Australian Best Practice Management Manual 2018

SILVERLEAF NIGHTSHADE Australian Best Practice Management Manual 2018

SILVERLEAF NIGHTSHADE

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CONTENTS

USING THIS MANUAL

This manual aims to provide a comprehensive reference for silverleaf nightshade management in Australia. Sections 1 and 2 provide summary and background information. Section 3 provides practical and specific management advice for a range of situations. Parts of Section 3 may be combined by managers to construct a customised plan for their individual situation. Section 4 presents case studies from various managers in different situations, and is a helpful additional guide for constructing a management plan. Take home message circles in each section summarise the main points at a glance.

INTRODUCTION

Silverleaf nightshade – brief overview

Silverleaf nightshade (*Solanum elaeagnifolium*) is a weed that reduces production in crop and pasture enterprises throughout the Australian wheat-sheep zone. It is a long-lived perennial plant with very deep, resilient roots. It grows during spring and summer and uses valuable moisture and nutrients needed for following crops and pastures. Crop yields can be reduced by 50 to 70% by dense infestations. Spread is relatively slow but, once established, it is extremely difficult to eradicate (Fig. 1). Established dense infestations are an ongoing annual burden on productivity and costs, and there are no suitable effective herbicide treatments that will kill dense infestations quickly.

SILVERLEAF NIGHTSHADE IS A SIGNIFICANT WEED THAT SHOULD BE CONTROLLED.

Silverleaf nightshade in Australia

First detected and reported in northern NSW in 1901, silverleaf nightshade has spread to most regions in the cropping areas of NSW, Vic and SA. WA has a relatively small number of infested farms, but it continues to spread. Qld also has some scattered populations. Despite its widespread distribution, there are vast areas of farming land where silverleaf nightshade has not been detected. Stopping its spread to clean land is a priority to minimise future losses. It is likely that most spread has been by livestock, particularly sheep. Silverleaf nightshade typically infests individual farms or paddocks as a mosaic within otherwise clean regions. Farm infestations range from a few isolated plants, through small patches in some paddocks, to heavily infested paddocks over the whole farm. Silverleaf nightshade is a sub-tropical plant, and fortunately does not readily establish from seed in the Mediterranean climate of Australia's wheat-sheep zone. It is not a significant weed of natural ecosystems or low-rainfall rangelands. Recent genetic studies suggest that there may be two major genetic groupings of silverleaf nightshade in Australia, centred in SA and NSW, that have intermingled over time (Gopurenko et al., 2014). Examination of silverleaf nightshade DNA from Australia and around the world has suggested that Australian silverleaf nightshade aligns with types found in South-West USA, and probably originated in the Kansas and Oklahoma regions (Gopurenko et al., in preparation, 2018).

FIGURE 1. Silverleaf nightshade can form dense monocultures under ideal conditions.

National Strategic Plan for silverleaf nightshade

Silverleaf nightshade was classified as a Weed of National Significance (WoNS) for Australia in 2012. There are 32 WoNS, and it is one of only a few agricultural weeds recognised. A National Strategic Plan for silverleaf nightshade was produced in 2013 covering priorities for management and investment in Australia. This plan has valuable additional information and can be found at: weeds.ala.org.au/WoNS/silverleafnightshade/docs/SLN_Strategic_Plan_030613.pdf

THIS MANUAL PROVIDES INFORMATION AND DESCRIBES BEST PRACTICE MANAGEMENT.

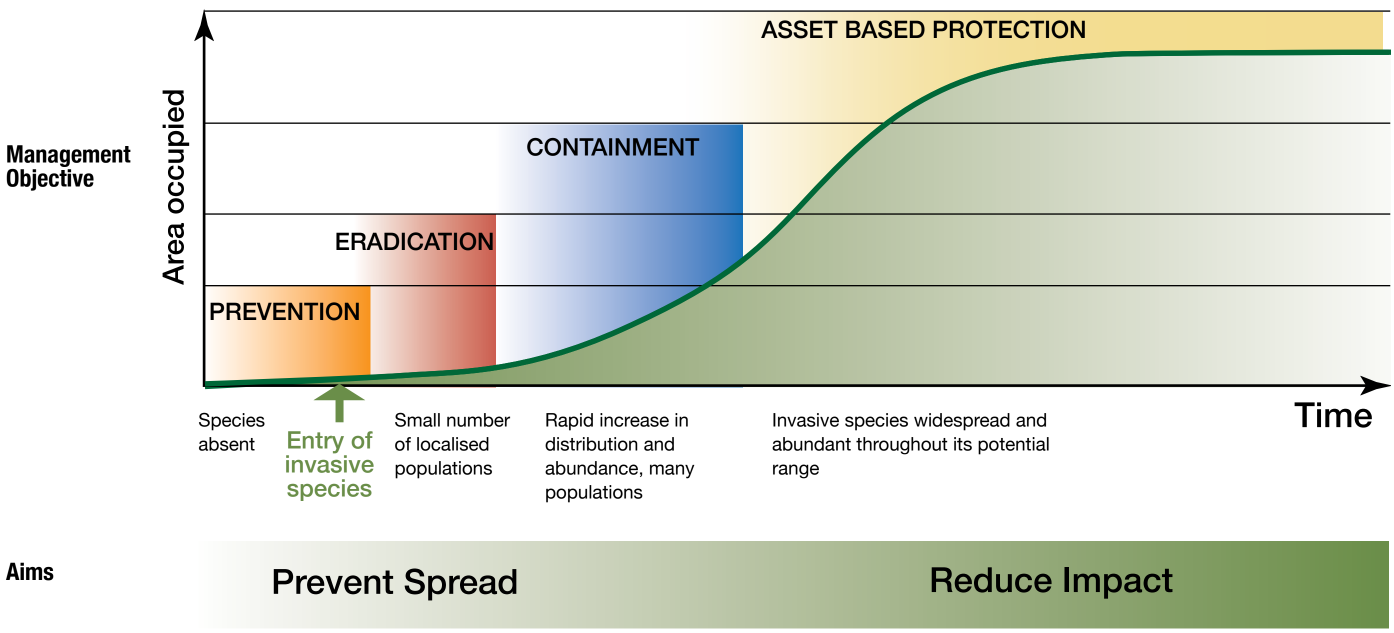
What can we do about silverleaf nightshade?

Action taken against silverleaf nightshade can reduce its spread and economic impact within our wheat-sheep zone. This will significantly increase farm profitability, and in some cases, viability. Figure 2 illustrates a typical "invasion curve" for weeds, and appropriate management options as the invasion situation gets worse over time. This curve applies to all geographic scales – from individual farms, to regions, and to Australia as a whole. In general, WA is approaching the Containment stage, while NSW, SA and Vic are at the Asset Based Protection stage.

Currently in Australia there are farms in every stage of the curve for silverleaf nightshade: Prevention, Eradication, Containment and Asset Protection. Reasons to manage silverleaf nightshade will vary depending on the stage of the curve. As with almost all weeds, the best, simplest and cheapest management plan is to prevent new infestations.

Sheep quarantine management and an effective surveillance strategy are critical for prevention. If infestations are detected, herbicide eradication treatments should be added to the management plan. If there are too many patches to eradicate, measures to prevent seed and fragment spread should be added to the plan. This typically affects livestock movement, and to a lesser extent farm machinery hygiene. When dense, established infestations are widespread, the emphasis shifts to protecting crop and pasture productivity. This will incur extra ongoing costs (e.g. herbicide, fertiliser, supplementary feeding) to minimise yield losses.

FIGURE 2. Stages of weed invasion with corresponding goals, management objectives and actions at each stage (Modified from Hobbs and Humphries, 1995).



SECTION 2

BIOLOGY AND THREAT

Impacts in Australia

General

Silverleaf nightshade reduces crop and pasture yields through competition for nutrients and water, and reduces land values of both infested and nearby properties (Fig. 3). It can also exude plant growth inhibitors, interfere with animal husbandry and harvesting practices, and is an alternative host for plant eating-insects and plant diseases and their vectors. It can reduce crop and pasture management options, such as the land use and the movement and sale of hay and livestock (Stanton et al., 2009). The Australian cereal cropping zone hosts a range of valuable major enterprises that are at risk from silverleaf nightshade, including production of cereals (e.g. wheat, barley, triticale, oats), pulses (e.g. peas, beans, lentils, lupins, vetch), oilseeds (e.g. canola), hay, grazing (e.g. sheep, cattle), and myriad minor enterprises. In addition, horticultural enterprises such as wine, vegetable and fruit production are at risk.

ANNUAL LOSSES IN AUSTRALIA ARE AROUND $60 MILLION TO $80 MILLION.

FIGURE 3. A dense paddock infestation of silverleaf nightshade in South Australia – valuable soil moisture is used during summer, reducing the productivity of following crops and pastures.

Crops and pastures

Silverleaf nightshade competes for water and nutrients in dryland and irrigated crops, and soil moisture losses have been measured at depths of up to 150 cm. It competes indirectly with winter crops and pastures through moisture and nutrient depletion during the summer fallow period. Yields of dryland crops are reduced over most of its range, and losses are most severe in sandy soils and seasons with low rainfall, but may be negligible on loams or clay-loam soils with abundant soil moisture (Heap, unpublished data). Yield loss experiments in winter cereal crops at 16 sites in NSW (1977) and SA (1990) estimated maximum yield reductions between 0 to 77%. Research results suggest that 20 to 40% yield losses are typical (Lemerle and Leys, 1991). Mature dry silverleaf nightshade stalks can also tangle in the tynes of reduced tillage seeding machines, causing expensive delays to seeding (Iggy Honan, pers comm.).

Exact annual losses to Australian agriculture are unknown, but estimates can be made. In SA (2017) an estimated 600,000 ha of crop land is infested and, assuming a modest average yield loss of 10%, silverleaf nightshade is causing annual crop yield losses of around $30M. Comparative observations and experience suggest that these figures may be $20M for NSW, and $20M for Vic. This adds up to an estimated $70M in yield losses for winter crops. It is assumed that the cost of any herbicide use will be neutralised by commensurate yield increases – i.e. estimates ignore herbicide costs. If pasture losses are estimated at 10% of crop losses, a further $7M is added. Additional minor losses (WA mixed farms, Australian horticultural

FIGURE 4. Silverleaf nightshade plants along irrigation banks can drop mature berries into the water, spreading seeds throughout the irrigation area.

crops (e.g. vines, cucurbits) are estimated at $2M. Based on these estimates, silverleaf nightshade probably causes losses to Australian agriculture of around $80M each year. A similar, independent, study based on NSW experience concluded that silverleaf nightshade is estimated to be directly costing Australian agriculture around $62M per year under current management practices. Additionally, the opportunity cost of industry not fully adopting Best Practice Management is around $50M per annum, with most of this cost experienced in higher rainfall agro-ecological zones (Behrendt et al., 2018, under review.).

Silverleaf nightshade in the WA wheat-belt occurs mostly in duplex soils, with about 30cm of ironstone sandy-loam over compacted grey clay, and summer rainfall is usually low. Consequently, most winter crops are grown using predominantly in-season rainfall and the importance of stored soil moisture is low. It is therefore possible that silverleaf nightshade is less damaging to crop and pasture yields in WA than in other states.

SILVERLEAF NIGHTSHADE IS A DEEP-ROOTED PERENNIAL PLANT FROM SOUTHERN USA, AND IT IS VERY DIFFICULT TO KILL.

The greatest unrealised threat to Australian agriculture is the widespread invasion of summer-irrigated land (Fig. 4), as silverleaf nightshade is a major problem in irrigated crops overseas. Silverleaf nightshade also infests hundreds of hectares of vineyards in SA, Vic and NSW, taking advantage of summer irrigation and low competition under and between the vine rows. It also grows in rice paddies, but flooding causes the infestations to decline rapidly. Abandoned rice paddies frequently revert to dense silverleaf nightshade infestations, as the soils slowly dry, and these are a problem for following crops.

Silverleaf nightshade competes directly with summer-growing pastures such as lucerne, and infestations occasionally restrict access to pasture beneath dense canopies. Emergence and growth rate of annual pastures in autumn can be delayed, resulting in reduced carrying capacity and a need for extended supplementary feeding. Glycoalkaloids produced by silverleaf nightshade may be hydrolysed in the gut to form nerve toxins such as alkaloids or alkamines. Sheep are more tolerant than cattle, and goats are unaffected (Boyd and Murray, 1981).

In Australia obvious acute poisoning of livestock appears to be rare. Silverleaf nightshade palatability for livestock is variable, and is influenced by availability of alternative pasture plants, the growth stage of silverleaf nightshade, and previous exposure to silverleaf nightshade. Farmers in WA, SA and NSW report that they do not notice any acute poisoning, but there remains the possibility of low-level chronic productivity losses. One report from the Eyre Peninsula of SA suggests that young lambs may develop a slight nasal discharge in reaction to grazing silverleaf nightshade shoots for the first time.

Identification and similar plants

Silverleaf nightshade (Fig. 5) is a member of the Solanaceae family of plants and is related to eggplant, potato, tomato, pepper and capsicum. It is relatively distinctive in the Australian wheat-sheep zone, but may be confused with two related native plants – quena (*Solanum esuriale*) and western nightshade (*Solanum coactiliferum*).

Green shoots emerge from the perennial root system from late spring to early summer (Fig. 6), depending on soil moisture. Seedlings are very rare in most seasons, although newly-emerged perennial shoots are often confused with seedlings (Fig. 7). Shoots are typically 30 to 60 cm high, but can grow to 100 cm high in an exceptional season (Fig. 8). There are commonly short (2 to 5 mm) prickles covering the stems, particularly the lower stems (Fig. 9).

Leaves have an outline shape similar to gum leaves, but the edges are often wavy, and they are "fuzzy" to touch. Leaf size and shape are very variable (Fig. 10), depending on clonal biotype, position on the plant, shading, and seasonal conditions.

Flowers are circular, 2 to 3 cm diameter, with a bright yellow cluster of anthers in the middle (Fig. 11). Flower petals are usually mid to dark purple, but may also be white, pinkish, or light to mid blue. It is not uncommon to find up to five distinct petal colours in the same paddock.

FIGURE 5. A typical silverleaf nightshade plant.

Round green berries with dark green stripes form and enlarge to 8 to 12 mm diameter (Fig. 12). Mature berries turn light yellow, and then orange-tan as they dry (Fig. 13). Dry berries can remain on dried stems into winter, if not disturbed (Fig. 14). Seeds are flat and oval, about 3mm long, and turn from green to tan-brown as they mature.

SILVERLEAF NIGHTSHADE CAN BE CONFUSED WITH SEVERAL NATIVE AUSTRALIAN PLANTS.

FIGURE 6. Newly-emerging shoots from perennial root systems are sometimes mistaken for seedling plants.

FIGURE 7. Silverleaf nightshade seedling with the second true leaf emerging. Note that shoots growing from perennial roots do not have the slender pair of cotyledon leaves.

FIGURE 8. Silverleaf nightshade shoot size depends on spring and summer rainfall – shoots of this size (90 cm high) are the largest likely to be encountered under most growing conditions.

FIGURE 9. Silverleaf nightshade stems showing typical tan coloured prickles. Note that some silverleaf nightshade types have very few prickles.

FIGURE 10. Silverleaf nightshade shoots from the same infestation exhibiting contrasting growth forms: from elongated (left) shoots, green berries and large leaves growing under tree shade, to shorter examples with mature berries growing in full sun (right).

FIGURE 11. Silverleaf nightshade flower, showing prominent yellow anthers.

FIGURE 12. Detail of developing berries. Note the dark green stripes and orange prickles on the stems.

FIGURE 13. Berries turning from green to a mature yellow-orange colour. As this happens the dark green stripes are no longer visible.

FIGURE 14. Mature berries form in late autumn, and may remain on the dead stems throughout winter.

There are some native Australian *Solanum* plants that look similar to silverleaf nightshade, and silverleaf nightshade was not recognised as a weed for years in SA because it was confused with native species. Silverleaf nightshade is most often confused with either quena (*Solanum esuriale*) or western nightshade (*Solanum coactiliferum*) in the Australian wheat belt. Table 1 illustrates the major differences between the three species. Silverleaf nightshade is taller and more robust than quena, and its leaves are wider and longer (10 cm compared to 5 cm) with wavier margins.

Quena is often found in sandy soils near creek beds or water pools. Western nightshade grows in sandy soils as a remnant of native vegetation and is not normally an aggressive weed (D.E. Symon pers. comm.). It is shorter than silverleaf nightshade and has smaller leaves. Sometimes it grows amongst silverleaf nightshade in cropping land in lower rainfall areas, and has been observed flowering in SA in mid-August. The earliest silverleaf nightshade flowers in SA is around eight weeks later, after mid-October.

Both of these species are widespread in NSW, SA and Vic, except for *S. coactiliferum* which is rare in Vic. There are many other native species with similar features to silverleaf nightshade (e.g. flowers or berries), and some of these are illustrated in Figs. 15 to 21. Assistance with identification may be sought from state Primary Industry departments, or state herbaria.

TABLE 1. Comparison between silverleaf nightshade (*Solanum elaeagnifolium*), quena (*Solanum esuriale*) and western nightshade (*Solanum coactiliferum*).

SILVERLEAF NIGHTSHADE (*Solanum elaeagnifolium*)





Plants: 40-60cm tall
Leaves: 5-10cm long
Flower: 5 pointed star
Anthers: (x5) 5 to 8mm long

Berries: spherical 8-14mm diam. Light green with dark green stripes. Orange when ripe.

QUENA (*Solanum esuriale*)

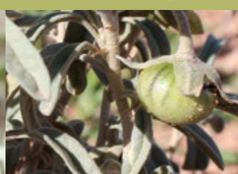



Plants: 15-30cm tall
Leaves: 5-8cm long
Flower: 5 pointed star
Anthers: (x5) 3 to 5mm long

Berries: spherical (ovoid) 10-15mm diam. Pale green, point on base. Light yellow/ brown when ripe.

