The impact of emergence time on silverleaf nightshade (*Solanum elaeagnifolium*) development and growth

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Summary Silverleaf nightshade is a serious perennial weed in Australian crop and pasture systems. Improved understanding of its life cycle will be useful for silverleaf nightshade management. This research showed that the development and growth of silverleaf nightshade plants are significantly affected by time of emergence. Plants (both root- and seed-generated) that emerged early in the season, such as in September and November, were significantly taller and produced more dry weight and fruits than plants that emerged in the January and March cohorts. This study also suggests effective management of silverleaf nightshade should be carried out before December to reduce seed production.

Keywords Silverleaf nightshade, *Solanum elaeagnifolium*, cohort, fecundity.

INTRODUCTION

Silverleaf nightshade (*Solanum elaeagnifolium*) is a summer growing perennial weed that propagates both sexually and asexually. Sexual reproduction is critical for dispersal of this weed, while vegetative propagation mainly contributes to localised infestations and reinfestation. Within Australia emergence from the seedbank and rootbank can occur in spring and autumn and plants are sensitive to frost and natural senescence in May (Stanton *et al.* 2009).

Ecological and phenological studies provide important information for weed management and for predicting seed production, infestation density and dynamics (Swanton and Murphy 1996). Boyd and Murray (1982) report that delay in seedling emergence reduced the amount of plant dry weight and fruits of silverleaf nightshade in America. However, such information is scarce in Australia. In addition, information on the impact of the stem emergence cohort (generated from roots) on the development and growth of silverleaf nightshade is not available.

The objectives of this study were to (i) determine the effect of different seedling or stem emergence cohorts on the development and growth of silverleaf nightshade and (ii) quantify and compare the life cycles between four emergence cohorts at September (Sep), November (Nov), January (Jan) and March (Mar).

MATERIALS AND METHODS

Seedling emergence experiments were conducted from Jan 2011 to May 2012, while stem emergence experiments from roots were conducted from Mar 2011 to May 2012. Experiments were conducted using 20 cm diameter pots filled with a 4:1 mixture of sandy loam and potting mix. Ten grams of slow release Osmocote fertilizer (16.6% nitrogen, 2% phosphorus, 6.6% potassium and 7.9% sulfur) was included in each pot. Pots were arranged in a randomised complete block. Experimental design was 4 cohorts × 3 replicates (pots). Treatments were watered as needed. All treatments were initially established in a glasshouse (25°C for 16 hours and 10°C for 8 hours) for a month then transferred to a green house where they were exposed to ambient conditions.

Seedling emergence Silverleaf nightshade fruits were hand harvested from a roadside near Narrandera, NSW (longitude: -34°46.53, latitude: 146°25.73) in Jan 2011. Fruits were then air dried and crushed to collect seeds. Seeds were washed and pre-germinated as described by Stanton *et al.* (2012).

Ten seedlings were sown in each pot at 1 cm depth in Jan, Mar, Sep and Nov 2011, separately, to mimic seedling emergence cohorts in each month. After 25 days, plants were thinned to six seedlings per pot.

Samples were taken 30, 60, 90 and 120 days after planting and after the first frost in May for root dry weight, shoot dry weight, fruit and flower dry weight and root: shoot ratio. Plants growing in Jan and Mar cohorts were harvested in May 2011 while in Sep and Nov cohorts plants were harvested in May 2012. Measurements were also taken every 30 days to determine plant height, number of leaves (leaf number on the main stem), number of fruits, time to first flowering and the number of stems (only measured for stem emergence experiments).

Stem emergence from roots Roots of silverleaf nightshade were collected from Narrandera in Mar, Sep and Nov 2011 and Jan 2012. Root samples were placed in ziplock plastic bags with moist soil for transport (Stanton *et al.* 2011). Root samples were trimmed to 10 cm length (1.0 g to 3.5 g) and buried horizontally at 4 cm depth in trays (13 × 8 × 4.5 cm) using the same soil medium as described above. The trays were maintained in a glasshouse for a month while stem emergence occurred. Regenerated plants were transplanted into 20 cm diameter pots (one plant in each pot) in a green house. The same measurements were made on root-generated plants as described above.

