The effect of integrating defoliation with herbicides on barley grass survival in a legume pasture

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Summary Barley grass (*Hordeum* spp.) is an annual weed of southern Australian mixed farming regions causing significant crop revenue loss and carcass damage in grazing sheep. Increased reliance on herbicides for management of barley grass has led to the development of herbicide resistance across southern Australia. Integrated weed management tactics have recently been used to manage barley grass populations, and have proven effective in reducing reliance on herbicides for management. Field studies performed in 2016 and 2017 examined the use of post-emergent herbicides and strategic defoliation through mowing on a barley grass infestation in a mixed legume pasture in Wagga Wagga, NSW. This paper presents data from the first year of the study. Significant differences between herbicide-only treatments revealed propaquizafop to be 99% effective in reducing barley grass survival and seed production in contrast to paraquat, which was generally ineffective. A significant interaction between mowing and date also influenced barley grass biomass, and complex interactions between herbicide, mowing and date influenced barley grass height. Barley grass control, as a result of propaquizafop application, was accompanied by an increase in the biomass of clover and other weeds including *Vulpia* spp., also a known carcass contaminant.

Keywords *Hordeum*, *Vulpia*, mowing, carcass contamination, integrated weed management.

INTRODUCTION

Historically, both pre- and post-emergent herbicides have been used extensively for management of barley grass (*Hordeum* spp.), a problematic weed of Australian crops and pastures, which is also associated with significant carcass damage in sheep across the Australian mixed farming zone (Kelly *et al.* 2018). Herbicide resistance has recently been noted in several barley grass populations in Western Australia and South Australia (Owen *et al.* 2012, Shergill *et al.* 2015), suggesting that IWM strategies for management are likely to be particularly useful in regions where herbicide resistance is more prevalent. Past reports have suggested that defoliation by mowing was an effective alternative tactic to herbicides in controlling annual pasture weeds, with success relying on the timing of mowing and the species targeted (Bowcher 2002). When mowing is timed to coincide with the reproductive phase of the target annual weed, a reduction in seed rain and significant shifts in botanical composition have been shown to occur (Bowcher 2002). Reductions in barley grass fecundity were also noted when plants were defoliated to a 5 cm height (El-Shatnawi *et al.* 1999) at the boot stage of growth (Zadok *et al.* 1974). Furthermore, mowing barley grass plants as the inflorescences turned colour resulted in smaller seeds (Smith 1968b), likely reducing seed viability. The combined efficacy of the integration of herbicide usage and mowing in controlling barley grass populations has not yet been investigated.

This study thus investigated the effect of integrating defoliation by mowing with the application of two commonly used graminicides, propaquizafop (Group A) and paraquat (Group L), to reduce barley grass survival within a heavily-infested standing legume crop in southern New South Wales (NSW). The integration of both tactics were compared to their use in isolation after 12 months.

MATERIALS AND METHODS

The experiment was conducted in Wagga Wagga NSW at Charles Sturt University's Ashmont field research site (35.0578°S, 147.3544°E, elevation 215 m). Soil was a red silty loam sodosol. The paddock was previously sown in 2012 to lucerne and a mixture of other legumes. A yearly application of superphosphate was applied from 2012 to 2016.

Plots measured 6 × 4 m with 2 m spacing between plots. Treatments consisted of an untreated control, two herbicide treatments, two mowing treatments, and various combinations of herbicide and mowing.

Propaquizafop at 100 g a.i. L^{-1} (as Shogun®), was applied at a rate of 250 mL ha^{-1} in autumn during tillering. Alcohol alkoxylate at 1000 g a.i. L^{-1} (as Cropwett 1000®) was added at a rate of 250 mL ha^{-1} as a wetting agent. Paraquat at 250 g a.i. L^{-1} (as Sinmosa 250®) was applied at a rate of 1.6 L ha^{-1} during rapid growth of barley grass in late winter. The single mowing treatment slashed the plots to an average height of 7.5 cm when 50% of the barley grass plants across each plot reached boot stage of growth (Zadoks 49) (Zadoks *et al.* 1974). The second mowing treatment was a repeated defoliation, when 50% of the barley grass regrowth across the plot reached boot stage of growth. If no barley grass regrowth was observed, the second mowing was not performed. Mown material was not removed. Each of the treatments was randomised in a strip plot design for ease of management and replicated five times.

Data collection was performed after all treatments were imposed by comparison with the untreated control, and all values were assessed on a square metre basis. Due to heavy rainfall events in winter and spring in 2016, treatments were applied when weather conditions allowed for optimal application.