WESTERN NIGHTSHADE (*Solanum coactiliferum*)





Plants: 15-30cm tall
Leaves: to 5cm long
Flower: usually 4 pointed
Anthers: (x4) 5 to 6mm long

Berries: flattened spherical 8-15mm diam. Faint green, stripes. Yellow/brown when ripe.

FIGURE 15. Silverleaf nightshade (right) and the native species western nightshade (left) from Warnertown in SA. Note the scarcity of spines on this biotype of silverleaf nightshade.

FIGURE 16. Silverleaf nightshade (left) and the native species western nightshade (right) from Warnertown in SA.

FIGURE 17. Western nightshade showing smaller leaves but similar flowers to silverleaf nightshade.

FIGURE 18. Quena growing near William Creek in SA, showing green berries that look similar to silverleaf nightshade.

FIGURE 19. Quena, showing leaves and flowers that look very similar to silverleaf nightshade.

FIGURE 20. *Solanum lithophilum* is a native species that has leaves and flowers that look similar to silverleaf nightshade.

FIGURE 21. *Solanum cleistogamum* is a native species with green and purple berries and long prickles.

Origin, distribution and habitat

Silverleaf nightshade is probably native to the Monterrey region of north-eastern Mexico. It has spread to many countries and is now a major problem in Australia, Argentina, Greece, India, Morocco, North America and South Africa. Silverleaf nightshade was introduced to England in 1823 as an ornamental flowering plant (Anon., 1923). It was first reported in Australia at Bingara (northern NSW) in 1901, but the route of introduction is not known. Infestations were then recorded at Tenterfield (1907), North Melbourne (1909), Singleton (1914), Hopetoun (1918) and Cowra (1923) (Cuthbertson et al.,1976).

Silverleaf nightshade is adapted to a wide range of habitats, which contributes to its weediness in diverse regions around the world. It grows in warm, temperate regions of Australia with an annual rainfall of 250–600 mm, and in a range of soil textures and pH values. Most dense infestations occur in a band within the south-eastern Australian temperate wheat-sheep zone (Fig. 22), from northern NSW, through Vic, and across to western SA. Corresponding regions in WA have also been infested since the 1930s, and it has been recognised as a problem since the 1970s. The wheat-sheep zone has typically been used for mixed farming enterprises, with sheep and cattle grazing combined with cropping. This has provided silverleaf nightshade with seed vectors (livestock) and a suitable seed bed during both cropping and pasture phases of the farming rotations. The heaviest infestations occur on sandy soils with low organic matter. For example, in SA and Vic it grows on heavy clays but is most abundant on the light-textured soils of the Mallee. The largest infestations are on cropping and grazing land, with smaller infestations being found in irrigated pastures, orchards and vineyards, roadsides, channel banks, disturbed amenity areas and stockyards. Silverleaf nightshade rarely invades undisturbed forest or arid rangeland areas, and remnant infestations in non-agricultural land can usually be attributed to earlier cropping or grazing activities. It grows prolifically following inundation, but prolonged water-logging, for example in a rice paddy, kills the shoots.

Silverleaf nightshade is widely distributed throughout the wheat-sheep zones of NSW, SA and Vic, and has a significant foot-hold (c. 180 established infestations) in WA (Fig. 22). It extends into southern Qld, is recorded twice in Alice Springs township (NT), and is occasionally recorded in south-east Tas but is not considered naturalised there. The potential distribution map (Fig. 22) indicates that the wheat-sheep zone is most vulnerable to invasion, and that WA has large farming areas at risk. Concentration of distribution in the wheat-sheep zone is probably due to suitable climatic conditions, disturbed agricultural habitats and the movement of contaminated sheep, produce and machinery throughout the zone. The less frequent occurrence of silverleaf nightshade along the eastern slopes north of NSW and southern Qld is probably caused by greater competition from other summer-growing species, much less sheep production (major seed vectors), and a suite of native sub-tropical insects that attack eggplants and other exotic *Solanum* species, and possibly silverleaf nightshade (Rachel McFadyen, pers. comm., 2013).

Observations from North America suggest that silverleaf nightshade has the potential to spread to impact summer cropping areas of Australia, especially in the cotton production areas of northern New South Wales and southern Queensland. The near absence of livestock to spread seed to these enterprises may be preventing this so far.

In NSW it infests large areas of the southern and central sheep-wheat zone, the north-western slopes, and the Murrumbidgee Irrigation Area (Stanton et al., 2009). Infestations increased from an estimated 20,000 ha to 140,000 ha between 1977 and 1992. Its importance was not recognised until 1960 when a series of wet summers accelerated spread. It also occurs in northern NSW but as rainfall increases in more northerly areas silverleaf nightshade, and co-incidentally sheep production, are less common.

It was first recorded in SA in 1914, possibly introduced in hay from the USA. All SA infestations prior to 1958 were confused with the native quena (*Solanum esuriale*). It occurs mostly in the Upper South East, Mallee, Lower and Mid-North, and Eastern Eyre Peninsula regions. By 1978 SA had about 16,000 ha infested, increasing to greater than 40,000 ha by 1990, and it is now (2018) estimated to infest 600,000 ha.

SILVERLEAF NIGHTSHADE AFFECTS CROPS AND PASTURES IN SOUTHERN AUSTRALIA.

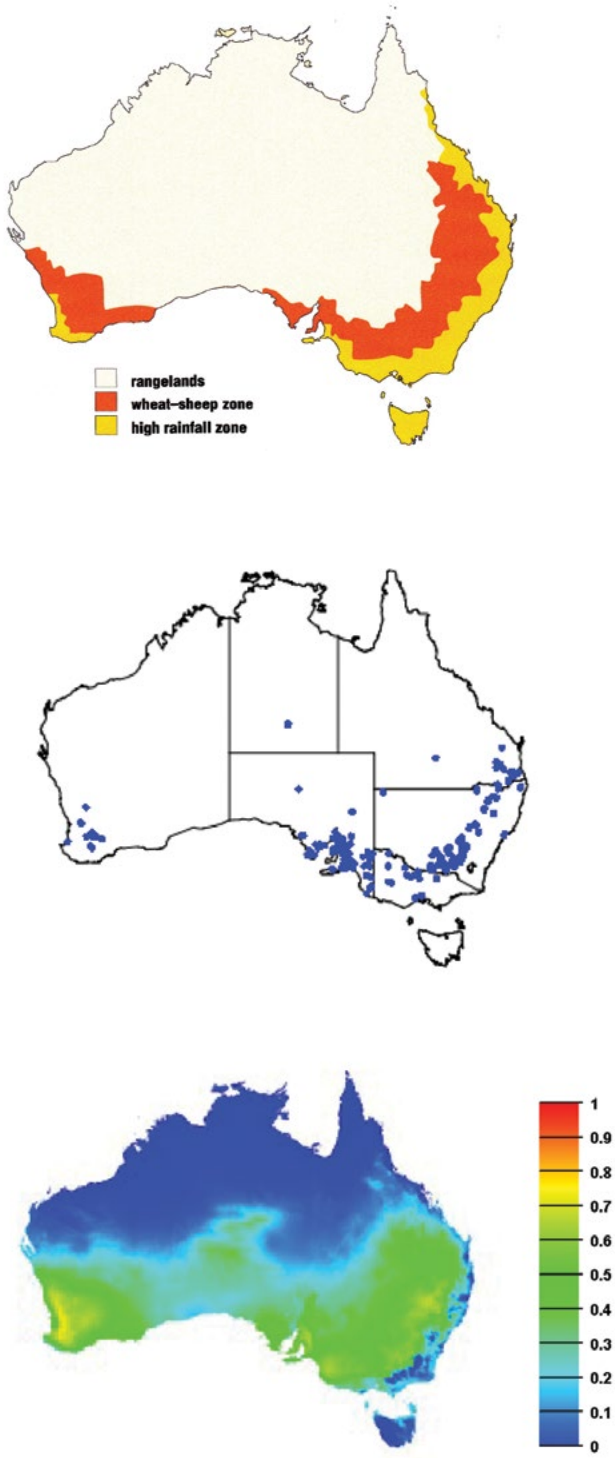


FIGURE 22. Australian wheat-sheep zone* (top); 2017 ALA silverleaf nightshade distribution (middle) **; and likely potential distribution (bottom): 0=Unlikely; 1=Likely (Wilson *et* al., 2011).

* ABARE Reproduced in a modified form in *Australia, State of the Environment, 1996*

** bie.ala.org.au/search?q=solanum+elaeagnifolium

In Vic silverleaf nightshade was declared a noxious weed in 1950. By 1973 there were an estimated 1,000 ha, with 90% occurring on six farms (similar to the current situation in WA). Infestations are now widespread, and occur throughout the Wimmera and Mallee regions in the west and north of Vic. The worst-affected areas are around Mildura (especially around Carwarp), Hopetoun, and Pyramid Hill.

In WA it was identified in 1950, and is now established on at least 180 farms in a band running from Perth south-east to Albany, and six to eight mixed farming properties are severely infested. It is currently established over only a small proportion of its potential high and medium risk distribution areas. It became a declared plant in WA in 1973, but was subsequently removed from the list in the late 1990s, and then re-instated in 2015. By 1978 it covered 150 ha, although only 17 ha of this area was densely infested. It probably arrived in Western Australia before 1921, possibly in Sudan grass (*Sorghum sudanense*) from eastern Australia.

Biology, life cycle and reproduction

The key to management of any weed is a good understanding of its biology and life cycle (Fig. 23). This information is used to identify points of vulnerability, and to design integrated management plans. The important questions to ask include where, how and when will it grow, and how does it spread?

Growth and development

Silverleaf nightshade is a shrub with a deep, extensive perennial root system and abundant fine root hairs. New shoots develop from buds on the roots each spring as the soil warms, and mature shoots are killed by cold during late autumn or early winter. Dead shoots stand through winter, retaining mature berries. In Australia shoots emerge from perennial roots in October to November and flowering commences in October and continues through to March. Herbicides, grazing or cultivation may extend the emergence of new shoots into late Autumn. In land used for agriculture, flowering and seed formation usually occur in sequential waves throughout spring and summer, influenced by rainfall (causing a new growth flush) and management strategies (e.g. grazing, spraying). In SA it is common to have at least two major flowering events during the growing season. Berry-shaped fruits normally form in January and then ripen and produce mature seeds about 4–8 weeks after fruit set.

Silverleaf nightshade is a significant weed primarily because it has an extensive and resilient perennial root system, and successful management strategies must reduce energy reserves stored in the roots. The deep root system allows silverleaf nightshade to survive drought, and to resist most management strategies. Root systems consist of two main parts: a main vertical tap root, and lateral horizontal roots that connect adjacent shoots. Shoots extend from near the top of the main tap root to the soil surface. About 70% of root mass is in the top 90cm of soil, but deep tap roots also reach to 3 to 4 m (Davis et al., 1945). The amount of energy stored in the roots as carbohydrates changes throughout the growing season and is an important consideration for management (e.g. timing of herbicide application). The root system uses stored energy to produce shoots in spring and levels are depleted to a minimum at flowering. During berry growth and seed formation levels rise again, and at the end of the growing season carbohydrates are exported back to roots from stems. After cultivation about 85% of new shoots arise from vertical tap roots and about 15% from horizontal lateral roots (McKenzie, 1980). Shoots can arise from as deep as 1.25 m over a period of 14 months (Davis et al., 1945).

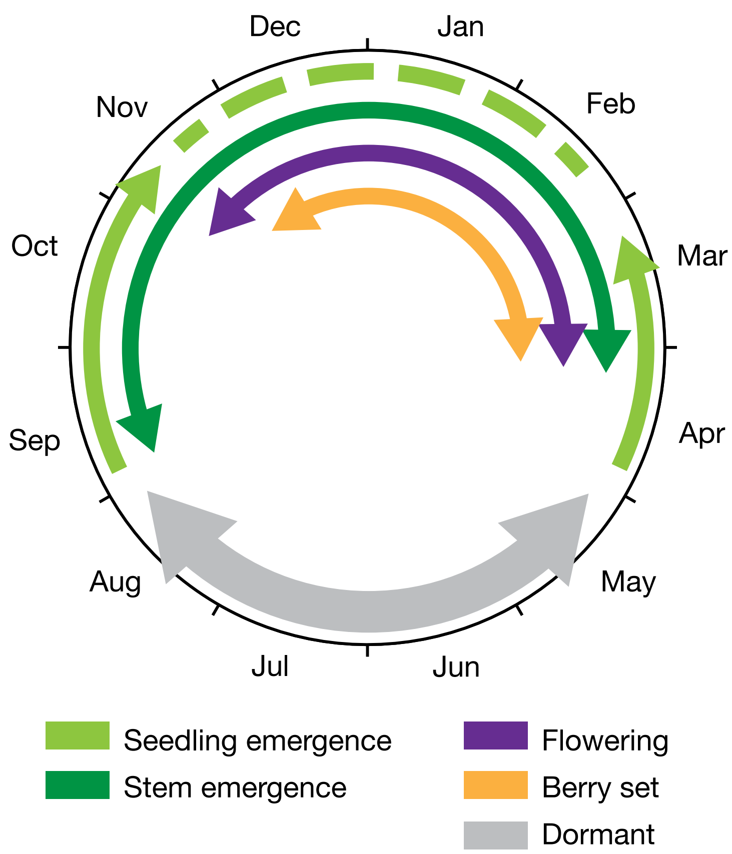


FIGURE 23. Typical annual growth cycle of silverleaf nightshade (NSW DPI).

Flowering

Flowering usually begins from mid-October to early January, depending on location, land use, seasonal rainfall and temperature. Flowers appear about three weeks after shoot emergence. Flowering and fruiting follow an indeterminate pattern, with some berries already formed or mature, while the same plant continues to produce new flowers (Fig. 24). Flowering and fruiting can continue through summer and autumn while conditions are suitable. Flowers are usually mid purple to purple-blue, but variation is common. In SA up to five or six different flower colours may occur within the same paddock (Fig. 25), including white-flowered colonies. Silverleaf nightshade flowers have both bisexual and male flowers on the same plant (andromonoecious) (Arthur, 2014) with conspicuous yellow anthers, and so are likely to be cross-pollinated by insects. Bees have been observed visiting silverleaf nightshade flowers in SA.

FIGURE 24. Silverleaf nightshade flower buds, flowers and various stages of berry development. Flowering will continue as long as conditions are favourable.

FIGURE 25. Five distinct flower colours found in one paddock near Pt. Pirie, SA. A similar array was observed in one paddock near Cleve, SA.

Seed and seedling biology

Shoots produce about 60 berries per season in Australia and each berry contains about 50 tomato-like seeds (Fig. 26). Soil seed banks in north-western Vic have been measured at 4,000 seeds per square metre (McKenzie, 1980). There has been little research done on the length of time seeds can remain viable in soil. Two studies in Australia (Heap and Honan, 1993; Stanton et al., 2012) have tracked survival of seeds buried under field conditions over several years. Both studies found a relatively rapid decline in viability, suggesting that silverleaf nightshade seed is not long-lived compared to some weeds.

The data suggest that the seedbank will probably be exhausted in about 6 to 8 years. This means that seeding must be prevented for at least this period of time before new seedlings are no longer a significant threat. It is likely that this survival time will be reduced if seed has passed through an animal gut, due to the effects of acid scarification on the seed coat and its gelatinous covering. Seeds within intact berries had higher survival for several years after burial, compared to buried bare seeds. Seed protected by berries may remain viable for a longer period, perhaps around 10 years. These observations highlight the importance of monitoring areas for new seedlings after the last silverleaf nightshade shoots have been controlled.

Germination occurs in light or darkness, and up to 80% of seeds can germinate under favourable conditions. Germination occurs when the soil is wet and temperatures are warm to hot. This typically occurs from October to March, especially following summer thunderstorms. Germination requires alternating temperatures and rates are highest with 15°C nights combined with 25°C days (Stanton et al., 2012). Large seedling emergence events are rare in Australia due to infrequent heavy rain during summer. A water soluble mucilaginous coating around the seed, which is reduced during soaking in water, is thought to chemically or physically inhibit germination. Alternate wetting and drying of seeds in soil accelerates germination.

FIGURE 26 (left). Mature silverleaf nightshade seeds – note the flattened oval shape.

FIGURE 27 (below). Silverleaf nightshade mature berries and seeds (left) and a range of seedlings from newly emerged with seed coat still attached, to two true leaf stage (right).

FIGURE 28. Silverleaf nightshade seedling with fully-expanded cotyledon leaves (similar to a tomato seedling) and the first true leaf emerging in the centre.

Emergence is favoured by soil disturbance. Seedlings (Figs. 27 to 29) can emerge from up to 60 mm deep in soil, but maximum emergence occurs from 30 mm. Seedling roots grow about 10 mm each day and seedlings clipped at the cotyledon stage or 15 days after emergence can regenerate (Boyd and Murray, 1982). On the rare occasions when large emergence events occur, seedling establishment and survival is typically very low. Most seedlings are killed by high temperatures and low soil moisture within a few weeks of emergence. Any survivors are then weakened by lower temperatures, and any herbicides applied, in late autumn and winter. As an example, mass seedling emergence events were recorded at silverleaf nightshade research sites at Ungarie (NSW) in 2007, and at Edinburgh (SA) in 2014. Subsequent monitoring failed to find any seedling survivors by the end of winter of the same years. As winter arrives most surviving seedlings turn yellow and rot due to cold temperatures and competition from winter-growing plants. This can occur even before the first frost of winter. Only rarely does a seedling survive winter and early spring in a suitable micro-habitat (Fig. 30), to resume growth in late spring. Subsequent growth during late spring allows its roots to grow deeper into moist soil and establish a viable perennial root system. Establishment of silverleaf nightshade seedlings is likely to occur more in northern NSW than in the rest of its range because repeated summer rainfall events, needed to sustain seedlings after emergence, are more frequent.

