CONTROL OF PHENOXY HERBICIDE RESISTANT NODDING THISTLE (*CARDUUS NUTANS*) IN PASTURE

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SUMMARY

The effectiveness of some phenoxy herbicides and their mixtures and some sulfonylurea herbicides on a phenoxy-resistant biotype of nodding thistle was evaluated in two pot experiments and two field trials. High tolerance to both 2,4-D and MCPA was confirmed but this varied between the resistant populations and with the age of the plant. Use of different formulations and adjuvants gave improved but variable results. Effective control was obtained with mixtures of clopyralid, mecoprop or dicamba with 2,4-D. Mecoprop and clopyralid were also effective when used alone. No cross resistance to sulfonylurea herbicides was found as they were equally phytotoxic to both biotypes. All these options lack selectivity in pastures but a mixture of 2,4-D with clopyralid or dicamba could be used as a short term measure to assist the integrated management of problem thistle populations.

Keywords: herbicide resistance, nodding thistle, *Carduus nutans*, 2,4-D, adjuvants

INTRODUCTION

Increased tolerance to MCPA in a population of nodding thistle was first demonstrated on a farm in Hawkes Bay (Harrington and Popay 1987; Harrington *et al.* 1988). Since then a number of sites have been found in Hawkes Bay and Waikato where nodding thistles have showed varying levels of resistance to phenoxy herbicides (Bourdôt *et al.* 1989; Harrington 1989; Rahman 1990). Resistance in all cases was correlated with historical exposure to phenoxy herbicides, supporting the hypothesis that it has evolved due to repeated herbicide use (Harrington 1990). Before this discovery in New Zealand, there was little evidence in the international literature that resistance to phenoxy herbicides developed because of their repeated use. Only three previous cases suggested a causal link, and these have been discussed in detail by Bourdôt *et al.*(1990).

Harrington (1989) found that the commonly used phenoxy herbicides MCPA, 2,4-D and MCPB are all tolerated by the resistant biotype of nodding thistle while herbicides such as clopyralid, dicamba and glyphosate are still effective against these populations. Surprisingly tribenuron (DPX-L5300), a sulphonylurea herbicide, was significantly less effective against the resistant population compared to the susceptible biotype. His results were obtained by using one application rate of each herbicide on young seedlings that were transplanted into the field. Our paper reports results of a two-year study which included pot experiments with both susceptible and resistant biotypes and field trials with established populations of the resistant biotype. The objectives were (a) to evaluate the relative tolerance to a number of herbicide formulations and mixtures, including hormones and sulfonylureas, and (b) to find out if any chemical treatment has sufficient efficacy on the resistant biotype to be included as a short term measure in the integrated management of this increasingly difficult to control weed.

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MATERIALS AND METHODS

Pot experiments

Two pot experiments were conducted in 1990/91 and 1991/92. Pre-germinated nodding thistle seedlings (three/pot) of susceptible and phenoxy-resistant biotypes were planted in 150 mm diameter pots in March of 1990 and 1991. Seeds of the susceptible biotype were from Karakariki, near Hamilton. The phenoxy-resistant populations were from Maungatautari near Cambridge and Waootu near Putaruru, areas reported to have resistance by Harrington (1989). The pots were maintained in the glasshouse for the first 2 months and were thinned to one plant per pot when they had two true leaves. They were maintained outdoors without shade or cover for the rest of the study. During this period the nodding thistle plants were regularly fed a nutrient supplement.

The herbicide treatments (Tables 1 and 2) were applied on 26.10.90 and 11.10.91 respectively, when the plants were about 6 months old, with a CO_2 powered sprayer in 300 litres/ha at 210 kPa. In 1990 six pots were selected at random for each treatment and in 1991 eight plants were treated in a similar way. After treatment the pots were left undisturbed for 24 h before being returned to a randomised block layout for the duration of the experiment. The plants were regularly assessed for damage (physical damage, size and vigour) by two or three observers.

