Management plan for Silverleaf Nightshade (*Solanum elaeagnifolium*) in South Australia

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FOR

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Executive summary

Silverleaf nightshade (*Solanum elaeagnifolium*) is a deep rooted perennial plant that inhabits warm temperate regions of Australia. Native to the Americas, it has been in Australia since the early twentieth century and is now recorded in all States and Territories apart from Tasmania. The most serious infestations occur in the wheat belt areas of New South Wales, Victoria and South Australia. In SA, up to 200,000 ha of land are infested.

Once established, silverleaf nightshade is very difficult to eradicate. Although aerial growth is usually up to 60 cm high, each plant has a very extensive root system that can extend to 3 m deep and 2 m horizontally. Silverleaf nightshade impacts significantly on cropping and pastures by reducing yield and carrying capacity.

There are currently very limited effective broadacre control methods as its extensive root system allows it to survive chemical and mechanical methods. *Prevention of spread to clean areas is the most effective management action*. Limits on stock movement in infested areas and sound hygiene practices are important actions to curb the spread of this weed. Where this weed is already established, co-ordinated control efforts are required for successful ongoing management.

This plan has been developed to provide an overarching strategy to guide NRM Boards and landholders in the management of silverleaf nightshade in South Australia, with the aim to prevent spread and maintain crop and pasture production.

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1. Introduction

Silverleaf nightshade (*Solanum elaeagnifolium*) is a deep rooted perennial plant that inhabits warm temperate regions of Australia in areas with 250-600 mm annual rainfall. It is native to central and south western North America and temperate South America. It has been introduced to many temperate areas around the world, and is a weed in many of these regions as well as in parts of its native range. It has been in Australia since the early twentieth century and is now recorded in all States and Territories apart from Tasmania. The most serious infestations occur in the wheat belt areas of New South Wales, Victoria and South Australia.

In an Australian wide weed risk assessment, silverleaf nightshade (SLN) ranked second, behind serrated tussock out of six significant temperate pasture weeds. This high ranking is a result of a high invasiveness and potential distribution score of 0.668 (out of 1) combined with a high impact score of 0.538 (out of 1) (Kwong, 2006). Silverleaf nightshade has also recently been ranked 5th out of more than 70 weeds as a priority for biological control (Paynter et al., 2009). These findings illustrate the importance of this weed on a national level and the need to support targeted and collaborative management.

At a State wide level, using the Biosecurity SA Weed Risk Assessment (WRA) protocol, silverleaf nightshade ranked as a high risk to crop/pasture and grazing landuses but with low feasibility for control. The resulting action is to manage the weed within these landuses. Within South Australia, each Natural Resource Management (NRM) Board has also undertaken a WRA, with results ranging from monitor to destroy infestations, thus each region will need to adapt their management strategies to their particular situation. The detailed WRA results for silverleaf nightshade within each region are in Appendix 1.

Once established, silverleaf nightshade is very difficult to eradicate. Keeping clean areas free of this weed is the most effective management action. Where already established, co-ordinated control efforts are required for successful ongoing management of this species.

1.1 Purpose and Context of the Management Plan

The purpose of this management plan is to provide an overarching strategy and resource to guide the NRM Boards in the management of silverleaf nightshade in South Australia. Currently, the Natural Resources Management Boards (NRMB's) have differing policies and management approaches for silverleaf nightshade, and a more co-ordinated state wide approach is desired to guide effective actions. The actions within this plan are suggested as best practice management and should be considered for adoption by the NRM Boards when developing their own strategic and operational weed management plans. This plan will be accompanied by an updated State wide silverleaf nightshade policy, and will provide direction for the development and review of regional policies relating to silverleaf nightshade.

The outcomes and actions within this plan are linked with outcomes from the National Weeds Strategy. Achievement of these outcomes will also contribute to regional pest management strategies.

This plan was developed with information gathered from published sources and key researchers and on-ground staff in a workshop held in May 2009. The workshop provided research updates and participants discussed current issues and research needs. Participants also provided input into the objectives and actions for this plan and suggested broader recommendations of what's required for silverleaf nightshade management in Australia. It is recommended that this plan is reviewed every five years to incorporate new management methods and actions.

