Research reports

The effect of herbicide and goats on survival and seed production of Illyrian thistle (*Onopordum illyricum* L.)

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Summary

An experiment was conducted at Galong, New South Wales, to compare separate and combined effects of herbicide and grazing with bush goats on a site moderately infested (20% of ground cover at late vegetative stage) with Illyrian thistle. Sheep were also grazed in August, September and November to remove excess pasture dry matter.

Goats included thistle in their diet in the rosette stage and selected flowering stems and seedheads as they developed. Both goats and herbicide alone reduced thistle plant number by up to 90% and together they controlled 80% of the seed production of the surviving plants. It was concluded that for Illyrian thistle seedhead control there needs to be one goat per hectare for each 3% thistle ground cover at one month post herbicide application. On non-arable sites goats alone at a sufficient stocking rate to graze all thistles, could provide an effective method of controlling seed production.

Introduction

In New South Wales (NSW), Illyrian thistle (*Onopordum illyricum* L.) is a major weed of pastures on the tablelands and slopes (Dellow and Holtkamp 1994). The thistle competes with pastures and its height, density and spines create a physical problem to livestock and dogs. Control of this species is difficult due to its biennial habit, high seed production and long-term seed viability (Briese 1990, Dellow and Holtkamp 1994, Allan and Holst 1996).

Present control techniques employ herbicides and/or cultivation and pasture management, with classical biological control techniques being a recent development (Woodburn and Briese 1996). Control of Illyrian thistle by herbicides is expensive, at times incompatible with legumes and, where the paddock is non-arable or adjacent to a stream or vineyard, may not be practical. A serious limitation is that present control techniques are often about 60% effective in killing the weed (J. Dellow personal communication).

As the thistle spreads by seed proliferation, Campbell *et al*. (1991) suggested that one method of control would be to stop seed production. Campbell and Holst (1990), Campbell *et al.* (1991) and Leigh *et al.* (1993) reported that goats preferentially graze the flowering seedheads of Illyrian thistle and together with the observation that ingested seeds are rendered non-viable (Allan and Holst 1996), goats provide a technique for stopping seed production. Allan *et al.* (1997) concluded that successful grazing control of moderate thistle infestations would require many goats and they suggested that an integrated approach of herbicide and goats (and if necessary cultivation) would be more practical. As the level of infestation reduces over time, the herbicide component could be withdrawn and grazing be the sole control method with desirable economic and environmental consequences.

The aim of this study was to evaluate the efficacy of goat grazing combined with herbicide application to reduce seed production of Illyrian thistle and to present a recommendation for an integrated control system.

Materials and methods

Site

The site was a non-arable 7 ha fenced hilltop with a barley grass (*Hordeum* spp.), brome (*Bromus* spp.) and clover (*Trifolium subterraneum* L.) pasture infested with 20% ground cover of Illyrian thistle as assessed in the late vegetative stage in September.

The study was conducted during winter/spring of 1996 and the following summer of 1997 at Galong on the south-west slopes of NSW. Rainfall of 634 mm was received in 1996.

Animals and management

Seventeen mature female bush goats with prior experience of thistles, equivalent on a stock unit basis to 30% of the sheep carrying capacity (7 DSE ha^{-1}), were maintained on the site throughout the experiment. When the pasture exceeded an estimated 2000 kg green DM ha^{-1} (in August, September and November) sheep in mob sizes of 200–400 were introduced and remained until the DM decreased to 1000 kg ha^{-1}.

Treatments

The design of the experiment was a 2 × 2 factorial (sprayed vs. non-sprayed; grazed vs. non-grazed) with a variable number of replicates depending on the parameter to be measured.

On 25 September a mixture of MCPA (625 g ha^{-1} as dimethylamine salt), clopyralid (75 mL ha^{-1}) and wetting agent was boom sprayed on 50% of the site from a four-wheeled bike. Two (10 × 20 m) livestock exclosures were then erected on both the sprayed and the non-sprayed areas.

Measurements

Quadrats over site. The 7 ha site was uniformly divided by 12 parallel transects. At 20 m spacings along each transect the ground cover, number of thistles and plant details were measured in a 1 m^2 quadrant. In total, 120 quadrats were measured at each sampling (see Table 1).

Transects.

i. Grazed; ± herbicide. Two fixed transects each 25 m long per treatment; two fixed transects each 5 m long per treatment; six fixed paired areas (5 × 1 m^2 (non sprayed); 1 × 40 m^2 (sprayed)) for herbicide effectiveness (plant density).

ii. Non-grazed; ± herbicide. Two fixed transects each 5 m long per treatment within the exclosures. Thistle plants contacting the transect were recorded for sampling. Measurements were: type of plant (seedling, vegetative or flowering), height and width (cm), number and type of seedheads (green, purple and brown) and health and grazing score as defined in Table 2. Dates for measurements are presented in Table 1.

Table1. Dates for thistle measurements.