Field trials

Two field trials were conducted at Maungatautari in the Waikato. The soil type of these sites was a Pukerata silt loam and the nodding thistle population was known to be resistant to 2,4-D. Trial 1 was on a cattle grazed pasture and the nodding thistle plants were large rosettes at the time of treatment on 24.5.91. Trial 2 was on a sheep grazed pasture on rolling terrain and the plants were very small seedlings when sprayed on 4.7.91. The herbicide treatments (Tables 3 and 4) were applied, approximately 10 days after grazing, with a CO_2 powered sprayer in 200 litres/ha water at 200 kPa using fan nozzles. Trial 1 was sprayed on a foggy morning with a fine day following, while Trial 2 was sprayed on a fine day following a frost. Both trials were of a randomised block design with six replicates and 2 x 10 m plots.

Nodding thistle damage was regularly assessed by three observers. The percent control scores in Tables 3 and 4 represent an estimate of physical damage, plant density, size and vigour and the overall appearance of plants. In Trial 2, where thistle density was low, number of plants were also counted in each plot.

RESULTS

Pot experiments

The initial effects of different treatments, which included burning and twisting of leaves, were similar on both the susceptible and phenoxy-resistant biotypes 11 days after treatment (Table 1). By 1 month after treatment (MAT) there were significant differences between the susceptible and phenoxy-resistant plants (Tables 1 and 2). In the first pot experiment, for which the phenoxy-resistant seed was collected from Maungatautari, these differences were observed only in the 2,4-D (alone or with LI 700) and MCPA LVE treatments (Table 1). In this trial there were no differences in the response of the two biotypes to MCPA 400, any of the phenoxy mixtures or any of the sulfonylurea herbicides. Also in this experiment the adjuvant Pulse enhanced the activity of 2,4-D sufficiently for it to produce good results on both biotypes whereas the adjuvants LI 700 and Freeway were of no added benefit. For the second pot experiment phenoxy-resistant seed was collected also from Waotu and this biotype appeared to have greater tolerance to the phenoxy herbicides (Table 2).

In both pot experiments the addition of either dicamba, mecoprop or clopyralid to 2,4-D resulted in better control of the nodding thistles and in particular the phenoxy-resistant biotypes. The speed with which these mixtures worked however, differed considerably: mecoprop gave 100% control within 6 weeks, dicamba within 8 weeks and clopyralid after about 10 weeks (data not presented). The addition of dicamba to MCPA 400 in the first pot experiment also significantly increased the level of control over MCPA 400 alone for both biotypes.

TABLE 1: Experiment 1: Percent damage (relative to untreated) to phenoxy resistant and susceptible nodding thistle plants grown in pots and treated on 26.10.90.

Treatment	Rate (kg ai/ha)	Damage (%) 6.11.90 R[1]	S	21.11.90 R	S	21.12.90 R	S
2,4-D	1.1	50	48	45	65	53	85
2,4-D	2.2	50	50	40	80	45	93
2,4-D + dicamba	1.1 + 0.05	53	48	53	55	88	88
2,4-D + dicamba	1.1 + 0.1	50	53	45	53	100	100
2,4-D + mecoprop	1.1 + 0.3	38	40	48	60	100	100
2,4-D + mecoprop	1.1 + 0.45	55	51	75	83	100	100
2,4-D + Pulse	1.1 + 0.1%	49	46	60	58	88	84
2,4-D + LI 700	1.1 + 0.09	48	53	40	65	55	88
2,4-D + Freeway	1.1 + 0.1%	33	40	35	45	65	64
2,4-D + clopyralid	1.1 + 0.03	55	43	64	59	95	88
MCPA 400	1.13	44	43	41	43	63	65
MCPA 400	2.25	45	50	58	58	75	72
MCPA 400 + dicamba	1.13 + 0.05	48	40	78	59	100	84
MCPA 400 + dicamba	1.13 + 0.1	48	45	86	70	100	100
MCPA LVE	1.1	45	40	38	74	55	100
MCPA LVE	2.2	49	40	35	48	55	96
metsulfuron	3.0 g	25	24	78	68	100	96
metsulfuron	6.0 g	28	25	58	55	93	93
tribenuron	15 g	23	20	40	50	90	90
tribenuron	30 g	10	10	60	40	93	90
primisulfuron	22.5 g	20	20	50	40	75	73
LSD (P<0.05)[2]		9.6		20.5		22.5	

