The extent of herbicide resistance in Tasmanian wild radish populations

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Abstract
Weeds are one of the major limiting factors in cropping systems and the development of resistance to herbicides used for their control can result in increased cost and complexity in managing these weed populations. With a high proportion of wild radish populations in Western Australia resistant to herbicides, along with a lower proportion in southern New South Wales it could be expected that some Tasmanian populations would also be resistant even though herbicide resistance in Tasmanian ryegrass populations occurs at a lower frequency than many other regions of Australia. For this reason wild radish seed samples were collected as part of a field survey of Tasmanian cropping paddocks in January 2015 to determine the extent of herbicide resistance in a number of weed species. A total of 75 paddocks in Tasmania were visited just prior to harvest from which 25 wild radish samples were collected, the second most common weed behind ryegrass. The samples were screened between March and May 2015 to six herbicides (chlorsulfuron, imazamox/imazapyr, atrazine, diflufenican, 2,4-D amine and glyphosate). The results from the screening will be compared with results from surveys conducted in Western Australia and southern New South Wales and the reasons for differences discussed.

Key words
2,4-D amine, chlorsulfuron, *Raphanus raphanistrum*,

Introduction
Herbicide resistant weeds are a major problem in the cropping regions of Australia. The first case in Australia was reported in annual ryegrass (*Lolium rigidum* Gaud.) in 1980 (Heap and Knight 1982), since then resistance has been reported in many weeds in Australia (Heap 2015). The first cases of resistance in wild radish (*Raphanus raphanistrum* L.) were reported in 2001(Hashem, et al. 2001; Walsh, et al. 2001).

Random surveys across the Western Australian cropping region have reported high proportions of wild radish populations that are herbicide resistant. In a 1999 random survey 21% of wild radish populations were found to be resistant to chlorsulfuron (Walsh, et al. 2001). This had increased to 54% in a survey conducted in 2003 when populations were found to also be resistant to 2,4-D amine (60%), diflufenican (40%) and atrazine (15%) with only 17% of the wild radish populations susceptible to all four tested herbicides (Walsh, et al. 2007). Surveys of the south west slopes region of New South Wales in 2011 and 2012 found 14% of wild radish populations were resistant to chlorsulfuron and 10% were resistant to imazamox+imazapyr, with no populations resistant to any of the other tested herbicides (atrazine, diflufenican, 2,4-D amine and glyphosate) (Broster, et al. 2014).

The extent of herbicide resistance in Tasmania is much lower than found on mainland Australia with a survey of Tasmania in 2010 finding 18% of ryegrass resistant to diclofop-methyl and 24% resistant to chlorsulfuron (Broster, et al. 2012a). This is much lower than found in Western Australia (Owen, et al. 2014), New South Wales (Broster, et al. 2011b; Broster, et al. 2013) and most regions of South Australia and Victoria (Boutsalis, et al. 2012). Similar findings were also recorded for wild oats in Tasmania with 13% of populations resistant to diclofop-methyl (Broster, et al. 2012a), again much lower than in Western Australia (Owen and Powles 2009) and southern New South Wales (Broster, et al. 2011a; Broster, et al. 2013).

With the lower level of herbicide resistant ryegrass in Tasmania than on mainland Australia it could be expected that resistance in other species would also be lower. This paper reports on the first survey of the Tasmanian cropping region to determine the level of herbicide resistance in wild radish.

Materials and Methods
Cropping or improved pasture paddocks in Tasmania were surveyed in January 2015 prior to the commencement of harvest. Paddocks were randomly selected at 10 km intervals, alternating left and right hand side of the survey transect where possible. The paddocks were surveyed by two people walking across

them for a ten to fifteen minute period. This resulted in 75 paddock being sampled of which 24 contained wild radish in sufficient numbers to collect enough seed for resistance screening. Eight other paddocks contained wild radish at densities too low to collect enough seed. The location of all sites were recorded using a GPS unit and the type of crop or pasture and all weed species present recorded with the density of any other weed species estimated.