2. Vision

The vision for silverleaf nightshade management within South Australia is:

Silverleaf nightshade effectively managed to prevent spread; protecting urban areas and maintaining agricultural production across the State

3. Key Outcomes

The following outcomes have been specified as steps towards meeting the desired vision for silverleaf nightshade management in South Australia. Specific actions and required stakeholders to meet these outcomes are detailed in Section 10: Implementation of the Plan.

Outcome 1: Further spread of silverleaf nightshade is prevented

Outcome 2: Land managers are informed and aware

4. Background

4.1 Description

The following description is adapted from Parsons & Cuthbertson (2001) unless referenced otherwise:

STEMS: Stems are herbaceous except at the base, sparingly branched. There are at least a few scattered reddish to yellow or brown spines 2-5 mm long near the base, and these may occur on the main veins of the leaves as well (Anonymous, 2007). However, plants can sometimes have almost no prickles (Symon, 1981).

FLOWERS: Flowers are normally purple to violet but occasionally white, with yellow centres about 3.5 cm in diameter, and five fused petals (Fig. 1). Variation in leaf shape and flower colour is very common, with flowers in Australia ranging from deep purple to pale purple and mauve pink or white (Symon, 1981).

FRUIT: Berries are smooth and globular, about 1.5 cm diameter, green when immature, turning yellow and orange and wrinkled when ripe.

SEED: 2.5- 4 mm diameter, round flat and smooth, light to dark brown and surrounded by mucilaginous material (Fig. 2).

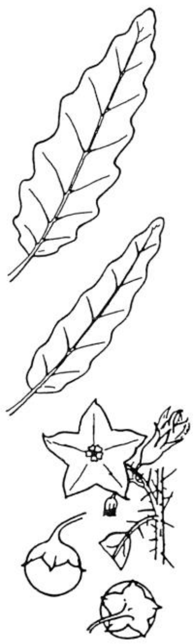
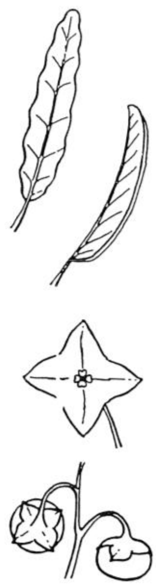
LEAVES: Leaves have a silvery white appearance from a dense covering of hairs, denser on the under surface. Lower leaves can be up to 15 cm long, upper leaves are smaller about 6-10 cm and 1-2 cm wide. Leaf shape is lanceolate to oblong, alternate and with undulate margins.

Figures 1 & 2: Flower and seeds of silverleaf nightshade. Photos courtesy R. Stanton

The variation in morphology displayed by silverleaf nightshade may suggest hybridisation with other species (Boyd et al., 1984), or as a result of multiple introductions (Heap et al., 1997). The facility for clonal reproduction also enables many variants to occur (Symon, 1981).

It can often be confused with many native solanums particularly native quena (*Solanum esuriale*) and western nightshade (*Solanum coactiliferum*) (Heap et al., 1997). However, silverleaf nightshade is taller with larger leaves that have a more pronounced wavy edge than the native species (Table 1) (Cuthbertson et al., 1976). The stamens on silverleaf nightshade are also longer than the native species and unripe berries have a green stripe that the native species don't (Kidston et al., 2007).

