Protecting Australia’s Agricultural Grasslands from Herbicide-Resistant Serrated Tussock
Protecting Australia’s Agricultural Grasslands from Herbicide-Resistant Serrated Tussock

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Foreword

Serrated tussock is an unpalatable South American perennial grass that is a Weed of National Significance in Australia because of its severe agricultural and environmental impacts.

Land managers in New South Wales, the Australian Capital Territory, Victoria and Tasmania will benefit from this research by learning how to recognise, manage and prevent serrated tussock herbicide resistance.

This research has found that serrated tussock’s resistance to flupropanate is becoming widespread, which has implications for further serrated tussock invasion, increased herbicide use, and higher management and labour costs for farmers.

The spread of serrated tussock flupropanate resistance will depend on the nature of the inheritance, the breeding system and the amount of gene flow, and, most importantly, the management practices of land managers.

It is crucial that weed management authorities wishing to contain serrated tussock resistance to flupropanate understand the current extent of resistance infestations.

This project was funded in Phase 1 of the National Weeds and Productivity Research Program, which was managed by the Australian Government Department of Agriculture, Fisheries and Forestry (DAFF) from 2008 to 2010. The Rural Industries Research and Development Corporation (RIRDC) is now publishing the final reports of these projects.

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Executive Summary

What the report is about

This project highlights the importance of investigations into biological control of serrated tussock and supports the continuation of this work.

Where are the relevant industries located in Australia?

Land managers in New South Wales, the Australian Capital Territory, Victoria and Tasmania will benefit from this research by learning how to recognise, manage and prevent serrated tussock herbicide resistance. It is their management practices, along with the nature of the inheritance, the breeding system and the amount of gene flow that will determine the spread of serrated tussock flupropanate resistance.

Background

Serrated tussock is an unpalatable South American perennial grass that is a Weed of National Significance in Australia because of its severe agricultural and environmental impacts.

Aims/objectives

This report aims to inform landholders about how to recognise, manage and prevent serrated tussock herbicide resistance.

Methods used

Detailed surveys of the extent of serrated tussock’s resistance to flupropanate have been conducted in the Armidale region of New South Wales and at Diggers Rest in the Rowsley Valley in Victoria. Serrated tussock samples were also received from two properties near Goulburn in southern New South Wales.

This report provides an assessment of the extent of serrated tussock resistance occurring in 100 regions of one square kilometre surrounding three known locations of resistant serrated tussock in Australia.

In addition, workshops with affected farmers and other land managers were held in Sunbury (30 participants) and the Rowsley Valley (26) in Victoria and in Armidale (16 participants) and Goulburn (82) in New South Wales.

Results/key findings

The report found that all locations surveyed have sites with flupropanate-resistant serrated tussock more than two kilometres from the properties initially identified with resistance. This suggests that flupropanate resistance has probably already escaped from the original sites to surrounding areas.

This shows that serrated tussock’s resistance to flupropanate is becoming widespread, which has implications for further serrated tussock invasion, increased herbicide use, and higher management and labour costs for farmers.

As a result of the survey findings, a national awareness campaign dealing with serrated tussock resistance has been undertaken which includes producing brochures on how to recognise, manage and
prevent serrated tussock herbicide resistance and distributing 10 000 to land managers in New South Wales, the Australian Capital Territory, Victoria and Tasmania.

Workshop participants also received detailed information about resistance in their localities and information about how to deal with the problem in future.

**Implications for relevant stakeholders**

As a result of this research it is obvious that land managers are increasingly going to have to deal with flupropanate-resistant serrated tussock, and the possible loss of flupropanate as a control tool will severely limit the options.

