Assessing the extent of serrated tussock resistance to the herbicide, flupropanate in Australia.

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Abstract

A serrated tussock population has been identified as resistant to the herbicide flupropanate at Diggers Rest, just north-west of Melbourne. This provoked a national mail survey to 5000 land managers impacted by serrated tussock across Australia. Survey results have shown that serrated tussock has spread widely throughout Victoria, NSW, ACT and Tasmania with 15 out of 400 respondents reporting resistance and requiring further investigation. The survey has also shown that serrated tussock is costing each land manager between $15,000 and $20,000 annually in control and lost production costs. This emphasises the importance of promoting integrated management of serrated tussock. The importance of integrated weed management is highlighted.

Introduction

Serrated tussock (*Nassella trichotoma* (Nees) Hack. ex Arechav.) is a declared Weed of National Significance (Thorp and Lynch 2000) that has been estimated to conservatively cost Victoria $5 million per year (Nicholson *et al.* 1997) and New South Wales $40.3 million per year (Jones and Vere 1998). It has been described as causing a greater reduction in pasture carrying capacity than any other weed in Australia with heavily infested paddocks in NSW carrying only 0.5 dry sheep equivalent (DSE) per hectare compared to 7 to 15 DSE on improved pasture without the weed (Parsons and Cuthbertson 1992). In 1977 it occupied 680,000 ha (Campbell 1977) and now occupies more than 870,000 ha in New South Wales with an estimated 2,000,000 ha at risk of infestation (Ian McGowan, NSW Department of Primary Industries, personal communication). In Victoria, serrated tussock has expanded its distribution from 4 ha in 1954 (Parsons 1973) to 30,000 ha by 1979 (Lane *et al.* 1980) to 130,000 ha by 1998 (McLaren *et al.* 1998). Serrated tussock is also found in Tasmania where it is currently spread in scattered populations over an area of approximately 1000 ha (Christian Gonninon, Tasmanian Department of Primary Industries Water and Environment, personal communication). The potential distribution of serrated tussock based on its current infestations in Australia has been estimated at 32 million ha with substantial areas of New South Wales, Victoria and Tasmania at risk of invasion (McLaren *et al.* 1998). Serrated tussock is being increasingly recognised as a serious environmental weed and the associated native vegetation being invaded by serrated tussock is described in McLaren *et al.* 1998.

Despite years of research, there are still limited control options for managing serrated tussock in Australia (Michalk *et al.* 1999). The only registered herbicides for control of serrated tussock in pastures are flupropanate, glyphosate, and 2,2-DPA (Propon). Flupropanate is widely regarded as the most selective and effective herbicide for controlling serrated tussock (Campbell and Vere 1995). Species such as phalaris, cocksfoot and kangaroo grass have some tolerance to flupropanate (Campbell 1979; Campbell *et al.* 1979; Campbell and Ridings 1988) while its residual action in the soil can prevent serrated tussock regrowing for three to five years (Campbell and Vere 1995). Flupropanate has been classified by the Herbicide Resistance Action Committee (HRAC) as a group N herbicide that affects fat synthesis using the Chloro-Carbonic-acids chemical group. 2,2-DPA is also classified as a group N herbicide within the Chloro-Carbonic-acids chemical group (Herbicide Resistance Action Committee 2005).

Flupropanate resistance has been identified in a population of serrated tussock in Victoria (Noble 2002). Serrated tussock plants suspected of being resistant to flupropanate were grown in a pot trial and treated with a range of flupropanate rates. The resistant serrated tussock survived application rates as high as 8 L/ha which is four times the recommended rate used for controlling this species (Noble 2002). Similarly, petri dish dose response trials undertaken on serrated tussock seeds have shown that the flupropanate dose required to reduce the germination of seeds from resistant plants by 50% was approximately 10 times higher than for susceptible seeds (Graeme Pritchard, Victorian Department of Primary Industries, personal communication). This

has prompted a national survey to try and determine whether serrated tussock resistance to flupropanate is wide spread and to raise resistance awareness and promote integrated management of serrated tussock.