Table 1: Distinguishing features of silverleaf nightshade and two native solanums, drawings courtesy Department of Agriculture, South Australia

S. elaeagnifolium	*S. esuriale* (native Quena)	*S. coactiliferum* (western nightshade)
		
Leaves 5- 10 cm long	Leaves up to 5cm long	Leaves up to 5 cm long
5 pointed petals	5 pointed petals	4 petals
5 stamens 7-9 mm long	5 stamens 3.5- 5mm long	4 stamens 3.5- 5mm long
light and dark green striped berries	Pale green berries	Pale green berries

4.2 Biology

Silverleaf nightshade is a deep rooted perennial broad leaved herb that can grow up to 1 m tall. It is a summer growing species with aerial growth normally dying back during winter, but surviving from extensive rootstock that can spread up to 3-4 m deep in Australia (Heap et al., 1997). The main tap root acts as a storage organ (Cuthbertson, 1976). About 15 to 30 cm below the surface, strong lateral roots (up to 6 per plant) branch off from the main tap root, and can extend for up to 3 m horizontally (Heap et al., 1997). The origin of these laterals is often less than 5 cm below the surface and they form a complex network in the top 10- 40 cm, depending on the soil (Honan pers., comm.). Lateral roots can be found as deep as 143 cm down the tap root (Heap & Carter, 1999). Plants will establish any time between November and March with adequate rainfall (Lemerle & Leys, 1991), although in the mid north of South Australia, growth begins as early as September (Moore et al., 1975). Field germination occurs readily when the 3 cm soil depth temperatures range from 10 to 23°C (Leys & Cuthbertson, 1977). Flowering usually commences in December, but can be as early as mid November in the mid north of SA (Moore et al., 1975). Flowering continues over summer until February or March (Heap & Carter, 1999). The fruit is first formed in January and berries ripen and seeds mature 4-8 weeks after fruit set (Moore et al., 1975). Figure 3 illustrates the yearly life cycle.

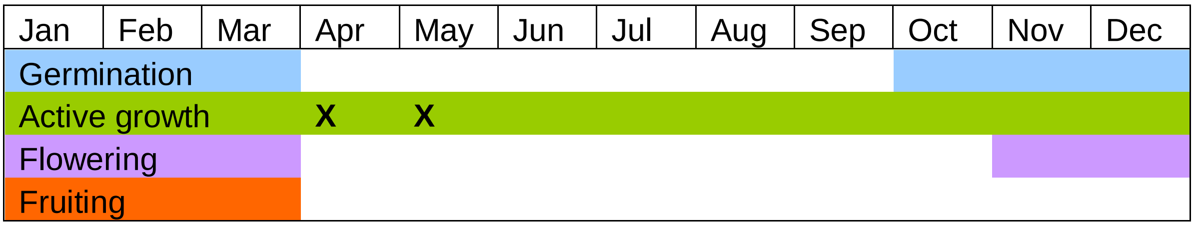


Figure 3: Yearly weed life cycle of Silverleaf nightshade. **X** denotes only roots are active, aerial growth is dying off. Adequate rainfall is required for germination.

Established plants are adapted to a wide range of habitats, are highly resistant to drought and tolerant of saline conditions but are sensitive to frost and waterlogging. However, in SA frosts occur prior to silverleaf nightshade's growing season, thus frosts don't have a significant impact. In south-eastern Australia, a two hectare infestation on heavy clay soil was apparently killed by an exceptionally wet winter (Heap & Carter, 1999). Plants will grow on soils ranging from heavy clays to solonised brown soils but it appears to prefer light-textured soils (Moore et al., 1975). and is known to thrive on low copper soils (Snell, 2003). Top- growth is killed off by the first autumn frosts, although the dead stems with berries can stand through winter months (Cuthbertson et al., 1976). In Texas, silverleaf nightshade can grow in areas which are below freezing for about one month of the year, as shoots will be killed but the roots survive (Heap, 1992).

4.3 Reproduction and dispersal

Silverleaf nightshade does not spread as rapidly as some species but once established it is very difficult to control. One single plant can produce many berries; in India variation ranged from 52 to 290 per plant (Khanna & Singh, 1987). Each berry can contain 60-120 seeds (Anonymous, 2007). In north-western Victoria, a dense infestation had 4000 seeds per m^2 in the top 10cm of soil (Heap et al., 1997). Seeds were thought to last up to 10 years in the soil, with a study in the early 1970s showing fresh seed germinated 29%, 3-year old seed germinated 72% and 10-year old seed germinated 60% (Moore et al., 1975). However, recent research in NSW showed 80% of fresh seed had decayed within 3 years (Kidston et al., 2007). As germination is infrequent, extensive viable seed banks may quickly build up. Seeds have survival mechanisms that allow them to withstand high temperatures and extreme desiccation for several days (Trione & Cony, 1990).