[1] R = resistant nodding thistle from Maungatautari, S = susceptible nodding thistle from Karakariki.
[2] The LSD value for each assessment date applies between the two populations as well as between the treatments. Scores of 100 were omitted from the analysis.

The sulfonylurea herbicides, metsulfuron and tribenuron, were extremely damaging to both biotypes in both experiments (Tables 1 and 2) but this only rarely resulted in the death of the plant. Typically all the existing leaves died off but the plants then regrew from the tap root producing spindly, deformed leaves often devoid of prickles. Primisulfuron produced similar damage but was less effective.

Field trials

Nodding thistle plants in Trial 1 were large rosettes at the time of spraying. All the herbicide treatments had some initial effect on thistles but damage by the 2,4-D and both MCPA treatments was not severe (<40%) and most plants went on to flower confirming the population was resistant to phenoxy herbicides. Efficacy of 2,4-D and MCPA was fairly similar initially but at equivalent rates MCPA was slightly more effective in the long term. Of the hormone type herbicides the mixture of 2,4-D with the high rate of mecoprop (600 g/ha) gave the best long term control (Table 3). Mixtures of 2,4-D with the low rate of mecoprop (300 g/ha), dicamba (100 g/ha), or clopyralid (30 g/ha) provided reasonable levels of control but some plants were still able to mature and flower. The three sulfonylurea herbicides were slow to act but the level of control improved with time, reaching between 65 to 88%, although this had declined considerably in the case of primisulfuron by 6 months after application (Table 3).

TABLE 2: Experiment 2: Percent damage (relative to untreated) to phenoxy resistant and susceptible nodding thistle plants grown in pots and treated on 11.10.91.

Treatment	Rate (kg ai/ha)	Damage (% of untreated) 8.11.91 R1[1]	R2[1]	S[1]	9.12.91 R1	R2	S
2,4-D	1.1	17	33	55	3	3	71
2,4-D	2.2	34	52	75	18	42	78
2,4-D + dicamba	1.1 + 0.05	58	63	82	76	96	87
2,4-D + dicamba	1.1 + 0.1	68	73	80	98	93	100
2,4-D + mecoprop	1.1 + 0.2	67	74	82	99	95	100
2,4-D + mecoprop	1.1 + 0.3	79	88	84	97	100	100
2,4-D + clopyralid	1.1 + 0.03	87	88	93	100	100	100
MCPA 400	1.13	47	72	67	35	78	91
MCPA 400	1.7	50	68	81	53	87	92
MCPA LVE	1.1	45	56	80	8	43	92
MCPA LVE	1.65	51	52	87	52	50	100
metsulfuron	3.0 g	54	48	62	87	85	77
metsulfuron	6.0 g	58	56	50	83	93	87
tribenuron	15 g	53	53	52	85	90	80
tribenuron	30 g	55	45	51	85	87	82
primisulfuron	30 g	53	40	53	37	39	42
primisulfuron	45 g	57	42	56	43	45	35
LSD (P<0.05)[2]			14.5			23.5	

[1] R1 = resistant nodding thistle from Waotu, R2 = resistant nodding thistle from Maungatautari, S = susceptible nodding thistle from Karakariki.
[2] The LSD value for each assessment date applies between the populations as well as between the treatments. Scores of 100 were omitted from the analysis.

TABLE 3: Field Trial 1 - Percent nodding thistle control after treatment of large thistles on 24.5.92.