Materials and Methods

In November 2004, a serrated tussock survey was mailed to land managers in Victoria, NSW, ACT and Tasmania. In Victoria and Tasmania, questionnaires were sent directly to landholders that had been recorded with serrated tussock on the land they managed. This also included a mailing list of 1130 within the Melton Shire in Victoria. The Melton Shire was targeted because the property identified with serrated tussock resistance to flupropanate was located within this Shire. A further 931 surveys were mailed directly to land managers recorded with serrated tussock on the Victorian Department of Sustainability and Environment's Integrated Pest Management System (IPMS). Twenty questionnaires were sent out to Victorian Park rangers, 10 to VicRoads and 30 directly to Victorian spray contractors. In Tasmania 275 questionnaires were mailed directly to land managers recorded with serrated tussock. In NSW 338 surveys were sent directly to NSW Landcare groups within serrated tussock infested locations while the remaining 2265 surveys were sent to NSW and ACT Weeds Inspectors for distribution to land managers in their districts. The surveys were targeted to regions thought likely to be infested by serrated tussock. A total of 5000 surveys were sent (2125 to Victoria, 2450 to NSW, 150 to ACT and 275 to TAS). A Cooperative Research Centre for Australian Weed Management Fact sheet entitled, *Understanding the mechanisms behind herbicide resistance*, was also mailed with the surveys to help land managers understand what herbicide resistance is and how it can be prevented. Each survey included a prepaid return envelope to aid land managers returning the survey.

Respondents were requested to provide information on the extent of land they manage and the coverage of serrated tussock infestation on their land. The infestations were categorized either as:

- Dense – monoculture or close to monoculture – very few native/other species present,
- Medium – roughly equal proportions of serrated tussock to other native/pasture/crop species present,
- Scattered - Native/pasture/crop species in much greater abundance than serrated tussock,
- Rare – Single or very few serrated tussock plants present or
- Absent.

They were also asked to classify what proportion of these infestations occurred on pasture land, native vegetation or other (roadside, cropping, forestry etc). Respondents were also asked to indicate the costs as "material costs," "labour costs" "Time (days/year) cost" and "other costs" to control serrated tussock infestations in "pasture", "native vegetation" and "other" land classes. Questions were asked about chemical control including what herbicides they used for serrated tussock, the number of times they used these herbicides and the year they first used these herbicides. They were also asked whether they had noticed serrated tussock on the land they managed that had not died after two or more applications of a serrated tussock herbicide and whether they thought this could have been due to resistance.

Results

Distribution and type of infestation

A response rate of approximately 8% (400) was obtained while approximately 250 surveys were returned address unknown. The respondents reported on a total area of approximately 0.42 million ha consisting of pasture, native vegetation and other (roadsides, cropping, etc) across Australia. The respondents reported serrated tussock infestations totaling approximately 102,048 ha comprising 48,747 ha on pasture, 43,019 ha in native vegetation and 10,281 ha on other areas (roadsides, cropping etc). Of this total, some 82,094 ha was in NSW, 8113 ha in Victoria, 11,520 ha in the ACT and 321 ha in Tasmania (Table 1). Thus this represents approximately 4% of the estimated 2.5 million ha infested by serrated tussock in Australia.

The most significant serrated tussock infestations reported occur in NSW where the majority of dense and medium infestations were reported on native vegetation with more scattered and rare infestations reported in pastures (Table 1). Similarly, in the ACT respondents reported greater areas of dense, medium and scattered serrated tussock infestations in native vegetation than pasture. However, in Victoria and Tasmania more serrated tussock was reported in pasture than in native vegetation. These results may also reflect that all the Victorian and Tasmanian land managers received surveys through direct mail. However, in NSW and the ACT, surveys were sent via weeds officers, environmental officers and agronomists for distribution to land managers. In some cases these professionals reported on an entire district or region. In Victoria, the "other" category recorded the largest area of dense serrated tussock. However, this was reported by a single landowner who did not provide contact details.

Table 1 Serrated tussock infestations categorised by State, land use and density reported from survey.