Silverleaf nightshade utilises both seedlings and vegetative growth for reproduction and seed viability is enhanced after animal digestion

Seed is most commonly spread by the movement of livestock. Seeds are also dispersed by wind, water and agricultural machinery and tools, as well as in feed and vehicles. Wind can also blow mature plants with attached berries along the ground, aiding dispersal.

Seed germination is thought to be enhanced by passage through the gastrointestinal tract of animals (Boyd et al., 1984). In sheep, seeds are excreted within 24 hours of ingestion and most seeds are excreted within 7-9 days (Heap & Honan, 1993). In Victoria, most seed has passed through sheep after 4 days and up to 14% of seed was recovered after excretion (McKenzie, 1975). Seed which passed through sheep was found to germinate quicker and resulted in a higher germination percentage (McKenzie, 1975).

High numbers of seedlings are only occasionally observed, as seeds have specific moisture and temperature requirements for germination (Heap et al., 1997). Seedlings that emerge in late spring or summer rarely survive in the dry conditions of southern Australia, despite potential for root elongation of 1 cm per day (Heap et al., 1997). High temperatures (20-34°C) are required, and full sunlight is favourable for normal germination and growth, although excluding light will not affect germination rates (Trione & Cony, 1990). Alternating temperatures for at least four days are a strict requirement for germination, and a rapid change in temperature has a stimulatory effect on the rate of germination (Trione & Cony, 1990). Constant temperatures stop the process of germination but do not reverse it (Trione and Cony, 1990). Boyd and Murray (1982b) found maximum germination occurred when pH was between 6 and 7, and germination declined rapidly with pH extremes. Sodium chloride concentrations above 2500 ppm also caused significant reductions in germination (Boyd & Murray, 1982b). At 6 cm depth, only 5% of seeds germinated and seeds from a depth of 12 cm did not germinate at all (Leys & Cuthbertson, 1977).

Alternating temperatures are a strict requirement for germination

Alternate wetting and drying of seeds accelerated germination (Vigna et al., 1983 cited in (Heap & Carter, 1999) but mechanical and chemical seed coat treatments had no effect on germination rates (Cooley & Smith, 1972). Immersing seeds in running water increased germination in a laboratory experiment. The longer the seeds were immersed in water, the greater was the subsequent germination, probably due to the break down of the mucilaginous layer around the seed (Rutherford 1978). Seeds have also been found to germinate under water (Trione & Cony, 1990). In WA, new infestations from seeds are closely related to the incidence of unusually wet summers (Rutherford, 1978), and spread within an infested property appears to be closely associated with a creek or flood prone watercourse (Rutherford, 1979).

Yannitsaros et al. (1974) found silverleaf nightshade has a particular pattern of spread in all directions from the first point of establishment. The spread is not continuous but occurs in leaps with space between colonies increasing with distance from the centre. Genetic studies have shown that the dispersal of seed (usually through livestock movement) is the major factor in spread of silverleaf nightshade across larger areas (Hawker, 2006).

Multiple regeneration from dormant buds on established roots is the most important method of multiplication in Australia (Wapshere, 1988). In Victoria, it was found that even with the removal of the plant and topsoil, established roots as deep as 125 cm below the surface could produce new growth within 14 months (Molnar & McKenzie, 1976). Root fragments can also regenerate even buried up to 20 cm deep and from pieces as small as 0.5 cm long (Anonymous, 2007). However, Boyd & Murray (1982b) found the length of root fragment affected shoot survival with plants grown from 20 cm long fragments producing 70% more dry matter than growth from 5 cm long fragments. In NSW, recent research shows that new plants will form when fragments are 10 cm long (R. Stanton, pers. comm.). However, observations in South Australia suggest regeneration from fragments is unlikely due to the lack of soil moisture (Honan and Heap, pers. comm.), as establishment of new plants from root pieces depends on sufficient soil moisture.

