Emergence patterns and herbicide control of prickly lettuce (*Lactuca serriola* L.)

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Summary Prickly lettuce (*Lactuca serriola* L.), an annual or biennial plant, is becoming an increasing problem in southern New South Wales; mostly in cereals and legume pastures. This study showed that eight prickly lettuce populations differed in their final cumulative emergence in a seedling tray trial, ranging from 39 to 341 plants m^{-2}, however, they had similar emergence patterns, with 69% emergence in late autumn and early winter, 27% in later winter, 2.4% in spring in the first year after burial and only 1.6% emergence between autumn and winter in the second year. Prickly lettuce in wheat also followed similar emergence patterns, but it had higher emergence (7.5%) between autumn and winter in the second year. In addition, the total emergence in wheat was only one tenth of that in the seedling trays (without competition). Glyphosate, 2,4-D amine + glyphosate, metsulfuron-methyl + glyphosate, glufosinate ammonium and fluroxypyr controlled mature prickly lettuce plants by 90–95%. Paraquat consistently achieved 100% control either used alone or as a ‘double knock’ treatment.

Keywords Herbicides, weeds, weed biology, weed management.

INTRODUCTION

Prickly lettuce (*Lactuca serriola* L.) is of Eurasian origin and is adapted to a summer-dry Mediterranean climate (Weaver and Downs 2003). It is distributed globally: in Australia; Europe; North Africa; North America; and West Asia (Prince *et al*. 1978). It has spread northwards since the beginning of the 19th century (D’Andrea *et al*. 2009).

In Australia, it was first recorded in 1899 in the Upper Hunter, New South Wales (NSW) and is now widely distributed across a number of states, particularly in NSW, Victoria and South Australia (ALA 2018). It is a common weed of fallows, roadsides, waste lands and gardens, and it has recently become an increasing problem in cereals and lucerne pastures in southern NSW.

Lactuca serriola can grow up to 2 m and is highly competitive with crops and pastures. If left uncontrolled, it competes for soil moisture and nutrients in summer. *Lactuca serriola* causes soybean yield losses by 10% at a density as low as 0.2–1.2 plants m^{-2} and by up to 80% at densities more than 50 plants m^{-2}. However, it did not cause significant yield loss in winter wheat (Weaver *et al*. 2006). Similarly, no yield losses of cereals or grain legumes due to prickly lettuce were reported in Australia, but grain quality and harvesting efficiency were severely compromised (Amor 1986a). Flowering buds are cut together with grain during harvest, resulting in grain contamination and reductions in value. In addition, cut stems release a milky sap which can clog the harvesting machinery and increase the moisture content of the grain (Amor 1986a).

Lactuca serriola can quickly build up its population due to its prolific production of wind-dispersed seeds that have little or no innate dormancy (Marks and Prince 1982). Seed production per plant ranged from 2200 to 67,000 in soybeans, and up to 87,000 in a non-crop area (Weaver *et al*. 2006). In Australia, Amor (1986b) estimated that prickly lettuce plants in crop stubble produced 48,000 seeds per plant while it produced 900 seeds per plant when in competition with a wheat crop.

The light-weight achene with a pappus is easily dispersed by wind and through surface run-off. The tall stem also facilitates dispersal (Weaver and Downs 2003). Optimum temperatures for germination are 12–24°C, with little or no germination at constant temperatures below 8°C (Marks and Prince 1982). Temperatures 26–35°C induced secondary dormancy (Marks and Prince 1982). However, Mikulka and Chodová (2003) reported that 95% germination was achieved at 30°C.

Lactuca serriola emerges predominantly in autumn, followed by limited emergence in spring (Amor 1986a, Marks and Prince 1982, Weaver *et al.* 2006). It forms a rosette of leaves after emergence and develops a strong taproot. Plants are difficult to control with herbicides once they start to elongate (Weaver and Downs 2003). Mechanical control is ineffective as the plant regrows after cutting or harvesting and progresses to set seeds (Amor 1986a, Mikulka and Chodová 2003).

The weed has evolved resistance to ALS inhibitor herbicides in both Australia and the United States of

America (USA), to synthetic auxins in USA in 2007, and most recently to EPSP synthase inhibitor in Australia in 2015 (Heap 2018).

Field emergence information of *L. serriola* is scarce in southern NSW. Effective herbicide control options are limited for mature plants. This study was conducted to compare emergence patterns of *L. serriola* with and without a growing crop, in the field, and to evaluate a range of herbicide options of distinct modes of action on mature *L. serriola* plants.