Treatment	Rate (kg ai/ha)	Nodding thistle control (%) 11.6.91	11.7.91	6.8.91	28.11.91
2,4-D	1.1	24	20	8	2
2,4-D	2.2	39	34	20	30
2,4-D + dicamba	1.1 + 0.05	29	52	51	35
2,4-D + dicamba	1.1 + 0.1	37	57	70	54
2,4-D + mecoprop	1.1 + 0.3	36	55	71	73
2,4-D + mecoprop	1.1 + 0.6	44	75	94	96
2,4-D + clopyralid	1.1 + 0.03	33	52	58	68
clopyralid	0.03	33	64	59	58
MCPA 400	1.13	28	30	33	39
MCPA LVE	1.1	28	29	27	30
metsulfuron	6 g	28	55	75	61
metsulfuron	9 g	31	54	88	79
tribenuron	20 g	26	50	77	40
tribenuron	30 g	23	54	77	52
primisulfuron	30 g	25	42	65	20
primisulfuron	60 g	25	45	68	13
untreated control	-	0	0	0	0
LSD (P<0.05)[1]		7.6	12.8	16.1	22.8

[1] Excludes untreated controls.

Trial 2 had very small thistle plants present at the time of spraying. Damage assessments and plant counts again showed relatively poor control by 2,4-D and MCPA 400 (although results were better at the high rate of 2,4-D) suggesting phenoxy-resistance as in Trial 1. Although similar initially, the efficacy of MCPA LVE formulation was better in the long term and was similar to the high rate of 2,4-D (Table 4). Overall, the best control was provided by mecoprop or clopyralid used alone or in mixture with 2,4-D. Dicamba mixtures were intermediate in effect, but dicamba alone provided unsatisfactory control, similar to that of 2,4-D and MCPA 400. The sulfonylurea herbicides in general were slow acting and caused varying levels of damage, with metsulfuron giving significantly better results. As was the case in pot experiments, however, most plants recovered and regrew, resulting in plant counts similar to the untreated control. The high rate of metsulfuron was the only treatment resulting in a significant reduction in thistle density at the last assessment in February (Table 4).

TABLE 4: Field Trial 2 - Assessment of percent control and counts of nodding thistles after treatment of small thistles on 4.7.91.

Treatment	Rate (kg ai/ha)	Control (%) 4.9.91	Numbers of nodding thistles/plot 9.10.91	28.11.91	4.2.92
2,4-D butyl-ester	1.1	17	35	25	36
2,4-D butyl-ester	2.2	46	15	10	12
2,4-D ester + dicamba	1.1 + 0.05	66	6.5	7.2	5.3
2,4-D ester + dicamba	1.1 + 0.1	74	2.5	3.3	2.5
2,4-D ester + mecoprop	1.1 + 0.3	77	3.2	2.3	1.0
2,4-D ester + mecoprop	1.1 + 0.6	86	2.2	1.2	1.2
2,4-D ester + clopyralid	1.1 + 0.03	81	0.5	0.7	0.5
clopyralid	0.03	78	2.2	0.5	0.8
mecoprop	0.6	95	1.2	0.2	0.2
dicamba	0.1	48	18	17	20
MCPA 400	1.13	17	26	17	26
MCPA LVE	1.1	18	14	12	8.7
metsulfuron	6 g	81	45	26	32
metsulfuron	9 g	89	33	19	15
tribenuron	20 g	33	47	27	48
tribenuron	30 g	45	40	19	41
primisulfuron	30 g	52	47	26	43
primisulfuron	60 g	55	49	31	44
untreated control		0	41	25	44
LSD (P<0.05)[1]		22			
M.S.R. (P<0.05[2]			2.4	2.2	2.7

[1] Excludes untreated controls.
[2] Mean significant Ratio; log (Y + 1) transformation used. Therefore add 1 to means before applying the MSR.