Removing aerial parts of the plant encourages sprouting, and seedlings as young as 10 days old can regenerate (Anonymous, 2007). After cultivation, 85% of shoots that emerged had arisen from the vertical tap root (Heap et al., 1997), and after 10 days the average shoot length was 8 cm (Molnar & McKenzie, 1976). Spread by root growth can increase grazed individual colonies by an average of 70 cm per year (Heap et al., 1997). Clipping seedlings as early as the cotyledon stage does not prevent regeneration (Cooley & Smith, 1972).

Shade levels have been shown to have an impact on germination and growth (Boyd & Murray, 1982a), with vegetative production declining markedly with increasing shade levels. No berries were produced under 92% shade, and the total non-structural carbohydrate (TNC) content of the roots decreased as shade increased (Boyd & Murray, 1981). Shade had less effect on regrowth of established plants than on growth of plants started from seed. Thus, once plants become established, greater shade densities are needed to reduce growth. Shade from a crop canopy will reduce the photosynthetic rate of silverleaf nightshade, possibly causing it to be a less vigorous competitor (Boyd & Murray, 1982a). However, the low summer rainfall in SA would prevent the use of summer crops as a mechanism to provide shade.

5 Distribution

Silverleaf nightshade is found in areas with a cool, wet winter and hot dry summer, and thrives on disturbed land. In Australia it is estimated to infest at least 350,000 ha and has the potential to invade up to 398 million ha (Kwong et al., 2008). In 1997 it was estimated that 50-60 000 ha of land in SA were infested (Heap et al., 1997) and current estimates are as high as 200,000 ha (Honan, pers. comm.) Figures 4 and 5 below illustrate the current distribution in SA.

Maps displaying the potential distribution in cropping and grazing areas are displayed in Appendix 3. However, climate change is also likely to impact on future distribution of silverleaf nightshade. Recent work by Kriticos et al. (2010) indicates that there is likely to be a substantial contraction in potential distribution in the north of SA and an increase in climatic suitability in the south and east (see map in Appendix 2).

