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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

Bram Mason and **Colin Hocking**, Victoria University, St. Albans Campus, PO Box 14428 MCMC, Melbourne 8001, Australia.

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

1998). They have slightly different invasion strategies but are both very effective. Serrated tussock is a prolific seeder that is able to widely distribute its seed via the wind and this high invasive potential is coupled with very low palatability to grazing animals (Campbell 1998). Chilean needlegrass has less seed set; however it produces cleistogenes in stem, nodes and roots and recruits and grows rapidly (Gardener and Sindel 1998). McLaren *et al.* (1998) have documented various personal observations by a range of researches and land managers which together demonstrate that Chilean needlegrass is able to tolerate a wide variety of climates and that it readily invades kangaroo grass dominated grasslands. The Australian Federal government now recognize Chilean needlegrass to be one of twenty Weeds of National Significance (WONS 2000), as is serrated tussock.

There have been a number of successful and unsuccessful attempts to control serrated tussock and other weeds in remnant grasslands using a method known as the 'spray and hay' method (see list below). This method involves killing the serrated tussock with herbicide, spreading kangaroo grass seed and a mulch over the resulting bare ground, and then burning or otherwise removing the mulch layer in mid spring. When kangaroo grass germinates it forms a stand of grass able to effectively out-compete any remaining or germinating serrated tussock for above and below ground resources. Reports on the practical applications of the method by McDougall (1989), Carr and Todd (1991), Carr and Muir (1993), Muir and Carr (1994), Phillips and Hocking (1996), Dare (1997), and Mason (1998) indicate problems with kangaroo grass seed germination, consistency of kangaroo grass establishment and weed control. Phillips (2000) outlines more specifically the conditions that are optimal for weed control and germination of kangaroo grass using the 'spray and hay' method. The optimal conditions from those examined were: weed removal (herbicide spray) in the Autumn, laying of kangaroo grass hay laden with ripe seed in August, and removal of the thatch layer in October (Phillips 2000). Under these conditions Phillips (2000) observed an establishment of a relatively weed free stand of kangaroo grass after several years. The earliest established plots from Phillips (2000) trials on establishment of kangaroo grass still remain relatively weed free after nearly ten years (Hocking, personal observation).

Besides appropriate timing, other limiting factors to the success of the spray and hay method come from seed quality and quantity used in the method (Phillips 2000 and Mason and Hocking unpublished data). The quality of harvested kangaroo grass seed can vary greatly between seasons and stand (Phillips 2000, Hocking, personal observation). Human error in assessing appropriate time for harvesting may account for some variation in seed quality.

The quantity of germinable kangaroo grass seed establishing in the soil seed bank also determines success of the 'spray and hay' method. This is because germinable seed availability partially determines the density of kangaroo grass seedlings that emerge and hence the extent of competitiveness with potential weed species. The effectiveness of penetration by kangaroo grass seed into the soil surface and how this might be improved has not yet been fully established. However, research into this question is underway at Victoria University. A more effective way of establishing kangaroo grass seed in the soil has been investigated by Mason (1998) and Wlodarczyk (personal communication). This modification to the spray and hay method includes using seed in the form of a chaff mixture (seed plus florets and no culms). The ease of seed broadcast and quantity of seed reaching the soil surface has been increased using this approach (Wlodarczyk personal communication).

The outcomes of a recent, successful weed control and establishment trial (a refined spray and hay method) will be presented in this report. The trial was set up on basaltic derived soil adjacent to the Kororoit Creek, Burnside, Victoria. The trial followed the Phillips (2000) optimum Spray and Hay regime mentioned above.

Method

A field site was set up at the Bullum Bullum reserve within the Shire of Melton, West of Melbourne, Victoria to test the optimum spray and hay regime on replacement of Chilean needlegrass with kangaroo grass. Chilean needlegrass on eight randomly located replicated plots measuring 1 m^2 with 0.5 m buffer zones were treated via knapsack sprayer with atrazine as Nufarm Nutrazine® at 8.7 kg a.i. ha^{-1} in Autumn 1999. An equivalent number of randomly located plots were left untreated. All vegetation was dead on the research site by August 1999. At this stage, seed bearing kangaroo grass chaff was applied to the site at a rate calculated to give 60 seedlings m^{-2} (Phillips 2000). This rate was calculated from the number of seeds per gram of chaff and the associated germination potential of the seed. Over the top of the chaff the equivalent of 1.5 kg m^{-2} of kangaroo grass (seedless) hay was laid as a thatch. The thatch layer was removed by burning in late October 1999.

Results

Data from assessments in Summer 2002, three years after initial trial set up are presented in Figures 1 and 2.

Three years after initial spray and hay treatment, kangaroo grass had come to dominate the treated sites, whereas Chilean needlegrass continued to dominate the untreated areas.