MATERIAL AND METHODS

Prickly lettuce field emergence Seeds of four populations of prickly lettuce were each collected from low and high rainfall areas in southern NSW in January 2016. On 1 February 2016, 150 seeds of each of the eight populations were placed in seedling emergence trays (34 cm × 28 cm) filled with a mixture of coco peat potting mix and garden soil (1:1). Seeds of each population were evenly spread across the tray surface and then lightly covered by the peat/soil mix. The trays were maintained in the field under natural conditions in Wagga Wagga.

Two populations (one each from the high and the low rainfall zones) were used to determine the emergence pattern in wheat. Glyphosate was used as a pre-sowing knockdown. Wheat cv. Corack was sown at 60 kg ha^{-1} on 14 June 2016 and on 8 June 2017, respectively, with a 6-row cone seeder at 23 cm row spacing using coulter knife points and press wheels. A basal fertiliser DAP was applied at 135 kg ha^{-1} each year at sowing. Prickly lettuce seeds (1000 seeds m^{-2}) were sown in plots (3 × 1.3 m^2) on 15 April 2016. Any surviving or late emerging plants of prickly lettuce were counted and manually removed to prevent any new seed replenishment.

Field emergence of prickly lettuce was recorded at monthly intervals from April 2016 to December 2018 in both trials.

Herbicide options Two trials were established after wheat harvest in December 2015, one at Lake Cowal and the other at Temora, NSW. Average prickly lettuce density was 9.5 plants m^{-2} at Lake Cowal and 10 plants m^{-2} at Temora. The plot size was 2 × 16 m. A total of 17 and 19 treatments were imposed, respectively, at Lake Cowal and Temora sites, each including an untreated control. After the initial application, each plot was equally sub-divided with one half of the plot receiving an additional application of paraquat as a 'double knock' treatment.

Herbicides were applied using a hand-held boom sprayer, calibrated to deliver 100 L ha^{-1} at 2 bar pressure. The first application of herbicides was applied at the Lake Cowal and Temora on 10 and 15 December, respectively, and the 'double knock' paraquat application (600 g a.i. ha^{-1}) at Lake Cowal and Temora on 16 and 21 December 2015, respectively. At the time of herbicide applications, prickly lettuce plants were at the elongation/re-branching stage after being cut during crop harvest and not under moisture stress.

A visual rating (% of control) in the single knock treatments was conducted on 8 January 2016. The number of surviving prickly lettuce plants was also recorded in a 1 × 6 m strip in each plot on 2 February 2016.

Design and statistical analysis The experiments were designed as a randomised complete block with four replications in the two emergence trials. A split plot design with three replications was used for in the two herbicide trials. The main plot was the absence and presence of the 'double knock' paraquat treatment and the subplot was the single knock treatments. An ANOVA was conducted using Genstat.

RESULTS AND DISCUSSION

Emergence patterns of prickly lettuce in the field Prickly lettuce populations differed in field emergence patterns and there were three distinct groups (Figure 1).

The first group had two populations (BARM 01 and WAGG 12), and had the highest cumulative emergence between April and August (323–340 plants m^{-2}) in the first year and no further emergence in the second year. The second group had five populations, which had the major emergences between April and October (170–259 plants m^{-2}), followed by limited emergences between June and September in the second year. The final group had one population (L-COW 06P) and had the lowest emergence, which occurred between April and June (39 plants m^{-2}) in the first year, followed by little emergence afterwards. It is not clear why this population had low cumulative emergence as this population had a high germination (97.8%) tested soon after collection (data not shown). The average of the eight populations, about 69% emergence occurred in late autumn and early winter, 27% in late winter and 2.4% in spring in the first year after burial, with only 1.6% emergence between autumn and winter in the second year.

The two prickly lettuce populations from different rainfall zones also differed in the emergence patterns in the wheat crop, with higher emergence between April and August 2016 in the high rainfall population COOT 07 when compared to the low rainfall population BARM 01 (Figure 2). Both populations also had limited emergence between May and September in

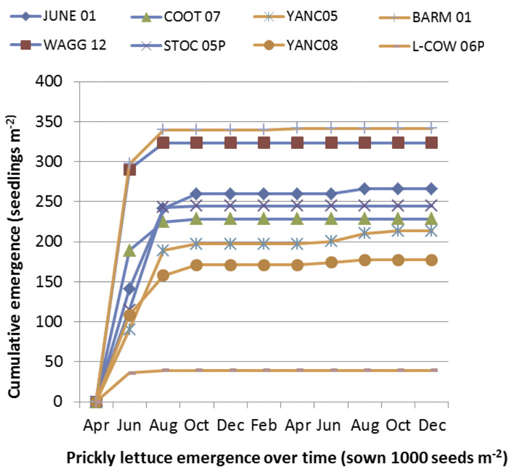

Figure 1. Emergence of prickly lettuce in seedling trays without crop competition under field conditions from April 2016 to December 2017. The number of seeds sown onto each tray was expressed as seeds m^{-2}.

