Serrated tussock resistance to flupropanate in Australia – is the genie out of the bottle?

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Summary Detailed regional surveys to assess the extent of serrated tussock resistance to flupropanate have been conducted in Armidale (NSW), Diggers Rest (Victoria) and the Rowsley Valley (Victoria). Results show that serrated tussock resistance to flupropanate is becoming widespread with implications of greater serrated tussock invasion, increased herbicide usage, increased management and labour costs for farmers as a consequence. Integrated weed management and a national project to raise awareness of the serrated tussock resistance to flupropanate are discussed.

Keywords Serrated tussock, resistance, flupropanate, integrated control.

INTRODUCTION

Serrated tussock (*Nassella trichotoma* (Nees) Arech.) is a South American unpalatable perennial grass that is a Weed of National Significance in Australia due to its severe agricultural and environmental impacts (Thorp and Lynch 2000). The only registered herbicides for control of serrated tussock in pastures are flupropanate, glyphosate and 2,2-DPA. The ability of organisms to develop resistance to a particular chemical control agent after constant exposure to that chemical over many generations is well documented in the scientific literature (Lebaron and Gressel 1982). Flupropanate is widely regarded as the most selective and effective herbicide for controlling serrated tussock while its residual action in the soil can prevent serrated tussock regrowing for 3–5 years (Campbell and Vere 1995). Flupropanate is classified as a Group J herbicide that inhibits plant lipid synthesis and is regarded as a relatively low risk herbicide for resistance (Croplife Australia 2008). Flupropanate resistance has been identified in a population of serrated tussock in Victoria with serrated tussock surviving application rates as high as 8 L ha^{-1}, which is four times the recommended rate used for controlling this species (Noble 2002). A national serrated tussock resistance survey was undertaken by the Victorian Department of Primary Industries during 2004 to determine the extent of resistance in Australia (McLaren *et al.* 2006) and resistance has now been confirmed at three sites in Australia (McLaren *et al.* 2008). Ramasamy (2008) 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 (2008) also showed that the majority (85–90%) of serrated tussock flowers don't physically open until after the stigma is receptive (pollen is transferred within the closed flower) meaning that only 10–15% of serrated tussock flowers are available for pollen transfer. The implications of this are that a serrated tussock plant resistant to flupropanate will produce at least 85–90% resistant seeds as they will fertilise within the unopened flower. However, only a relatively small proportion (10–15%) of the flowers will produce resistant pollen to potentially spread flupropanate resistance great distances.

A critical issue for weed management authorities wishing to contain serrated tussock resistance to flupropanate is understanding the current extent of resistance infestations. If the resistant serrated tussock is confined within a very small area (i.e. to a single property), then the serrated tussock resistance can be prioritised for management with Government assistance for direct control costs and compliance. If the serrated tussock resistance is widespread then management becomes more problematic and Government investment is likely to be directed towards extension and advice promoting integrated control.

This paper reports on an assessment of the extent of serrated tussock resistance occurring within 100 regions of 1 km^2 surrounding three known serrated tussock resistance locations in Australia.

MATERIALS AND METHODS

Field component – serrated tussock sampling Known serrated tussock populations resistant to flupropanate occur on properties in Armidale NSW (30°32'S, 151°36'E), Diggers Rest Victoria (37°39'S, 144°41'E) and the Rowsley Valley Victoria (37°41'S, 144°21'E) (McLaren *et al.* 2008). To assess whether serrated tussock populations within the general vicinity of these 'resistant properties' were also resistant to flupropanate, serrated tussock samples (a serrated tussock tiller with roots attached) were collected from within a 5 km radius (100 km^2) of these properties during May 2008 (Rowsley Valley) and July 2009 (Armidale and Diggers Rest). The 100 km^2 were gridded and assigned numbers (1–100). For a 2 km radius (16 km^2) surrounding the known serrated tussock resistant property, roadside and paddock collections of serrated tussock samples were made within each 1 km^2. For the additional 84 km^2 away from the 16 km^2 selected around the affected property, 50% of the grid squares were selected at random. At each of the sampled sites, 10 (Rowsley Valley) or 12 (Armidale and Diggers Rest) individual serrated tussock plant samples (tiller and roots) were collected and placed into a labelled plastic bag recording date collected, location name and latitude/longitude. An additional 118 individual known flupropanate susceptible serrated tussock plants were grown as treated and untreated controls. In total approximately 600 individual serrated tussock plants were collected for assessment at each of the three locations assessed.

Samples were transported to the Department of Primary Industries Frankston in Victoria and each serrated tussock sample was potted into 15 cm pots using standard potting mix with three plants planted into each pot. After potting, the serrated tussock plants had their leaves trimmed to aid in recovery after transplanting and were then grown for 3 months in a greenhouse at an average temperature of 20°C, 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 g a.i. ha^{-1} flupropanate) using a mechanical track sprayer in a spray cabinet with a flat nozzle (AI11002), to deliver a spray volume of 150 L ha^{-1} at 280 kPa at the recommended field rate (1.49 kg a.i. ha^{-1}). Assessment of flupropanate resistance was based on a visible injury scale of 0 = healthy to 9 = dead for each individual serrated tussock plant sampled. Assessments of flupropanate impacts to the surveyed serrated tussock samples were made 3 months after treatment.

RESULTS

Statistical analysis Sites plus untreated controls were analysed as a two replicate fully randomised one-way analysis of variance with Rowsley Valley plants and a four replicate randomised block analysis of variance with Diggers Rest and Armidale plants (Payne 2006). In all analyses a pot containing 3–5 plants, depending on trial, was the unit of analysis.