Although rare in Australia, successful seedling establishment leading to establishment of perennial colonies is highly significant because it facilitates long-distance spread and new infestations. As an example, in the WA wheat belt during the 2011/12 harvest there were five thunderstorm events totalling 125 to 150 mm over five weeks. Growers subsequently reported seeing a lot of new silverleaf nightshade patches, probably arising from surviving seedlings. Long-term modelling predicts that a successful seedling establishment event is expected to occur in about 1 in 10 years in the low rainfall area of Cleve, SA and 4 in 10 years in the high rainfall area of Parkes, NSW (Behrendt et al., 2018, under review.).

FIGURE 29. Silverleaf nightshade seedling with two true leaves emerged.

FIGURE 30. Silverleaf nightshade established as a perennial plant.

Vegetative reproduction

Silverleaf nightshade has an extensive, robust and resilient perennial root system (Fig. 31). Energy reserves stored within the root system allow the plant to survive underground to avoid low air temperatures during winter and early spring, resist most management strategies, and to rapidly re-establish a competitive shoot canopy during the warmer months. The network of lateral roots growing below the cultivation layer (15 to 60 cm deep) produce new daughter shoots and increase clonal colonies by 1 to 2 m in diameter each year. There are about five lateral shoots arising from each tap root, and these grow horizontally to about 2 m long before turning to grow down. Fragmentation damage caused by cultivation can increase shoot density as new shoots arise from buds on damaged roots. New shoots originate from 1 to 50 cm deep, depending on cultivation depth.

FIGURE 31. Excavated silverleaf nightshade root system on Eyre Peninsula in SA – note the depth of tap roots, and the horizontal connection between the two tap roots (Photo: Iggy Honan).

Spread

Silverleaf nightshade invasion at the district level typically begins with one roadside or paddock infestation, usually from seed. Clusters of nearby farms are then colonised, usually by movement of livestock that have recently grazed silverleaf nightshade berries. These distinct clusters can still be observed in some districts but usually, over 50 years or more, clusters overlap and coalesce into region-wide infestations. It is important to note that clean paddocks and farms can be protected from invasion, even in heavily-infested districts, by careful management and good farm biosecurity practices.

New infestations of silverleaf nightshade typically increase slowly within paddocks that were previously clean, and there may be a lag phase of at least 5 to 10 years between silverleaf nightshade seed introduction and recognition of a developing problem. Usually only a small number of colonies arise in the first year of establishment and often remain undetected. These plants produce berries containing viable seeds that can be dispersed to different parts of the paddock by sheep, vehicles, wind or other vectors. This annual process of seed dispersal may continue for a number of years before there is an "establishment window" created by an unusual series of summer or autumn rainfall events. At this favourable time a larger number of colonies can establish, and the problem will be more likely to be noticed. This pattern of seed dispersal and sporadic establishment continues over decades, increasing the total annual seed output within the paddock, and hence increasing the probability of rare establishment events occurring. Although spread by seed is relatively rare, it is highly significant for silverleaf nightshade dispersal.

Spread by sheep and cattle

There is strong scientific, observational and anecdotal evidence that sheep are the most important vector for seed dispersal in Australia (Heap and Honan, 1993). Sheep eat mature berries, and viable seeds may then be deposited in dung for the next two to three weeks. There is also very strong anecdotal evidence that cattle spread seed in a similar way.

Scientific studies in SA have demonstrated that sheep eat berries, ingested seeds retain some viability, and that seeds can be passed for up to 31 days after ingestion. However, the majority of seed is passed within 14 days (Heap and Honan, 1993). There is also abundant observational evidence that sheep spread silverleaf nightshade. For example, some roadside infestations occur only on one side of the road between two gates, where contaminated sheep have been moved along the roadside from an infested paddock to an adjacent paddock.

It is also common to observe infestations that are halted by paddock fences. In these cases, creeping lateral roots may produce new shoots just over the fence line, but if contaminated grazing animals are not allowed into the clean paddock then further colonisation is very limited. In one example, a farmer in WA described how each year he drove contaminated sheep from an infested farm to a nearby shearing shed on a clean property. The sheep were carefully restricted to a narrow laneway and then kept in small yards. Regular searches of the previously-clean laneway and yards each year often identified new silverleaf nightshade plants, which were destroyed. The clean farm is still free of silverleaf nightshade after 25 years of careful management of contaminated sheep and regular surveillance. Silverleaf nightshade is also commonly found around shearing sheds (Fig. 32) and in livestock saleyards in infested regions. These facilities are not cultivated or cropped, providing further observational evidence that livestock spread seed. Silverleaf nightshade berries also stick to the wool of sheep, but this is not considered to be a major pathway for spread.

Sheep most commonly eat mature silverleaf nightshade berries during summer and autumn, when pasture reserves are very low (Fig. 33). Sheep movements from an infested paddock to a clean paddock are therefore most risky during the mid-summer to early winter period. Although exceptions may occur, movement during spring and early summer have much less risk. At this time there is usually adequate preferred pasture on offer, and mature silverleaf nightshade berries are generally rare.

IT IS SUBJECT TO LEGISLATION IN SOME JURISDICTIONS – REPORTING, MOVEMENT AND CONTROL.

SILVERLEAF NIGHTSHADE IS PRIMARILY SPREAD BY SHEEP, AND DRAGGED ROOT FRAGMENTS.

Grazing of silverleaf nightshade shoots and berries appears to be learned, and sheep that have been previously exposed to silverleaf nightshade seek it more readily. Young sheep that are introduced to soft vegetative leaves first are more likely to eat berries later. Cross-bred sheep reportedly eat berries more readily than merinos. Experienced sheep have been observed to scratch through sandy soil to find buried berries. If silverleaf nightshade is only lightly scattered throughout a paddock, sheep may ignore it (Iggy Honan, pers. comm.).

There have been changes in farming systems over the last decade that have reduced the potential risk from spread by sheep. Sheep numbers have declined significantly, many mixed farms have moved to cropping enterprises with fewer, or no, livestock and roadside droving is now uncommon. Most sheep are moved during spring on trucks (Fig. 34). Despite this, sheep remain the main risk of further spread.

FIGURE 32. Silverleaf nightshade around shearing sheds and yards, established from seeds in contaminated sheep dung. This can be a source of further spread if hungry sheep eat mature berries during shearing.

FIGURE 33. Silverleaf nightshade berries are most likely to be eaten by sheep when pasture reserves are very low at the end of autumn.

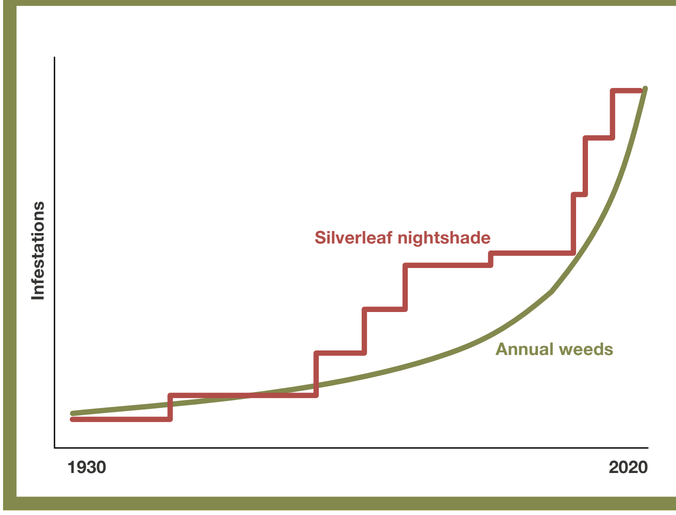
FIGURE 34. Silverleaf nightshade seeds can travel large distances inside sheep and cattle – a quarantine plan for livestock arrivals is essential to keeping properties free from silverleaf nightshade.

BREAKOUT 1

SILVERLEAF NIGHTSHADE SPREADS IN LEAPS AND BOUNDS …

Strong anecdotal evidence from many regions suggests that silverleaf nightshade does not spread in a smooth predictable way, as most annual weeds appear to do (see stylised graphs below). Instead there appear to be sudden jumps, interspersed with periods of relatively slow spread. Spread is often driven by significant seedling survival, which only occurs in years with wet summers. In normal seasons spread is slow. This pattern occurs at all scales – within a paddock, within a region, and at a national scale.

This staggered pattern of spread can sometimes cause new infestations to go undetected for years, while seeds continue to move to new localities. Subsequently, when a suitably wet summer occurs, silverleaf nightshade "suddenly appears" at many new sites.



BREAKOUT 2

SILVERLEAF NIGHTSHADE NEEDS HELP TO SPREAD – THE UNGARIE SHEEP DIP IN NSW

The Ungarie sheep dip site tells us a lot about silverleaf nightshade spread. Sheep from many regions of NSW arrived by train during the 1920s to 1930s and were swum through a plunge dip trench to control lice. Sheep were kept in a small holding yard adjacent to the dip, and silverleaf nightshade seeds were left behind in sheep dung. Silverleaf nightshade established within the holding yards in bare, disturbed soil with high nutrient levels.

At some stage a cohort of silverleaf nightshade seedlings survived and is still growing today, around fifty years after the dip closed in the 1950s. The old post and rail fences have now fallen into disrepair, and the site has remained a fenced reserve, with no grazing or cultivation. Most of the reserve is open woodland, but next to the dip is a neat square of dense silverleaf nightshade growing within the bounds of the old sheep yard. There is only the odd plant a few metres outside of the yard, probably arising from underground clonal growth, which is presumably very restricted by competition from perennial grasses.

This time capsule gives us several important insights: silverleaf nightshade does not continue to spread readily without sheep, cultivation, or floods; perennial silverleaf nightshade infestations can last for over fifty years, perhaps without seedling recruitment; and seedlings do not establish readily amongst adjacent competitive groundcover, even when birds, kangaroos and other wildlife visit the site. The main lesson is that silverleaf nightshade spreads poorly without human assistance, and sheep.

The plunge sheep dip trench leading out of the holding yard.

The holding yard, with a neat square of dense and undisturbed silverleaf nightshade that has not moved in over fifty years.

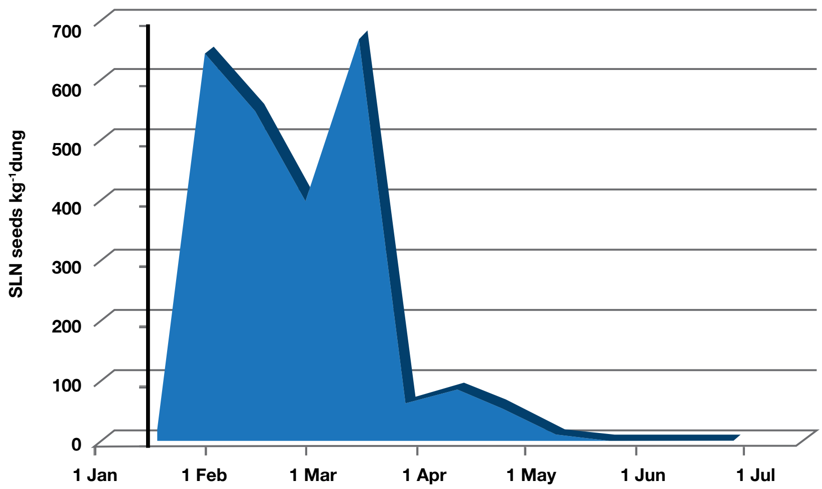
BREAKOUT 3

SHEEP – THE NUMBER ONE CULPRITS FOR SPREAD!

Sheep are a major vector for spreading silverleaf nightshade seed. Experiments in SA have shown that they can spread seed in dung from January through to May (Graph 1, below). Seed excretion declines by late autumn, because most berries have already been eaten, and grazing switches to fresh green pasture growth. The 'danger period" will vary a few weeks from season to season, according to flowering time (summer) and the break of the season (autumn). Once berries are eaten, most seeds are excreted within the first week (Graph 2, below). However, significant numbers may be excreted for up to two weeks, and an occasional seed can pass at least 31 days after ingestion.

If sheep are moved from a paddock infested with silverleaf nightshade during December to June, they should be quarantined in a small paddock for at least one week if possible. Longer quarantine periods will reduce the risk of silverleaf nightshade spread. It is up to the manager to balance quarantine time with acceptable risk.

GRAPH 1. Seed in sheep dung over a summer to winter period. Grazed volunteer annual pasture on Eyre Peninsula, SA.



GRAPH 2. Seed excretion in sheep dung after a single ingestion of silverleaf nightshade berries on day zero.

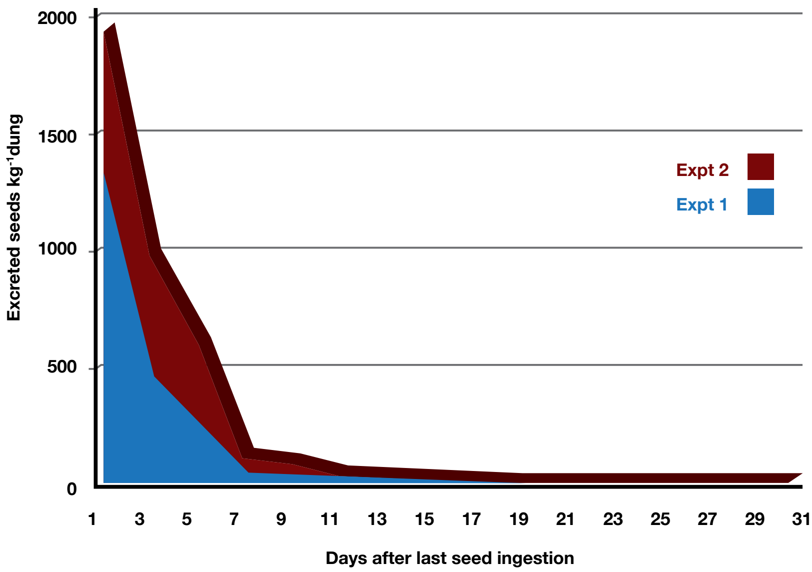


FIGURE 35. Silverleaf nightshade fragments and mature berries can spread on cultivation equipment.

Root and shoot fragments

Silverleaf nightshade root and shoot fragments are primarily produced by soil cultivation. Modern seeding equipment (e.g. knife-points, Speedtiller) can produce and drag fragments. These points typically dig to 15 cm in the soil (to disrupt rhizoctonia fungi), and drag up horizontal roots (Fig. 35). Disc seeders are less likely to drag fragments. All parts of the root system and lower shoot stem can regenerate under favourable moisture and temperature conditions (Fig. 36).

Fragments possess small dormant growth buds that are activated when broken from the parent plant. The buds produce new roots and shoots, using energy and moisture stored in the fragment and soil. Fragments must establish a deep root and adequate leaf area to sustain continued growth to establish a viable new plant. Under ideal temperature and moisture conditions most fragments will establish a new plant, but conditions in the field are rarely ideal in Australia. It is likely that most fragments, but not all, produced during autumn/winter seeding operations in southern Australia rot and die because temperatures are too low for active growth.

Cultivation during late spring to mid-autumn, when temperatures are higher, is now uncommon in most regions. Fragments produced during these times are likely to experience hot days and drying soils after cultivation, leading to desiccation and death. In summary, it is rare for fragments to encounter field conditions conducive to survival, and over-all this is not an important mode of spread, especially over long distances. Research attempts to grow silverleaf nightshade root fragments under field conditions on Eyre Peninsula (SA) failed due to desiccation (Iggy Honan, pers. comm.). In areas such as the Eyre Peninsula spread by fragments is not observed, and is effectively ignored as a vector.

However, in central and northern NSW more frequent summer rainfall events lead to more common late spring to mid-autumn cultivation. Conditions are more likely to remain moist from follow-up rain events and high air humidity. In these regions dragged fragments can significantly increase spread within paddocks, and to neighbouring paddocks. Some farmers in these regions clean tyned implements after traversing an silverleaf nightshade patch, and before leaving an infested paddock. For example, in the West Wyalong/ Temora region of NSW silverleaf nightshade infestations have been observed to follow cultivation lines around 90 degree corners. Although summer cultivation has not been common since the 1990's, fragments are still considered to be more important than seeds as a vector in this region.

FIGURE 36. Newly-emerging shoots from stem cuttings buried vertically or horizontally, under favourable glasshouse conditions.

Creeping clonal root growth

Established silverleaf nightshade patches commonly expand in a roughly circular shape as the roots grow out from the edges. This clonal growth is usually slow, about 1 to 2 m per year, but over 30 to 40 years a whole paddock can be covered as many individual patches grow into each other (Fig. 37). In drought years the patch boundaries may temporarily retreat a few metres.

Agricultural seeds and fodder

Regional opinion around Australia often suggests that silverleaf nightshade was introduced to various areas in the early part of the 20th century as a contaminant of sowing seed or fodder. It is difficult to verify these claims, but silverleaf nightshade berries are found as a contaminant of some agricultural grains and hay. Small berries sometimes contaminate field pea seed and are difficult to remove because their size and shape are similar. Small berries have also been found in harvested oat seed. In SA wheaten hay contaminated with dry silverleaf nightshade stalks and mature berries established new infestations when fed out on a clean property in the 1990's.

Machinery and vehicles

Contaminated machinery and vehicles are not likely to be significant vectors for silverleaf nightshade, but good machinery and vehicle hygiene are a fundamental part of any comprehensive farm biosecurity plan. The main concerns are that stems with mature berries can tangle with the underside of machinery and vehicles, or that mud containing berries or seed may be carried from infested paddocks. On roadsides, grading equipment can drag seeds and fragments along the road. The greater depth of fragment burial during grading is likely to result in more frequent establishment than in cropping paddocks. Slashers used in infested areas may collect berries on top of the cutting deck, and machinery and vehicles used to store or transport contaminated hay or seed also pose a small risk.

