ECOLOGY AND MANAGEMENT OF SAFFRON THISTLE (*CARTHAMUS LANATUS* L.) IN NEW SOUTH WALES PASTURES

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Abstract Saffron thistle (*Carthamus lanatus* L.) is a major weed of Australian pastures, and is difficult to control using conventional techniques. Surprisingly, very little is known about the plant's ecology and population dynamics, making integrated management difficult. By monitoring plant populations over two years, we have found two 'weak links' in the life cycle of saffron thistle - the suppression of seedling establishment under good pasture cover, and the susceptibility of early bolting plants to grazing. We have suggested grazing strategies which target these two stages to help control saffron thistle.

INTRODUCTION

Saffron thistle (*Carthamus lanatus* L.) is Australia's most abundant thistle, infesting over 110 000 km^2 of pasture and cropping land, and costing producers over $111 million each year (Jupp, unpublished data). It is an annual thistle with palatable seedlings and rosettes.

Two classical biological control agents are showing promise for release in Australia (Aeschlimann 1997), and Crump *et al.* (1996) have achieved high mortality rates with native fungi. The effects of these agents on thistle populations cannot be predicted without some baseline understanding of the plants ecology and population dynamics.

Herbicides alone often fail to give satisfactory control (Trotter 1998), and so an integrated weed management strategy is therefore required. This work investigated the dynamics of saffron thistle populations in NSW pastures, especially the effects of grazing and competition, and suggests how grazing and pasture management can be used in saffron thistle control.

METHODS

Site descriptions The Armidale site was situated on a sheep-grazed property of the University of New England, on the Northern Tablelands of NSW. The pasture had a high diversity of native and exotic grasses, especially paspalum (*Paspalum dilatatum*) and redgrass (*Bothriochloa macra*).

The Barraba site, on the North-West Slopes of NSW, was a mixed cattle/sheep property on native pasture dominated by redgrass.

The site near Canberra (Southern Tablelands) was grazed by sheep, and was a severely degraded pasture on previously cropped land. The vegetation was dominated by silver grasses (*Vulpia* spp.), subterranean clover (*Trifolium subterraneum*), and saffron thistle. Paddocks at all sites were set stocked.

Treatments Three treatments were applied at each of the three sites:

- grazed;
- ungrazed, vegetated; and
- ungrazed, bare, where plants other than saffron thistle have been removed by spraying and hand weeding.

There were five replicates per treatment, in a blocked design at each site.

Seedling emergence Emergence of thistles was monitored monthly at the Armidale site between June 1997 and February 1998.

Survivorship The large cohort of seedlings which germinated in May 1998 at Armidale was monitored throughout its life cycle. Individual plants were tagged and checked monthly.

Seed production The timing of flowering and seed production was determined by subjective visual assessment.

Seed production was measured at all three sites after flowering but before capitula opened. Five mature plants were sampled per replicate, before any seed was released, and we counted the number of seeds produced by each plant. We regressed seed production against plant height, crown diameter, and number of capitula and treatment. This allowed us to predict the seed production of other plants within the treatment. Seed production in each of the three treatments was compared for each site using ANOVA on square root transformed data.

RESULTS

Seedling emergence A very large germination flush occurred in May 1998 at Armidale, when heavy autumn rains fell on a pasture with little cover following a dry summer. Smaller cohorts emerged in spring of both years, and in February and March 1998.

Emergence was significantly reduced in the vegetated treatment, where a good pasture cover and litter layer were present (Figure 1). In the large germination flush in May 1998, there were 53 times more seedlings in the bare than in the vegetated plots. There was no significant difference in seedling emergence between the grazed and bare plots for the May 1998 cohort.

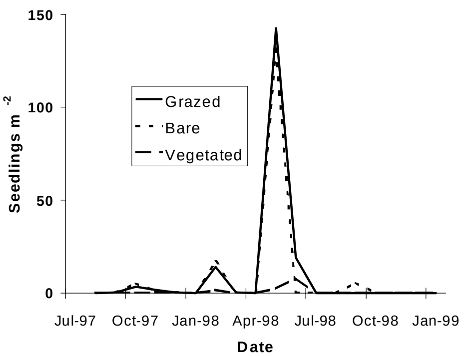

Figure 1. The number of saffron thistle seedlings which emerged over time, at Armidale, with three different treatments

Survivorship Figure 2 shows the survivorship for the cohort which emerged in May 1998. Seedling and rosette survival rates were fairly high in all treatments. The highest mortality rates in all treatments occurred when flowering stems began to elongate in October and November. This effect was most pronounced in the grazed treatment, where 76% of thistles died in November, and 96% of those remaining died in December 1998, before flowering. Grazing stock killed plants by trampling and by eating the meristems. All plants which survived to maturity died in March after setting seed.

