Root regenerative ability of silverleaf nightshade (*Solanum elaeagnifolium* Cav.) in the glasshouse

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Abstract

Silverleaf nightshade is considered amongst the worst weeds of crop and pasture systems in Australia due to its extensive root system. Cultivation may exacerbate the problem due to the regenerative capacity of the root system. Glasshouse experiments were conducted to determine the importance of cultivation in the spread of silverleaf nightshade by investigating the regenerative abilities of various root fragment lengths (1, 2.5, 5 and 10 cm) buried at three soil depths of 2.5, 5 and 10 cm. Regeneration occurred from root fragments as short as 1 cm, with shoot production increasing with root fragment length. Optimum burial depth was 5 cm for 1 and 2.5 cm root fragments, while 5 and 10 cm root fragments were equally prolific at stem production from the 2.5 cm burial depth. High levels of fragment mortality occurred in 1 cm fragments, with mortality levels significantly declining as fragment length increased. This research suggests that minimum tillage techniques should be encouraged on areas with silverleaf nightshade infestations. Implements should be thoroughly cleaned before leaving the infested area, as even short root fragments adhered to machinery are capable of starting a new infestation in a clean field.

Introduction

Silverleaf nightshade (*Solanum elaeagnifolium* Cav.) is a deep-rooted, summer-growing perennial weed of the Solanaceae family that grows in the cropping/pasture zone of southern Australia. Silverleaf nightshade arrived in Australia in the early 1900s as a contaminant of grain and fodder (Parsons and Cuthbertson 2001). Isolated patches of the weed appear to increase in size slowly (Moore *et al.* 1975) and it was not until the 1960s that silverleaf nightshade became an important weed (Cuthbertson *et al.* 1976).

Surveys report that silverleaf nightshade infested nearly 22 000 ha in south-eastern Australia in the early 1970s, with 90% on the infested land being used for agricultural purposes (McKenzie 1976). There was a five-fold increase in area infested within twenty years, with 140 000 ha infested by 1992 (Heap and Carter 1999). Silverleaf nightshade is a declared noxious weed in mainland states of Australia where it occurs and is difficult to eradicate once established.

Worldwide, silverleaf nightshade is a significant weed of cotton and grain sorghum (Boyd and Murray 1982) and wheat and lucerne (Boyd and Murray 1982, Hoffmann *et al.* 1998) and can cause important economic losses. Grain yield losses of 12% were reported from Australia as a result of an infestation of 9 plants m^{-2} (Leys and Cuthbertson 1977). Yields from North American cotton crops indicate less effect by silverleaf nightshade when irrigated, suggesting that competition for moisture is a significant factor (Green *et al.* 1988). A survey of 254 land managers in south eastern Australia estimated that average total farm impact of silverleaf nightshade was $1730 per year in direct control costs and $7786 in lost production (McLaren *et al.* 2004).

Seed and root fragments are dispersal propagules for silverleaf nightshade (Wapshere 1988, Richardson and McKenzie 1981). Seed can be dispersed by livestock by attachment to fibre or via ingestion, mechanically by attachment to vehicles or machinery and naturally via wind or water movement. Root fragments may be dispersed as a contaminant of agricultural produce or attached to machinery (Gmira *et al.* 1998, Wapshere 1988).

The extensive root system consists of a main vertical taproot to depths of 2 m or more (Monaghan and Brownlee 1979, Richardson 1979, Richardson and McKenzie 1981) and numerous lateral roots in the upper soil layers. Cultivation can lead to root fragmentation and therefore plays an important role in increasing the density of silverleaf nightshade infestations and the spread in a localized area. The type of cultivation will influence root fragment size and burial depth. Previous research (Richardson and McKenzie 1981, Boyd and Murray 1982) reports the effect of single burial depths on regeneration of shoots, but the interaction between burial depth and root fragment length is not clearly understood. In a similar deep-rooted perennial solanum weed, Faulkner and Young (2006) reported that root fragments of prairie ground cherry (*Physalis viscosa* L.) as short as 1.5 cm were capable of forming new plants. The aim of this study was to determine the ability of various lengths of silverleaf nightshade taproot to regenerate from different depths in the soil. It is hypothesized that reduced cultivation will reduce the opportunity for silverleaf nightshade propagation from root fragments.