**Recommendations**

It is crucial that weed management authorities wishing to contain serrated tussock resistance to flupropanate understand the current extent of resistance infestations. If the resistant tussock is confined within a very small area (that is, a single property), the resistance can be nominated for management using government assistance for direct control costs and compliance. If the resistance is widespread, management becomes more problematic, and government assistance is likely to be directed at extension and advice promoting integrated control.
Introduction

Serrated tussock, *Nassella trichotoma* (Nees) Arech., is an unpalatable South American perennial grass that is a weed of national significance in Australia because of its severe agricultural and environmental impacts (Thorp & Lynch 2000). The only herbicides registered for control of the species in pastures are flupropanate, glyphosate and 2,2-DPA. Organisms’ ability to develop resistance to a particular chemical control agent after constant exposure to that chemical over generations is well documented in the scientific literature (Lebaron & Gressel 1982). Flupropanate is widely regarded as the most selective and effective herbicide for controlling serrated tussock, and its residual action in the soil can prevent the species regrowing for three to five years (Campbell & Vere 1995). It is classified as a Group J herbicide that inhibits plant lipid synthesis and is regarded as posing a relatively low risk of resistance (Croplife Australia 2008). Flupropanate resistance has, however, been identified in a population of serrated tussock in Victoria: the tussock survived application rates as high as 8 litres per hectare, which is four times the recommended rate for controlling this species (Noble 2002). The Victorian Department of Primary Industries carried out a national serrated tussock resistance survey during 2004 to determine the extent of resistance in Australia (McLaren et al. 2006), and resistance has now been confirmed at three sites (McLaren et al. 2008).

Ramasamy (2008) has conducted detailed serrated tussock population crossing studies of known flupropanate-resistant and -susceptible serrated tussock plants. The results show that resistance can come from the seed parent, but some gene flow in the pollen is also possible. Ramasamy also showed that the majority (85 to 90 per cent) of serrated tussock flowers do not physically open until after the stigma is receptive (pollen is transferred within the closed flower), meaning that only 10 to 15 per cent of serrated tussock flowers are available for pollen transfer. The consequence of this is that a serrated tussock plant resistant to flupropanate will produce at least 85 to 90 per cent resistant seeds since they will fertilise within the unopened flower. Only a relatively small proportion (10 to 15 per cent) of the flowers will produce resistant pollen to potentially spread flupropanate resistance great distances.

It is crucial that weed management authorities wishing to contain serrated tussock resistance to flupropanate understand the current extent of resistance infestations. If the resistant tussock is confined within a very small area (that is, a single property), the resistance can be nominated for management using government assistance for direct control costs and compliance. If the resistance is widespread, management becomes more problematic, and government assistance is likely to be directed at extension and advice promoting integrated control.

This report provides an assessment of the extent of serrated tussock resistance occurring in 100 regions of 1 square kilometre surrounding three known locations of resistant serrated tussock in Australia.
Materials and methods

Field component: resistance sampling

Serrated tussock populations resistant to flupropanate are known to occur on properties at Armidale in New South Wales (30°32'S, 151°36'E) and at Diggers Rest (37°39'S, 144°41'E) and in the Rowsley Valley in Victoria (37°41'S, 144°21'E) (McLaren et al. 2008).

To assess whether serrated tussock populations in the general vicinity of these ‘resistant properties’ were also resistant to flupropanate, samples (a serrated tussock tiller with roots attached) were collected from within a 5-kilometre radius (100 square kilometres) of these properties during May 2008 (Rowsley Valley) and July 2009 (Armidale and Diggers Rest). The 100 square kilometres was gridded and each ‘cell’ assigned a number (1 to 100) (see Figure 1). For a 2-kilometre radius (16 square kilometres) surrounding the property with known resistant serrated tussock roadside and paddock collections of serrated tussock samples were made within each square kilometre. For the additional 84 square kilometres away from the sampled 16 square kilometres 50 per cent of the grid squares were sampled at random. At each of the sampled sites—10 in the Rowsley Valley and 12 at Armidale and Diggers Rest—individual serrated tussock samples (tiller and roots) were collected and placed in a labelled plastic bag on which was recorded the date collected, the location name, and the latitude and longitude. An additional 118 individual known flupropanate-susceptible serrated tussock plants were grown as treated and untreated controls. In total, about 600 individual plants were collected for assessment at each of the three locations studied.

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Notes: A = property identified with resistance. Shaded areas 4 x 4 km all sampled. Area B (84 km²): random numbers were used to select a further 42 sites (50% of area) for sampling.