Biomass of main species (barley grass, *Medicago sativa* L. (lucerne), mixed clover species, V*ulpia* spp. and other weed species) was collected by cutting to ground level, drying and separating herbage fractions within two random quadrats per plot (25 × 25 cm). The number of barley grass inflorescences m^{-2} was also obtained from biomass samples at plant maturity. Seed number per inflorescence was calculated by averaging the number of seeds contained within 20 random inflorescences per plot at plant maturity, where possible. Fecundity was determined by multiplying inflorescence number m^{-2} in each plot by the mean seed number per inflorescence. Seed mass was calculated as the mass in grams of 100 randomly collected mature seeds taken from each plot at plant maturity.

Plant density was determined by counting the number of barley grass plants within a 10 × 10 cm area representative of the species composition within each of two random 25 × 25 cm quadrats per plot. Barley grass plant height was assessed fortnightly, and measured from ground level to the tip of the inflorescence, at three equally spaced and random points along a diagonal transect and averaged across each plot. The experiment was concluded at the time of seed fall in November 2016.

Statistical analysis Data were subjected to a factorial ANOVA for a strip plot experimental design using IBM SPSS software, version 20 (SPSS 2011). Assumptions of normality and homoscedasticity were investigated using residual plots and when violated, the data were transformed using square root or log transformations as necessary to meet the assumptions. A comparison of means was performed using the least significant difference (LSD) test (P<0.05). Pooled standard errors are presented.

RESULTS

Herbicide effects Herbicide treatment resulted in significant differences in barley grass (F = 40.272, df = 2, P<0.001), clover (F = 9.177, df = 2, P<0.001) and weed biomass (F = 64.493, df = 2, P<0.001), as well as barley grass inflorescence number (F = 16.155, df = 2, P<0.05), plant density (F = 62.155, df = 2, P<0.001) and fecundity (F = 15.04, df = 2, P<0.05). No significant treatment effects or interactions were observed for lucerne biomass or barley grass seed weight (P>0.05). Propaquizafop in particular significantly reduced barley grass biomass, inflorescence number, fecundity and plant density by at least 99% compared to both the untreated control and the paraquat treatment (Figure 1). No significant differences were observed between the control and paraquat application for barley grass establishment and fecundity. Conversely, after barley grass was completely controlled by the application of propaquizafop, the biomass of clover was increased by 79.4% and other weeds by 128%. In contrast, the application of paraquat significantly reduced the biomass of clover and other weeds by 65% and 36.5%, respectively, in relation to the control (Figure 1). The eradication of barley grass plants by propaquizafop resulted in a lack of production of barley grass seed and no seed rain in plots in late 2016. No significant differences in barley grass fecundity were observed between the control (33602.5 ± 4856.2 seeds m^{-2}) and paraquat-treated plots (31474.2 ± 4856.2 seeds m^{-2}).

Mowing*date effects Barley grass biomass was significantly reduced (F = 4.843, df = 2, P<0.05) in the one-mow treatment during October (160.8 ± 38.3 g m^{-2}) and also in the repeat-mow treatment during November (120.3 ± 38.3 g m^{-2}) when compared to the zero-mow treatment in November (349.2 ± 38.3 g m^{-2} (Figure 2).

DISCUSSION

A single application of propaquizafop was most effective in reducing the biomass, density and reproductive capacity of barley grass compared to all other treatments one year following application (Figure 1). This was not unexpected, given the reported efficacy of other Group A herbicides in managing barley grass

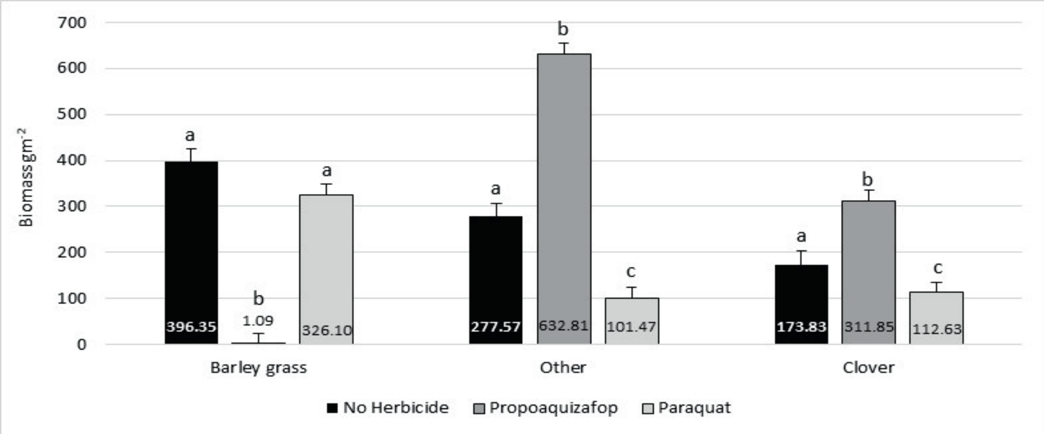

Figure 1. Mean barley grass, other weed and clover biomass (g m^{-2}) following herbicide application during 2016. Separate analyses were conducted across treatments within each species group. Bars with the same letter are not significantly different ($P<0.05$). Numbers within bars signify treatment means.