In terms of percentage cover (Figure 2) kangaroo grass was present in over 85% of the treated areas and Chilean needlegrass

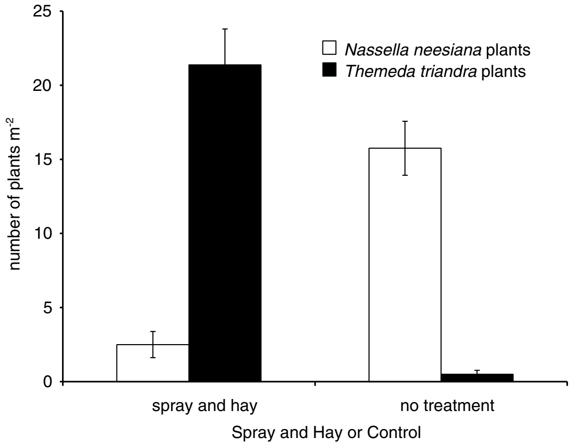

Figure 1. Density of kangaroo grass and Chilean needlegrass plants at Bullum Bullum Reserve three years after 'spray and hay' establishment of kangaroo grass: Bars show standard error (n=8). □ *Nassella neesiana* plants, ■ *Themeda triandra* plants.

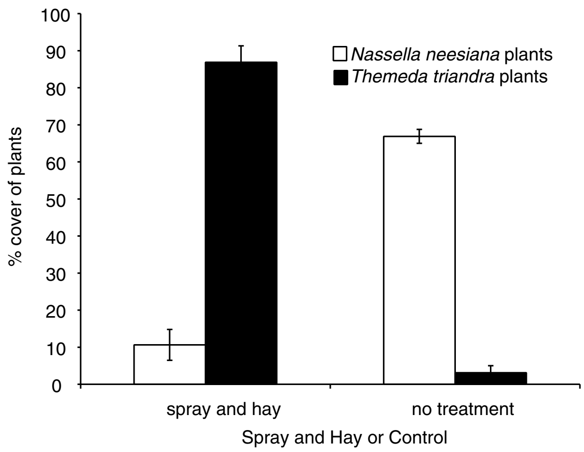

Figure 2. Percentage cover of kangaroo grass and Chilean needlegrass plants at Bullum Bullum Reserve three years after 'spray and hay' establishment of kangaroo grass: Bars show standard error (n=8). □ *Nassella neesiana* plants, ■ *Themeda triandra* plants.

only covered 10% of the treated areas after three years. In the untreated areas, Chilean needlegrass maintained coverage of over 60%. In untreated areas remnant kangaroo grass occupied less than 5% of the coverage.

Discussion

The results show that it is possible to replace Chilean needlegrass with kangaroo grass as the dominant tussock grass on Chilean needlegrass infested sites. The established kangaroo grass appears to control re-establishment of Chilean needlegrass for up to three years. A density of kangaroo grass plants of 20 m^{-2} appears to keep Chilean needlegrass densities at low levels three years after establishment (Figure 1). Currently kangaroo grass is being used as a model for developing more general techniques for replacing Chilean needlegrass with native grasses at Victoria University. Researchers at Victoria University hope to develop approaches and techniques that can be applied more widely to a range of native grass species in direct seed broadcast trials. Other research based at Victoria University is focusing on ways to incorporate native forb species into areas where native grasses are used to control Chilean needlegrass and other weeds.

From the work being conducted at Victoria University, the following points appear to be vital in achieving successful re-establishment using kangaroo grass.