Figure 1  The sampling method
The samples were taken to the Department of Primary Industries at Frankston in Victoria and samples were placed in 15-centimetre pots using standard potting mix with three plants in each pot. After potting, the plants’ leaves were trimmed to assist recovery after transplanting, and the plants were then grown for three months in a greenhouse at an average temperature of 20°C, being watered on alternate days and randomised fortnightly until plants were growing actively.

Application of flupropanate

The sampled serrated tussock plants were sprayed with Taskforce® (745 grams a.i. L ha\(^{-1}\) flupropanate), using a mechanical track sprayer in a spray cabinet with a flat nozzle (AI11002) to deliver a spray volume of 150 litres per hectare at 280 kilopascals at the recommended field rate (1.49 kilograms a.i. L ha\(^{-1}\)). Assessment of flupropanate resistance was based on a visible injury scale—from 0 = healthy to 9 = dead—for each plant sampled. The assessments of flupropanate impacts were made three months after treatment.

Development of the brochures

The brochure on serrated tussock resistance focused on six main themes:

- herbicide resistance in general
- serrated tussock resistance to flupropanate
- management implications of serrated tussock resistance to flupropanate
- determining whether serrated tussock resistance is occurring
- ways to avoid herbicide resistance
- integrated weed management.

Project personnel liaised closely with the National Serrated Tussock Management Group, the Victorian Serrated Tussock Working Party and the relevant government departments in Victoria, New South Wales and Tasmania.

The workshops

Following the surveys a series of workshops were organised to raise awareness of the problem of serrated tussock resistance to flupropanate and to provide to farmers information to help them deal with the situation. In each case a set procedure was followed to arrange the workshop:

- development and issuing of a press release
- development of an invitation letter for individual landowners
- booking of a suitable venue
- in some cases, letter-boxing of individual land mangers.

Twenty-six people attended the Rowsley Valley workshop, which was held on 3 September 2009; 16 attended the Armidale workshop, on 15 June 2010; 82 attended the Goulburn workshop, on 16 June 2010; and 30 attended the workshop held in Sunbury on 17 June 2010.
Results

Statistical analysis

Sites plus untreated controls were analysed as a two-replicate fully randomised one-way analysis of variance with Rowsley Valley serrated tussock plants and a four-replicate randomised block analysis of variance with Diggers Rest and Armidale plants (Payne 2006). In all analyses a pot containing three to five plants, depending on the trial, was the unit of analysis.

The mean damage scores of each survey site, and of the untreated control, were compared with the known flupropanate-susceptible treated control serrated tussock plants using 95 per cent hypothesis tests and one-sided Dunnett’s simultaneous comparisons (Miller 1981). These tests allow comparison of many treatments with a control while maintaining the nominal significance level.

Resistance results

The results of the assessment of resistance at the three locations are shown in Figures 2 to 4. The Diggers Rest site had 38 out of 59 sites exhibiting healthy serrated tussock six months after application with label-rate flupropanate (64 per cent), which was substantially more than the Armidale (21 out of 54, or 38 per cent) and Rowsley Valley (19 out of 61, or 31 per cent) locations. Eleven out of the 16 sites (67 per cent) sampled directly around the original property at Diggers Rest had healthy plants six months after application. This was substantially more than the seven out of 16 (44 per cent) for Armidale and the five out of 16 (31 per cent) for the Rowsley Valley.

Notes: Application rate was 2 litres per hectare. Red bars are known susceptible serrated tussock plants. Green bars are significantly resistant sites. Numbers at base of bars are the numbers of healthy (0–3) (resistant) serrated tussock plants out of 12 plants sampled.

Figure 2  Survival of serrated tussock six months after application of flupropanate, Armidale
Survival of Roswley Valley serrated tussock 6 months after application of flupropanate at 2 L/ha.

Notes: Application rate was 2 litres per hectare. Red bars are known susceptible serrated tussock plants. Green bars are significantly resistant sites. Numbers at base of bars are the numbers of healthy (0–3) (resistant) serrated tussock plants out of 10 plants sampled at each site.

Figure 3 Survival of serrated tussock six months after application of flupropanate, Rowsley Valley

Survival of Diggers Rest serrated tussock 6 months after application of flupropanate at 2lt/ha

Notes: Application rate was 2 litres per hectare. Red bars are known susceptible serrated tussock plants. Green bars are significantly resistant sites. Numbers at base of bars are the numbers of healthy (0–3) (resistant) serrated tussock plants out of 10 plants sampled at each site.

