Integrated weed management (IWM) in perennial pasture using pasture and grazing management, herbicide strategies and biological control

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Summary This paper describes preliminary results from a multi-site experiment set up to test the relevance of an integrated weed management approach to broadleaf weeds in perennial pasture using herbicide strategies, biological control, and pasture and grazing management. Pasture management consisted of targeted fertiliser application and over-sowing with perennial grass seeds. Grazing management consisted of controlling stocking rates, using spray-grazing and strategic rests. The results suggest that if perennial grasses make up a significant component of the pasture at the start of applying IWM, the restoration of the pasture to a desirably balanced composition can be quite rapid (2–3 years). Such strategies may prevent the need to fully re-sow perennial grasses. In such instances beneficial interactions were found between pasture management and herbicide strategies through which the perennial grasses contributed to long-term weed suppression. The undesirable annual grass component of the pasture was also reduced in successful treatment combinations. These preliminary results also suggested beneficial biological control impacts on target weeds are not incompatible with other management techniques.

Keywords Grazing management, broadleaf weed control, pasture ecosystem, biocontrol, competitiveness.

INTRODUCTION

Many attempts to control weeds in the past with a single control technique have not been successful in the long-term. McWhorther and Shaw (1982) suggest the need for IWM and taking a multidisciplinary approach. We considered whether sustainable management of broadleaf weeds in perennial pasture could be achieved by manipulating the pasture ecosystem, focusing on plant competition and herbivory. A multidisciplinary and holistic approach was used to look at the whole pasture ecosystem, initiating shifts in the ecological balance and striving for more desirable composition.

In a national first, the Cooperative Research Centre for Weed Management Systems, in collaboration with CSIRO Entomology and NSW Agriculture carried out a major study on Integrated Weed Management (IWM) of broadleaf weeds in pasture, in which this question was investigated.

An extensive set of field trials was established in high rainfall grazing areas in south-eastern Australia, looking at management of nodding thistle, *Carduus nutans* L., Scotch thistle, *Onopordum* spp. (Asteraceae) and Paterson's curse, *Echium plantagineum* L. (Boraginaceae), which are a major problem for graziers in southern Australia.

The control methods under investigation were grazing management, manipulation of competitive perennial species, herbicide strategies (including lethal application rates and spray-grazing; Pearce, 1969) and biological control.

The aim of the study was to test whether an integrated management strategy that is readily adoptable by landholders could lead to sustainable long-term management of these weeds through increased perennial grass cover.

ECOLOGICAL CONCEPT

Desirable pasture composition The IWM project combined biological control with different grazing and herbicide techniques, focusing on pasture composition. The composition of the pasture is the key to achieve sustainability, and strong perennial pastures are more resilient to weeds (Kemp *et al*. 1996a, Kemp *et al*. 2000). Optimal pasture composition varies according to the season. For perennial pasture in high rainfall areas in southern Australia, a composition of 50–60% perennial grasses, 30–40% legumes, 0–20% annual grasses 0–20% broadleaf weeds has been considered as desirable (Kemp and Dowling 1991, Kemp *et al.* 1996ba, Dowling, pers. com.). The impacts of grazing, herbicides and biological control on the pasture were investigated.

Pasture system and interactions A very simplified model of the pasture system consists of desirable and less desirable components. According to Harper (1977) plant competition and herbivory impact on species composition and would also be two important factors with regards to the pasture system. There are also likely to be indirect interactions between herbivory and plant competition.

Sheppard (1996) found that interaction between competition and herbivory can lead to three outcomes. First, the *substitutive effect* is where one factor totally dominates the other. Second, the *multiplicative effect* is the most common outcome, where both factors have an independent impact, but there is no interaction between the factors. Third, the *synergistic effect* is where the combined effect of both factors exceeds the simple combination of each single factor effect. Only with interactions of this third sort are integrated strategies likely to be more effective than simply adding the management strategy impacts together. Willis and Ash (1996) showed that the concept is extendable to other stress factors used to weaken the competitiveness of weeds in the IWM project, such as nutrient supply and water stress.

EXPERIMENTAL DESIGN

Each target weed was studied at a separate field site in southern NSW (*E. plantagineum* and *Onopordum* spp. at Boorowa and *C. nutans* at Adaminaby).