FIGURE 37. Clonal spread of a white-flowered type amongst a background of purple-flowered types. The shoots of a clonal colony are usually inter-connected by an underground root network.

Water, soil and wind

Mature berries float in water (Fig. 38) and new infestations can arise downstream in irrigated land, creeks, drainage lines and wash ways. In WA berries were observed to wash into clean farms in flood waters, initiating new infestations as the soil slowly dried under warm conditions. Silverleaf nightshade berries have washed kilometres downstream, infesting the banks of the Driver River (Eyre Peninsula, SA) and subsequently adjoining farms. Observations from road building projects around Adelaide have suggested that silverleaf nightshade can be spread in contaminated soil, and that new infestations can arise within a few years of building. In strong winds, dry silverleaf nightshade stalks with attached berries have also been observed to blow and tumble through fences to establish infestations in previously clean paddocks.

Birds and other animals

Most information on wildlife as vectors is anecdotal and difficult to confirm. In any case, these are likely to be minor vectors compared to sheep. It is likely that birds spread seed, because several plants have been seen growing under power lines, and above the ground – on a wooden fence (1m), and in a rotting tree hollow (3m). However, whirly-winds might also account for these sightings. A number of other animals have been implicated, but there is no strong confirming evidence.

Australian legislation

Various jurisdictions have legal requirements relating to silverleaf nightshade reporting, movement and control. At the time of writing (2018), silverleaf nightshade is listed as a noxious weed across most of NSW, Vic, SA, WA and Tas. Legislation relating to weeds frequently changes and readers are encouraged to check the list of weeds, for their state, territory or region, to be sure of its current legal status. A list of agencies and 2018 websites is given in Section 5, "Further Information".

FIGURE 38. Although green berries sink, mature orange berries float, and are easily transported by flowing water.

INTEGRATED WEED MANAGEMENT FOR SILVERLEAF NIGHTSHADE

What is Integrated Weed Management?

Weed management has evolved and improved over thousands of years of agriculture around the world. Trial and error, and astute observations, identified many techniques that reduced the effects of weeds, and returned increased food and fibre yields. Soil cultivation, crop rotations, grazing, slashing, crop competition, sowing rate, fertiliser use, irrigation, hand-weeding, mechanical weeding, and biological control were used in combinations tailored to specific conditions. This is called Integrated Weed Management. Following World War 2 a string of herbicides was developed that dramatically changed weed control within a few decades. However, a range of problems associated with herbicide use has now led agricultural production back towards Integrated Weed Management, which is more robust and sustainable than reliance on herbicides alone.

Silverleaf nightshade is a long-lived perennial with a very resilient root system, and its management must be planned over at least a five to ten-year time frame. Uncoordinated and erratic control efforts are likely to result in futile expenditure with little gain over the long-term. The management suggestions below are based on research, observations, experience and practical knowledge, and are under-pinned by the information summarised in Section 2 above. If land is leased out, it may be prudent to include silverleaf nightshade management as part of the leasing agreement to protect the long-term productivity of the land. Cooperation and communication amongst local property managers within affected areas is a valuable way to share knowledge and help to reduce spread to unaffected properties and regions.

This section discusses many facets of silverleaf nightshade management. The reader is encouraged to consider their own particular situation and to construct an Integrated Weed Management Plan, based on a range of tactics that takes into account their local resources and constraints.

THE BIG QUESTIONS...

Whatever the situation, managers are encouraged to ask three questions:

1) What is the current situation?
2) What would I like the situation to be – what does "success" look like, and by when?
3) What is a feasible Integrated Weed Management Plan to achieve success?

Developing an Integrated Weed Management Plan

Silverleaf nightshade infests a wide range of land types over diverse regions, and it is unlikely that one plan will be equally applicable to all of these situations. Suggested strategies and tactics for a range of scenarios and enterprises are discussed under separate headings. It is likely that land managers will address several of these scenarios as they tailor their own particular Integrated Weed Management Plan.

Some managers may not have silverleaf nightshade, and so their focus will be on surveillance and hygiene to ensure that it is kept out. Others may have just a few scattered patches in a few paddocks. There are also properties with extensive and dense infestations in most paddocks. All three of these scenarios might apply to different areas of the same property. The invasion curve presented in (Fig. 2; Section 1) illustrates the increase in effort, cost and complexity as properties move from uninfested to heavily infested.

FIGURE 39. The area to right of the fence line has a dense infestation, and a solitary plant to the left of the fence suggests the beginning of the invasion process in that paddock. These early invaders should be a priority for control.

Where do we start?

Designing a management plan for silverleaf nightshade can be a daunting task at first. But careful and logical thought will produce a plan that directs time and money to where it is most needed over the long journey. Large, dense, established infestations attract immediate attention, but careful consideration of the situation may identify higher priorities. The two highest priorities should be to stop seed and fragment movement to clean areas, and to control isolated outlier patches of silverleaf nightshade. Large dense infestations will still need to be managed, but the potential damage that can result from ignoring newly-established colonies (Fig. 39) dictates that they should take priority. The plan is analogous to fighting a bushfire – the main fire needs to be controlled and extinguished, but finding and extinguishing new spot fires is essential to prevent development of a second or third main fire. Table 2 may help to decide on strategies for each paddock.

	DENSITY		
AREA	**Light** (<1 stem/m^2) <10% ground cover	**Medium** (1-5 stems/m^2) 10-50% ground cover	**Heavy** (>5 stems/m^2) 50% ground cover
Localised (< 0.25 ha) small patch	Eradicate	Eradicate	Eradicate
Small (0.25-1 ha) part of paddock	Eradicate	Control	Control
Medium (1-10 ha) small paddock	Control	Control	Contain
Large (>10 ha) large paddock(s)	Control	Contain	Contain

TABLE 2. Prioritising silverleaf nightshade management (NSW DPI).

Preventing spread to clean areas

Protecting a clean area requires minimising introduction of silverleaf nightshade seeds and fragments, by identifying and blocking invasion pathways, backed up by regular surveillance to find any escapes. Practical experience from diligent farmers across Australia has demonstrated that clean properties and paddocks can be defended against colonisation for decades, despite annual influx of seeds.

Creeping lateral root growth

Silverleaf nightshade can spread 1 to 2 m per year via creeping horizontal lateral roots. This is usually of minor importance, except where colonies grow under fence lines and allow livestock in adjoining clean paddocks to access and spread the berries. If infested paddocks adjoin clean paddocks, consideration may be given to maintaining a “firebreak” buffer area (c. 5 to 10m) around the infested paddock, using herbicides, cultivation or slashing. This will minimise the chance of mature berries or lateral roots crossing the fence line. This spread should also be considered where silverleaf nightshade grows from a roadside towards a paddock fence, and around shearing sheds and livestock yards. Creeping lateral root growth also increases the area and density of infestations within paddocks, but is probably less important than seed or fragment movement to different parts of the paddock.

Vegetative spread via fragments

Root and stem fragments produced by soil cultivation can be dragged within a paddock, or to nearby paddocks. This is most likely to occur with tyned cultivators and deep seeding points. Long-distance spread is possible if contaminated machinery is transported to other areas and then used within a few weeks. Fragments are most likely to establish when conditions are warm and moist for several weeks after cultivation, but anecdotal evidence suggests that fragments may also survive in cool moist soils after sowing, to grow and re-establish during spring. Machinery should be cleaned before leaving an infested paddock – remove fragments caught on tynes, and knock off as much soil as is practical to dislodge any mature berries or seeds. Some growers also stop after traversing isolated patches and clean fragments from the tynes or points before proceeding into uninfested parts of the paddock. The probability of totally clean properties becoming infested via root or shoot fragments is relatively low in Mediterranean climates, unless contaminated machinery comes directly from working on another property that is infested. The risk is higher in central and northern NSW, where humidity and summer rainfall are higher.

UNINFESTED PADDOCKS AND PROPERTIES CAN BE KEPT CLEAN.

Spread by seeds

Establishment of new silverleaf nightshade infestations on clean land overwhelmingly originate from seeds ingested by livestock. There are other invasion pathways but sheep, in particular, are the main vector for seeds. The best defence for managers is to ask specific questions about properties that sheep are sourced from. If an assurance that silverleaf nightshade does not grow on the source property cannot be given, then the receiving property should take precautions. Late autumn and early winter is a particularly risky period because hungry stock are most likely to eat mature silverleaf nightshade berries on mature shoots, or from the soil surface (Fig. 40). Conversely, stock moved during spring are much less likely to be contaminated, but a visual check for mature berries stuck to wool may be prudent before release.

FIGURE 40. Mature silverleaf nightshade berries can be sought out and eaten by hungry sheep during autumn, when pasture reserves are low.

FIGURE 41. Sheep can eat silverleaf nightshade berries during late summer and autumn – moving them to a clean paddock or farm can start a new infestation.

If investigations suggest that livestock may have been grazing in paddocks infested with silverleaf nightshade (Fig. 41) within the last three weeks, during the mid-January to July period, then a quarantine period should be considered. The ideal situation would be that the livestock are contained on a fenced clean area on the source property, and then feed clean fodder for four weeks prior to transport. This is rarely a practical option, so managers need to balance risk with practicality. Alternatively, livestock could be restricted to a secure small holding paddock on the receiving property that is easy to inspect regularly for silverleaf nightshade. Whatever the quarantine period is, the receiving paddock should be one that is traversed frequently, to maximise the likelihood of finding any new infestations.

Silverleaf nightshade seed excretion peaks about 24 hours after ingestion, and then there is a steady decline over seven days to a low level. For the next seven days the output remains at a low level. In experiments single seeds were excreted 17 and 31 days after ingestion. There is no specific safe or risky quarantine period, because risk declines gradually with quarantine time. As a guide four days would be a minimum, but this might still have a significant risk. Seven days would be preferable, and after this the extra reduction of risk may not warrant the opportunity cost of continued quarantine. After four weeks the risk will be negligible, but this length of quarantine may be impractical for most. It should be noted that these suggestions do not reduce the risk to zero. It is always possible that a sheep may eat the odd mature berry at an unexpected time, but the relatively low number of seeds means that the probability of starting a new infestation is low.

Seed can also be introduced onto a clean property in contaminated seed for sowing, or hay. Again, it is prudent ask suppliers about any weeds of concern that may be present in the produce. Suspect seed or hay could be refused, or fed out in a small quarantine paddock as described above. Machinery coming from known infested areas should be cleaned as well as is practical to minimise the chance of seeds dropping in mud, and construction soil should not be imported from pits infested with silverleaf nightshade. The risk of incursion due to wind or wildlife is low, but floodwater that has flowed through land or waterways infested with silverleaf nightshade is a high risk that warrants intensive surveillance once the waters recede.

Surveillance

Surveillance over many years is a critical component of any plan to exclude or eradicate silverleaf nightshade from an area. Unfortunately, there is no substitute for thorough and regular searches at carefully selected times of the year. Timing of searches is determined by land use and management. Pasture paddocks, fence lines and roadsides are best inspected when shoots are green and fresh, and in flower. This is usually in December, except when pastures have been heavily grazed. In this case it may take two to four weeks after stock removal for shoots to recover and flower. Shoot emergence is usually delayed in cropped paddocks, and it may take four to six weeks after harvest for plants to be easily seen. Silverleaf nightshade shoots in crop stubbles, especially canola, may also be smaller because of extraction of subsoil moisture by the crop. A second search in mid-autumn may be warranted, especially if there has been heavy rain during summer.

Paddocks should ideally be searched on regular parallel transects, and GPS guidance units used for seeding and harvesting can be utilised to achieve this. A GPS or physical marking system should be used to mark or record any plants found, for follow-up herbicide treatment. Any unfamiliar plant with a purple, white, or blue flower should be investigated and identified. In addition, some areas should be checked regularly – gates, trough areas, shade trees, stock yards and shearing shed yards, dam banks, flood-ways, creek-lines and sand hill "blow-outs". It should be noted that individual shoots or small patches often may not be detected for several years, resulting in an established soil seed bank. As an example, a newly-acquired 1,000 ha property in WA was initially searched by one person using a ute to map the baseline silverleaf nightshade infestation. This took the equivalent of about four weeks to complete. Searching in early morning light may allow flowering plants to be seen more easily than when the sun is overhead.

EFFECTIVE CONTROL TAKES AT LEAST 4-5 YEARS – DILIGENCE AND PERSISTENCE ARE ESSENTIAL.

BREAKOUT 4

HOLDING THE LINE IS POSSIBLE ....

Tim Dowdell bought an additional property in WA that was already infested with silverleaf nightshade. They still take sheep back to the nearby home property (clean of silverleaf nightshade, run by his father) to shear. They are careful to restrict sheep movements to the same tracks and areas. They frequently get new infestations (especially in wet summers) from sheep carrying seed to the home farm, but have managed to keep the home property clean through vigilance and spot-spraying – after 25 years of seed attack, the home farm is still clean! See Case Study 3 for more details.

Tim Dowdell and his father have prevented this situation from occurring on their clean home farm by vigilant surveillance and careful spot-spraying.

Eradicating isolated plants and patches

As clean paddocks are invaded by silverleaf nightshade, isolated individual plants and small clonal patches develop throughout the paddock. At this stage the aim should be to eradicate them from that paddock. Isolated plants around gates, trough areas, shade trees, stock yards and shearing shed yards, dam banks, flood-ways, creek-lines and sand hill “blow-outs” also warrant repeated eradication. Eradication plans must be made for at least 5 to 10 years, due to the soil seed bank and regrowth from perennial root systems. Successful plans will include excellent surveillance and record keeping, and effective herbicides. A GPS is very helpful for revisiting treatment sites and annual photo point pictures help to track progress. Unfortunately, for many farmers, surveillance and spot-spraying may coincide with plans for holidays.

It is very difficult and labour-intensive to eradicate established plants without herbicides. An exception may be smothering a small number of plants with black plastic over several years. Digging, cultivation, grazing, and mowing are usually ineffective. There are a number of herbicides suitable for spot-treatment of silverleaf nightshade – please refer to the Herbicides section below.

Silverleaf nightshade frequently produces new shoots after initial herbicide treatment, and monitoring and re-treatment should be expected and planned for. Silverleaf nightshade shoots may take several years to re-appear following initial treatment. When using picloram, a residual soil active herbicide, it is very important to spray the shoot, and the soil for a 2m radius around the shoot. This is to allow picloram to move through the soil profile and be absorbed by the horizontal lateral roots.

Treatment of just the shoot often results in the emergence of a ring of daughter shoots from surviving lateral roots. High volume jets assist in soaking the silverleaf nightshade shoot and surrounding soil. Glyphosate is only absorbed through active shoots, so soil treatment is ineffective. Spot-spraying is best done early in the morning while plants are fresh, and flowering plants are easier to see. It is important to find and treat new plants as quickly as possible, because younger plants have a smaller root reserve and are more easily killed by herbicides. Soil residual herbicides may leave a bare patch of soil for several years (Fig. 42).

FIGURE 42. Residues of soil active herbicides (e.g. picloram) often create bare patches that can persist for many years after application.

Managing established infestations

When silverleaf nightshade density increases to the point when spot-treatment is no longer practical, different tactics are needed. The aim now is to contain and weaken the infestation, and to protect crop and pasture yield.

The first two goals are relatively easy to achieve, however exhausting the root system takes years of persistent effort to reap the rewards. It may take three to five years of persistent spraying to notice a reduction in shoot density.

THE BIG GOALS…

There are three major goals when managing dense, established infestations:

1) Prevent seed production.
2) Kill shoots during summer/autumn to protect following crop and pasture yield.
3) Reduce the size and vigour of the root system over time.

A "DUAL-ACTION" IS USUALLY USED – CONTROLLING IT TWICE DURING SUMMER/AUTUMN.

"Dual Action" approach – the foundation of silverleaf nightshade management

Experience and research suggests that a "Dual Action" approach is most suited to long-term control of silverleaf nightshade. Action One, in early summer, is aimed at stopping seeding, and Action Two is aimed at weakening the root system in late summer or autumn. Tables 3 and 4 outline Dual-Action approaches for both crops and pastures.

TABLE 3. Suggested Dual-Action approaches for cropping (NSW DPI).

'DUAL ACTION' STRATEGIES FOR CROPPING
EARLY: An early action aims to achieve 100% seeding (seedbank) control in November or December when there are only a few stems distributed across the paddock which have just flowered. Options include knockdown herbicides, slashing, grazing, spray/graze or burning. The choice of products will be influenced by other weed species present and which crop types are to be planted in the future. Careful attention should be paid to plant-back periods listed on product labels to avoid damage to following crops. Control at this stage may help to synchronise the growth stages of subsequent shoot emergence.
LATE: A late summer or autumn herbicide treatment is applied when plants start to shut down naturally as the temperature declines. This coincides with the translocation of carbohydrates (energy) from the growing points down into the perennial roots. The aim of the treatment is to utilise the carbohydrate transfer to carry herbicides into the roots, maximising the potential for injury to them. The choice of product will be influenced by the plant-back requirement for following crops, and the levels of infestation.

TABLE 4. Suggested Dual-Action approaches for pastures (NSW DPI).

'DUAL ACTION' STRATEGIES FOR GRAZING
Dense infestations are often found in degraded pastures. Paddock renovation may begin with cropping prior to re-sowing a grass-based pasture, which allows the use of selective herbicides during the season. Depending on the silverleaf nightshade density, fluroxypyr, 2,4-D or even picloram products can be used in autumn to maximise root-bank control.
For scattered infestations the 1st action uses grazing (or spray/graze), hay-cut or silage, followed by the 2nd action in autumn by spot-spraying picloram products to target the root-bank.