State	Land use types	Serrated tussock infestation density (ha)				
		Dense	Medium	Scattered	Rare	Total
NSW	Pasture	878	1078	17,909	19,735	39,600
	Native	1099	4303	16,798	10,855	33,055
	Other	143	12	3910	5,375	9439
	Total	2120	5393	38,617	35,965	82,094
Vic	Pasture	37	371	2353	2754	5515
	Native	6	195	939	816	1956
	Other	99	70	225	247	642
	Total	142	636	3517	3817	8113
Tas	Pasture	30	31	121	39	221
	Native	1	2	64	28	95
	Other	0	0	5	0	5
	Total	31	33	190	37	321
ACT	Pasture	190	25	2130	1067	3412
	Native	370	1030	5976	537	7913
	Other	0	0	45	150	195
	Total	560	1055	8151	1754	11,520
Total Australia		2853	7117	50,475	41,603	102,048

Table 2 The annual costs of serrated tussock control to various pasture systems in NSW, Vic, Tas and ACT reported from survey.

State	Land use types	The annual costs of serrated tussock control to various pasture systems in NSW, Vic, Tas and ACT reported from survey				Average per respondent ($/yr)
		Materials	Labour	Other	Total	
NSW	Pasture	165,714	177,110	23,970	366,794	2134
	Native	50,180	116,172	87,570	253,922	3199
	Other	15,347	41,286	14,410	71,043	2412
	Total	213,241	334,568	125,950	691,759	7745
Vic	Pasture	53,609	79,478	26,460	156,547	1010
	Native	16,142	50,898	17,600	84,640	918
	Other	9275	43,800	8425	61,500	1934
	Total	79,026	171,176	52,485	302,687	3862
Tas	Pasture	2050	5390	3350	10,790	715
	Native	2325	4650	2500	9475	1415
	Other	0	0	0	0	-
	Total	4375	10,040	5850	20,265	2130
ACT	Pasture	21,550	30,760	40,300	92,610	5438
	Native	43,450	13,640	17,800	74,890	3755
	Other	110	500	100	710	212
	Total	65,110	44,900	58,200	168,210	9405
Total Australia		379,752	560,684	242,485	1,182,921	3714

Economic impact

As expected, NSW, the state with the most significant serrated tussock infestations were spending the most money on serrated tussock control (Table 2). Land managers from the ACT were spending on average twice and four times as much on serrated tussock control compared to Victoria and Tasmania respectively. Labour was recorded as the greatest cost component in all land use types except in native vegetation in the ACT where expenditure on materials was three times that of the labour cost. On average, land managers were spending approximately $3714 per year on serrated tussock management.

In total, production losses were estimated at $662,820 while the average losses per respondent were approximately $13,000/year (Table 3). In total, serrated tussock was estimated to be costing the respondents approximately $1.8 million in management costs and lost production or about $15–20,000/year/respondent (Tables 2 + 3).

Herbicide Resistance

Almost twice as many respondents were reported using flupropanate to glyphosate in NSW and vice versa for Victoria (Table 4). Respondents from NSW and the ACT have used flupropanate on average for more than ten years or on ten occasions. Glyphosate has been used more frequently than flupropanate in Victoria and Tasmania (Table 4).

Serrated tussock resistance to flupropanate was identified by nine land managers and resistance to glyphosate by a total of six land managers (Table 5 and Figure 1). All the Victorian flupropanate resistance reports were from properties in the Diggers Rest, Sydenham, and Bulla locality just north of Melbourne.

Discussion

This survey has confirmed the massive impacts this weed is having on Australian agriculture with average annual serrated tussock costs ranging from $15,000 to $20,000 per year per respondent.

Table 3 Annual total production loss caused by serrated tussock by State ($/yr).

State	Number of replies	Total $	Average per respondent $
NSW	31	478,600	15,439
Vic	15	91,740	6116
Tas	1	1000	1000
ACT	4	91,480	22,870
Australia	51	662,820	12,996

Extent of Resistance

To date only one property in Victoria has been confirmed with serrated tussock resistant to flupropanate. This survey however, also identified nine (2% of survey respondents) land managers reporting serrated tussock suspected of being resistant to flupropanate, three in NSW and six in Victoria. A process of contacting these land managers and obtaining serrated tussock samples for testing resistance is underway. Similarly, six land managers have also expressed concern that glyphosate is not killing serrated tussock and that this could be due to resistance. The Victorian Department of Primary Industries has been working in collaboration with the Melton Shire Council to ensure that all serrated tussock on and surrounding the property confirmed with resistant serrated tussock is controlled. In addition, RMIT University in collaboration with the Victorian Department of Primary Industries have commenced a PhD project investigating the heritability and mechanisms causing resistance to flupropanate by serrated tussock. Herbicide resistance to flupropanate has also been identified in a giant parramatta grass, (*Sporobolus fertilis* (Steud.) Clayton), infestation near Grafton in NSW (G. Pritchard and David Officer, personal communication).