- The quality of kangaroo grass seed used needs to be high to achieve efficient re-establishment. Phillips (2000) demonstrated how variable the quality and quantity of wild harvested kangaroo grass seed can be. Other trials by McDougall (1989), Phillips (2000) and unpublished information by Wlodarczyk (personal communication) and Hocking (personal communication) show that the time of harvesting, the type of harvester used, drying of the seed and storage to optimize release from potential dormancy all need to be considered.
- When assessing the quality of kangaroo grass seed consideration must be given to the quantity of viable seed that is introduced to the proposed site. The results of Phillips (2000) suggest that for kangaroo grass to effectively compete with serrated tussock, establishment densities of approximately 60 seedlings m^{-2} will be necessary. If poor quality seed is being used, a larger amount of total seed will be required to achieve this number of seedlings. Obviously using high quality seed will require less seed to be introduced per square meter to obtain 60 seedlings m^{-2}. In the past the spray and hay method used kangaroo grass hay laden with seed as the vehicle for seed introduction to the treatment area. Advancements in harvesting techniques by Peter Wlodarczyk of Gagin Pty. Ltd. have rendered this method inefficient. Chaff containing seed and florets only (no culms) can now be harvested, greatly increasing the number of seed per kilogram of harvested material. This not only reduces the weight of kangaroo grass seed to hay/floret ratio introduced on to treatment sites but makes harvesting the required number of kangaroo grass seeds for re-establishment more time effective, and therefore increases cost effectiveness of harvesting and hence the re-establishment method.
- Even when seed quality and quantity are optimized, the method of introducing the seed onto the proposed re-establishment area can be a problem. Direct drilling trials using cleaned native grass seed including kangaroo grass seed have produced varied and low germination results (Briggs 2001). This may be a result of the quality/quantity issues mentioned above. The trials at Victoria University utilize the mechanism for introducing seed to the soil that kangaroo grass seeds have evolved with. Direct broadcasting of seed laded chaff allows the hygroscopic awn to be left attached to the seed and therefore allows the awn to push the seed into the soil as variations occur in moisture and temperature in the microclimate of the seed on the ground.
- Phillips (2000) identified the effects of optimal timing of prior weed control, broadcasting of seed and the type of removal of the thatch layer as key parameters affecting the successful implementation of the 'spray and hay' method for re-establishment of kangaroo grass. Weed control in Autumn allows time for the herbicide to effectively kill the problem weeds before kangaroo grass seed is introduced to the treatment area in August. For the herbicide atrazine to work effectively the target plant must be actively growing. Soil moisture is instrumental in this process. Not only is soil moisture essential for the growth of plants, the concentration of herbicide in soil water controls the biological availability and mobility of the herbicide (Hance and Holly 1990). Atrazine and similar triazine herbicides are relatively uncharged chemically (at pH values >5), and as a result they displace water molecules from the soil particles (Hance and Holly 1990). To increase the amount of these triazine herbicides that are biologically available, soil moisture needs to be in an amount that increases the proportion of herbicide in the water phase of the soil matrix. Therefore application of atrazine in Autumn must occur after there is a significant amount of water in the soil. However, care must be taken not to spray immediately before rain as leaching of herbicide may occur. Other methods of weed control are available but have not been comprehensively trialed with the spray and hay method of re-establishment. Atrazine has been preferentially used in these trials due to its selectivity for C3 photosynthetic plant species (including exotic stipoid species and flatweeds including thistles).
- The timing of introduction of kangaroo grass seed in August is likely to serve three main purposes (subject to conformation by further research). The first is related to weed death on the re-establishment area, which occurs after Autumn herbicide treatment. Weed death leads to less above ground vegetation to hinder the accessibility of kangaroo grass seed to the soil surface, and hence the quantity of viable kangaroo grass seed reaching the soil surface is optimized. The second purpose of introducing kangaroo grass seed in August, approximately seven months after harvesting in Summer, is to allow for the kangaroo grass seed dormancy to be broken during this period of time in storage. The seed is kept dry, at a relatively constant temperature and away from grainivores. This affects the quality of germinable seed available in the soil. The third reason is related to the time taken for the awns on the kangaroo grass seed to drill the seed into the soil. Excess thatch is removed in October preferably by burning. The three months before this (August to October) allow for the seed to drill into the soil and this appears to be adequate for this function to be served (Phillips 2000).
- The timing for removal of thatch material is critical for germination to occur within the first year of re-establishment. A thatch is used over the broadcast seed for two main purposes. The first is to allow for moisture retention in the soil to enhance the drilling of the kangaroo grass seed in to the soil. The second purpose is to act as a weed suppressant until the conditions are optimal for kangaroo grass germination. Kangaroo grass utilizes a C4 photosynthetic pathway. For kangaroo grass seeds to germinate at greatest efficiency they need warm temperature and moisture (Hagon 1977). Both of these conditions are provided in mid-late October depending on the latitude, longitude, elevation and climatic conditions of the year of establishment. Fire is recommended for the removal of the thatch layer. Both Mason (1998) and Phillips (2000), compared removal of thatch by fire and hand removal of thatch with the purpose of kangaroo

grass re-establishment. A significant difference in the number of kangaroo grass seedlings was found in these trials favouring thatch removal by fire. Removal of thatch by fire also serves to remove any annual weeds that may have germinated. However, it also should be noted that manual removal of thatch, in circumstances where fire is not possible, can also result in acceptable densities of kangaroo grass seedlings.

Conclusion

The spray and hay method for weed control and re-establishment of kangaroo grass can be effective if the above critical steps are followed. Only one trial has been presented in this article for example. Other successful trials have been conducted by Victoria University over the past ten years and the method is being further developed to optimize the amount of kangaroo grass germination, reduce costs and minimize the effects of drought. The aim in the future is to be able to control grassy weeds and re-establish a diverse representation of native grasses and forbs in remnants of native grasslands with patch infestations of exotic stipoid grasses. Other potential longer term uses for the spray and hay method of kangaroo grass re-establishment include broader scale weed control in remnant grasslands, establishment of native grasses for drought resistant grazing, pasture cropping (Seis 2001), supplying increasing demand for native grass seed, and in promoting native grassland retention via its value as a source of saleable seed

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