sequence of clopyralid gave similar results to applications of clopyralid alone, but the mixture of simazine with metazachlor did improve efficacy resulting in only 7% ground cover in September.

Tribenuron alone in May gave good control with significant reductions in growth relatively quickly and only 14% cover of stunted plants in September. The tribenuron + clopyralid mixtures gave slightly better control than clopyralid alone.

Expt 2

Due to the cold wet spring in 1998 growth of *C. arvense* was very slow which resulted in the later application of treatments compared with 1997. Long-term none of the treatments completely killed the *C. arvense,* although in October 98 there was no visible growth present on the plots treated with the mixture of paraquat + atrazine + cyanazine followed by two applications of clopyralid; however by the following spring there was a slight amount of regrowth. Many of the treatments resulted in statistically significant in regrowth the following spring reductions (< 48% ground cover) and several of these had less than 20% cover (Table 3).

The pre-emergence treatment of atrazine + cyanazine was not effective; however when it was followed by a full dose of clopyralid in June growth was significantly reduced and flowering prevented but there was considerable regrowth the following spring (37%).

The mixture of paraquat + atrazine + cyanazine applied early post-emergence was not effective. When this mixture was followed by a full dose of clopyralid in June growth was significantly reduced throughout the growing season resulting in 6% cover in the autumn. However regrowth occurred the following spring resulting in 24% cover. Where the mixture was followed by a sequence of a half dose of clopyralid in June and a full dose in July shoots were completely killed with no visible growth in October 98. However there was a small amount of regrowth the following spring amounting to 9% cover.

The pre-emergence application of simazine + metazachlor alone was ineffective, but when this was followed by either a full dose of clopyralid in early June, or a sequence of half dose clopyralid in early June followed by a full dose three weeks later, growth was considerably reduced leaving only stunted shoots with no flowers.

The application of clopyralid either as a single application at full dose in June, or as a sequence of half dose in May or early June followed by full dose 3 weeks later gave very significant long-term reductions in growth with no extending shoots produced in the season of spraying.

Table 2. *Effect of herbicide treatments on the % ground cover of live* Cirsium arvense *(Expt 1)*

Code	Herbicide	23 May 97	17 June 97	23 July 97	2 September 97
1	atrazine + cyanazine (2 April)	28	32	48	80
2	atrazine + cyanazine (2 April) + clopyralid (May)	28	11	7	31
3	atrazine + cyanazine (2 April) + tribenuron (May)	30	18	22	45
4	atrazine + cyanazine (2 April) + glyphosate (June)	27	27	1	7
5	simazine (2 April) + clopyralid (May)	57	12	4	16
6	simazine + metazachlor (2 April) + clopyralid (May)	52	18	3	7
7	amitrole + atrazine (30 April)	12	18	42	70
8	glufosinate + atrazine (30 April)	33	38	68	85
9	glyphosate + atrazine (30 April)	23	47	75	85
10	clopyralid (30 April)	20	17	20	40
11	clopyralid (30 April) + clopyralid (May)	33	12	7	10
12	clopyralid (May)	65	28	7	11
13	clopyralid (May) + clopyralid (June)	65	42	5	1
14	clopyralid (June)	-	78	53	15
15	clopyralid + tribenuron (May)	65	17	3	7
16	clopyralid + wetter (May)	73	22	7	10
17	clopyralid + tribenuron (June)	-	87	25	8
18	tribenuron (May)	62	50	14	14
Untreated		57	74	84	85
SED		7.20	7.44	8.35	6.86
df		35	39	39	39

Table 3. *Effect of herbicide treatments on the % ground cover of live* Cirsium arvense *(Expt 2)*

