Competition between native grasses and serrated tussock (*Nassella trichotoma*) at low fertility – initial results

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Introduction

Serrated tussock (*Nassella trichotoma*) is considered the worst perennial grass weed in southern Australia. The latest estimates of its distribution indicate that it infests around 1 million hectares of the temperate perennial pasture zone in south-eastern Australia (Jones and Vere 1998, McLaren *et al.* 1998). The area of serrated tussock has been increasing annually and if left unchecked it is possible that its distribution could exceed 30 million hectares (McLaren *et al.* 1998).

Serrated tussock has several characteristics that have enabled it to become very widely distributed. It is a highly unpalatable grass that appears to be rarely eaten, even as a seedling. It has an exceptionally low digestibility of the whole tussock of 17–25% (McManus *et al*. 1972). The few measurements of its forage quality have found that it has low protein levels (4%; Campbell 1965, Campbell and Barkus 1961) and a very high fibre content (86%, neutral detergent; Campbell and Irvine 1966).

Serrated tussock produces a very high number of wind dispersed seeds. A single mature serrated tussock plant may produce up to 140 000 seeds per annum (Taylor 1987). Limited data is available on actual seed dispersal distances, but Healy (1945) documents a dispersal event of 16 km and even longer distances would seem possible. It is rare for a hardy long-lived perennial grass to have such a high seed production that is so efficiently dispersed. This suggests that, as a species, it displays some ruderal characteristics i.e. it disperses seeds widely to maximize its opportunity to find suitable niches rather than being a dominant competitor at fewer sites.

There is little information available on the microsite soil surface conditions that are required for serrated tussock seedlings to establish. Anecdotal evidence suggests that it requires bare soil and disturbed conditions to establish, but there is little scientific evidence to confirm this (Michalk *et al*. 1999). Healy (1945) stated that provided cover is 'weak' seedlings would establish well in autumn. Wells (1974) noted that reduction in competition from pasture is the largest single factor in the spread of serrated tussock. Observations in New Zealand (Healy 1945) and Australia (Hocking 1998) have supported the theory that serrated tussock does not invade native grasslands which have not been modified or disturbed. Disturbance is arguably one of the most important requirements for serrated tussock establishment.

The main techniques recommended for the control of serrated tussock have been the use of herbicides, especially flupropanate (Campbell *et al.* 1979), and the sowing of competitive pastures (Campbell 1974, Campbell and Murison 1985). The more competitive pastures have been based upon *Phalaris aquatica*. Sowing competitive pastures can be uneconomic but will depend on current commodity prices. Generally it is more profitable to sow competitive pastures in areas that have a higher rainfall and are more fertile. Pasture establishment on low fertility soil or in areas that have a low effective rainfall often fail, or these pastures do not persist when constantly grazed. Unfortunately the main problems with serrated tussock are now in these less fertile, lower rainfall regions. New, low cost, longer-term practices need to be developed to manage serrated tussock in these areas.

Using the existing structure of native grasses as a competitive base to prevent the invasion of serrated tussock or limit the spread of existing tussocks is a potentially valuable management tool. There is some anecdotal evidence to suggest that summer growing perennial grasses, in particular *Themeda triandra* and *Bothriochloa macra* can resist invasion from serrated tussock (Hocking 1998, Michalk *et al.* 1999). Lunt and Morgan (2000) found a negative association between the invasion of *Nassella neesiana* (Chilean needlegrass) and *Themeda triandra*. In a survey of serrated tussock infested areas of New South Wales, Badgery *et al.* (2001) also found that there was a negative association between C4 (summer growing) perennial native grasses and serrated tussock but no such correlation between C3 (winter growing) perennial native grasses and serrated tussock.

To develop management practices that promote the competition of native grasses with serrated tussock it is important to determine the mechanisms that are involved and the factors that influence them. In this paper we will report on the preliminary results from an experiment that is examining the impact of grazing and of fertility on competition between grass species within a low productivity native grassland infested with serrated tussock.