Materials and methods

Silverleaf nightshade roots were collected in October 2006 and October 2007 from a cropping field near Narrandera, NSW. The field had an average silverleaf nightshade infestation of 5.5 shoots m^{-2} and root material was located by the presence of dead shoots from the previous season. Root material was exhumed, dead aerial growth removed at the crown and the roots placed in a plastic container with moist soil for transport.

The experiment was repeated over two years using six replicates in 2006 and four replicates in 2007 respectively. A randomized compete block design was used with two variables, root fragment length (1, 2.5, 5 and 10 cm) and root burial depth (2.5, 5 and 10 cm).

A 10 cm root fragment was used for each pot, and was cut into ten, four and two fragments respectively for the 1, 2.5 and 5 cm length treatments. Therefore, there were 10, 4, 2 and 1 pieces of root fragments for the 1, 2.5, 5 and 10 cm length treatments, respectively. Each fragment was weighed then placed into 20 cm diameter pots partially filled with a 4:1 mixture of sandy loam and potting mix. Root fragments were then covered with the same media to achieve burial depths of 2.5, 5 and 10 cm. Pots were maintained in a glasshouse and watered regularly.

Shoot emergence was monitored every three to four days for each root fragment for six months, then aerial growth was harvested at the soil surface and fresh weight recorded. Root fragments were exhumed individually, washed of excess soil, blotted dry and root weight recorded.

Root fragments that had not lost weight or had produced shoots were classified as alive. Root fragments that had not produced a stem and had lost weight were classified as dead. The average weight gain or loss was determined for the live and dead fragments, respectively. Mortality for each pot was determined as the percentage of dead root fragments in the pot. Data were analysed using analysis of variance and post hoc Fishers tests used to determine statistically different means.

Results and discussion

There was no significant difference between years in regard to the emergence of stems, therefore combined data are presented. Burial depth (P <0.001) and root fragment length (P <0.001) had significant impacts on the time to first stem emergence (Table 1). Generally, average time to first stem emergence increased with burial depth except for the 2.5 and 5 cm length treatments buried at 5 cm depth, where emergence time was the same as, or shorter than, emergence from 1 cm burial depth. Emergence from 10 cm soil depth occurred around one week later than emergence from 2.5 and 5 cm soil depths, except for 1 cm root fragment lengths which did not emerge from 10 cm soil depth. The last emergence from all depths occurred after three months, with the average time to emergence being 18 days. Shallow burial depths of 2.5 cm may expose short root fragments to adverse fluctuating moisture and temperature cycles, while short fragments buried deeper may not have sufficient energy reserves to enable a shoot to reach the soil surface. Root fragments of 1 cm in lengths did not regenerate when buried at 10 cm depth. Increasing fragment length resulted in decreased time to first stem emergence, irrespective of burial depths.

One centimetre fragments in all replicates produced only one shoot at the burial depth of 2.5 cm, possibly due to the more extreme fluctuations in temperature and moisture levels. Richardson and McKenzie (1981) reported that 0.5 and 1.0 cm root lengths produce 0 and 0.2 shoots per fragment respectively when buried at 2 cm in pots in a glasshouse. Similarly, Faulkner and Young (2006) reported that shoot emergence decreased with decreasing fragment length in prairie ground cherry, a weed from the same Solanaceae family as silverleaf nightshade.

Burial depths significantly affected the number of emerged shoots per treatment (P <0.01). There was less shoot emergence at the 10 cm burial depth than at the 2.5 cm or 5 cm burial depth regardless of root fragment size (Table 2). Root fragment sizes also had significant effects on shoot emergence. The number of emerged shoots increased with fragment length at 2.5 cm or 10 cm soil depths. However, when root fragments were buried at the 5 cm soil depth, the 2.5 cm root length produced the highest number of emerged shoots (2.9 shoots pot^{-1}), while other root lengths only produced 1.6–1.9 shoots pot^{-1}. The 5 and 10 cm root fragments tended to produce a high number of stems when buried at 2.5 cm depth, and the 1 and 2.5 cm root fragments produced the most stems when buried at 5 cm soil depth, although these interactions were not significant (P >0.05).

The optimal depth for regeneration of silverleaf nightshade from root fragments was 5 cm, with fragments as short as 1 cm capable of producing shoots. Similarly, Boyd and Murray (1982) reported that 1–3 shoots are produced from 5 and 10 cm long root fragments respectively when buried at 8 cm depth in the field, with significantly more shoots produced from 15 and 20 cm long root fragments.