Time	1	2	3	4	5	6	7	8
Date	25/9/96	24/10/96	7/11/96	27/11/96	11/12/96	19/12/96	30/12/96	13/1/97

Seed viability. Viability of seed was determined on samples of 100 seeds by tetrazolium testing (Ellis *et al.* 1985).

Results

Effect of grazing (without herbicide)

Plant size. Thistle height for flowering plants was not affected by grazing up to Time 4 ($P>0.05$), but thereafter height was reduced ($P<0.001$) by goat grazing from Time 4 (45.3 ± 4.3 vs. 66.8 ± 3.6 cm); and at each measurement day till Time 8 (27.3 ± 4.4 vs. 76.0 ± 5.0 cm).

Similarly, width was not significantly different until Time 4 when goat grazing reduced ($P<0.001$) the width of flowering thistle plants (25.1 ± 2.5 vs. 43.3 ± 2.4 cm) but not of vegetative plants (38.6 ± 5.0 vs. 38.2 ± 1.3 cm). The grazing effect continued to be significant ($P<0.01$) and from Time 6 both types of plants (flowering and vegetative) were smaller on grazed transects.

Grazing score. Goats began to graze the thistles between Time 3 and Time 4 which is the early flowering stage of development. Grazing score was significantly different ($P<0.001$) between non-grazed (1.0 ± 0.01) and grazed areas for both flowering (2.4 ± 0.1) and vegetative plants (3.0 ± 0.2). The grazing score for flowering stems increased until Time 8 (3.7 ± 0.2) whereas for vegetative plants it progressively decreased from Time 5 (2.4 ± 0.2) to Time 8 (1.2 ± 0.1).

Seedheads. The total number of seedheads per flowering plant decreased ($P<0.001$) from Time 4 for grazed plants while increasing in non-grazed plants over the flowering period (Figure 1).

Table 2. Definition of criteria for thistle health and grazing scores.

Score	%	Health of plants	Amount grazed
1	0	healthy, all green	not grazed
2	25	bottom leaves edges dead	edges of some leaves and / or stem
3	50	leaves half yellow and dead	leaves and / or stem moderately grazed
4	75	leaves mostly yellow; dead tips	most of plant
5	100	dead	only stem remaining

Table 3. Plant measurements from grazed quadrats taken over site.

	Time				
	27 / 11 / 96	11 / 12 / 96	19 / 12 / 96	30 / 12 / 96	13 / 1 / 97
Measurement[A]	4	5	6	7	8
FS m^2	1.5	1.7	1.7	1.7	1.8
Seedheads per plant	0.6	0.7	0.7	1.0	0.9
Area covered (%)	7.0	7.0	4.5	4.4	4.3
Av. Health score	1.8	2.0	2.3	2.0	na
Av. Eaten score	2.9	2.8	2.8	2.5	2.4
FS (total)	175	215	201	202	201
FSE	119	161	130	138	150
% FSE	68	75	65	68	75

[A] FS = Flowering stems. FSE = Flowering stems eaten. na = not sampled.

Effect of herbicide (without grazing)

Plant size. The height of vegetative plants was similar for each herbicide treatment at the time of application (Time 1). One month later at Time 2 plant height for sprayed plants was less ($P<0.001$) than the unsprayed plants (22.9 ± 0.8 vs. 34.6 ± 0.7 cm). This difference continued until Time 4 but thereafter plants were of similar height.

Similarly, widths of surviving vegetative sprayed plants were significantly smaller ($P<0.001$) at Time 2 (25.9 ± 1.2 vs. 31.1 ± 1.0 cm). Surviving plants that flowered were significantly ($P<0.001$) wider on sprayed transects at Time 8. At all other times differences due to herbicide were not significant.

Plant kill. One month after spraying (Time 2) the average health score for sprayed vegetative plants was significantly higher ($P<0.001$) than for non-sprayed vegetative plants (3.1 ± 0.1 vs. 1.1 ± 0.1).

The distribution of health scores (Figure 2) 4 to 6 weeks post herbicide application was significantly different ($P<0.001$) between sprayed and non-sprayed plants. There was a rapid reduction of plants m^{-2} between Times 3 to 5, and by Time 5 sprayed and unsprayed plants had similar scores.

Seedheads. The number of seedheads per flowering plant (Figure 1) was not significantly different for sprayed plants except

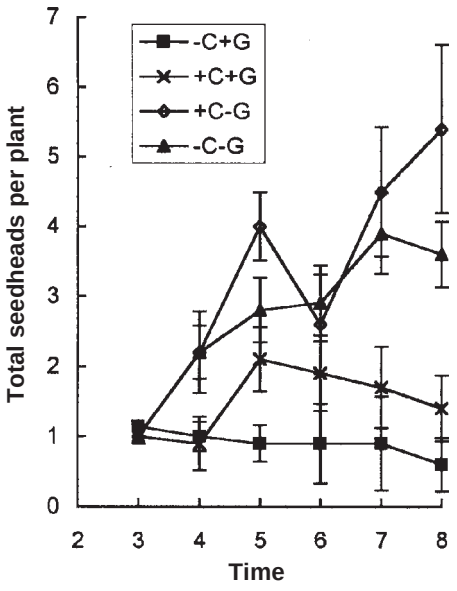

Figure 1. Effect of chemical (C) and grazing (G) on seedheads per plant.