What are the herbicide/non herbicide options for control: It is critical that land managers don't rely solely on one herbicide type to control serrated tussock. There are currently three herbicides -

Table 4 Herbicides used to control serrated tussock (number of respondents) and average years/times used.

State	Flupropanate		Glyphosate		Total number reporting
	Number of responses	Average years of use	Number of responses	Average years of use	
NSW	96	10.7	68	7.6	164
Vic	57	5.1	120	5.6	177
Tas	7	1.4	4	6.0	11
ACT	10	10.9	11	3.8	21
Australia	168	8.0	203	6.3	337

Table 5 Number of survey respondents reporting possible resistance to fluproponate and glyphosate.

State	Flupropanate resistance ?	Glyphosate resistance ?
NSW	2	1
Vic	6*	5
Tas	0	0
ACT	1	0
Australia	9	6

* Includes 1 property confirmed with resistance

flupropanate, glyphosate and 2,2-DPA registered for control of serrated tussock in pastures. If using chemical control, land managers should alternate the use of these herbicides from year to year. Land managers should also be aware that 2,2-DPA is a closely related herbicide to flupropanate, belonging to the HRAC group N chemicals affecting lipid synthesis. *Sporobolus fertilis* plants resistant to flupropanate have also shown some resistance to 2,2-DPA (G. Pritchard, personal communication). To reduce the likelihood of developing resistance, land managers should attempt to keep serrated tussock populations as low as possible. Fewer serrated tussock individuals will mean fewer chances of selecting resistant individuals. Increasing beneficial plant competition is a key factor in managing serrated tussock. Practicing good agronomy by using competitive pasture species with appropriate use of fertiliser, grazing management, disease management and weed control is critical. Mechanical control through chipping and cultivation are excellent ways of controlling serrated tussock and

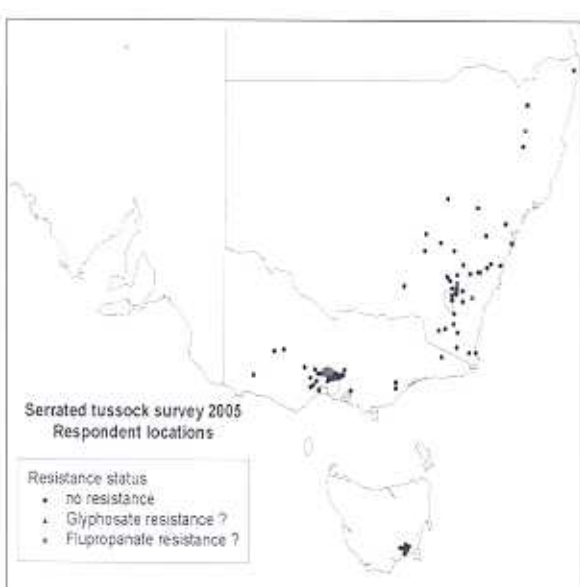

Figure 1 Distribution of survey respondents reporting resistance.

minimising resistance. Land managers should also consider crop/pasture rotations to help minimise resistance where appropriate. The key to serrated tussock management is reducing the seedbank. If land managers can prevent seed set for several years and there is little recruitment from surrounding properties, then the serrated tussock seedbank will decrease through time. In some situations slashing, burning or spray topping serrated tussock can be useful tools to reduce seeding. Using combinations of grazing to reduce the height of beneficial grasses and chemical wipers to apply herbicide selectively to serrated tussock is also a very useful tool. Development of new seed drill technology for rocky terrain (eg Rockhoppa© developed by AG-RECON Pty Ltd) is also providing more options for rehabilitation of what was previously non-arable land. In some situations it may be better to attempt to reduce serrated tussock populations through changes in land use. Agroforestry (Campbell and Nicol 1999) or simply locking land up and removing grazing can be enough to provide enough competition to reduce serrated tussock dominance.