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

Resistance survey The statistical analysis of flupropanate impact on serrated tussock surveyed from the Armidale, Diggers Rest and the Rowsley Valley locations is summarised in Figure 1. The Rowsley Valley site had the largest number of serrated tussock flupropanate resistant sites (17 out of 60) followed by Armidale (7 out of 54) and Diggers Rest (1 out of 59). Thus, almost a third of the sites surveyed in the Rowsley Valley were resistant to flupropanate and 7 out of these 17 resistant sites occurred within the 16 km^2 surveyed within the vicinity of the original property identified with resistance. Similarly, the Armidale location had 13% of sites resistant to flupropanate with the majority (4 out of 7) of these being within the 16 km^2 surveyed near the original property identified with resistance. The least serrated tussock resistance to flupropanate (1 out of 59 sites) was identified at the Diggers Rest site.

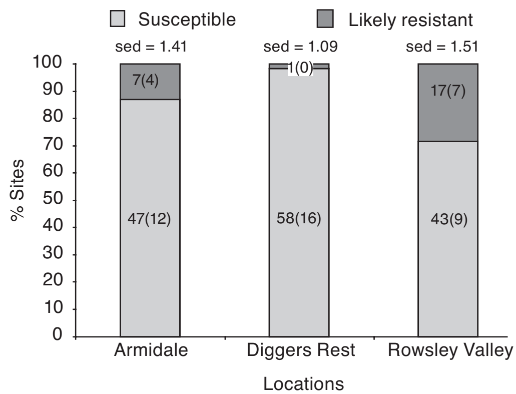

Figure 1. Comparison of proportion of resistant and susceptible serrated tussock sites identified 3 months after treatment with label rate flupropanate (Dunnett's simultaneous comparisons). Numbers within columns represent the number of sites assessed as susceptible or resistant at 95% level of probability. Numbers in brackets within columns represent number of sites affected within the 16 km^2 grid immediately surrounding the property identified with resistance.

DISCUSSION

The 100 km^2 serrated tussock resistance surveys undertaken at Armidale, Diggers Rest and Rowsley Valley locations have confirmed that serrated tussock resistance has now become widespread. All locations surveyed have sites identified with flupropanate resistant serrated tussock more than 2 km from the properties initially identified with resistance. The Rowley Valley location had the greatest number (17) of sites identified showing serrated tussock resistance to flupropanate while Diggers Rest had the least (1). This resistant site occurred outside the 16 km^2 flupropanate treatment surveyed surrounding the original property identified with resistance (Figure 1). The Diggers Rest location was the first property identified with flupropanate resistance to serrated tussock in Australia (Noble 2002). The significant integrated serrated tussock control measures implemented by the affected land manager, the Department of Primary Industries and the Melton Shire may explain the relatively few resistant serrated tussock sites identified at this location in the current study.

The likely spread of serrated tussock flupropanate resistance will depend upon the nature of the inheritance, the breeding system, the amount of gene flow and, most importantly, the type of management practices being undertaken by the land managers. The maternal nature of the inheritance, coupled with the high proportion of self-pollination (Harding 1983) and cleistogamy, has probably resulted in rapid establishment of resistant seeds among the field populations (Ramasamy 2008). Another factor is infrequent but potentially long distant gene flow through pollen (Ramasamy 2008).

The data from this trial suggest that flupropanate resistance has already escaped from the original sites to surrounding areas and that the serrated tussock flupropanate resistance ‘genie’ is out of the bottle. Farmers and land managers are therefore increasingly going to have to deal with flupropanate-resistant serrated tussock. The potential loss of flupropanate as a control tool for serrated tussock due to resistance would severely limit control options for land managers. Flupropanate is the most popular herbicide for large scale broad acre serrated tussock control, and thus resistance to flupropanate is likely to become common. The appearance of herbicide resistance in a plant population is an example of rapid weed evolution and typically develops when a weed species has been exposed to many years of continual application from a particular herbicide group or type. Large weed populations increase the likelihood of developing resistance. A consequence of serrated tussock resistance to flupropanate will be reduced grazing opportunities for animals, greater herbicide usage, increased time spent by land managers controlling serrated tussock, increased costs to land managers and greater environmental pollution and damage to the environment as a consequence. To overcome this issue land managers will need to mechanically remove resistant plants or treat them with a registered herbicide from a different herbicide group such as glyphosate (Group M). It will be important to rotate the herbicide types used with different modes of action, e.g. Group J (flupropanate and 2,2-DPA) or Group M (glyphosate). Herbicide use will also need to be integrated with other control strategies (i.e. practice Integrated Weed Management (IWM)), including the use of chipping, cultivation, mulching, cropping, pasture rehabilitation, fire, grazing management, forestry/native re-vegetation, strategic fencing, use of shelter belts/windbreaks, slashing, strategic stock management, vehicle/machinery hygiene where appropriate and most importantly always monitor and follow up control (chip out) any re-growing serrated tussock plants (Osmond *et al.* 2008). A national serrated tussock best management practices program involving more than 180 farmers in eight workshops across Australia considered these serrated tussock IWM practices as useful but also highlighted several research gaps in effectiveness of these IWM tools (Fullerton *et al.* 2008). A national serrated tussock resistance awareness campaign is currently being implemented including production and distribution of a serrated tussock resistance brochure. Affected land managers identified through this project have also attended a series of serrated tussock resistance workshops in Victoria and NSW. It is expected that increased awareness of serrated tussock resistance to flupropanate will lead to increased uptake of IWM by land managers, otherwise the ‘genie will be truly out of the bottle’ and Australia will have lost an important management tool for combating serrated tussock.

The potential loss of flupropanate as a management tool highlights the importance and supports continuation of investigations into biological control of serrated tussock. Biological control aims to utilise natural enemies (pathogens) of serrated tussock and if successful may potentially reduce its competitiveness as a weed.

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