Management in broad-acre crops and grazed pastures

Preventing seed production and killing shoots

Prevention of seed production each year is desirable because over a four to six-year period the soil seed bank can be reduced to low levels. This will almost stop further spread within the paddock, and it also eliminates the risk of livestock spreading seed to clean areas. The sooner seed production is halted, the sooner spread within that paddock will be brought under control. If seeding is allowed to occur unchecked in a paddock with only a few scattered silverleaf nightshade plants, practical experience shows that over time the paddock may become almost totally covered. Although this may happen slowly, over a period of 15 to 20 years, the process is difficult and expensive to reverse, and losses will occur every year. As with most weeds, if seeding is allowed, the management plan may be set back many years. Tables 5 and 6 summarise a range of management tactics at various times of the year, and at different silverleaf nightshade growth stages.

TABLE 5. Silverleaf nightshade control calendar for various situations (NSW DPI).

SEASON	CROPPING/FALLOW	PASTURE	FALLOW, FENCE LINES AND NON-ARABLE AREAS
Spring	Good crop competition to deplete soil moisture at depth	Good pasture competition to deplete soil moisture at depth	Grazing or grass-selective knockdown herbicides to prevent seeding
Early summer (Dec-Jan)	Grazing, mowing or knockdown herbicides to prevent seeding	Grazing, hay cut or silage to prevent seeding	Grazing or knockdown herbicides to prevent seeding
Late summer (Jan-Feb)	Grazing if needed, or knock-down herbicides, to prevent flowering	Grazing, hay cut, silage or spray/graze to prevent flowering	Grazing if needed, or knock-down herbicides, to prevent seeding
Autumn	Picloram or glyphosate herbicides to reduce root vigour	Grazing, hay cut silage, or spray/graze to prevent seeding or spot spraying if possible to reduce root vigour	Picloram herbicides (spot or boom spray) to reduce root vigour
Winter	Hygiene and quarantine when re-stocking. Scout the paddocks, collect and burn any missed berries to prevent spread to other paddocks.		

TABLE 6. Silverleaf nightshade detection, control and seasonal life stages (NSW DPI).

	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL
Monitoring			●	●	●	●	●	●	●			
Dual action timing				1st	1st			2nd	2nd			
Dormant	●									●	●	●
Stem emergence		●	●	●	●	●	●	●				
Active growth		●	●	●	●	●	●	●	●			
Flowering				●	●	●	●	●	●			
Berry set					●	●	●	●	●			

BREAKOUT 5

SILVERLEAF NIGHTSHADE CONTROL – TIMING IS EVERYTHING!

The range of silverleaf nightshade growth stages that can occur at one location, on any one day, creates difficultly when control at a particular growth stage is specified. The photos below were all taken at the same site on 8 December 2017 near Pt Pirie, SA. SLN growth stages ranged from newly-emerged shoots to mature plants in the same paddock; and from flower buds, to flowering and to full-sized green berries on the same plant.

FIGURE 43. Silverleaf nightshade ungrazed (left) and grazed by cattle (right) during summer – grazing can help to delay and synchronise flowering before herbicide application.

Silverleaf nightshade flowers from November to April, and it is common to have several flowering periods over summer and autumn. Silverleaf nightshade is often sprayed during operations primarily targeted to control a suite of other summer-growing weeds (melons, caltrop, heliotrope etc.), and so the flowering stage of silverleaf nightshade is incidental, and timing is often sub-optimal for preventing seed production. Shoot emergence in summer is usually staggered over several months, so that flowering is not synchronous. This means that there is rarely a single spray window that will prevent all seed production. Staggered shoot emergence patterns and hence flowering is often influenced by summer rain, and in wet summers several herbicide treatments may be needed.

The best time to spray is when there are only a few scattered flowers present in the paddock. Research has shown that to prevent seed production, silverleaf nightshade should be sprayed before the diameter of young berries exceeds 2 mm. This could occur from late spring onwards, depending on location and seasonal conditions.

Shoots that emerge after the initial spray may produce a new flowering event under favourable conditions. In unsprayed and ungrazed silverleaf nightshade, it is common to have a range of stem development stages present on a single plant - from flower buds, to open flowers, through to full-sized green berries (see Breakout 5).

Hard grazing from late December, using sheep or cattle, may control emerging shoots and minimise flowering (Fig. 43). Goats have also been used effectively on some properties. If livestock are accustomed to eating silverleaf nightshade, and stocking rates are sufficient, it may be possible to keep shoots pruned to prevent flowering until most of the shoots have emerged by mid-summer. Stock can then be removed to allow a more or less even flowering event as all shoots recover from grazing at the same time. Repeated grazing may be required to prevent flowering for the remainder of the summer/autumn period, especially when there are significant summer rainfall events which may trigger emergence of new shoots.

Care should be taken when grazing heavy infestations of silverleaf nightshade as stock poisoning has occurred overseas, although there have been no such reports in Australia. A research study found that dry matter intake and body weight gain in goats decreased when silverleaf nightshade contributed more than 25% of the daily dry matter intake (Mellado et al., 2008). In addition, stock may also eat mature berries lying on the ground from the previous summer, and this may present a movement risk for a few weeks after removal.

Spray/graze techniques can increase the palatability of silverleaf nightshade to help reduce seed production. Alternatively, degraded pastures can be rotated to cereals for grazing or cropping for 3 to 5 years to allow the use of herbicides to reduce shoot density. The spray/graze or grazing control option is used immediately after harvest. Stubbles are grazed for three weeks at normal stocking rates when very few other weeds are present, or at double the rate when alternative green feed is abundant. Pregnant ewes may need supplementary feeding for extended grazing periods.

Competitive pastures, such as summer-active sub-tropical grasses, can suppress silverleaf nightshade effectively in northern NSW. Silverleaf nightshade growth is weakened when pasture roots reduce available deep soil moisture, and silverleaf nightshade density and vigour can be significantly affected (Stanton et al., 2011). Summer-active grasses can be sown into degraded clover and lucerne pastures to increase livestock productivity and profits in northern NSW. Some promising tropical grasses include Bambatsi panic, Premier digit grass, Strickland finger grass and the Rhodes grasses. A minimum of 3 t/ha of dry pasture biomass is required to have a significant effect, often requiring fertiliser application. Excess biomass above 3 t/ha can be grazed or cut for hay, and herbicides can be applied in autumn to control silverleaf nightshade. Lambs weaned in late spring may also benefit from the growth of fresh green grass as the clover plants begin to senesce in summer.

Aside from preventing seed production, managers often kill silverleaf nightshade shoots during summer to help conserve stored soil moisture for following crops. Silverleaf nightshade tap roots and lateral roots can extract water throughout the rooting depth of annual crops and pastures. A dense infestation of silverleaf nightshade can use much of the stored moisture which contributes to yield of following crops, and in a dry spring large yield losses can occur (e.g. 50 to 70% in cereals). It is difficult to predict spring rainfall, however the same risk management strategies that apply to control of annual summer weeds should apply equally to silverleaf nightshade. The aim is to control silverleaf nightshade shoots early in summer, with herbicides or grazing, to minimise soil water depletion. A repeat treatment may be required in late summer or early autumn, especially following significant summer rainfall. Competitive crops or pastures reduce soil moisture throughout the soil profile during spring and early summer, and this can delay and reduce the emergence of silverleaf nightshade stems.

There is a range of herbicide options available to kill shoots in dense, established infestations. It should be noted that commonly-used treatments have little long-term effect on the perennial roots of silverleaf nightshade, and new shoots soon form. Slashing or cultivation are rarely used to prevent seed production because flowers may develop below slasher height, and soil cultivation during summer should be avoided for a number of agronomic reasons.

Dense infestations are often found in degraded pastures (Fig. 44). These areas may benefit from being sown to cereal crops or tropical grass pastures (NSW) for several years, allowing the use of selective herbicides to be used in autumn to maximise damage to the roots.

FIGURE 44. Silverleaf nightshade in a degraded lucerne pasture.

Exhausting the root system

As described above, it is relatively easy to kill silverleaf nightshade shoots with a range of herbicides. The application rates normally applied to kill shoots result in little long-term damage to the root system. Sprayed shoots translocate herbicides to their connection with the root system, and wither over two to four weeks. New shoot buds are rapidly activated, and healthy replacement shoots can emerge through the soil surface within four to six weeks. The perennial tap root typically grows to 2 to 3 m deep, with about five major horizontal lateral roots that grow out to 2 m from the tap root before turning and growing down. Energy reserves in the extensive root network are very large, and the small losses of energy suffered from the sporadic shoot death does little to weaken it. In experiments in USA, 2,4-D was used to kill emerged shoots for 36 consecutive months, with no significant effect on root survival.

Silverleaf nightshade appears to have mechanisms to excrete some herbicides from its roots (Richardson, 1979a and 1979b), and translocation within the root system is usually very limited. As a consequence, long-term control of the root system requires a relentless campaign of attrition to exhaust the energy reserves over many years. A lapse in pressure that allows healthy shoots to establish will allow a recharge of stored carbohydrate reserves, reversing most of the previous gains. Research suggests that the same herbicides used for shoot control may cause useful damage to the root system if applied at higher rates. In addition to killing shoots, sufficient herbicide is translocated into the root system to kill or injure parts of it, thus reducing its ability to produce shoots. For example, glyphosate applied at 1.68 kg a.i. ha^{-1} several times per season over three years gradually weakened the root system and reduced the shoot density to below 10% of original. Glyphosate can also kill shoots at the much lower rate of 0.56 kg a.i. ha^{-1}, but damage to the root system is minimal. To the casual observer the effect on shoots is the same for both rates, and there is no apparent reason to use the higher rate unless the effect on the root system is understood.

Farmer experience has identified that continuous cropping is the fastest way to reduce silverleaf nightshade density in severely-infested paddocks. Continuous cropping usually provides multiple opportunities to apply a range of herbicides, and agronomic practices that maximise water-use efficiency. Strong crop root growth can extract most available moisture from the soil profile during spring. This depletion of moisture can delay silverleaf nightshade shoot emergence, and reduce shoot vigour. NSW growers who grow winter and summer crops in rotation also report accelerated reduction of silverleaf nightshade density. Canola is especially effective at reducing silverleaf nightshade vigour because it has a deep root system that extracts moisture around more of the silverleaf nightshade root system.

CONTROL HAS TWO MAIN TARGETS – PREVENT SEEDING, AND WEAKEN THE PERENNIAL ROOTS.

Integrated Weed Management plan – bringing it all together in an example

As an example, consider a hypothetical scenario where a 2000 ha cropping/grazing property with silverleaf nightshade is newly-purchased in north-western Vic. In the first summer it is apparent that 6 of the 16 paddocks on the property have extensive silverleaf nightshade infestations, and small patches can be seen while driving past most of the paddocks. Four or five of the paddocks appear to be clean. A quick check confirms that silverleaf nightshade is a serious weed that will require careful management. Using the information above, a management plan is devised.

The first step is to gather as much knowledge about silverleaf nightshade as possible, and talk to other managers and advisors with experience in managing the weed. Next, a survey is done of the whole property after Christmas. This confirms that six paddocks are between 20 and 80% infested by silverleaf nightshade, and that a further seven paddocks have between 3 and 24 scattered patches. Three paddocks appear to have no silverleaf nightshade. In addition, there are odd plants around two dams and the shearing shed yards.

The three questions posed earlier are then asked:

1. What is the current situation?
2. What would I like the situation to be – what does “success” look like?
3. What is a feasible integrated weed management plan to achieve success?

The first question has been answered by the property survey. The manager decides that it should be long-term goal to try to get rid of silverleaf nightshade from the whole property. A long-term plan is needed.

After much thought a few things become clear:

1. There are some clean paddocks that must be kept clean.
2. The odd plants growing around the dams and shearing shed are a danger and should be destroyed as soon as possible.
3. It seems possible to spot-spray the seven paddocks with scattered patches.
4. The heavily infested paddocks will need a lot of coordinated control to reduce the density.

The priority actions identified are:

1. Stop any more spread around the property. Sheep will not be moved to clean paddocks between December and July.
2. Destroy odd plants around the dams and yards where sheep and cattle can eat the berries.
3. Find, map and spot-treat the patches in the seven lightly infested paddocks.
4. Stop seeding in the heavily infested paddocks, and apply robust rates of glyphosate or fluroxypyr annually to weaken the root system over time. Heavy grazing at the very early flowering stage can be used to delay and synchronise flowering.

FIGURE 45. Silverleaf nightshade growing in a spray-boom washout area illustrates the resilience of perennial roots growing in soil herbicide residues accumulated over many years. Note the absence of any other plant species.

Herbicides

The overall plan is to concentrate on eradicating plants in all areas of the property, except the heavily-infested paddocks. It is expected that this will take at three to five years before an annual inspection and minor mop-up stage is achieved. Close monitoring is necessary over many years to find and kill any new plants that grow from seeds in the soil. During this time, stopping seed production in the heavily-infested paddocks will run down the soil seed bank to near zero. The high rates of glyphosate will have weakened the root system, and shoot density should be declining year by year. With the required eradication effort reduced to a low level over most of the property, emphasis can now shift to the heavily infested paddocks. The management will continue in these paddocks, and as time allows small outlier patches can be spot-treated to drive the infestations back into core patches. It is hoped that sometime in the future these patches will thin out to point that more can be spot-treated, and eradicated.

Why is silverleaf nightshade so hard to kill?

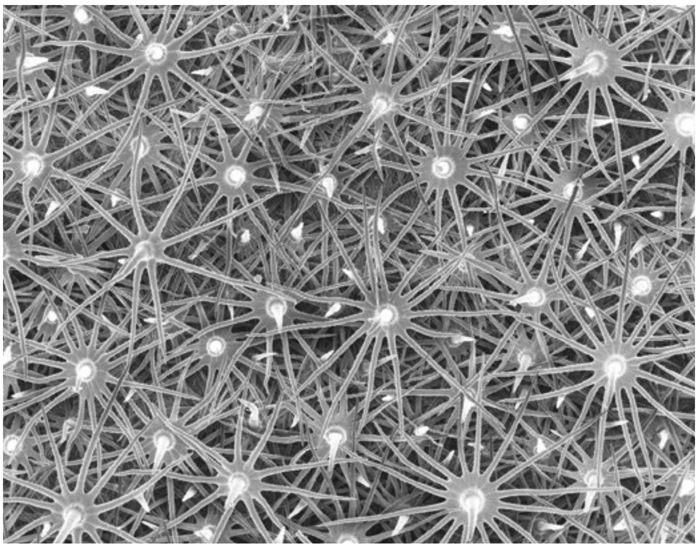
Silverleaf nightshade seedlings are very weak, and usually die of natural causes at an early stage under temperate Australian conditions. The shoots that arise from the perennial root bank each spring are also easily killed by a range of herbicides or cultivation. However, silverleaf nightshade is still one of Australia's worst weeds. This is because it has enormous energy reserves stored underground in an extensive and inter-connected root system, and the shoots are like the tip of the iceberg.

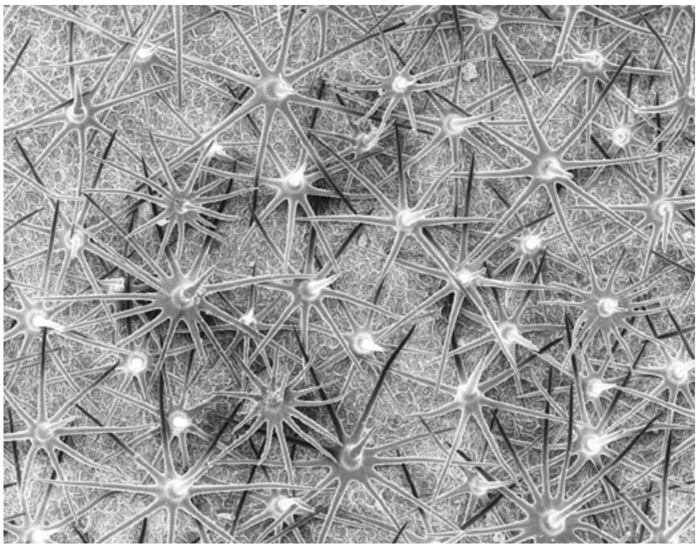
Any management that aims to reduce the density of silverleaf nightshade must damage and exhaust the root reserves faster than the shoots can replenish the energy supply. To do this, control tactics need to be applied carefully and relentlessly for at least 5 to 10 years. In the absence of effective biological control agents for the time being, herbicides, grazing and competition are the main tactics available.

Figure 45 shows an area on an Australian farm that has been used to empty and washout herbicides from a boom sprayer for decades. The area is devoid of any plant growth – except established silverleaf nightshade shoots. These plants were probably already established before spraying started, but they have withstood an annual onslaught of cropping herbicides. This illustrates that herbicide selection, rate and timing must be very carefully chosen to weaken the root system.

Silverleaf nightshade has several layers of defence against herbicides. Firstly, it has a thick layer of waxy branched hairs (trichomes) on upper and lower leaf surfaces (Fig. 46). These structures intercept herbicide droplets and hold them away from the leaf surface so that absorption into the leaves is reduced. The next layer of defence is a low and slow rate of translocation from the leaves to the roots. This effect varies between different herbicides. NSW research found that about 63% of the applied fluroxypyr (e.g. Starane®) remained in the treated leaf, and only 2% was translocated to the roots (Stanton et al., 2010). The next level of defence is the ability of silverleaf nightshade to exude some herbicides (e.g. picloram) from the roots into the surrounding soil. The last layer of defence is the length of the root system – in some cases herbicides need to travel 2 to 3 m to reach the extremities.

FIGURE 46. Scanning electron microscopy (high-powered microscope) showing the trichomes on the upper (left) and lower (right) leaf surfaces of silverleaf nightshade (Burrows et al., 2013).





How can herbicides help?