Root fragment mortality was significantly affected by fragment length (P <0.01) and to a lesser extent by burial depth (P <0.05). Root fragment mortality increases with decreasing fragment length. The 1 cm root length treatments had the highest root mortality (up to 99%) and the 10 cm root length treatments the lowest (10%), irrespective of burial depths (Table 3). Among the three burial depths, mortality levels were lower at 5 cm soil depth compared to the 10 cm depth for the 1 and 2.5 cm fragment lengths, which was in line with the shoot emergence being best from this depth, and mortality levels were greater at 10 cm burial depth.

No significant difference occurred in root and shoot weights in 2007 experiment, therefore only data from 2006 experiment are presented. The length of root fragment significantly affected shoot biomass (P <0.01) and root biomass (P <0.01) production (Table 4). The length of the original root fragment was directly proportional to the amount of new root and shoot biomass produced. The depth of burial did not affect shoot biomass production (P >0.05) (data not shown), however average root production was significantly decreased (P <0.05) at 10 cm compared to 5 cm depth (6.6 and 14.2 g, respectively), but there was no significant interaction between fragment length and burial depth. At 2.5 cm depth, only 9.4 g of root was produced, suggesting that conditions are less favourable closer to the soil surface. Initially, an average of 2.9 g of root was buried in each pot, therefore up to a six fold increase in average root weight occurred over the six months for the 10 cm root fragments. Where root fragments were deemed to have died, weight loss significantly increased as root fragment length decreased (P <0.01) until root length was 2.5 cm or less (Table 4). Root fragments of 10 cm length only lost an average of 3.5% of fresh biomass.

Root fragments less than 10 cm in length produced less biomass of roots and shoots during this experiment, than the 10 cm root length treatment. The reduction in vigour may lead to less seed production per plant in that season. However, if allowed to become established, the plant will most likely produce seeds in subsequent seasons. It is important that any new plants created as a result of cultivation are controlled. The reduced biomass of plants derived from small root fragments may lead to the plants being more susceptible to control with herbicides.

Silverleaf nightshade roots of 10 cm in length readily produce one or more shoots. Creation of smaller fragments through increased cultivation can increase mortality of individual fragments as fragment length decreases. However, the total number of viable fragments can result in a net increase in new plants being created as a consequence of cultivation unless roots are fragmented to 1 cm or less in length.

Fragmentation of roots can be accomplished by rotary hoes or multiple passes with discs (Culpin 1981). The current

Table 1. The effect of silverleaf nightshade root fragment length and burial depth on average time to first shoot emergence.

Root length (cm)	Burial depth (cm) 2.5	5	10
	Time for first shoot emergence (days)		
1	10	30	–
2.5	15	15	22
5	11	12	21
10	9	11	17
LSD (P = 0.05)		3.7	

Table 2. The effect of silverleaf nightshade root fragment length and burial depth on number of shoots produced per 10 cm of root.

Root length (cm)	Burial depth (cm) 2.5	5	10
	Average stems per 10 cm of root		
1	0.1	1.9	0.0
2.5	1.4	2.9	0.3
5	2.1	1.6	0.6
10	2.2	1.8	1.4
LSD (P = 0.05)		1.5	

Table 3. The effect of silverleaf nightshade root fragment length and burial depth on mortality levels.

Root length (cm)	Burial depth (cm) 2.5	5	10
	Mortality (%)		
1	99	83	99
2.5	53	40	80
5	20	35	55
10	10	10	10
LSD (P = 0.05)		27	

Table 4. The effect of silverleaf nightshade root fragment length on shoot and root biomass.

Root length (cm)	Fresh shoot biomass (g)	Live root fresh biomass gain (g)	Per cent weight loss for dead roots (%)
1	1.5	2.8	54.9
2.5	5.2	9.1	44.6
5	7.3	9.7	23.8
10	15.5	18.6	3.5
LSD (P = 0.05)	4.8	6.5	13.7

research has shown that cultivation can potentially encourage the regeneration and spread of silverleaf nightshade. To achieve any reduction in silverleaf nightshade populations, fragments would need to be either accumulated on the soil surface or buried to at least 10 cm depth to maximize mortality. The inability to control burial depth suggests that cultivation should be minimized in fields where silverleaf nightshade occurs.

Silverleaf nightshade root systems typically extend well below the normal cultivation depth (Stanton *et al.* 2009) and will form new stems in addition to the stems arising from fragments created by cultivation. Therefore, cultivation will not provide control of existing silverleaf nightshade populations.

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