Statistical analysis The software R v. 2.14 was used for the statistical analyses. Root dry weight, shoot dry weight, root: shoot ratio, number of stems, number of leaves, plant height, and time to first flowering were log transformed before analysis. One-way ANOVA was conducted to analyse the impact of cohort on the time to first flowering and two-way ANOVA was utilized to test the impact of cohort and growth duration (1 month, 2 months, *etc.*) on the other measured variable. Fisher's LSD test at P <0.05 was used to determine statistically different means.

RESULTS AND DISCUSSION

Cohort and growth duration significantly affected the root dry weight, shoot dry weight, number of leaves and plant height of both seed- and root-generated silverleaf nightshade (Table 1). Plants generated from both seeds and roots in the Sep and Nov cohorts grew significantly taller and had larger biomass than Jan and Mar cohorts.

Cohort significantly affected the time to first flowering (Table 1). Root-generated plants from the Sep, Nov and Jan cohorts flowered, but plants from the Mar cohort did not flower before the final harvest in May. In addition, a significantly ($p < 0.05$) longer vegetative phase was observed in the Sep and Nov cohorts. First flowers were observed 79.7 ± 6.7, 63.3 ± 3.1 and 50.0 ± 1.0 days after planting in the Sep, Nov and Jan cohorts, respectively (Figure 1). By contrast, seedlings only flowered in the Sep and Nov cohorts. Similar to root-generated plants, the vegetative phase was significantly longer in the Sep cohort, with time to first flowering decreasing from 110.0 ± 2.6 in the Sep cohort to 83.7 ± 12.9 in the Nov cohort).

Fruit production of root-generated plants was significantly ($p < 0.001$) affected by cohort, growth duration and the interaction of these two factors. Fruit and flower dry weight was significantly ($p < 0.001$) affected by cohort and growth duration in root-generated silverleaf nightshade (Table 1). Fruit production of root-generated silverleaf nightshade peaked at the sixth (126.0 ± 26.5), fourth (35.0 ± 8.2) and second (1.7±1.2) growing month in Sep, Nov and Jan cohorts, respectively (Table 2 and Figure 2). These three mean

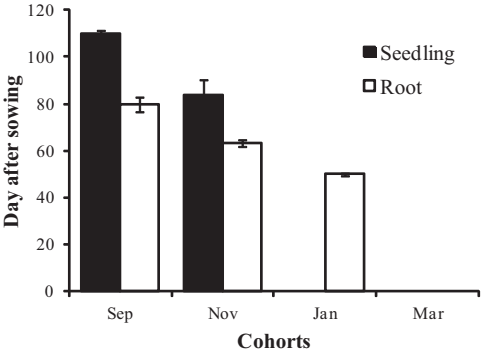

Figure 1. Time to first flowering in silverleaf nightshade at different emergence cohorts.

Table 1. Summary of ANOVA results. Values are p-values, ** = p <0.01 and *** = p <0.001.

Source	RDW	SDW	RS	NOSt	NOL	PH	FDW	NOF	TF
Root									
Cohort	***	***	0.07	0.65	***	***	***	***	***
GD	***	***	0.52	0.68	***	***	***	***	-
Cohort*GD	***	***	**	0.40	***	***	0.90	***	-
Seedling									
Cohort	***	***	***	-	***	***	0.28	***	*
GD	***	***	***	-	***	***	**	***	-
Cohort*GD	***	***	***	-	***	***	0.25	***	-

RDW: root dry weight, SDW: shoot dry weight, RS: root: shoot ratio, NOSt: the number of stems, NOL: number of leaves, PH: plant height, FDW: fruit and flower dry weight, NOF: number of fruits, TF: time to first flowering and GD: growth duration.

peak fruit production durations were the same on the calendar month (Mar).