Stock management The experiment was integrated within larger continuously grazed paddocks using an open communal grazing design. Sheep accessed the fenced-off experimental plots within the larger paddock (Michalk and McFarlaine 1978). The total flock size was altered as required. Each treatment plot was 10 × 15 m in size and the plot was the level of replication. The whole set of treatment combinations was replicated across five separately fenced-off blocks within each paddock.

Grazing background The background grazing was either unmanaged or actively managed. Unmanaged meant that the paddock was continuously grazed at regional and seasonally recommended stocking rates (10–15 DSE ha^{-1}). In actively managed treatments, background pasture management tools included fertiliser applications, over-sowing with perennial grasses and subterranean clover and strategic resting of pasture, to improve competitiveness of desirable pasture components. The actively managed pasture treatment was not used at the *C. nutans* sites because of the health of the desirable pasture components. Biological control agents for the target weeds were also manipulated (presence/absence) at the *C. nutans* site at the start of the experiment.

Herbicide strategies Two treatments were used at all sites; a) a lethal herbicide treatment using recommended herbicides and rates at the optimum time of year and b) a spray-grazing treatment involving a sub-lethal herbicide application followed by grazing at increased stocking rates (generally 200 DSE ha^{-1}). Unsprayed ungrazed and unsprayed continuously grazed plots were the two control treatments.

Biological control Where biological control agents were absent or at low density, they were released into each plot (*E. plantagineum* and *Onopordum* spp. sites). These were the crown weevil, *Mogulones larvatus*, on *E. plantagineum*, the stem-boring weevil, *Lixus cardui*, and the seed-head weevil, *Larinus latus*, on *Onpordum* spp. and the crown weevil, *Trichosirocalus horridus*, on *C. nutans.* Where already present, attempts were made to remove them within defined areas of each plot.

Data collection The impacts of the different control treatments were monitored by assessing pasture composition, the weed demography and biological control agent activity.

Pasture composition was determined by using BOTANAL (Tothill *et al.* 1992), a technique to evaluate pasture composition in the field, by ranking the three major pasture components and estimating yield and green dry matter.

Weed population: Weed density and seed rain were regularly monitored in permanent quadrats.

Biological control agents: The proportion of plants attacked by the different agents was recorded and the amount of damage rated.

Analysis ANOVA and regression analysis were applied as appropriate to test whether different treatments and combinations had any effect on the different pasture components and the weeds.

RESULTS

Pasture composition Examples of the results from different treatments on pasture composition at the *Echium* site are given in Figure 1. The target weed and perennial grasses were the two key pasture components. This preliminary presentation of the results will therefore focus on the biomass of these components.

Echium site: Pasture management treatments had no effect on *E. plantagineum* biomass, but significantly increased biomass of perennial grasses. Herbicide treatments ($P<0.001$) and no grazing ($P<0.001$) led to significantly lower *E. plantagineum* biomass. The reduction in the lethal herbicide treatment was significantly greater than in the sublethal herbicide treatment ($P<0.001$). There was a significant interaction between herbicide and pasture management