DISCUSSION

In the two pot experiments large differences in damage scores were apparent within 1 MAT between the susceptible and phenoxy resistant biotypes. However, the degree of resistance varied between the two populations collected from different farms. In the field trials a much higher level of resistance was observed in Trial 1 where thistle plants were much larger and more established than in Trial 2. On young thistle plants in Trial 2, even the high rate of 2,4-D provided a significant reduction in plant numbers in the long term. These results are in agreement with those of Harrington

(1989) and support his belief that farmers at some sites where resistance was detected were still able to obtain reasonable control with phenoxy herbicides by applying them to young plants and/or by using higher than recommended rates.

In Experiment 1 the resistance to MCPA 400 was lower than to 2,4-D or MCPA LVE. However, there were no consistent differences between the two formulations of MCPA in their efficacy on the resistant biotype. Addition of the adjuvant Pulse enhanced the efficacy of 2,4-D in some instances, but this and other additives have not provided consistent improvement in other experiments (data not presented). It would appear therefore that resistance cannot always be overcome by altering the formulation, as also reported by Harrington (1989), or with the help of adjuvants.

Overall, good long term control of both biotypes was achieved with mecoprop, clopyralid or mixtures of these herbicides with 2,4-D. The dicamba mixture with 2,4-D significantly improved the level of control over 2,4-D but on its own dicamba provided unsatisfactory control (tested in only one trial, Table 4). Results on the efficacy of these herbicides are in agreement with those reported on transplanted seedlings (Harrington 1989) and in the case of clopyralid also reported from field trials (Harrington *et al.* 1988). However, our results differ from Harrington (1989) with respect to the sulfonylurea herbicide tribenuron which showed similar efficacy on both biotypes in pot experiments (Tables 1 and 2) and reasonable efficacy on large thistles in the field (Table 3). The similar efficacy of other sulfonylureas, metsulfuron and primisulfuron, on both biotypes recorded in our studies provides further evidence that cross resistance has not occurred in these phenoxy-resistant biotypes.

The above results show that a few options could be available to effectively control the phenoxy-resistant biotype. In practice, however, these would not be preferred options as the 'hormone' herbicides cause severe damage to clovers (James *et al.* 1993) and the sulfonylurea herbicides cause extensive damage to both ryegrass and clover components (Rahman *et al.* 1993). It would appear, however, that the two combinations which resulted in the least clover damage in the above studies, viz. 2,4-D plus clopyralid and 2,4-D plus dicamba could be used as a short term measure to assist in the integrated management of resistant/tolerant nodding thistle populations. Evidence suggests that resistance has developed in populations of nodding thistle *only* where use of phenoxy herbicides has continued every year for several years (Harrington 1990; Bourdôt *et al.* 1989). However, the appearance of phenoxy herbicide resistance in two pasture weeds, nodding thistle and giant buttercup (*Ranunculus acris*) (Bourdôt *et al.* 1989), raises serious questions about the sustainability of our current weed management strategies that rely largely on herbicides. To prevent further escalation of this problem and the effective loss of useful herbicides, a different approach to weed control is required, by placing more emphasis on agronomic grazing management methods and by rotating and mixing herbicides with different modes of action (Bourdôt *et al.* 1990).

APPENDIX

Herbicides used were; 2,4-D (2,4-D Ester 80 EC, butyl ester, 720 g ai/kg), MCPA 400 (Nufarm MCPA 400, potassium salt, 375 g ai/kg), MCPA LVE (Low Volatile iso-octyl Ester, Nufarm, 500 g ai/kg) , dicamba (Banvel 200, dimethylamine salt, 200 g ai./kg), mecoprop (non-commercial sample CMPP-P DMA, 600 g ai/kg), clopyralid (Versatill, amine salt, 300 g ai/kg), metsulfuron (Escort, 600 g ai/kg), tribenuron (Granstar, 750 g ai/kg), primisulfuron (Beacon, 750 g ai/kg) Pulse (organo-silicone co-polymer, silwet-M), Freeway (1020 g ai/litre modified organo-silicone compound) and LI700 (proprietary spray additive containing an organic acid and a soya bean derivative).

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