Methods

Site

The experiment is located at Trunky Creek in the Central Tablelands of New South Wales (33.832°S, 149.352°E) at an elevation of 860 m and with an average annual rainfall of 765 mm. The grassland is predominantly native and naturalized species, including both C4 and C3 perennial native grasses, with up to 50% serrated tussock dispersed throughout the paddock. Prior to the establishment of the site it had been moderately to heavily grazed, mostly by sheep. The site has a gently sloping easterly aspect and light sedimentary soils (pH $_{CaCl2}$ = 4.6, P = 7 mg kg^{-1} (Bray), EC = <0.05 ds m^{-1}).

Design

The experiment design is based upon a factorial combination of 3 grazing treatments × 3 fertility treatments laid out in a split plot design with three replicates. Grazing treatments; NG (nil grazing), Active[1] and CG (constant grazing at 4.5 DSE ha^{-1}), are the main factors in the experiment within 20 × 10 m plots. Fertility treatments; F+ (120 kg N ha^{-1} and 30 kg P ha^{-1} per year), NF (no fertilizer) and F– (sugar added to stimulate competition from micro-organisms for available nutrients) are then sub plots (20 × 3.3 m). In this paper we will only report the initial results from the major contrasts i.e. the NG (no grazing) and CG (constant grazing) treatments, and the NF (no fertilizer) and F+ (Fertility +) treatments.

Establishment and measurements

Treatments were applied to the grasslands in October 2000. All plots were fenced to manage grazing, the fertility treatments applied and initial measurements taken. In each treatment nine 0.09 m^2 permanent quadrats were located for estimates of plant species composition. Dry weight ranks of the three most abundant species, and the total dry weight of all species, were estimated for each 0.09 m^2 quadrat using Botanal procedures (Tothill *et al.* 1992). Dry weight estimates were then corrected using ten calibration cuts per site. The nine quadrats were averaged for the whole treatment to give an estimate of species composition. Measurements are taken every three months. In this paper we will present the results for the first year of the experiment from summer 2001 (i.e. three months after establishing the experiment) until summer 2002.

Data analysis

Data was analysed using a range of statistical procedures. The herbage mass and percentages for each individual species were regressed against one another and hierarchical clustering was used to identify those species that were behaving similarly. It was found that species could be conveniently grouped into functional groups and these have been used for presentation here. The groups used are serrated tussock, C4 perennial grasses, C3 perennial grasses and 'others' (Appendix 1). The 'others' were variable and not as consistent in behaviour (predominantly annual grasses, but included legumes and other minor forbs, i.e. typical 'gap fillers') as the other groups, but were used as a group as the main emphasis in this paper is on the interactions between the perennial grasses. Analyses of variance were performed on the total species/group dry matter (DM), percent DM and on the percent change in DM from year 1 to year 2. Similar results were found for the analyses on actual DM vs. per cent DM as a consequence of no overall significance in the total herbage mass between samples. Changes in percent DM between the two samples are then used to illustrate treatment effects as all treatments did not have the same starting composition and the main interest is in the relative change.

Results

Seasonal conditions and general growth

Growing conditions throughout the year were typical of that to be expected in this area. Total growth (estimated from nil grazed plots) was 1.8 t DM ha^{-1} yr^{-1}. Over all treatments, serrated tussock was the greater single contributor to total DM (Figure 1). The next major group were the C4 perennial grasses that on average had twice the herbage mass of C3 perennial grasses. Other species were variable and increased over time due to an increase of annual grasses in the fertilized plots. The difference in mean herbage mass for serrated tussock or for all species between years was not significant.