Seed production The timing of seed production varied between years and between sites, as shown in Table 1. Although the onset of flowering varied between plants, virtually all plants at each site finished flowering within two weeks of each other.

A separate polynomial equation for each site was used to accurately predict the seed production for all plants within each treatment ($0.81<r^2< 0.86$). There were very large variances in seed production, due to variability within plots and between individual plants. Many plants failed to produce seed, while some earlier-germinating plants produced over 2000 seeds each.

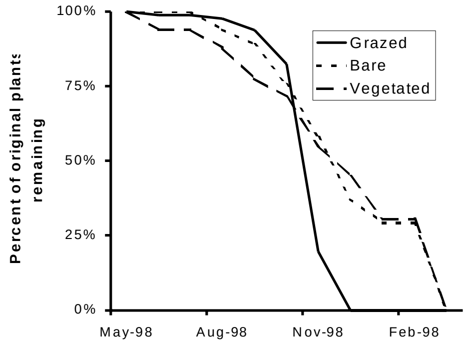

Figure 2. Survivorship curve of a cohort of saffron thistle which emerged in May 1998 at Armidale. Plants were subjected to three treatments

Table 1. The timing of seed maturation of plants at three sites for two seasons.

Site	1997-98 season	1998-99 season
Armidale	March	February
Barraba	February	January
Canberra	January	January

The grazed treatments produced the lowest number of seeds (5 m^{-2}) at the Armidale plots (Figure 3), due to the to the large proportion of plants that were killed by grazing before setting seed.

The vegetated plots at Armidale produced similar numbers of seeds m^{-2} to the bare treatments. There were fewer saffron thistles in the vegetated plots, however, those that did survive to maturity had interspecific and intraspecific competition reduced by the thick litter layer in these plots, and were highly fecund.

While there were no significant differences between treatments at Canberra due to large variability in the results, the bare treatment produced the most seeds. The bare treatment produced significantly more seed than the other two treatments at Barraba. These two results suggest competition from other pasture species may reduce the seed production of saffron thistle per unit area.

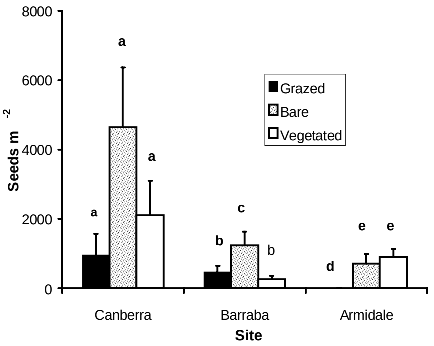

Figure 3. Seed production of saffron thistle under three treatments, at three sites for the 1998-99 season. Vertical bars show the standard error of the mean, and different letters denote significantly different means within each site ($P<0.05$)

DISCUSSION

Seedling emergence The presence of good groundcover in the vegetated plots dramatically reduced emergence of saffron thistle seedlings when the rains fell. This result may have been achieved by preventing light from reaching the seeds, thereby preventing germination (Wright *et al.* 1980). Many farmers comment that good pasture cover may not totally prevent thistle establishment (McCormack, pers. comm.), but its large effect on saffron thistle populations indicates that it should be included in an integrated management strategy.

Mortality rates Neither competition nor grazing affected the survival of seedlings or rosettes. Although rosettes are palatable, their flat habit in grazed pastures makes them largely unavailable to stock (Parsons 1973). Research within our project into rotational grazing to increase pasture growth and make saffron thistles grow more upright, and therefore more available to grazing sheep, is producing good rosette kill rates. The two potential biological control agents may be very useful for the management of saffron thistle, because they both attack rosettes (Aeschlimann 1997), which would otherwise have high survivorship rates.

Mortality rates increased once flowering stems began to elongate in spring, especially when grazed. Increased stocking rates when plants begin bolting may therefore lead to better weed control. If the pasture contains summer-growing species, heavy grazing in spring should not substantially reduce groundcover when autumn rains occur. Ideally, stocking rates over summer should be low in infested paddocks. A strongly competitive pasture will also help control thistle populations.

Seed production Grazing, and in some cases, vegetation cover, reduced seed production in saffron thistles. With the exception of the grazed treatment at Armidale, saffron thistle seed production was much greater than seedling emergence throughout the year. A large soil seedbank of saffron thistle seeds has been recorded as part of this project.

CONCLUSIONS

Infestations are very patchy, and the timing of saffron thistle life cycles and densities of infestation vary between years, and between sites. The timing of control methods must therefore be adapted to local and seasonal conditions.

Results to date suggest that strategic grazing may be effective in controlling saffron thistle. Good pasture cover can limit the emergence of seedlings in autumn, and grazing plants when they begin to produce flowering stems can kill many plants before seed is set. We suggest that grazing management aimed at control of saffron thistle should include 'crash grazing' when plants begin bolting, followed by a low stocking rate over summer to maximise groundcover in autumn.

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