Figure 4 Survival of serrated tussock six months after application of flupropanate, Diggers Rest
Discussion

The 100–square kilometre serrated tussock resistance surveys carried out at the Armidale, Diggers Rest and Rowsley Valley locations confirmed that serrated tussock resistance has become widespread. Two further properties with serrated tussock resistant to flupropanate have also been identified near Goulburn in southern New South Wales. All locations surveyed have sites with flupropanate-resistant serrated tussock more than 2 kilometres from the properties initially identified with resistance. The Diggers Rest location had the greatest number (38) of sites with serrated tussock resistant to flupropanate six months after application; the Rowsley Valley had the fewest (one). In the latter case the resistant site occurred outside the 16–square kilometre treatment area surveyed surrounding the original property identified with resistance. The Diggers Rest location was the first property in Australia found to have serrated tussock resistant to flupropanate (Noble 2002), and the significant control measures implemented by the affected land manager, the Department of Primary Industries and Melton Shire explain the relatively few resistant serrated tussock sites identified at this location in the present study.

The spread of serrated tussock flupropanate resistance will depend on the nature of the inheritance, the breeding system and the amount of gene flow, and, most importantly, the management practices of land managers. The maternal nature of the inheritance, coupled with the high proportion of self-pollination (Harding 1983) and cleistogamy and infrequent but potentially long-distance gene flow through pollen, have probably resulted in rapid establishment of resistant seeds among the field populations (Ramasamy 2008). The trial data suggest that flupropanate resistance has probably already escaped from the original sites to surrounding areas. If this is indeed the case, ‘the genie is out of the bottle’. Land managers are therefore increasingly going to have to deal with flupropanate-resistant serrated tussock, and the possible loss of flupropanate as a control tool will severely limit the options.

Flupropanate is the most popular herbicide for large-scale broad-acre serrated tussock control, so probable results of the spread of resistance are the species’ increased dominance as a weed and consequent reduced grazing opportunities for animals, greater herbicide use, increased time spent by land managers controlling serrated tussock, increased costs to land managers, and greater damage to the environment.

To overcome the problem, land managers will be obliged to mechanically remove resistant plants or treat them with a registered herbicide from a different herbicide group, such as glyphosate (Group M). Another possibility is rotating the herbicide types used—for example, Group J (flupropanate and 2,2-DPA) or Group M (glyphosate). It will also be necessary to integrate herbicide use with other control strategies (that is, practice integrated weed management) such as chipping, cultivation, mulching, cropping, pasture rehabilitation, fire, grazing management, forestry and native revegetation, strategic fencing, use of shelter belts and windbreaks, slashing, strategic stock management, vehicle and machinery hygiene where appropriate, and, most importantly, constant monitoring and follow-up control (chipping out) of any regrowing serrated tussock plants (Osmond et al. 2008).

A national awareness campaign dealing with serrated tussock resistance is being implemented; it includes production and distribution of a brochure on the subject. Affected land managers identified through this current project are also being invited to attend a series of workshops. It is expected that greater awareness of serrated tussock’s resistance to flupropanate will lead to increased uptake of integrated weed management by land managers; in the absence of this, Australia will have lost an important management tool for combating serrated tussock.

This project highlights the importance of investigations into biological control of serrated tussock and supports the continuation of this work.
References


Ramasamy, DR 2008, ‘Investigations into Nassella trichotoma and Sporobolus fertilis resistance to the herbicide flupropanate and biological control of S. fertilis using the pathogen Nigrospora oryzae’, PhD thesis, Department of Biotechnology and Environmental Biology, RMIT University, Melbourne.

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Land managers in New South Wales, the Australian Capital Territory, Victoria and Tasmania will benefit from this research by learning how to recognise, manage and prevent serrated tussock herbicide resistance.

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The spread of serrated tussock flupropanate resistance will depend on the nature of the inheritance, the breeding system and the amount of gene flow, and, most importantly, the management practices of land managers.

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