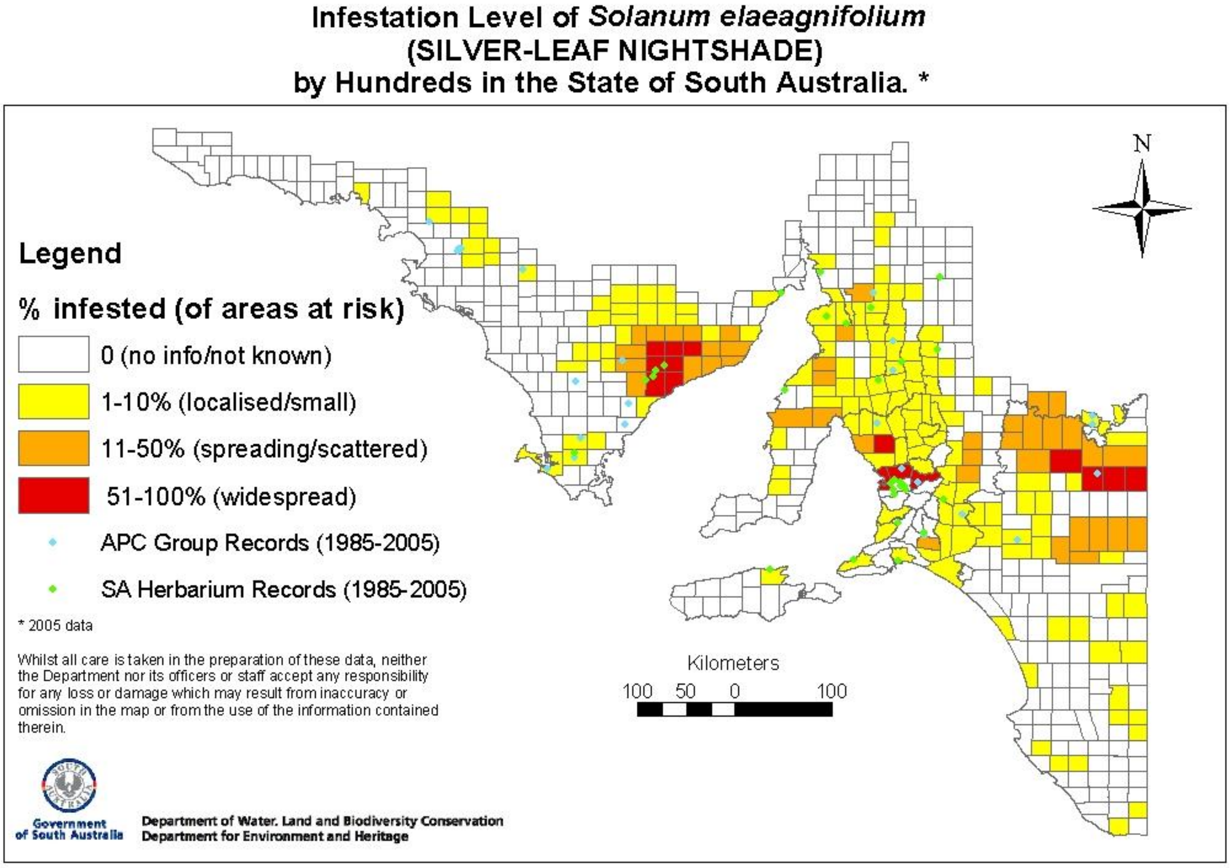


Figure 4: Infestation level of silverleaf nightshade in South Australia in 2005

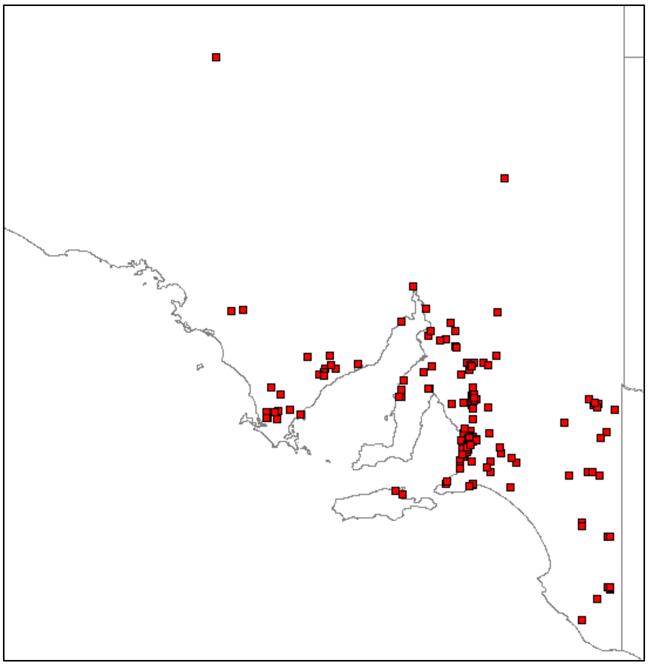


Figure 5: Known records of silverleaf nightshade in South Australia from Australia's virtual herbarium (accessed online 12 Feb 2009)

5.1 History of silverleaf nightshade in SA

Silverleaf nightshade was first recorded in Australia at Bingara, NSW in 1901 and introductions to South Australia are thought to have arisen from contaminated hay imported from North America during the 1914 drought (Heap et al 1997). J.M. Black first recorded silverleaf nightshade at North Adelaide in 1918 and herbarium records show that it was scattered across the Adelaide plains prior to World War II. It wasn't until the 1950s that the Department of Agriculture realised the weed was widespread. By 1958 it was recorded in Clare, Cleve, Hilltown, Keith, Lameroo, Owen, Reynella, Roseworthy, Rhynie and the Upper Murray (Heap & Carter, 1999). In the early 1970s a survey by Department of Agriculture in SA found the weed was growing over 14, 000 ha in 875 infestations, including at Cleve, Franklin Harbour, Port Lincoln, Tumby Bay, Tarlee and Riverton (Smith, 1975, Moore et al., 1975). Over 99% of infestations occurred in paddocks with only 0.4% on roadsides (Smith, 1975). Between 1972 and 1993 silverleaf nightshade distribution had almost doubled from presence in 90 hundreds to over 160 hundreds (Heap et al., 1997), and from 16,000 ha to over 40,000 ha (Heap & Carter, 1999). The genetic diversity of populations across SA indicates that there have been repeated introductions to SA (Hawker, 2006). Silverleaf nightshade has been a declared weed in SA since the 1960s.