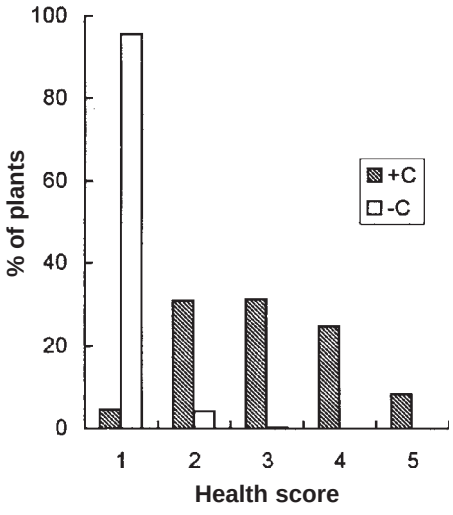

Figure 2. Effect of chemical (C) on plant health, 4–6 weeks after chemical application. 1 = healthy, 5 = dead.

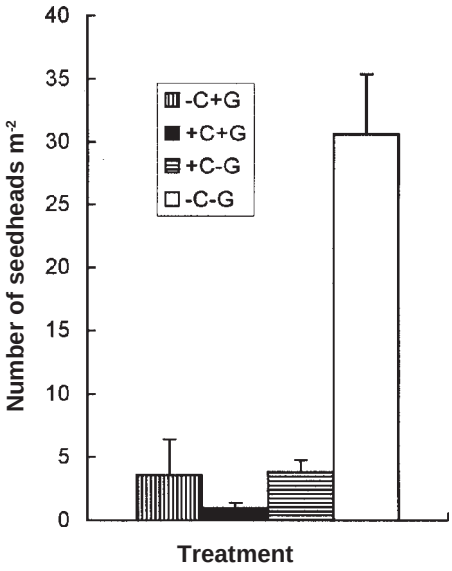

Figure 3. Effect of chemical (C) and grazing (G) on seedheads per square metre.

for Time 8 ($P<0.001$) where sprayed plants had more seedheads than the non-sprayed plants.

Herbicide effectiveness. Herbicide application reduced plant density by over 90% in six paired sites ($P<0.001$) at Time 8; from 9.6 ± 0.7 (non-sprayed) to 0.7 ± 0.1 for (sprayed).

Seed viability as assessed by the tetrozolium test was 19% lower as a result of herbicide application.

Grazed quadrats. A summary of the data obtained from the 120 quadrats uniformly distributed over the site and including both sprayed and unsprayed areas is presented in Table 3.

Seeds in soil. The percentage change in viable seeds in the soil after seed rain was -28 ± 15.6 for herbicide and goats compared with $+56 \pm 32.3$ for no control. Tetrazolium staining of seed embryos indicated that 63% were viable.

Viability of ingested seeds. All faecal samples were free of viable thistle seeds.

Discussion

Goats began to include thistles in their diet in November and there was a preference for flowering plants. Although leaves were eaten the goats preferred the flowering stems and seedheads. Goat grazing reduced the number of seedheads per plant from 3.6 to 0.6 for the transects (average for sprayed and unsprayed) and to 0.9 for the quadrats. This represents a 75 to 80% control of seed set with the majority (70%) of flowering plants having no seedheads. The stocking rate used in this study was insufficient to control all thistles even though herbicide application at the late vegetative stage reduced plant numbers on sprayed areas by an estimated 90%. However those plants not killed by herbicide produced more viable seeds per plant than non-sprayed plants because of lower competition from other plants.

Grazing and herbicide treatments had a positive effect in reducing the number of seedheads per m^2 (Figure 3). Overall when the thistle (10% ground cover) was assessed one month post herbicide application, 80% of seed production had been controlled by the combination of herbicide and 2.4 goats ha^{-1}. In another experiment (D. Stanley *et al.* unpublished data) variegated thistle seedhead control was related to the area of thistle for each goat. The present data suggest that for Illyrian thistle seedhead control there needs to be 1 goat per hectare for each 3% ($0.8 \times 10 / 2.4 = 3.33\%$ cover) ground cover one month post herbicide application. Analysis of the faeces samples collected over the flowering period detected no viable seeds. Holst and Allan (1996) fed Illyrian seed to goats and less than 1% retained an embryo after passing through the rumen.

Soil seeds reserves over the season showed a rapid reduction in all of the treatments except where there was no control. This reduction is similar to that observed by Allan and Holst (1996) who also stated that viable seed remained in soil for at least eight years despite full control of seeding.

Conclusion

The use of herbicide in September to reduce the thistle population, followed by grazing with goats having previous experience of thistle, offers an integrated approach to thistle control especially on associated non arable sites where ground herbicide application is more difficult. As the infestation is reduced to a low level, goats alone can control the scattered plants and are a low cost, sustainable alternative to herbicide use.

Acknowledgments

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