Herbicides can be used to achieve three major strategic goals – stopping seeding, damaging the root system, and increasing crop and pasture yield by reducing competition from silverleaf nightshade. The choice of herbicides will depend on what the required goal is.

Stopping seeding reduces the risk of stock spreading seeds to clean areas, and after around 8 years it will exhaust the bank of viable seeds in the soil. Damaging and weakening the root system during summer and autumn will reduce the shoot density over time. As a bonus, it will also be expected to increase the yield of crops and pastures in the following winter to summer period by conserving more moisture in the soil profile. In some situations, shoot control will reduce surface trash loads and make crop seeding easier.

Products and rates

Herbicide brand names, formulation types and strengths, and suggested rates for various weeds can change rapidly over time. Also, herbicide registrations and permits differ between states. Consequently, no attempt will be made to summarise the current information here because it will likely be out of date, and hence unreliable, soon after publication. A number of long-established herbicides are discussed below, but for all current registrations, permits and suggested rates please consult the product labels, and websites or current weed control publications from your state's Primary Industries Department or other relevant authorities.

Types of herbicides

Some herbicides kill the shoots but have very little effect on the roots (e.g. 2,4-D), others kill the shoots and have some effect on the roots (e.g. Starane (fluroxypyr)), and some are used mainly against the roots (e.g. Tordon (picloram)). Whichever herbicides are chosen, there are only two ways for them to enter the plant – through the shoots (leaves and stems), or absorbed as residues in the soil by the roots. Soil active herbicides such as picloram (e.g. Tordon) are applied to the soil surface, are then moved down into the soil profile by rainfall, and may persist for several years. When applying soil-active herbicides it is important to spray a 2m radius of soil around each shoot, to ensure that distant lateral roots are exposed to the herbicide. Almost all herbicides used to control silverleaf nightshade are absorbed and translocated within the plant to at least some extent. If herbicides with short soil residual lives (e.g. 2,4-D, glyphosate) are applied at very high rates in an attempt to increase efficacy there is a risk that the shoot will be damaged too quickly, resulting in reduced translocation to the roots.

Herbicide risks to crops, pastures and trees

Herbicides used for prevention of seed production should be selected carefully so that they don't affect the growth of perennial summer pastures, where grown. Herbicides used in autumn for root control should have suitable plant back period safety for following winter crop or pasture types.

Soil active herbicides (especially picloram) have the inherent risk of affecting the growth of following crops and pastures in the farming system. "Plant-back times" or "Re-cropping intervals" are explained on the herbicide labels for various situations. These times are the safe minimum period of time between herbicide application and the subsequent growth of susceptible crops or pastures. The periods are typically from several weeks to one year, and apply to herbicides that persist as residues in soil or dry plant material (e.g. straw). Picloram-based herbicides are effective for damaging the silverleaf nightshade root system, but the soil residues can preclude sowing susceptible crops and pastures for long periods, depending on the rate applied. Very high rates of picloram applied as a spot-spraying treatment often results in bare soil patches for at least several years. These areas are therefore non-productive and are at risk of erosion before grasses re-establish. Picloram products are therefore only suitable for spot spraying isolated patches.

Some soil-active herbicides (e.g. picloram) can be taken up from the soil by tree roots, causing damage and sometimes even death. As a general rule, spraying within a radius equal to 3 to 5 times the height of trees should be avoided. As an example, if a tree is 10 metres tall, do not spray within 30 to 50 metres of the tree. Please consult herbicide labels for specific advice.

Herbicide drift

Herbicide drift can cause damage to neighbouring crops and pastures. This happens when fine droplets or volatile vapours move in the air and contact the leaves of non-target plants. To minimise the risk, use large droplets, adjuvants to reduce drift (consult herbicide label), and avoid spraying when weather conditions are risky. The herbicide 2,4-D ester has caused the most problems in the past. An invisible vapour cloud of 2,4-D ester can rise and travel away from the surface of a sprayed paddock and severely damage susceptible crops up to 15 km away. The use of 2,4-D

FIGURE 47. Silverleaf nightshade plants sprayed after berries reach 2 mm diameter are likely to produce viable seeds. Application timing should be at the very early flowering stage to achieve maximum reduction of seed production.

ester is now not allowed or restricted in most states. There are a number of excellent guides available to explain the dangers in detail. For further information on herbicide drift please visit your state's Primary Industry Department website, or request a leaflet.

Spraying conditions and timing – the keys to success

Damaging the roots of silverleaf nightshade is a challenge, and it is important to choose the most favourable timing and conditions to get the best result for the investment. In practice, herbicides are not always applied under optimal conditions for pragmatic reasons. However, careful study of weather forecasts and forward planning can often improve the end result. Identify a target growth stage or time window for spraying. Prepare equipment, herbicides and adjuvants ahead of the target timing. As the start of the window approaches, try to identify when forecast climatic conditions will be best. It may be prudent to spray a little earlier than planned if very good conditions are forecast.

As discussed above, spraying at the very early flowering stage in early summer is very important to prevent seeding, regardless of the date. This window is usually relatively short, but sub-optimal climatic conditions can be better tolerated at this time than with late-season applications. Australian research (Stanton et al., 2010) has shown that, when herbicides are applied at the flowering stage, seed formation was prevented. However, when herbicides were applied at the early berry stage, viable seed production was only halved by fluroxypyr, glyphosate and 2,4-D amine (Fig. 47).

The late summer/early autumn application window is timed to maximise translocation of herbicides to the root system, and usually offers more timing flexibility to exploit favourable application conditions. However, it is important that these applications are still applied at or before early flowering to prevent seeding.

In addition to adjuvants (see below) there are a number of climatic conditions that can increase herbicide uptake and translocation to the roots. Aim to apply herbicides when the roots are well-watered, and the shoots are fresh, clean, and growing actively. Moist soil, cool temperatures, and high humidity are the most favourable conditions. Dusty leaves are not ideal, but limited research suggests that the effect may be less important than previously thought (Heap, unpublished data). Small amounts of light rain during or immediately after spraying are not expected to reduce herbicide effectiveness. Spraying in cool conditions a day or two after a summer thunderstorm (> 15mm of rain) is ideal. At this time the roots have taken moisture from the soil, the shoots are fresh, clean and growing, and the air is usually humid.

A silverleaf nightshade field trial with glyphosate/2,4-D amine mixtures in SA (Hart, 2012, unpublished) suggested that spray application volumes between 60-90 L/ha, ground speeds between 12-17 km/hr, and pressures between 3 to 4 bar (300 to 400 kPa) gave acceptable control. The same trial recorded little effect from varying droplet size.

Adjuvants (additives) for spraying – very important

Use of spray mixture adjuvants such as spraying oils and surfactants are crucial to maximise spray results. These adjuvants can increase herbicide uptake and translocation within silverleaf nightshade, increase effectiveness under harsh climatic conditions, reduce droplet drift, and reduce antagonism between herbicides in mixtures. The suggested adjuvant products and rates vary from herbicide to herbicide, but current information is provided on herbicide labels. Results from Australian research suggest that control of shoots is influenced more by herbicide and adjuvant choice than time of application (Stanton et al., 2010).

Major herbicides for silverleaf nightshade control

The major herbicides used for control of silverleaf nightshade are discussed below. Please refer to current herbicide labels for Directions for Use and information on adjuvants.

Silverleaf nightshade is sometimes a secondary target when a suite of summer weeds (e.g. heliotrope, melons etc.) is sprayed using various regional herbicide mixtures. Most of these general mixtures can control silverleaf nightshade shoots adequately and prevent seeding if applied at the very early flowering stage. However, damage to the root system will be less than with herbicides and rates specifically chosen for silverleaf nightshade. Also, if the timing is late then the typical rates and herbicides used will probably allow viable seeds to develop. Herbicide symptoms are usually apparent within two days to a week after spraying, depending on the product and climatic conditions. Usually shoot death should be complete by around three weeks after spraying.

2,4-D amine (e.g. Amicide Advanced ®)

Commonly-used for silverleaf nightshade control for over 50 years in Australia. It kills shoots and stops seeding. First symptoms are visible within a few days after spraying (Fig. 48). There is very little long-term effect on the root system. 2,4-D has been available as both an amine or ester formulation. The ester formulation kills the shoots faster, but it is a significant off-target drift damage risk and so its use is not allowed or restricted in many states. There can be a chemical antagonism between glyphosate and 2,4-D amine herbicide mixtures in the spray tank, leading to poor silverleaf nightshade control. Seek advice on water quality and adjuvants to minimise the risk.

Fluroxypyr (e.g. Starane ®)

Used for both killing shoots (Fig. 49) and damaging the root system. It can be used to prevent seeding when the very first flowers are visible. It is also used in late summer/autumn to weaken the root system. Although fluroxypyr and 2,4-D amine have been used interchangeably, recent experience suggests that annual applications of fluroxypyr for 4 or 5 consecutive years can reduce the shoot density. It is very likely that fluroxypyr is more effective than 2,4-D. The addition of Uptake Spraying Oil (refer to herbicide label) appears to reduce shoot density more than fluroxypyr alone.

Glyphosate (e.g. RoundUp ®)

Commonly-used for silverleaf nightshade control for over 40 years in Australia. It kills shoots and stops seeding. First symptoms are visible within about a week after spraying. There is a very useful long-term effect on the root system, but this is only apparent after 3 to 5 years of consecutive annual applications. Use of robust rates and appropriate adjuvants each year gives the best results. There can be a chemical antagonism between glyphosate and 2,4-D amine herbicide mixtures in the spray tank, leading to poor silverleaf nightshade control. Seek advice on water quality and adjuvants to minimise the risk.

Picloram products (e.g. Tordon 75-D ®)

Picloram is a soil-active herbicide that can persist in the soil for at least several years. Extreme care should be used when planting following susceptible crops and pastures. Picloram is usually mixed with a foliar-absorbed herbicide (e.g. 2,4-D amine, triclopyr) so that the shoots are killed by the companion herbicide, and extended residual control is provided by picloram washed into the soil profile. It is used at lower rates as a broad-acre application, and at high rates as a spot-spray treatment. As discussed above, when using picloram as a spot-spray treatment it is very important to treat soil in a 1.5 m radius around each shoot to ensure horizontal lateral roots receive a lethal dose.

Picloram/aminopyralid/2,4-D amine (e.g. FallowBoss Tordon ®)

Used in certain cereal and grass crops for general broad-leaved weed control. Used in stubbles and fallows prior to sowing a range of crops, subject to plant-back restrictions. The rates used prior to cropping would only be expected to kill silverleaf nightshade shoots to prevent seeding, with little effect expected on root systems.

BREAKOUT 6

BUSTER DAWES – IN FOR THE LONG RUN ….

The following written information was supplied by Mr Buster Dawes, farmer near Narrogin (WA). Buster was 84 in 2012, and has long experience in his relentless and dedicated management of silverleaf nightshade over decades. Between 1980 to 2018 the Dawes have removed over 90% of silverleaf nightshade from their property and they now still boom spray 300 to 400 ha.

Buster wrote down his thoughts and experiences to help others battling silverleaf nightshade:

1) Spray in November to stop seeding. Sheep and animals carry the seeds into clean country.
2) Glyphosate at 1.5 to 2 L/ha kills silverleaf nightshade shoots – use early in the season.
3) Spot-spray Tordon on small patches. Use of colour dye in mist is very important, as is the need to spray 1.5m outside the edge of patch to cover roots not on the surface.
4) Keep sheep out for approximately four weeks before spraying. Best time to spray is in the morning as patches can easily be seen.
5) Later in season, i.e. March-April, is the best time to spray to hit it before the dormant period.
6) Check all dam banks, tree lines, and where sheep camp for patches.
7) Check all paddocks for missed spots or new arrivals 4 to 6 weeks after spot spraying.
8) Any paddocks that have been cleaned up need to be checked every year, especially after summer rains.
9) In areas not cropped or on sandy country silverleaf nightshade is easily killed. Clay country is harder.

IMAGE: Buster Dawes – silverleaf nightshade champion in for the long run.

GOOD FARM BIOSECURITY PRACTICES AND REGULAR SEARCHES ARE THE MOST COST-EFFECTIVE.

FIGURE 48. Silverleaf nightshade plant 7 to 10 days after 2,4-D amine application.

FIGURE 49. Dense infestation in SA 7 to 10 days after treatment with glyphosate and fluroxypyr.

FIGURE 50. In addition to cropping and grazing enterprises, silverleaf nightshade can also be a problem in horticulture.

Management in horticultural crops

There is little published information available on silverleaf nightshade management in Australian horticultural crops, and this area would benefit from further research. Observations from some horticultural regions (e.g. Leeton/Yanco, NSW; Northern Adelaide Plains, SA) confirm that silverleaf nightshade readily colonises irrigation channels, and irrigated annual vegetables and vineyards can be heavily infested (Figs. 50 and 51). These enterprises rarely have access to grazing livestock, and the traditional weed control tactics (e.g. cultivation, slashing) are ineffective against silverleaf nightshade. In addition, the range of herbicides available is very limited, due to the constraints of soil residues and drift onto neighbouring crops. Fluroxypyr (Starane), 2,4-D, and soil-residual spot treatments cannot be used. The only practical option for management appears to be glyphosate before or between crops. There is one advantage, however, because most silverleaf nightshade can be irrigated prior to glyphosate application, thus improving efficacy.

Much irrigated horticultural land in warm regions (including cotton areas) is probably free of silverleaf nightshade so far because there are no strong invasion pathways. It is rare that contaminated livestock are moved onto horticultural land, and cultivation equipment is usually specialised and different from broad-acre crop equipment. Most infested horticultural land was probably infested while it was used for grazing, prior to horticulture. There can be little doubt that silverleaf nightshade is well-suited to warm season irrigated horticultural land.

It would be prudent to consider and monitor the two most likely pathways that might introduce silverleaf nightshade: berries floating in irrigation water delivered from contaminated irrigation channels; and contaminated sheep manure brought from infested properties for use as fertiliser.

FIGURE 51. Silverleaf nightshade growing as a weed of summer-irrigated melons in NSW.

Management in non-agricultural land

Silverleaf nightshade can be found in a range of non-agricultural and urban situations including roadsides, fence lines, footpaths, median strips, along waterways and channels, around buildings, in urban parklands and home gardens, and around amenity and utility areas. In some cases, it is a surviving remnant of infestations established previously while the land was used for cropping and grazing. It can also be moved during earthworks and new infestations can occur along new roads. Most roadside infestations in rural areas appear to have established from transport or droving of contaminated livestock, and can be further spread by grading. Silverleaf nightshade in these situations is generally not actively managed, because it is not perceived as a significant problem or threat. Spot treatments are sometimes used and soil-residual treatments can be safely used in some situations. In others glyphosate is most commonly used, to avoid persistent bare soil patches and minimise damage to desirable vegetation.

Roadsides

Weed control along roadsides can be complicated because roadside native vegetation is valued for a range of reasons (e.g. biodiversity, reducing erosion, wildlife corridor, aesthetic value). Roadsides can be under the jurisdiction of a number of government authorities, and permitted weed control activities may vary between regions and locations. Options are often constrained by the need to preserve roadside native vegetation. Land managers are encouraged to negotiate with relevant government authorities before applying herbicides to weeds on road reserves, or fence lines that border road reserves (Fig. 52).

A combination of mowing and herbicides is often used for general weed management on roadsides. However, silverleaf nightshade should be mowed before it flowers, to avoid spreading seed. The use of non-selective herbicides (e.g. glyphosate) is not ideal for roadside silverleaf nightshade control, as it will create bare ground and reduce competition with silverleaf nightshade. Fluroxypyr, 2,4-D, picloram or their mixtures are often used instead, allowing grasses to re-establish to compete with silverleaf nightshade. Picloram should not be used near desirable roadside vegetation. Non-selective herbicides however are sometimes used to maintain the narrow margin of bare ground adjacent to the roadway to allow water movement and preserve line of sight for motorists.

Fence lines

The best practice management for internal fence lines (Fig. 53) is to apply the 'Dual Action' strategy, including the use of grazing as the first action, before flowering. Picloram-based products can be spot sprayed for rapid results and root-bank control. Landholders should discuss planned weed control options and treatments on fence lines with adjoining neighbours.

FIGURE 52. Silverleaf nightshade along a roadside in Central Victoria.

FIGURE 53. Silverleaf nightshade can move from one paddock to the next under fence lines, further invading cropping and grazing land.

Physical control – cultivation, slashing, mulching, burning and competition

Physical control methods can be used as a tactic to prevent flowering and seeding, however they cause little damage to perennial root reserves and are ineffective for reducing shoot density over time.

Cultivation and slashing to reduce shoot density in Australia are generally ineffective. Cultivation is ineffective in Australia because most of the roots and shoot buds are below the depth of cultivation and new plants may also establish from transplanted fragments. Australian research has found that a combination of slashing or cultivation, combined with herbicide application, did not improve control above the level of herbicides alone. Mulching and burning have little effect due to the large energy reserves in the root system.

Vigorous crops and pastures, especially those based on perennial summer-growing species (Fig. 54), can significantly suppress silverleaf nightshade growth. Competitive grasses such as Bambatsi panic, Premier digit grass, Strickland finger grass, Currie Cocksfoot, Sirolan Phalaris, Wallaby grass, Red grass, Cotton Panic, Green Panic, Topcut Rhodes grass have been effective in reducing silverleaf nightshade growth in NSW experiments (Bob Thompson, unpublished). The use of competitive grasses will also allow the application of broadleaf herbicides to target silverleaf nightshade roots in autumn. Dense and vigorous lucerne stands provide competition deep in the soil profile, and can reduce silverleaf nightshade growth and vigour. Similarly, canola can delay shoot emergence and reduce silverleaf nightshade vigour because it has deep tap roots that can extract moisture from deep in the soil profile.