Resistance screening

The 24 samples were sown in March 2015 with approximately 25 seeds placed in each pot. Two weeks after sowing all samples were counted. Pots were kept in a temperature controlled glasshouse (10°C minimum, 25°C maximum) and watered and fertilised as required. Where possible three replicates were sown, however as some samples had low seed numbers not all were able to be sown with three replicates or to all herbicides.

The samples were screened with six post-emergent herbicides across Groups B (chlorsulfuron and imazamox/imazapyr), C (atrazine), F (diflufenican), I (2.4-D amine) and M (glyphosate). All herbicides were applied when the plants were at the growth stage and rate recommended by the herbicide label (Table 1). The herbicides were applied using an automated laboratory-sized cabinet sprayer with a two nozzle moving boom, applying a water volume of 84 L/ha equivalent at 250 kPa. Adjuvants were added to herbicides as specified by label requirement. A standard susceptible biotype and a known resistant biotype, where available, were included with each cohort of samples.

Table 1: Herbicides and rates used for resistance screening (adjuvants were added as per label instructions).

Herbicide	Group	Rate (g a.i./ha)
chlorsulfuron	B (SU)	15
imazamox/imazapyr	B (imi)	16.5/7.5
atrazine	C	1000
diflufenican	F	100
2,4-D amine	I	875
glyphosate	M	648

Herbicide evaluation

All samples were assessed 28 days after treatment. Seedlings were counted before and after treatment to enable survival percentages to be calculated. Samples were classified as resistant if the mean survival percentage was greater than 20% for post-emergent herbicides while samples with survival percentages of between 10 and 19% were classified as developing resistance. The samples were categorised into respective Australian Bureau of Statistics Local Government Areas (LGA) and results were then compared between the regions (Australian Bureau of Statistics 2015).

Results

Of the 24 wild radish populations, all were screened to chlorsulfuron and two were classed as resistant. Due to low seed availability only 19 of the samples (including both chlorsulfuron resistant samples) were screened to imazamox/imazapyr, however six were classed as resistant and one as developing resistance (Table 2). One sample was resistant to both herbicides but the others were only resistant to one herbicide.

Two samples were resistant to 2,4-D amine and two were developing resistance. One of the resistant samples was resistant to chlorsulfuron but susceptible to imazamox/imazapyr while the other was susceptible to both Group B herbicides (Table 2). Both the samples developing resistance to 2,4-D amine were resistant to imazamox/imazapyr and susceptible to chlorsulfuron. None of the samples were classed as resistant or developing resistance to the other screened herbicides, atrazine, difluflenican or glyphosate (Table 2).

The 75 paddocks visited during this survey contained 13 different crop types of which wild radish was collected from seven. Wheat was the major crop sampled comprising 39 of the 75 visited paddocks and also the major source of the wild radish samples providing 16 samples. Other crops from which wild radish samples were collected were alkaloid poppies (4 samples from 4 paddocks), field peas (3/3), pyrethrum (3/4), barley (3/10), potatoes (1/2), forage rape (1/1) and clover pasture (1/4). Crops visited that contained

no wild radish included lucerne, oats and carrots (each 2 paddocks) and triticale and onions (1 each). Five of the samples from wheat crops and all three from barley crops provided insufficient seed for resistance screening.

Table 2: Wild radish resistance levels for the screened herbicides (Res – resistant; DR – developing resistance; TR – total resistant = resistant and developing resistance combined).

Herbicide	Tested (no.)	Res (no.)	DR (no.)	**TR (%)**
chlorsulfuron	24	2	0	**8**
imazamox/imazapyr	19	6	1	**37**
atrazine	20	0	0	**0**
diflufenican	21	0	0	**0**
2,4-D amine	23	2	2	**17**
glyphosate	19	0	0	**0**