Perennial grass interactions

The relative change in serrated tussock content between summer 2001 and summer 2002 was negatively related to the relative change in other perennial grass groups. There was a significant relationship in relative change between serrated tussock and C4 perennial grasses (Figure 2) and a steeper relationship with the

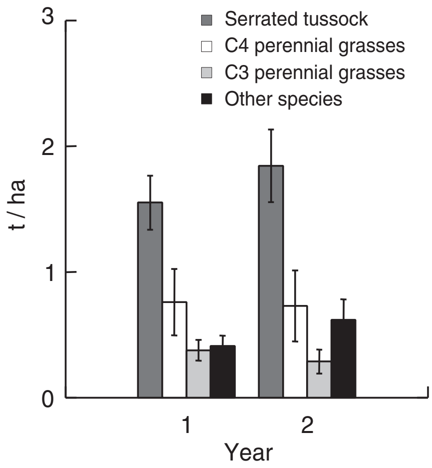

Figure 1. The average dry matter of all treatments when sampled in summer 2001 and summer 2002.

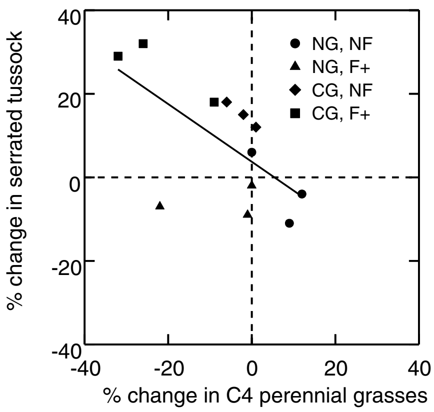

Figure 2. The percentage change in composition between serrated tussock and C4 perennial grasses under four treatments (Nil grazing/Nil fertilizer, Nil grazing/Fertilizer +, Constant grazing/Nil fertilizer and Constant grazing/Fertilizer +). The fitted line was significant (P <0.05).

content of C3 perennial grasses (Figure 3). In both cases the content of serrated tussock remained similar in ungrazed areas (albeit with a small non-significant decline at this stage), but increased in grazed treatments (up to 30%), especially when fertilized. Under grazed and fertilized conditions the relative increase in serrated tussock content was around 30%, matched by a 30% decline in the content of C4 perennial grasses, but only a 10% decline in C3 perennial grasses. The C4 perennial grasses declined under grazing and when not grazed there was a decline in fertilized plots, but a small increase in unfertilized treatments (again a non-significant trend at this stage). C3 perennial grass contents declined when grazed but did not change when not grazed.

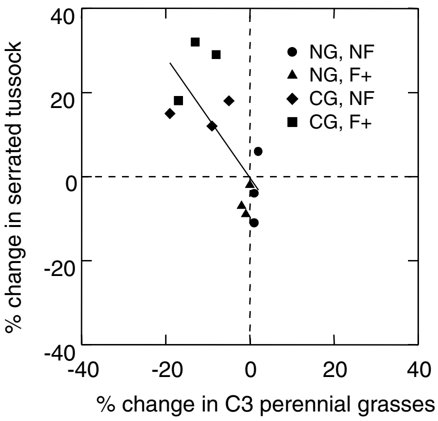

Figure 3. The percentage change in composition between serrated tussock and C3 perennial grasses under four treatments (Nil grazing/Nil fertilizer, Nil grazing/Fertilizer +, Constant grazing/Nil fertilizer and Constant grazing/Fertilizer +). The fitted line was significant (P <0.05).

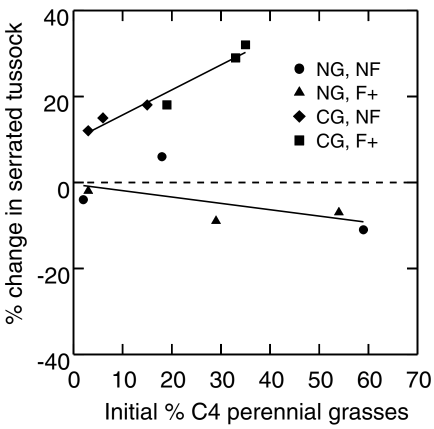

Figure 4. The percentage change in composition between serrated tussock compared to the initial composition of C4 perennial grasses under four treatments (Nil grazing/Nil fertilizer, Nil grazing/Fertilizer +, Constant grazing/Nil fertilizer and Constant grazing/Fertilizer +). The fitted lines were significant at P <0.05 (upper) and P <0.2 (lower).