Demonstration trials in SA and NSW suggest that several *Eucalyptus* spp. have some ability to control silverleaf nightshade growth within the canopy drip-line through allelopathy – where growth retarding chemicals exuded from the trees stunt the growth of silverleaf nightshade. This management approach may be suited to silverleaf nightshade that has spread to inaccessible areas in rocky hilltops or along creeks. These areas can become nursery areas, producing seed that can re-infest clean paddocks. A number of *Eucalyptus* species from the Kalgoorlie region of WA are known to have allelopathic effects on silverleaf nightshade, including Gimlet, Swamp Mallee, Dundas Blackbutt and Dundas Mahogany (Stanton et al., 2008).

FIGURE 54. A well-watered perennial pasture, in this case kikuyu lawn in SA (left), can suppress silverleaf nightshade growth (centre). The silverleaf nightshade is growing in the dry pasture (right) but outside of the sprinkler zone it is short and stunted.

Biological control

BIOLOGICAL CONTROL IS BEING ACTIVELY RESEARCHED, BUT IT IS A LONG-TERM PROJECT.

There was a determined research effort against silverleaf nightshade in Australia during the 1970s and 1980s. This effort declined as researchers had little success with herbicides, and the next hope was a break-through in biological control. In the intervening 30 years silverleaf nightshade has continued to spread, and in 2016 work began on the biological control agent, silverleaf nightshade leaf beetle (*Leptinotarsa texana*).

Silverleaf nightshade was declared a target for biological control in Australia by the Standing Committee on Agriculture in February 1986, in response to an application from the Victorian Department of Conservation. A range of potential agents was identified from southern USA (Wapshere, 1988) and a benefit:cost analysis for biological control in 2006 estimated a benefit of $140 million over a 30 year period, providing a benefit to cost ratio of 58:1 (Kwong et al., 2006). However, as of 2018 there has not been any release of an agent for silverleaf nightshade control in Australia. One potential biological control agent, the leaf-galling nematode *Ditylenchus phyllobius*, was tested in Australia under quarantine in the late 1980s but it was rejected due to its unacceptably broad host-range, including eggplants and thirteen native Australian solanums. South African scientists were also testing agents throughout the 1980s and early 1990s, and released four biological control agents in that country.

The most successful of the South African introductions was the silverleaf nightshade leaf beetle, *Leptinotarsa texana* (Fig. 55). Encouraging results from South Africa combined with continued spread of silverleaf nightshade in Australia, and the limitations of current control methods, prompted renewed interest in classical biological control. An assessment of the suitability of the silverleaf nightshade leaf beetle for introduction to Australia began in 2016. A national team imported the beetle into quarantine and conducted extensive host specificity testing. In late 2017 it was confirmed that a group of potato varieties, along with a group of native Australian *Solanum* plants, were attacked under laboratory conditions. Due to the seriousness of the threat posed a decision was made by the research team that *Leptinotarsa texana* was not suitable for release in Australia. At the time of writing (2018) a second national research project is underway to evaluate other candidate agents for silverleaf nightshade, and also to explore Argentina for potential agents.

Kwong et al., (2006) discussed a number of potential agents from South America, and encouraged further exploration of areas with similar climates to southern Australia. New research began in 2016 to consider other potential agents from poorly explored regions in central Argentina, particularly the Buenos Aires and Pampa provinces, and in the central regions of Chile (Greg Lefoe, pers. comm). A recent genetic analysis of silverleaf nightshade populations from Australian and around the world informed planned natural enemy surveys throughout the weed's range, possibly including Argentina and Chile. Risk analysis for silverleaf nightshade biological control in Australia is inherently complex, due to the large number of closely related native, ornamental and crop species that occur in Australia. Considerable research effort will therefore be necessary to assess the risk of off-target damage of prospective agents. A number of naturally-occurring insect species have been observed attacking silverleaf nightshade berries and lower stems throughout Australia. In some cases, localised damage can be significant but none of the species has caused significant reductions in silverleaf nightshade density.

FIGURE 55. An adult silverleaf nightshade leaf beetle (*Leptinotarsa texana*) feeding on silverleaf nightshade leaf (Photo: Greg Lefoe).

Economics of silverleaf nightshade control

Silverleaf nightshade is a perennial weed that can only be controlled through persistent efforts over at least 5 years. Accordingly, assessments of the economic benefits of control need to consider costs and returns over many years. Across southern Australia, from Narrogin in WA to Mudgee in NSW, there are many different enterprises and farming systems. Each property will have its own particular economic circumstances, and the analysis of the economics of silverleaf nightshade control will be unique to each farm or region.

The best that we can do is to consider a range of case studies (Section 4), and to analyse "average" or "generic" data. These snapshots and analyses will give a "ball park" feel for the potential costs and returns associated with silverleaf nightshade control. Of course the seasonal conditions and commodity prices will vary unpredictably from season to season and this can greatly influence outcomes over any particular time period.

Economic modelling research conducted in NSW as part of a Meat and Livestock Australia project (Stanton et al., 2010) made a series of assumptions and estimates to analyse expected outcomes from three different control strategies over ten years. Two livestock enterprises were compared - wool production and prime lamb production. The three strategies considered were 1) do nothing; 2) use current practices (one early application of glyphosate at 1080 g active ingredient/ha); and 3a) and 3b) use the Dual Action, Best Practice Management (BPM) approach advocated in this manual for a) dense populations, and b) sparse populations. The results of this analysis are shown in Table 7.

The model assumed that doing nothing would result in a steady increase in silverleaf nightshade density, and that a single annual application of glyphosate would decrease the density very slowly. The Best Practice Management scenario assumed a steady decrease in density, with significant control gained within five years.

Initially, using Best Practice Management, the costs were higher and associated profits were lower. However, over the ten-year modelling time this management scenario had the highest profits, with the early costs of control off-set by bigger profits later. Table 7 shows that not controlling silverleaf nightshade results in the lowest profits for both enterprises. Applying glyphosate once annually is profitable, but still results in significant losses. Best Practice Management was predicted to be the most profitable approach, returning 2 to 3 times the profit compared to doing nothing. The modelling also shows that the most profitable management for both enterprises is to control silverleaf nightshade early, before populations become dense.

As an example, consider a Prime Lamb enterprise in North East Victoria with a gross margin of $137/ha and a dense silverleaf nightshade infestation. The modelling shows that each year Best Practice Management has a direct control cost of $31/ha (herbicide, lost production, labour and machinery) and generates a net profit

TABLE 7. Cost and profit analysis of silverleaf nightshade management, comparing three strategies in two livestock enterprises (cumulative profit/ha over ten years).

		WOOL ENTERPRISE			PRIME LAMB ENTERPRISE		
	Stocking rate (DSE/ha)		8.9			7.8	
	Gross margin ($/DSE)		$13			$16	
	Gross margin ($/ha)		$106			$137	
STRATEGY		$ LOST PRODUCTION	CHEMICAL COST	ACTUAL PROFIT	$ LOST PRODUCTION	CHEMICAL COST	ACTUAL PROFIT
1	No control	$711	$0	$396	$919	$0	$512
2	Current Practice (glypho x1)	$286	$229	$593	$370	$229	$833
3a	BPM:dense (>10 stems/m^2)	$69	$217	$822	$89	$217	$1,126
3b	BPM:sparse (<2.5 stems/m^2)	$51	$63	$994	$66	$63	$1,303

ECONOMIC MODELLING PREDICTS THAT RETURNS CAN BE INCREASED BY C. $160/HA/YEAR.

of $113/ha, while the Current Practice (single annual glyphosate application) management costs growers $60/ha with a profit of $83/ha. In this example over a ten-year period, the Best Practice Management returns an extra $59/ha each year compared to a single annual glyphosate application. The increase in profits would have been even higher if silverleaf nightshade had been tackled early, before it became dense (Stanton et al., 2010).

A recent economic modelling study, projecting 20 years into the future (Behrendt et al., 2018, under review), found similar benefits from using Best Practice Management for silverleaf nightshade. When Best Practice Management is used during both the cropping and pasture phases of the rotation, returns are predicted to increase by $57-116 per ha. each year at Parkes (NSW) and $96-131 at Ungarie (NSW), compared to Current Practice. When Best Practice Management was compared to No Management, the increases to returns were even higher – $136-195 at Parkes and $147-182 at Ungarie.

BREAKOUT 7

BACK OF THE ENVELOPE – $5,000 EXTRA PROFIT FOR CROP PADDOCK

The economics of silverleaf nightshade control to protect crop yields will vary from region to region, and will ultimately be influenced most by winter-spring rainfall during crop growth. As a simplified example, consider a 100 ha sandy-loam paddock that is 50% covered by dense silverleaf nightshade. If not sprayed in the summer/autumn prior to sowing wheat, a 30% yield reduction might be expected in those areas. If the wheat yield was 2.5 t per ha in clean areas, at a price of $200 per tonne, then the whole paddock would return $50,000 if there were no silverleaf nightshade. However, the yield losses (30% lower, compared to sprayed paddocks, over 50 ha) would cost $7,500. The cost of herbicide treatment during the preceding summer-autumn ($25 ha-1, over 100 ha) would be $2,500, resulting in $5,000 extra return for the paddock. There may also be an additional return from controlling other summer weeds present before sowing crops.

IMAGE: Spraying SLN during the summer and autumn before cropping can conserve valuable sub-soil moisture and return greater profits.

CASE STUDIES

CASE STUDY 1
"The Ranch" (crops and livestock)

Harry and Lochie Rowling, "The Ranch", Ungarie, NSW

Father and son Harry and Lochie Rowling manage a mixed farming property (3,200ha) with 50% cropping and 50% pasture at Ungarie, in the Riverina region of New South Wales.

The production system

Crops: wheat, barley, oats and lupins

Pastures: lucerne, clovers and medics sown into native grasses.

Livestock: 1,400 Merino breeding ewes (and lambs) for wool production and 500 crossbred ewes joined to Suffolk rams for prime lamb production.

The rotations, three years of cropping followed by three years of pastures, are designed to reduce weed problems and crop diseases. The farm is zoned to avoid damage to frost-prone crops in low lying areas. Early- and late-maturating wheat varieties (Spitfire and Suntop) are grown to avoid frosts. Oats are grown as a dual-purpose crop, grazed early then harvested for seed. Crop stubbles are grazed. Pastures are set-stocked but rotationally-grazed when the opportunity arises in wet summers. Soils are mainly clays (2,800ha) with some loams (400ha).

Silverleaf nightshade

Silverleaf nightshade became obvious on a few properties around the district in the 1960s. It may have been present before that time as an inconsequential weed but became a notable problem after the wet years in the mid to late 1950s. The first report came from a sheep dip area known as Glencoe and it spread to other properties including one neighbouring the Rowling's property. Originally cultivation was tried as a control method, but this and livestock have spread it. There was less cropping during that period so it was mainly spread by livestock. It established easily on the lighter soils but soon was growing across all soil types in the district. Most surrounding farms now have silverleaf nightshade infestations and they try to keep it under control with limited resources. The local council contributes by managing the roadside populations.

The Rowlings have two properties. On one there is about 2,000 ha with mainly scattered, medium density patches of silverleaf nightshade, and about 150 ha is densely infested. The main impact of silverleaf nightshade is the time and money spent on keeping it under control, especially after harvest when it would be good to have a holiday instead. Silverleaf nightshade is the hardest weed the Rowlings have had to deal with, particularly due to its long flowering period and persistence. It is their highest priority weed and needs to be sprayed after harvest.

Control and management strategies

Control of silverleaf nightshade is relatively simple in the cropping phase of the rotation, using routine normal summer fallow sprays to keep it under control. The Rowlings have used a range of herbicides, but it appears that the application rates needed have increased over the years. In the pasture phase silverleaf nightshade always tends to come back to some extent. It grows predominately in competition with the winter annual pasture species, even with use of Starane® herbicide during the cropping phase. Growing summer active grasses can help, but getting these grasses established can be difficult in their area.

Herbicides

Herbicides used include glyphosate, 2,4-D amine and Starane® (fluroxypyr). Tordon® (picloram/2,4-D) has been tried but it is expensive, and it does not appear to be economic for broad-acre spraying. Dual Action treatments have proven to be beneficial. There is a need to stop flowering first but the follow-up autumn spray is also needed in most years. Spray conditions are often not ideal with hot dry, dusty conditions reducing herbicide efficacy - but there is no choice sometimes. The Rowlings have been using the best management guidelines for 10 years by controlling seeding and running down the root reserves. The aim has been to reduce the numbers to scattered populations that can be spot-sprayed. Surveillance searches for new patches have become part of the Rowlings normal farming operations. They have observed disease-affected plants, and some damage to silverleaf nightshade from grubs that eat berries.

Benefits and costs

The Rowlings think that silverleaf nightshade has affected property values in the range of $125-250 per ha and if buyers are aware of the weed then it can take a long time to sell the land. They have recently lost some valuable rams that were feeding in an infested paddock. Stock losses are rare, but silverleaf nightshade may also cause ill-thrift.

SUMMARY OF ESTIMATED ANNUAL SILVERLEAF NIGHTSHADE RELATED COSTS		
Crop Production Loss	$38,281	(yield losses due to competition)
Stock Production Loss	$110,836	(lost carrying capacity)
Direct Control Costs	$44,220	(herbicides, labour)
Total annual farm costs	**$193,337**	

KEYS TO SUCCESS

Harry and Lochie's key messages and advice for managing silverleaf nightshade:

- If you have silverleaf nightshade on your property, it should be one of your highest weed priorities.
- Fence off smaller bad areas to prevent stock grazing and cultivation.
- Be vigilant, keep up the spray program, and don't ever neglect it.
- A Dual Action approach used for 10 years controls seeding and runs down root reserves.
- It will take 6 to7 years to bring the population down to scattered patches.
- Support research trials so that the new regional controls can be developed.

CASE STUDY 2
Rutherglen and Toolang (crops and livestock)

Russell and Buster Dawes, “Rutherglen” and “Toolang”, Yealering, WA

The Dawes family has farmed in the Great Southern area of the WA wheat belt for over 40 years. They have had success in keeping silverleaf nightshade under control with considerable time and effort.

The production system

The Dawes family farms 5,000 ha. Silverleaf nightshade is a problem over the whole area, but only about 400 ha is heavily infested. This is mainly in non-crop areas in tree lines, laneways and along the creeks. They operate a mixed farming enterprise, and the main income is derived from cropping cereals (wheat and barley) and canola, and running Merino sheep for wool production. Approximately 400 ha of each crop (wheat, barley and canola) is grown each year, with the balance of the area under pasture. The Dawes are no-till croppers, using a flexicoil airseeder with knifepoints. Crop rotations vary according to the weed situation in each paddock. Some areas are continuously cropped, but others are rotated with grazed pastures. Other problem weeds include herbicide resistant annual ryegrass, wild radish, barley grass, wild turnip and capeweed.

Silverleaf nightshade

The Dawes family purchased their two farms about 40 years ago, when silverleaf nightshade was already present. It is understood to have come onto the farm in the 1950’s, in oats brought in from SA. Silverleaf nightshade has been spread around the farm by livestock, cultivation and in grain used for hand feeding livestock. Russell also suspects that native animals may spread seed.

Control and management strategies

Silverleaf nightshade has not caused changes in management but it needs to be constantly monitored to keep it in check. The Dawes are able to maintain their cropping regime and continue spraying with a range of chemicals. Russell has found that for best results spraying needs to start as soon after harvest as possible. This often means that summer holidays are postponed until all summer weed control is completed. He has diligently applied the theory that all seeding must be prevented, even in their Mediterranean climate of hot, dry summers. Silverleaf nightshade will draw moisture from deep down in the profile and will often be the only plant alive during this period. In this climate there are no competitive plants, such as summer grasses that can be sown, and the landscape browns off over the summer months.

Herbicides

The Dawes have developed some basic guidelines to keep silverleaf nightshade in check:

1. A summer spray is done when the first flowers are seen to prevent seeding, using a mixture of herbicides. Stubble paddocks infested with silverleaf nightshade are grazed before flowering. Stock are removed before berry set to prevent seed movement and so that sprays can be applied. The herbicides used over summer are:
   - glyphosate
   - 2,4-D amine
   - Garlon 600®
   - Starane Advanced® and adjuvants to ensure good penetration of the chemical.
2. The post-harvest treatment is followed by a pre-sowing weed clean-up using the same herbicides.
   - Russell's father, Buster Dawes, uses a 30m wide boom and water rates of 50-100 litres per ha, depending on the seasonal conditions. For fence lines and in non-cropping areas they use a ute-mounted sprayer. There is considerable time spent on this weed. Over summer it takes one person about a month to spray the cropping paddocks. At other times of the year Buster (now over 80 years old) is involved in spot spraying the fence lines. The Dawes are interested in buying a Weed Seeker® as this would allow the use of higher rates, or more expensive herbicides over the cropping areas.

Benefits and costs

Yield losses are noted in cropping areas when there is a spray miss (up to 40% in cereals), but there has been total loss of crop in areas with infestations of 10 stems per square metre or more. Silverleaf nightshade will severely deplete stored soil moisture available to the following crop if it is not controlled in the crop fallow before seeding.

SUMMARY OF ESTIMATED ANNUAL SILVERLEAF NIGHTSHADE RELATED COSTS		
Crop Production Loss	$52,272	(yield losses due to competition)
Stock Production Loss	$117,655	(lost carrying capacity)
Direct Control Costs	$29,920	(herbicides, labour)
Total annual farm costs	**$199,847**	

KEYS TO SUCCESS

Russell's key messages and advice for managing silverleaf nightshade is to:

- Don't let silverleaf nightshade go to seed.
- Don't go on holidays until the summer spray is done.
- Develop some basic guidelines on your farm to keep silverleaf nightshade in check.