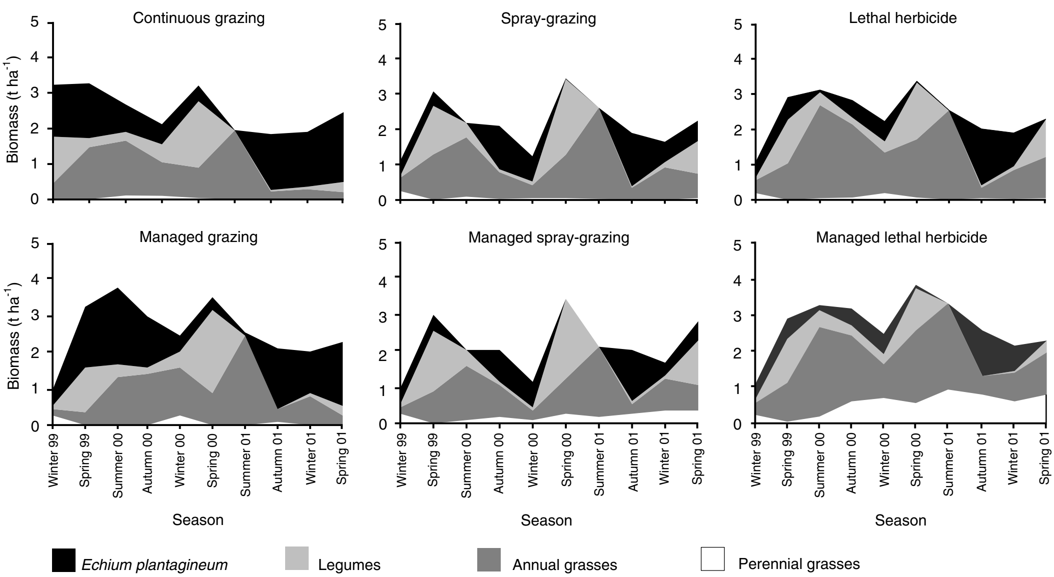

Figure 1. Changes of pasture composition at *Echium* site between winter 1999 and spring 2001, comparing non-managed with actively managed treatments (including summer rest, over-sowing and fertilising).

treatments on *Echium* biomass (P<0.001). Biomass of perennial grasses was higher without grazing (P<0.001) and following the herbicide treatments (sublethal P=0.02, lethal P<0.001) with no significant difference between herbicide treatments. There was also a significant interaction term for the effects of herbicide and pasture management on the biomass of perennial grasses (P<0.01).

Onopordum site: Active pasture management had no effect on *Onopordum* spp. biomass, but did significantly increase the biomass of perennial grasses (P<0.01). *Onopordum* biomass was significantly less in all herbicide treatments (P=0.02), but no difference between these treatments. Perennial grass biomass was significantly lower in all herbicide treatments (P<0.001), but not between them. There were no significant interaction terms between treatment types for either perennial grass of *Onopordum* biomass. Grazing had no significant effect on perennial grasses or *Onopordum*.

Carduus site: *C. nutans* biomass was significantly reduced without grazing (P=0.01), while perennial grass biomass was significantly higher in the herbicide treatments (sublethal P<0.01, lethal P<0.05) and the crash-grazing treatment in November (P<0.001).

Integration of biological control and herbicides Data on attack rates from the *E. plantagineum* site at Boorowa showed that attack rates by *M. larvatus* were significantly lowest in the continuously grazed and sprayed treatments (P<0.05). However, the biological control agent seems to be getting a chance to utilise some of the weeds before they are sprayed and its population is able to persist (Smyth and Sheppard 1996).

There was however no significant treatment effect of attack rates from *T. horridus* on *C. nutans* (P= 0.718). For *L. cardui* and *L. latus*, the sprayed *Onopordum* spp. plants died before the biological control agents could utilise them. Unsprayed plants within the design provided refugia for such agents. Data on the levels of attack by these agents per plant suggested that isolated plants that survived in the sprayed treatments experienced the same damage levels as plants in nearby unsprayed plots.

DISCUSSION AND CONCLUSIONS

While in general, herbicides successfully decreased the amount of the weed species at each site and the pasture management (where used) increased the amount of perennial grass, the presence of significant interactions between herbicide strategies and pasture management on weed and perennial grass biomass at the *E. plantagineum* site bodes well for successful integrated weed management in pastures. These interactions suggested two beneficial synergistic outcomes of IWM. First, while pasture management alone had no effect on weed biomass, the use of pasture management with herbicide strategies is leading overall to effective long-term weed control. Second, while herbicides alone tended to suppress perennial grass biomass, when combined with pasture management, such negative effects of herbicides on the perennial components could be alleviated. To achieve such benefits however, there needs to be reasonable base levels of perennial grass to respond to the management. For example, the level of perennials at the *Onopordum* spp. site were low (data not shown), the beneficial changes were only very slight and no significant treatment interactions were found. While IWM in pastures is quite a slow process, the speed of the success appears to depend on the starting composition of the pastures. IWM may be less relevant in situations of high pasture degradation. Only in some of the treatment combinations did the pasture get close to a preferred range for composition within the timeframe of this experiment.

A further outcome of this experiment was that in addition to reductions of the broadleaf weeds the other weedy component in the pasture system, the annual grasses, also showed some decline; suggesting that this IWM approach may provide a more holistic management solution. That the competition from perennial grasses was important in long-term weed suppression agreed with previous studies.

The impacts of biological control on these weeds take the longest to eventuate (e.g. Sheppard *et al.* 1999). Judging from the results to date, the other weed removal treatments, at least at this spatial scale, did not appear to hinder such impacts. We certainly anticipate that the most effective long term weed management strategy is likely to be the availability of biological control together with herbicide and pasture management strategies (*cf.* Smyth and Sheppard 1996).

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