The relative changes in serrated tussock content were further investigated in relation to the initial content of each species group. The relative change in serrated tussock content was not related to the initial content of serrated tussock (data not shown). There were though some interesting trends with C4 perennial grasses that depended upon whether the plots were grazed or not (Figure 4). Relative to the initial C4 perennial grass content, serrated tussock increased in grazed treatments and showed a small decline in ungrazed treatments. Under grazing the proportional decline in C3 and C4 perennial grasses was related to their initial content (data not shown).

Discussion

Serrated tussock has proved to be an almost intractable problem for many producers. It is a highly successful plant that is continuing to increase and cause hardship for agricultural producers in many regions. The main area of concern is often the lower rainfall and lower fertility soils where the economics of replacing serrated tussock with a vigorous competitor such as phalaris are marginal at best. Regular applications of herbicide are also unlikely to be the ideal solution in those areas. Long-term solutions to the management of serrated tussock will require the maintenance of competitive species within infested grasslands. Limited work has been done to date on native species that could be the competitive. The first step in this work is to identify those species that offer the better prospects for competing with serrated tussock under lower soil fertility. We then need to develop management practices that enhance the competitiveness of those species against serrated tussock.

The work presented here is in its early stages and the results are preliminary. Nevertheless, there are some interesting trends that have implications for the future management of serrated tussock. Within the naturalized grasslands where serrated tussock is the major problem, both C3 and C4 perennial grasses often still exist. This preliminary work has indicated that they both interact with serrated tussock, but there seems to be a more consistent, negative relationship with C4 perennial grasses in the data presented here. That result is also supported by a survey of serrated tussock infested grasslands (Badgery *et al.* in preparation). However the more interesting trend was that the ungrazed C4 grasses showed a small increase between years that was associated with a negative trend in serrated tussock content (Figure 2), especially in plots that had 30–60% C4 perennial grass at the start (Figure 4).

It has been proposed that the ability of C4 grasses to out-compete C3 grasses are enhanced under low soil nitrogen conditions (Wedin 1999, Wedin and Tilman, 1996). Evidence in this study support that view with the greater increase in serrated tussock, relative to C4 perennial grasses occurring in grazed and fertilized treatments. When grazing is removed the amount of available N is decreased due to slower recycling resulting in the enhanced competitive ability of C4 perennial grasses. These conditions benefit C4 perennial grasses providing them with a competitive advantage over C3 perennial grass species.

There are a number of potential outcomes from this work that need to be explored in further studies and firmer conclusions on the mechanisms underpinning these competitive interactions will not be possible until the current experiment has run for another few years. If the superior competitive ability of C4 perennial grasses is substantiated then their better management should become the focus of serrated tussock management in lower fertility areas. Since grazing reduced the competitiveness of the desirable C4 perennial grasses, management strategies need to be developed to maximize the growth rates of these species. A likely solution is to provide a protracted rest period over the warmer late spring/summer period and confine grazing of serrated tussock paddocks to the winter period. This may have the added benefit of reducing recruitment of serrated tussock seedlings. In practice, this rest/grazing sequence would need to be continued until the contribution of the C4 perennial grasses exceeds about 50% of grassland composition because only when this threshold is reached was sufficient pressure exerted on serrated tussock to reduce its content. At lower levels of C4 perennial grass, serrated tussock still increased, especially when subjected to continuous grazing.

A further implication is that fertilizer applications will not reduce the serrated tussock content, unless grazing is also removed. Producers who apply fertilizer obviously want an early return, but this can accentuate the problems if tactical rest is not also applied as is evident in this study (Figure 4). We conclude that a focus on keeping fertility low and not grazing C4 perennial grasses during their main growing season give us some non-herbicide management options to reduce the serrated tussock content to a manageable level in these poorer grasslands.