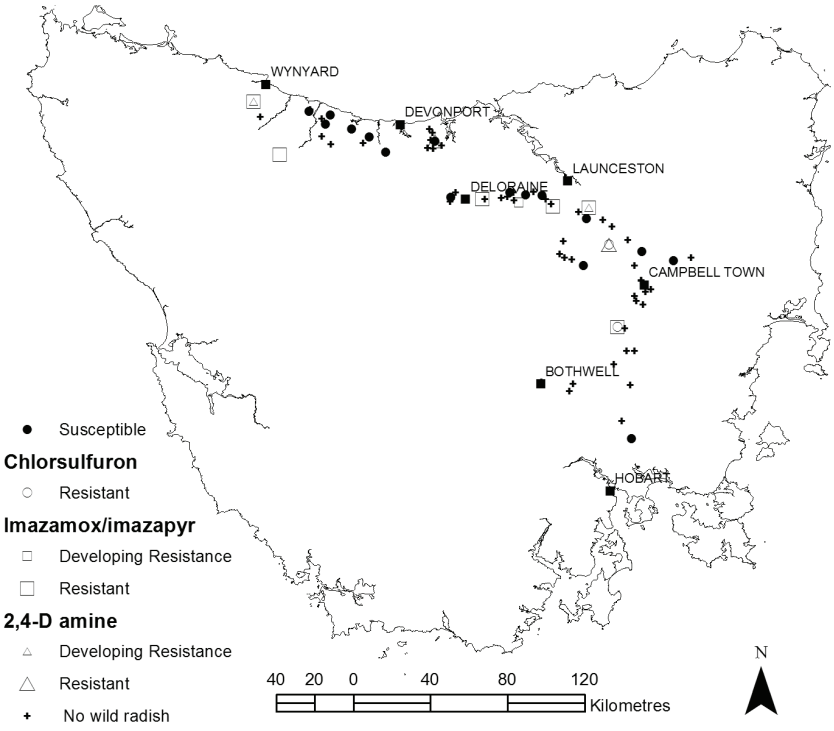

Figure 1: Map showing paddocks visited, wild radish locations and resistance status of wild radish

Discussion

Resistance was found to three herbicides in this survey, chlorsulfuron, imazamox/imazapyr and 2,4-D amine. The extent of resistance to chlorsulfuron was significantly lower than in Western Australia where 54% of samples were resistant and slightly lower than the 14% resistant found in southern New South Wales, however, resistance to imazamox/imazapyr was much higher in this survey than in southern New South Wales (37% cf. 20%) (Broster, et al. 2014; Walsh, et al. 2007). While no resistance to herbicides other than Group B was found in New South Wales, in Tasmania resistance was also found to a Group I (2,4-D amine) herbicide, albeit at an extent much lower than reported from Western Australia, 17% cf. 60% (Broster, et al. 2014; Walsh, et al. 2007).

The majority of the wild radish populations were found in the northern part of the surveyed region and at a higher proportion of paddocks visited. Only eight samples came from the Southern Midlands, Northern Midlands and Central Highlands LGAs from the 34 paddocks (24%) visited in these LGAs. Nine samples came from 23 visited paddocks (39%) in north coast LGAs (Waratah/Wynyard, Burnie, Central Coast, Kentish and Latrobe) while seven of the 18 paddocks (39%) visited in the Meander Valley contained wild radish. This higher prevalence of wild radish in the north of the surveyed area relative to the south was also noted when Tasmania was last surveyed for resistance to the grass weeds (J. Broster pers. obs.).

This could be the result of the different crops grown in the northern region to the Northern and Southern Midlands LGAs. In both the Northern and Southern Midlands LGAs the ratios of cereal crops to both vegetables and non-cereal broadacre crops were well above 1:1 compared with the north west region of the survey (Burnie, Central Coast, Kentish, Latrobe and Waratah/Wynyard LGA) where the ratios are below 0.25:1 (Broster, et al. 2012a). Crops such as pulses are less competitive than cereals and broadleaf weeds are also harder to control in these crops. That none of the barley or oat crops and less than 30% of the wheat crops visited provided sufficient wild radish seeds for resistance screening compared to all of the alkaloid poppy and pea crops and three of four pyrethrum crops supports this suggestion.

While this survey shows that the extent of resistance in wild radish is lower than in Western Australia, it is still significant. Resistance was present in two herbicide groups and wild radish was found in 43% of paddocks compared with New South Wales where wild radish was found in less than 10% of paddocks and resistant to only one herbicide group (Broster, et al. 2014; Broster, et al. 2012b). This suggests that in Tasmania the control of wild radish is of major importance and care needs to be taken to reduce the rate at which resistance develops further complicating wild radish control in the vast range of crops grown in Tasmania.

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