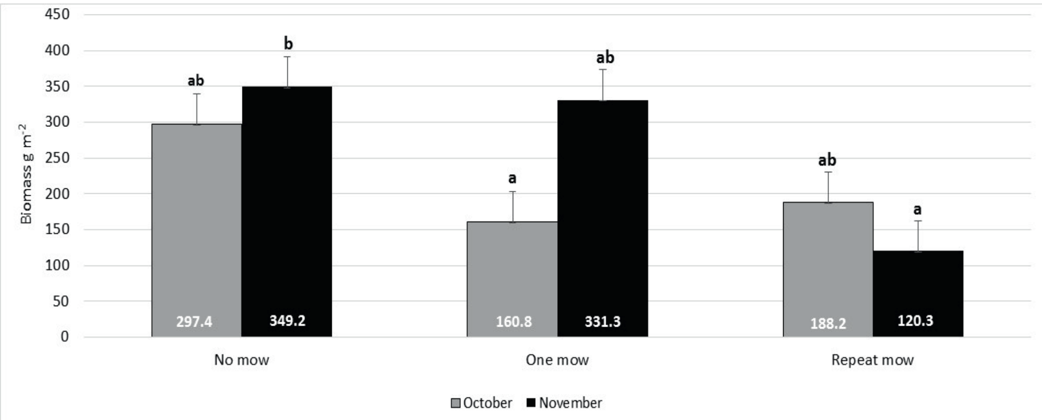

Figure 2. Mean barley grass biomass (g m^{-2}) as influenced by mowing during the months of October and November 2016. Bars with different letters are significantly different ($P<0.05$). Numbers within and above bars signify treatment means.

populations (Stephenson and Mitchell 1993). Further, the increase in clover and other accompanying weeds such as *Vulpia* spp. and capeweed was consistent with previous findings, where the ingress of capeweed was observed to accompany an increase in clover following applications of propyzamide (Thorn and Perry 1987). It is likely that the rapid and virtual eradication of barley grass in the current study provided spatial gaps in existing vegetation, allowing the introgression of legume and weed species. Weed species proliferation was likely aided by the availability of soil nitrogen and phosphorus resulting from the long-standing presence of legumes and the regular history of annual superphosphate applications, conditions known to create an environment well suited for encouraging proliferation of these other weeds (Rossiter 1964). Furthermore, subsequent to barley grass removal, the conditions present in the paddock may have also stimulated a competition response in the legume component of the crop.

Less efficacious control of barley grass by paraquat (Figure 1) was consistent with results of Stephenson and Mitchell (1993), who reported similar results in clover pastures after 12 months. Paraquat is

a common Group L herbicide used in the control of grass weeds in crops (Owen *et al*. 2012). As a contact herbicide, it requiries sufficient leaf area for high efficacy (Fuerst and Vaughn, 1990). It is likely that the timing of late spring paraquat applications may have resulted in reduced herbicide efficacy due to shading from more mature plants, thereby preventing adequate contact of herbicide with barley grass foliage. The late paraquat application also reduced clover biomass in comparison to the control and propaquizafop treatments, a result also consistent with previous studies (Barrett *et al.* 1973).

Despite the lack of efficacy of mowing in reducing barley grass biomass during October, mowing was effective in November, and repeat mowing treatments resulted in significantly lower barley grass biomass than the control. As mowing results were inconsistent over time, it is possible that mowing at an even later barley grass maturity stage would have been be more effective, particularly when rainfall events were limited (Butterfield and Malmström 2009). Additional experimentation performed under more typical rainfall conditions will be useful in evaluating the use of mowing in conjunction with herbicide application for reduction in barley grass fecundity.

CONCLUSIONS AND FUTURE RESEARCH

Propaquizafop treatment was more effective in controlling barley grass 12 months following application than various combinations of herbicide and mowing. Despite the virtual eradication of barley grass by propaquizafop, the pasture was infested by later emerging weeds such as *Vulpia* spp. (Collins *et al*. 2013). Data obtained from additional years of experimentation will be useful in determining the success of propaquizafop and other herbicides in sustaining pasture composition and may offer further insight into the value of integrating a timely mowing with herbicide application for barley grass control over the longer term

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