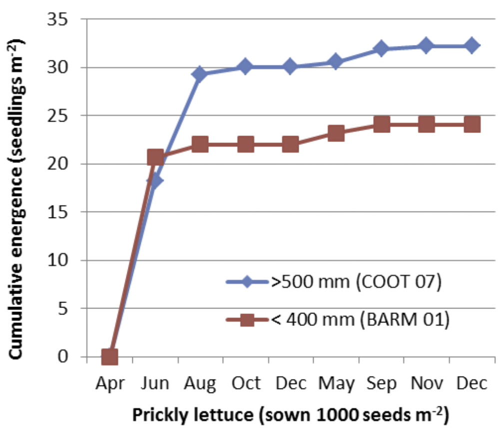

Figure 2. Emergence of prickly lettuce in a wheat crop grown under field conditions from April 2016 to December 2017 (the populations COOT07 and BARM 01 were collected from high and low rainfall zones, respectively).

the second year after sowing. On average, there was 69% emergence in late autumn and early winter, 22% in later winter and 1.4% in spring in the first year after burial, with 7.5% emergence between autumn and winter in the second year. The final cumulative emergence at 18 December 2017 was 32 and 24 plants m^{-2} for the high and low rainfall populations, respectively, while the final cumulative emergence for the two populations (COOT07 and BARM 01) in the above seeding tray trial in the absence of crop competition was 228 and 341 plants m^{-2}, respectively. These results indicate that the emergence of prickly lettuce in a standing crop is only one tenth of that in a bare ground.

The emergence patterns with and without a competing crop in this study support the findings of Prince *et al*. (1978) who reported that prickly lettuce emerged predominantly in autumn followed by limited emergence throughout winter, that a second emergence cohort occurred in spring and that no emergence occurred in summer due to the dry soil conditions. Prickly lettuce management should therefore focus on the major emergence cohorts in autumn prior to elongation stage to achieve effective control. A fallow control soon after harvest is also necessary to control the spring emergence cohort.

Effects of herbicides on prickly lettuce in summer fallows At Lake Cowal site, a single knock application of herbicides differed significantly in controlling prickly lettuce (Table 1). Five treatments, glyphosate, 2,4-D amine + glyphosate, metsulfuron-methyl + glyphosate, glufosinate ammonium and fluroxypyr achieved good control with more than 90% mortality, while the remaining 11 treatments only controlled 30–88% of prickly lettuce. The follow-up 'double knock' treatment with paraquat at 600 g a.i. ha^{-1} provided 100% control on prickly lettuce, even in the untreated plots which did not have the first knock of herbicide applications (data not shown).

The control of the single knock herbicide application at Temora was generally less effective than at Lake Cowal. Only four treatments had >80% control efficacy including 2,4-D amine + glyphosate, a prepacked mixture of 2,4-D amine and picloram + glyphosate, glufosinate ammonium and a prepacked mixture of amitrole (250 g L^{-1}) and ammonium thiocyanate (220 g L^{-1}). The other 14 treatments resulted in poor control of prickly lettuce (7–72%, Table 2). The follow-up 'double knock' treatment with paraquat also provided near 100% control on prickly lettuce, with less than 0.1 surviving plant m^{-2}.

In general, no single treatments, except paraquat achieved 100% control of mature prickly lettuce plant after crop harvest. Many plants, even though severely damaged, managed to survive and re-branch. The paraquat application was the only outstanding treatment, achieving complete control of the mature prickly lettuce plants.

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Table 1. Herbicide control efficacy on mature prickly lettuce plants at Lake Cowal.