Fruit production of seed-generated plants was significantly ($p < 0.001$) affected by cohort, growth duration and the interaction of these two factors as well. But fruit and flower dry weight was significantly ($p < 0.01$) affected by growth duration (Table 1). Similar to the root-generated silverleaf nightshade, fruit production of seed-generated plants increased with length of growth duration (Table 3 and Figure 3), resulting in a higher number of fruit produced in the Sep cohort compared to the Nov cohort. Similarly, fruit production of seed-generated plants also peaked at Mar.

Anecdotal evidence suggested that silverleaf nightshade seedlings do not flower in the first year under Australian climatic conditions. However, this study suggests that silverleaf nightshade seedlings that emerge in Sep and Nov can flower and set seeds in the first year of growth. Spring rainfall events can encourage seedling emergence. It is important to control these seedlings to minimize input into the seedbank and rootbank. Average fruit production per plant of silverleaf nightshade in early summer seedling cohorts was 13.3 in America (Boyd and Murray 1982) which is similar to this investigation (22.3 ± 2.5, in Sep cohort). This research also highlighted that fruit of silverleaf nightshade started to show up between December and January and peaked in March. According to this, effective management of silverleaf nightshade should be carried out before December to reduce seed production.

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Table 2. Fruit production per plant in different root-generated silverleaf nightshade cohorts.

GD	Cohort		
	Sep	Nov	Jan
2M	-	-	1.7[a]
3M	0.7[a]	33.7[b]	1.7[a]
4M	65.0[c]	35.0[b]	
5M	109.7[d]	34.3[b]	
6M	126.0 [d]		

GD: growth duration. 2M: second month, 3M: third month, *etc*. Values sharing the same letter are not significantly different according to Fisher's LSD test ($P < 0.05$).

Table 3. Fruit production per plant in different seed-generated silverleaf nightshade cohorts.

GD	Cohort		
	Sep	Nov	Jan
3M	-	1.1[a]	-
4M	4.1[b]	5.2[b]	-
5M	20.1[c]	5.5[b]	
6M	22.3[c]		

GD: growth duration. 3M: third month, 4M: fourth month, *etc*. Values sharing the same letter are not significantly different according to Fisher's LSD test ($P < 0.05$).

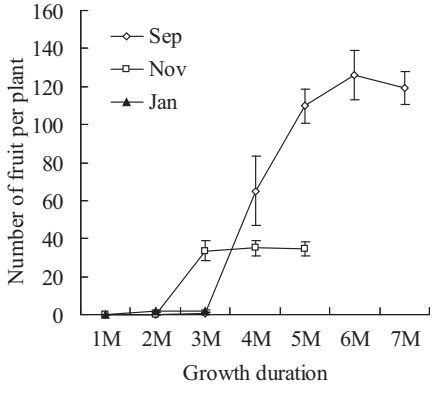

Figure 2. Fruit production in different root-generated silverleaf nightshade cohorts. 1M: first month, 2M: second month, *etc*.

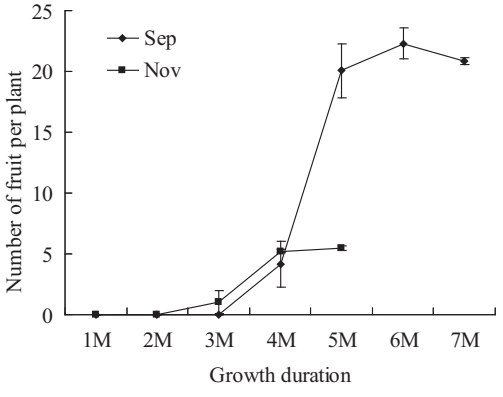

Figure 3. Fruit production in different seed-generated silverleaf nightshade cohorts.

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