Code	Herbicide treatments	4 June 98	25 June 98	27 July 98	28 August 98	1 October 98	1 June 99
1	atrazine + cyanazine (March)	21	38	50	65	74	64
2	atrazine + cyanazine (March) + clopyralid (4 June)	21	23	7	14	23	37
3	paraquat + atrazine + cyanazine (May)	17	28	43	61	65	64
4	paraquat + atrazine + cyanazine (May) + clopyralid (25 June) + clopyralid (25 July)	14	24	16	1	0	9
5	paraquat + atrazine + cyanazine (May) + clopyralid (25 June)	15	31	17	6	6	24
6	simazine + metazachlor (March)	24	40	54	73	73	68
7	simazine + metazachlor (March) + clopyralid (4 June)	24	24	13	11	17	26
8	simazine + metazachlor (March) + clopyralid (4 June) + clopyralid (25 June)	36	39	8	5	5	15
9	clopyralid (May)	24	35	36	49	48	50
10	clopyralid (May) + clopyralid (4 June)	23	18	8	5	5	18
11	clopyralid (4 June)	46	34	7	7	10	29
12	clopyralid (4 June) + clopyralid (25 June)	45	55	7	1	3	20
13	clopyralid (25 June)			30	13	2	6
14	Untreated	28	45	60	69	65	70
SED		6.46	8.86	7.45	6.28	7.44	10.85
df		44	44	43	43	43	43

The single application in May was not very effective resulting in a considerable number of flowering shoots during the summer and considerable regrowth the following spring. However the single application at the end of June gave the best over all long-term control of *C. arvense* with regrowth only amounting to 6% ground cover in June 99.

Discussion

Long-term control of *C. arvense* during the establishment of farm woodland is particularly difficult as there is little or no suppression of weeds by the crop unless trees are planted at very close spacing (1 m x 1 m or less) and are growing vigorously. Where annual weeds are controlled by residual herbicides, growth of perennial weeds such as *C. arvense* is often vigorous. Pre-emergence or early post-emergence application of soil-acting herbicides appeared to offer little advantage over foliar-acting herbicides in these experiments. However, they may give control of the initial establishment of *C. arvense* by seed, and this is the subject of further experimentation. Clopyralid is frequently used as a directed spray in this situation (Willoughby & Clay, 1996) and may be sufficiently selective for use as an overall spray on some species (Willoughby & Clay, 1999). It is used either as a single dose of 0.2 kg a.e. ha^{-1}, or as a sequential application of 0.1 and 0.2 kg a.e ha^{-1} 3 weeks apart. However results are not always satisfactory and strong regrowth later in the season can result.

The results of these experiments show that the sequential treatment of clopyralid is generally more effective than the single dose but that a later application to extending shoots may be better than applying the first dose to the weeds at the rosette stage as recommended (Dow, 1999). In both of these experiments the land was ploughed and cultivated the previous winter, which fragmented the *C. arvense* roots. It is possible that treatment of previously undisturbed *C. arvense* at the rosette stage as in grassland may have been more effective.

In the second experiment treatment with the higher dose of clopyralid in mid-June to shoots at the flower bud stage was very effective with some evidence of improved control in the following year. Application of other foliar-acting herbicides such as amitrole, glyphosate, glufosinate and paraquat in mixtures with atrazine + cyanazine in spring did not give long-term control but the mixture with paraquat followed by clopyralid in summer was very effective. A summer application of glyphosate alone was also effective. Use of these broad-spectrum foliar-acting herbicides in farm woodland requires careful spray application to avoid crop damage whereas clopyralid has a larger degree of selectivity (Willoughby & Clay, 1999). Tribenuron-methyl has been shown to give some control of *C. arvense* (Donald, 1992) and possibly be safe as an overall spray in young trees (Lawrie & Clay, 1994*a,b*). Tribenuron-methyl applied in May gave good suppression of the weed but the mixture with clopyralid in May or June did not improve clopyralid activity significantly.

The work reported confirmed the useful activity of clopyralid on this weed and suggests that applying the first of the two doses of a sequence to extending shoots rather than at the rosette stage may be preferable in newly-planted farm woodland. Applications to larger plants in June may be effective but by that stage the weed could already have had an adverse effect on the growth of small trees.

Acknowledgements

This work was funded by Forest Research. Clopyralid was supplied by Dow AgroSciences Ltd.

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