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Footnote

[1] 'Active grazing' is a rotational grazing treatment that is grazed at ~270 DSE ha^{-1} for ~2 days twice a year (i.e. equivalent to 3 DSE ha^{-1} annually) Grazing occurs when the edible DM reaches 2t ha^{-1} and is grazed until it is 1t ha^{-1}. Grazing does not occur in the summer months to maximize the growth of the desirable C4 native perennial grasses.

The potential for repair of exotic stipoid grass infested sites with kangaroo grass (*Themeda triandra* Forssk.) with special reference to remnant native grasslands

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Summary

There are various new successful examples of using the 'spray and hay' method to re-establish kangaroo grass on weed infested sites in native grasslands but this method has had problems with reliability. Current investigations by Victoria University focus on increasing the reliability of the method and expanding its range of uses. Invading patches of Chilean needlegrass (*Nassella neesiana*) have been controlled by modified 'spray and hay' re-establishment of kangaroo grass at the Bullum Bullum reserve field trial site in the Shire of Melton, Victoria. After three years the dominance of Chilean needlegrass in the trial areas has been changed from above 65% cover to approximately 10% cover. Treatments were successfully applied in replicated trial plots in two consecutive years across very different yearly rainfall patterns. At the same time, in treated areas kangaroo grass increased from approximately 5% cover to above 85% cover within a period of three years. Key factors for the success of this trial are seed quality, seed quantity, methods for introducing seed to the soil, timing of weed control, timing of seed broadcasting and timing of removal of thatch. These and parallel investigations suggest that modifications to the 'spray and hay' method are likely to result in improvements in reliability and efficiency of the method.

Introduction

Grassland ecosystems are a reservoir for a vast array of biodiversity that have the potential to contribute to sustainable agriculture. It has been reported that a biodiversity rich agriculture can produce 100 units of energy for the input of 5 units, compared with a monoculture agriculture that produces 100 units of energy for 300 units of input (Suzuki and Dressell 1999). We as a human species will need to be more dependent upon low input systems than high input systems if we are to achieve a balance with the ecosystem we live within. Many of our remaining remnant grassland ecosystems in the south-east of Australia which contain wild type biodiversity necessary for this transformation are now highly fragmented (Stuwe and Parson 1977, Stuwe 1986, DCE 1992). Fragmentation can increase the susceptibility of grassland ecosystems to weed invasion and loss of biodiversity (Stuwe and Parsons 1977, Lunt 1990a,b).

Weed invasions often result when an existing remnant ecosystem becomes degraded in some way. There are two broad categories that are attributed to the degradation of grassland ecosystems. First, improperly managed or unmanaged grasslands can lead to a monoculture of native or exotic grasses. In the absence of some type of above ground vegetation removal (via grazing, burning or slash and removal) the dominant native grass begins to senesce. Senescence is the breakdown of the structure (above and below ground) of individual plants that leads to plant death. When these plants die, a flush of available nutrients is released to the soil (Wijesuriya 1999). If native grass tussocks and forbs are removed, weed seeds in the soil can germinate utilizing the excess available nutrients (if suitable moisture levels are present in the soil) below ground and abundant light above ground (Hocking and Mason 2001). The second category of grassland degradation relates to massive vegetation disturbance. This usually involves killing of native vegetation and soil disturbance. The result of this disturbance is a reduction of above-ground competition for resources and reduction of below-ground competition for resources such as available nutrients which result from the decomposition of the vegetation killed during disturbance. Both of these types of degradation categories allow massive weed invasion. It would appear that the capacity of native grasses to re-establish after these types of degradation are limited by the capacity of native grasses to compete with weeds at seed production and seedling establishment stages.

Of primary concern in South Eastern Australian grasslands is the potential of American stipoid grasses to become the dominant vegetation type in degrading grassland ecosystems (Campbell 1998, Gardener and Sindel 1998, and McLaren *et al.* 1998, Hocking 1998). *Nassella* species are one major type of invasive stipoid grass. Chilean needlegrass will be used as a case study in this report. Chilean needlegrass and serrated tussock are known to have a high invasion potential in native grasslands and crop lands (Hocking