Treatment	Rate (mL or g ha^{-1})	Adjuvant	Single_knock[A]	
			Visual rating[A] (%)	Density (plants m^{-2})[B]
2,4-D amine (700 g L^{-1})	1150 mL	Liase at 2%	30.0	3.7
2,4-D amine + glyphosate (540 g L^{-1})	515 mL + 1300 mL	LI700 at 0.3%	93.3	0.6
Glyphosate	1300 mL	LI700 at 0.3%	90.0	2.0
Fluroxypyr (333 g L^{-1})	600 mL	Uptake 0.5%	95.0	0.8
Fluroxypyr + glyphosate	600 mL + 1300 mL		88.3	2.4
Metsulfuron-methyl (600 g kg^{-1}) + glyphosate	7 g + 1300 mL		95.0	1.6
Oxyfluorfen (240 g L^{-1}) + glyphosate	75 mL + 1300 mL	BS1000 at 1%	86.7	2.1
Dicamba (500 g L^{-1}) + glyphosate	240 mL + 1300 mL		85.0	4.5
Glufosinate ammonium (200 g L^{-1})	4000 mL		91.7	1.8
Mixture of amitrole (250 g L^{-1}) and ammonium thiocyanate (220 g L^{-1})	5600 mL	LI700 at 0.3%	85.0	1.6
Mixture of 2,4-D amine (300 g L^{-1}) and picloram (75 g L^{-1})	700 mL		53.3	3.9
Mixture of MCPA (250 g L^{-1}) and diflufenican (25 g L^{-1})	1000 mL		81.7	3.7
Carfentrazone-ethyl (240 g L^{-1}) + MCPA amine (750 g L^{-1})	100 mL + 333 mL		76.7	2.5
Clopyralid (300 g L^{-1}) + LVE MCPA (570 g L^{-1})	150 mL +1000 mL		63.3	2.4
LVE MCPA	1000 mL		40.0	4.3
Mixture of aminopyralid (10 g L^{-1}) and fluroxypyr (140 g L^{-1}) + LVE MCPA	750 mL +1000 mL		86.7	3.5
Control			0.0	6.2
$l.s.d_{0.05}$			17.93	1.89

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Table 2. Herbicide control efficacy on mature prickly lettuce plants at Temora.

Treatment	Rate (mL or g ha^{-1})	Adjuvant	Visual rating[A] (%)	Density (plants m^{-2})[B]	
				Single_ knock[A]	Double_ knock[A]
2,4-D amine (700 g L^{-1})	1150 mL	Liase at 2%	51.7	4.6	0.0
2,4-D amine + glyphosate (540 g L^{-1})	515 mL + 1300 mL	LI700 at 0.3%	80.0	1.2	0.1
Glyphosate	1300 mL	LI700 at 0.3%	78.3	4.2	0.0
Metsulfuron-methyl (600 g kg^{-1}) + glyphosate	7 g + 1300 mL		28.3	5.5	0.0
Oxyfluorfen (240 g L^{-1}) + glyphosate	75 mL + 1300 mL	BS1000 at 1%	60.0	8.7	0.0
Dicamba (500 g L^{-1}) + glyphosate	240 mL + 1300 mL		71.7	2.6	0.0
Fluroxypyr (333 g L^{-1})	600 mL	Uptake at 0.5%	53.3	6.8	0.1
Fluroxypyr + glyphosate	600 mL + 1300 mL		63.3	5.7	0.1
Mixture of 2,4-D amine (300 g L^{-1}) and picloram (75 g L^{-1}) + glyphosate	700 mL + 1300 mL		81.7	2.6	0.1
Triclopyr (600 g L^{-1}) + glyphosate	700 mL + 1300 mL	Uptake 0.5%	53.3	5.8	0.1
Saflufenacil (700 g kg^{-1}) + glyphosate	34 g + 1300 mL	Bonza at 1%	53.3	5.0	0.1
Glufosinate ammonium (200 g L^{-1})	4000 mL		83.3	1.3	0.1
Mixture of amitrole (250 g L^{-1}) and ammonium thiocyanate (220 g L^{-1})	5600 mL	LI 700 at 0.3%	81.7	4.9	0.1
Mixture of 2,4-D amine (300 g L^{-1}) and picloram (75 g L^{-1})	700 mL		30.0	6.1	0.1
Carfentrazone-ethyl (240 g L^{-1}) + MCPA amine (750 g L^{-1})	100 mL + 333mL		6.7	5.4	0.1
Clopyralid (300 g L^{-1}) + LVE MCPA (570 g L^{-1})	150 mL +1000 mL	Uptake at 0.5%	30.0	6.3	0.0
LVE MCPA	1000 mL		28.3	5.7	0.0
Mixture of aminopyralid (10 g L^{-1}) and fluroxypyr (140 g L^{-1}) + LVE MCPA	750 mL +1000 mL		58.3	5.8	0.0
Control			0.0	7.4	0.0
l.s.d$_{0.05}$			21.6	3.9	0.3

[A] Single knock treatments applied on 15 December 2015 and the 'Double knock' paraquat on 21 December 2015, followed by a visual rating in the single-know treatments conducted on 08 January 2016.
[B] The surviving prickly lettuce plants were recorded on 02 February 2016.