Importance of Integrated Control

This survey has identified several new serrated tussock populations potentially resistant to flupropanate and glyphosate. There is a real risk that these herbicides will become less effective if land mangers don't quickly change the way they are using them. The consequences are more herbicide usage, greater serrated tussock dominance, greater herbicide pollution, increased environmental damage and reduced profits for farmers. Land mangers need to consider mechanical control, cropping rotations, pasture rehabilitation and grazing management to reduce the likelihood of resistance. A common theme with herbicide resistance is that weeds will quickly adapt through natural selection if they are constantly exposed to the same management technique (Warwick 1991). Land managers need to combat the weed by applying a range of different weed management techniques. This survey reinforces the need to practice integrated weed management to control serrated tussock.

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References

Campbell, M.H. (1977). Assessing the area and distribution of serrated tussock (*Nassella trichotoma*), St John's Wort (*Hypericum perforatum* var angustifolium) and Sifton Bush (*Cassinia arcuata*). *New South Wales. Department of Agriculture, NSW, Technical Bulletin* **18**, 1–23.

Campbell, M.H. (1979). Selective removal of *Nassella trichotoma* from a *Phalaris aquatica* pasture. *In* 'Proceedings 7th Asian Pacific Weed Sciences Society Conference'. Sydney. pp. 129–130.

Campbell, M. H. and Nicol, H.I. (1996). Establishing trees on non-arable land to control weeds. *In* 'Proceeding of 11th AustralianWeeds Conference'. University of Melbourne. pp. 493–496.

Campbell, M. H. and Vere, D.T. (1995). *Nassella trichotoma* (Nees) Arech. *In* 'The Biology of Australian Weeds'. (Eds. R. H. Groves, Shepherd, R.C.H. and Richardson, R.G.). R.G and F.J. Richardson, Melbourne. **1**, 189–202.

Campbell, M.H. and Ridings, H.I. (1988). Tolerance of grazed and ungrazed *Phalaris aquatica* to glyphosate, tetrapion and 2,2-DPA. *Australian Journal Experimental Agriculture* **28**, 747–751.

Campbell, M.H., Gilmour, A.R. and Vere, D.T. (1979). Effect of time and rate of application of herbicides on serrated tussock (*Nassella trichotoma*) and improved pasture species 2. Flupropanate. *Australian Journal Experimental Agriculture and Animal Husbandry* **19**, 479–480.

Herbicide Resistance Action Committee (2005). http://www.plantprotection.org/hrac/Bindex.cfm?doc=moa2002.htm Jones, R.E. and Vere, D.T. (1998). The economics of serrated tussock in New South Wales. *Plant Protection Quarterly* **13(2)**, 70–76

Lane, D., Riches, K. and Combellack, H. (1980). A survey of distribution of the noxious weeds in Victoria. Unpublished report. Department of Conservation and Natural Resources, Keith Turnbull Research Institute, Victoria.

Llewellyn, R. S., Lindner, R. K., Pannell, D. J. and. Powles, S. B (2001). Herbicide resistance and the decision to conserve the herbicide resource: Review and famework. Agreibusiness Review 9 http://www.agrifood.info/review/2001/Llewellyn.html.

McLaren, D.A.; Stajsic, V. and Gardener, M.R. (1998). The distribution and impact of South\North American stipoid grasses (Poaceae: Stipeae) in Australia. *Plant Protection Quarterly* **13(2)**, 62–70.

Michalk, D., Kemp, D., Cambell, M. and McLaren, D.A. (1999). Control of serrated tussock – problems in developing IWM systems. *In* 'Proceedings of the 12th AustralianWeeds Conference'. Hobart Tasmania. pp. 20–24.

Nicholson, C., Patterson, A. and Miller, L. (1997). The cost of serrated tussock control in central western Victoria. Unpublished report prepared for the Victorian serrated tussock working group.

Noble S. (2002). An investigation into the herbicide resistance of serrated tussock. Honours thesis, RMIT University, Department of Applied Biology and Biotechnology. pp. 1–84.

Parsons, W.T. (1973). Noxious weeds of Victoria. Inkata Press, Melbourne, Sydney.

Parsons, W.T. and Cuthbertson, E.G. (1992). Noxious Weeds of Australia, Inkata Press, Melbourne, Sydney.

Thorp, J.R. and Lynch, R. (2000). The determination of weeds of national significance. National Weeds Strategy Executive Committee, Launceston.

Warwick, S.I. (1991). Herbicide resistance in weedy plants: Physiology and population biology. *Annual Review of Ecological Systems* **22**, 95–114.