CASE STUDY 3 (crops and livestock)

Tim Dowdell, Harrismith, WA

Western Australian farmer Tim Dowdell has seen silverleaf nightshade cover up to 70% of some paddocks in his region. He believes that changes to summer weather patterns are encouraging the spread of this weed.

The production system

The Dowdell family farms 2,500 ha in the Harrismith area near Narrogin, in WA. This includes three properties that are run as mixed farming operations, with 1,200 ha of crop and Merino wool production on improved pastures (1,300 ha). Wheat (500 ha), barley (500 ha), and oats (200 ha; for supplementary sheep feed) are grown. Soils are 'grey clay' overlain with up to 30 cm of sand. Tim's father's farm is clean – he is very careful with sheep movement in and out of the property.

Silverleaf nightshade

Tim believes that silverleaf nightshade was brought onto the farm in oat seed from eastern Australia during the 1940s. Silverleaf nightshade grows on all soil types, but seems to be most vigorous on grey clay soils. Tim has not yet recognised any silverleaf nightshade seedlings, and believes that shoots most likely arise from perennial roots. Shoots first appear in crops and crop stubble, then later (December/January) in pasture. Tim believes that silverleaf nightshade is slowly getting worse, particularly since 1988, and believes the main reason is a change in the summer weather patterns. Rainfall events in October to November encourage thick silverleaf nightshade in the following summer, with infestations covering 70% of some paddocks.

Although Tim has not noted spread patterns that match cultivation patterns, he believes that minimum tillage practices are encouraging fragments. The knife point system he currently uses can penetrate 15 to 18 cm into the soil, while older cultivation equipment with shears only penetrated 5 to 8 cm. Root fragments are caught on the seeder bar, so sowing equipment requires regular cleaning to avoid further spread. Green silverleaf nightshade berries can contaminate wheat and barley samples. While older sheep eat silverleaf nightshade, Tim has noticed that younger sheep take time to become accustomed to it.

Control and management strategies

Older ewes will graze emerging shoots as a last resort, when there is very little alternative paddock feed. Tim hasn't noticed sheep eating berries, and he hasn't noticed any toxicity symptoms. By spot-spraying new infestations, Tim and his father have protected 'clean' areas for over 25 years.

Herbicides

Summer fallow sprays targeting melons are also effective against silverleaf nightshade shoots. They use Roundup + 2,4-D. Tordon® is used for spot-spraying and Tim makes sure to spray the soil within a 1.5 m radius of silverleaf nightshade plants. The usual summer spray program for cropping takes about two weeks of full-time work but, if spot-spraying is required during a wet season, then another two to three days may be needed.

Benefits and costs

The Dowdell family have been managing silverleaf nightshade for over 30 years. Whilst they still have a moderate-to-low level of infestation over 2,500 ha, they have been able to contain and reduce the level of infestation across the property.

SUMMARY OF ESTIMATED ANNUAL SILVERLEAF NIGHTSHADE RELATED COSTS		
Crop Production Loss	$38,000	(yield losses due to competition)
Stock Production Loss	$31,943	(lost carrying capacity)
Direct Control Costs	$24,220	(herbicides, labour)
Total annual farm costs	**$96,513**	

KEYS TO SUCCESS

Tim's key messages and advice for managing silverleaf nightshade:

- Quarantine new sheep into small paddocks, where any silverleaf nightshade can easily be managed, before releasing them to the rest of the farm.
- Plan, and monitor silverleaf nightshade over several years.
- The benefits of managing this weed greatly outweigh the control costs.

CASE STUDY 4
(crops and livestock)

Trent Harris, Cleve, South Australia

Trent Harris manages his 5,000 ha family property on the Eyre Peninsula. Silverleaf nightshade was detected by his father in 1944, introduced by sheep that had been agisted elsewhere.

The production system

The Harris family has 5,000 ha of mixed farming operations. Around 3,500 ha is cropped (mainly wheat, lupins and barley), with the remaining area growing vetch and medic pasture for their sheep meat enterprise (1,400 Merino ewes joined to white Suffolk rams). The farm business used to produce 50% crop and 50% livestock, but now has a more intensive cropping program. The average annual rainfall varies from 400 mm in the hilly areas, to 350 mm in the 'home' block. In the Cleve area farmers aim to achieve maximum crop water use efficiency. If that is possible then there is not much available soil moisture for the silverleaf nightshade plant to utilise after harvest.

Silverleaf nightshade

Silverleaf nightshade has been present on the family farm since World War II, when the land was originally cleared in the late 1940s. Trent's father agisted sheep on another property, and when they returned they spread seed of "tomato bush", as it was earlier known. There are now four to five recognisable variants of silverleaf nightshade in the Cleve area, including white and purple petal variants. According to Trent, the Cleve district was "a sea of silverleaf nightshade" five years ago, but diligent management has greatly reduced its prevalence in the district.

Control and management strategies

Twenty years ago Trent's father relied on cultivation to kill silverleaf nightshade plants. No herbicides were used and the end result was very dense and widespread infestations. Now, control has been so successful that Trent thinks that you would have to search to find a single plant. The density of silverleaf nightshade infestations dictates the farming practice for each paddock - heavily infested paddocks are sown to cereals first to keep silverleaf nightshade levels under control. Trent finds that silverleaf nightshade shoot emergence is more staggered on heavier soil types than in the sandy soils, making it difficult to develop a well-timed control program. Emergence on sandy soil seems to be more consistent.

While Trent's father used to spend many hours monitoring and spot-spraying, this is no longer a major commitment as the spray program is on a broad-acre scale. Trent believes that the reduced level of infestation has been due to a combination of strategic herbicide application and a shift from cultivation to direct drilling, which has reduced the spread of root fragments. Risk of new infestations is minimized by quarantining purchased sheep in a holding area that is easily monitored for weeds.

Herbicides

It took four years of summer control using glyphosate before the Harris family started to see big benefits. To begin with, in order to save money, Trent only sprayed every two years. The moment he sprayed every year, he saw results.

Silverleaf nightshade typically starts to emerge around late October in the Cleve District. The first herbicide treatment is around early January, depending on the summer rain. Trent will apply a second spray if there is summer rain to trigger new shoot emergence. He found that spraying in February was too late, as silverleaf nightshade plants have produced berries by then. Trent uses a combination of glyphosate and 2,4-D amine. He no longer uses 2,4-D ester as it burns the silverleaf nightshade leaves too quickly. He believes that the slower action of the amine formulation and high water rates with glyphosate allows better herbicide absorption and efficacy on the root system. He also believes that a dew increases efficacy.

Benefits and costs

Trent has seen yield penalties in heavily infested areas, with silverleaf nightshade plants competing for water and nutrients. For example, barley yields increased from about 1.1 t/ha on heavily infested areas to 4.4t/ha when silverleaf nightshade populations were controlled. Trent believes that it would take two summer sprays per year, for three to four years, to be able to see results in a paddock with infestation levels of 70% silverleaf nightshade. Trent believes the benefits are more obvious on sandy country than on heavy country, as the sandy soil can produce a higher gross margin.

SUMMARY OF ESTIMATED ANNUAL SILVERLEAF NIGHTSHADE RELATED COSTS

Crop Production Loss	$86,050	(yield losses due to competition)
Stock Production Loss	$34,870	(lost carrying capacity)
Direct Control Costs	$89,000	(herbicides, labour)
Total annual farm costs	**$209,920**	

KEYS TO SUCCESS

Trent's key messages and advice for managing silverleaf nightshade:

- Summer spraying is very important.
- Spot-spraying every hectare regardless of pasture or crop with a minimum of two applications (if required). This is critical to success.
- Spray your silverleaf nightshade infestations at the right time – often at 3 am with some dew. The fresher the plant, the more effective it will be.
- Use robust chemical rates but not too high either. Often a slow kill is a better kill.

CASE STUDY 5 (continuous cropping)

Paul Bammann, Cleve Hills, South Australia

The production system

Geoff Bammann and his son Paul have a continuous winter cropping program, cropping two thirds of their 6,000 ha farm to oilseeds, pulses, and cereals, with the remaining third of the farm either leased or share farmed. Their crop sequence is generally two to four cereals, followed by pulses. They have not run sheep since 1999. Their farm area includes soils with sodic subsoils, through to sand over clay, to deep sands. The average annual rainfall ranges from 325 mm in sandy country to 375 mm in the foothills, with a winter-dominant growing season rainfall of 270 mm. Besides silverleaf nightshade, their biggest weed issues are milk thistles, marshmallow, herbicide resistant barley grass and brome grass.

Silverleaf nightshade

The Bammanns have found that silverleaf nightshade infestations are thickest on sandy soils, where soil fertility is low and the crops and pastures are not as competitive. Paul has observed silverleaf nightshade densities of up to 40 stems per square metre in sandy soil. When Paul returned to the farm in the mid-90s, silverleaf nightshade was rife, spread mostly by sheep. Although Geoff's father was worried about silverleaf nightshade, it went under the radar as at the time farmers were more worried about other weeds, such as skeleton weed. Now, Paul estimates silverleaf nightshade density is 10-20% less, with patches of infestation rather than general coverage. Paul and Geoff found that the removing livestock from their farm was a big game changer in reducing silverleaf nightshade. They found that while they had sheep on their property, they were short of feed in the summer, and management commitments meant that they were never able to complete a full summer spray program to effectively manage silverleaf nightshade.

Geoff and Paul believe that because of the limited summer rainfall on the Eyre Peninsula, very little silverleaf nightshade is spread via seed. The exception is in wet summers. They feel that this has helped to limit its spread to other areas outside the Cleve District.

Control and management strategies

With low rainfall over the summer period, there are few options for competitive summer crops. Paul has considered French white millet in times where he has sufficient rainfall to utilize moisture and compete with silverleaf nightshade on sandy soils. Paul and Geoff are confident in managing silverleaf nightshade populations with a control program that they have had in place since 1997 - regular summer spraying, with no-till practices minimizing spread via root fragments. Paul has found that it takes around 10 years to manage silverleaf nightshade effectively, with a dramatic decline in populations evident after three years.

Herbicides

Geoff and Paul have historically relied on the herbicide glyphosate for summer spraying, and often use it in a tank mix with other herbicides such as Garlon 600®, 2,4-D, Ally® and Goal®.

The summer spray program has been simplified with advances in spray equipment, and since they no longer have livestock in their system. An effective summer control program also means that valuable soil moisture is conserved for winter cropping.

Benefits and costs

Knowing how long it would take to bring the silverleaf nightshade levels under control, Paul would not be keen to purchase a new farm if he knew it was heavily infested with silverleaf nightshade. He knows of a heavily infested block in the district that has just not sold. He estimates this block would be devalued between 30-50% compared with cleaner blocks due to silverleaf nightshade and also other weeds, such as couch grass.

SUMMARY OF ESTIMATED ANNUAL SILVERLEAF NIGHTSHADE RELATED COSTS		
Crop Production Loss	$187,000	(yield losses due to competition)
Direct Control Costs	$54,500	(chemicals, labour)
Lost Land Value	$8,000	(lost market value appreciation)
Total annual farm costs	**$249,500**	

KEYS TO SUCCESS

Geoff and Paul's key messages and advice for managing silverleaf nightshade:

- Rainfall dictates the timing of silverleaf nightshade control programs, usually starting three weeks after rain.
- Don't ever miss a summer spray as you are never completely killing the plant with one spray.
- Restrict the movement of your stock around the farm to limit the spread of silverleaf nightshade.

CASE STUDY 6
Nil Desperandum (grazing)

Bill Twigg, "Nil Desperandum", Bears Lagoon, Victoria

Bill Twigg has spent his life investing in the profitability of his third generation 2,300 ha property, in Central Victoria. His silverleaf nightshade control program includes a minimum of three herbicide applications per year.

The production system

Bill's grandfather originally bought a 600 ha farm in Central Victoria. It was passed on to his father, who battled with it through the depression of the 1930s. The family built up the farm size and it was eventually split between Bill and his brother, who both now own 2,300 ha. Bill rarely grows crops, instead growing perennial plants such as lucerne at sparse densities, to imitate the native salt bush. In contrast to pastures made up of annual plants, perennial pastures provide him with complete ground cover for most of the year. He regards no plant as a weed on the farm so long as his stock will eat it. Bill believes his success is due to his beliefs in nature - if he has a problem, he looks to nature for the solution.

Bill runs 5,000 first cross ewes for prime lamb production. Lambing in the spring only, Bill contends that his stocking rate is twice that of anyone else in the district because of lucerne and spring lambing. Bill usually grows wheat (average yield of 2.5 t/ha) as a cover crop to establish lucerne pastures. The average annual rainfall in the region is 450 mm and the soil type is typically a red-brown clay loam.

Silverleaf nightshade

Bill remembers exactly when silverleaf nightshade arrived in the area over 60 years ago, when a drover grazed sheep "down the road". Bill's father immediately considered it a weed and tried to cut it out with a shovel. He didn't succeed and needless to say that silverleaf nightshade spread to their neighbour's farm and beyond.

Bill has relatively light silverleaf nightshade infestations and estimates stem numbers to range from 10 to 150 stems over 40 ha. This compares to 2005 when he had ineffective control, and observed 150 to 200 silverleaf nightshade stems over the same 40 ha area. Bill has some neighbours who do not control silverleaf nightshade, resulting in paddocks with 80% silverleaf nightshade cover. A neighbour with high silverleaf nightshade densities chose to continually crop his paddocks and, as a result, seems to have it under control.

Bill believes that seed dispersal is the main risk for silverleaf nightshade spread on his farm. Therefore, although Bill does not believe stock willingly eat silverleaf nightshade, he doesn't allow neighbours with silverleaf nightshade infestations, or farmers with unknown silverleaf nightshade status, to bring sheep onto his property.

Control and management strategies

Silverleaf nightshade is his number one weed priority, mainly because it is so hard to detect compared to other weeds, such as horehound and burrs. Bill is committed to spraying every year because he doesn't want silverleaf nightshade densities to be at a level where it will compete for soil moisture and affect production, as Bill has observed on nearby properties. He also feels obligated to hand on his farm in a healthy state. Silverleaf nightshade usually emergences around October, with new emergence occurring up until April, depending on rainfall. Bill currently spends over three months per year of solid work controlling silverleaf nightshade. He sometimes uses lucerne as a non-chemical management option, sowing it at a high rate to compete with silverleaf nightshade for moisture.

Herbicides

Bill previously used 2,4-D 15 years ago but now uses glyphosate and Starane®, with a wetter. He has found that while glyphosate may burn lucerne plants, it does not kill them.

Bill has applied herbicides a minimum of three times per year and has been doing so for more than 10 years. When he was a boy weed control was very slow and was done on foot with a backpack sprayer and was hence much slower. Now he uses a 4-wheel bike sprayer.

Benefits and costs

Bill believes that farmers who have experience dealing with this weed would not likely want to touch it. He currently spends around $17,300 per year on herbicides and labour alone, but thinks that he is applying less herbicide now than he did 10 years ago. He accepts that if he didn't spray for a couple of years, silverleaf nightshade densities would affect the productivity of his farm. Bill estimates that heavily infested land would be valued at least 50% less than clean land.

SUMMARY OF ESTIMATED ANNUAL SILVERLEAF NIGHTSHADE RELATED COSTS		
Crop Production Loss	$7,750	(yield losses due to competition)
Stock Production Loss	$ 50,368	(lost carrying capacity)
Direct Control Costs	$17,300	(herbicides, labour)
Lost Land Value	$8,000	(lost market value appreciation)
Total annual farm costs	**$82,418**	

KEYS TO SUCCESS

Bill's key messages and advice for managing silverleaf nightshade:

- If Bill inherited a farm that was heavily infested with silverleaf nightshade, he would continually crop it for 10 years to run down the silverleaf nightshade populations.
- Biological control is the only long-term solution for complete silverleaf nightshade control.
- Adjuvants greatly increase the efficacy of herbicides on silverleaf nightshade. He previously sprayed without a wetter and often observed that silverleaf nightshade leaves were still half alive after application.

FURTHER INFORMATION

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Contacts – State agencies

Weed legislation, herbicide registration and use, and state agency names are subject to frequent change. Current Australian herbicide labels are usually available from the manufacturer's website as a pdf document. At the time of writing in 2018, the following contacts may provide information on these subjects. As a general rule, if any of the contacts below are no longer current, state agriculture or environment agencies are a good place to start.

STATE	AGENCY	CONTACTS
NSW	NSW Department of Primary Industries (NSW DPI)	General: www.dpi.nsw.gov.au Biosecurity: Locked Bag 21, Orange NSW 2800 Phone: 1800 680 244 Email: biosecurity@dpi.nsw.gov.au
SA	Primary Industries and Regions SA (PIRSA)	General: www.pir.sa.gov.au Postal: GPO Box 1671, Adelaide, South Australia, 5001 Office: Level 14, 25 Grenfell Street, Adelaide, S.A. 5000 Phone: 8 8226 0995 Biosecurity: www.pir.sa.gov.au/biosecurity/weeds_and_pest_animals Invasive Species Unit: Phone: (08) 8303 9620 0r (08) 8429 0832 Email: invasivespecies@sa.gov.au
Vic	The Department of Economic Development, Jobs, Transport and Resources (DEDJTR)	General: economicdevelopment.vic.gov.au Postal: GPO Box 4509, Melbourne VIC 3001 Office: 1 Spring Street Melbourne VIC 3000 Phone (03) 9651 9999 or 136 186 Biosecurity: agriculture.vic.gov.au/agriculture/biosecurity
WA	Primary Industries and Regional Development (PIRD) – Agriculture and Food	General: www.agric.wa.gov.au Biosecurity: Pest and Disease Information Service (PaDIS) Department of Agriculture and Food Postal: Locked Bag 4 Bentley Delivery Centre WA 6983 Office: 3 Baron-Hay Court, South Perth WA 6151 Phone: 1800 084 881 Email: info@agric.wa.gov.au

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