A co-ordinated control program was undertaken on the Eyre Peninsula between 1964 and 1989, and successfully controlled small satellite infestations with picloram, although it took up to 19 years from the first report until eradication. Satellite infestations that were treated regularly did not develop into main foci (Carter, 1992). Thus in areas where isolated infestations exist it is critical to begin control immediately to minimise the spread of this weed.

6 Impacts (and uses)

Known to be a problem in parts of its native range, silverleaf nightshade is also now a major weed in Texas, infesting over 1.2 million hectares, and is also becoming problematic in Morocco, India, Greece and Israel (Snell, 2003). In Australia, silverleaf nightshade competes with horticultural crops, broad acre crops and pastures (Kidston et al., 2007). It competes directly with summer crops and indirectly with winter crops by reducing available moisture and nutrients. Annual winter pastures are affected through delayed autumn emergence and lower productivity, resulting in reduced carrying capacity (Heap & Carter, 1999). Silverleaf nightshade infestations do not severely affect orchards or vineyards but do compete with cover crops grown in these situations (Parsons & Cuthbertson, 2001).

When infestations are heavy, the closed canopy cover restricts available light for other vegetation, and restricts access of stock to the feed below (Leys & Cuthbertson, 1977). Infestations can interrupt tillage and harvesting practices as well as blocking drains and irrigation channels (Anonymous, 2007). Grain contamination of wheat can become a problem if there is a wet spring and early flowering of silverleaf nightshade (Snell, 2003).

Infestations are more serious in dryland crops, probably because of the advantage provided by the extensive root system. (Green et al., 1988) found that the presence of silverleaf nightshade in cotton crops reduced water content up to 60 cm deeper in the soil profile than when cotton was grown alone.

Silverleaf nightshade competes with pastures and crops for moisture, sunlight and nutrients

On the Eyre Peninsula, yield losses range from 5-15% in heavy red clays to 30-50% in light sandy soils (Honan pers. comm.). Silverleaf nightshade reduced cotton height at weed densities of only four per 10m row and lint yield decreased by 50% when weed densities increased to 32/10 m row (Green et al., 1987). The primary competition factor between the two species was soil water. Nine plants per square metre reduced grain yield by 12% in NSW (Cuthbertson et al., 1976). At densities of 16 and 32 plants/10 m row, mechanical harvest efficiency was also reduced (Green et al., 1987). 3-5 shoots/m^2 reduced the yield of wheat by up to 60% in South Australia (Lemerle & Leys, 1991), with the largest losses occurring on light sands with low rainfall. The shoot density of silverleaf nightshade can increase dramatically in just one season, and each additional shoot/m^2 has been shown to reduce the yield of wheat by 21-23 kg/ha (Lemerle & Leys, 1991).

Infestations of silverleaf nightshade increase production costs through control requirements and reduce return and productivity of land. In Morocco, the value of infested lands decreased by 25% (Gmira et al. 1998 cited in (Anonymous, 2007).
In SA, more than $10 million per year is estimated to be spent by producers on control costs (Kwong et al., 2008). The total farm costs for control (from a survey in farmers in Victoria, NSW and SA) were $1730 per year, with production losses of $7786 per year (McLaren et al., 2004). Cropping was the most affected land use (56%) followed by grazing (34%) (McLaren et al., 2004). A cost:benefit analysis undertaken by (Kwong, 2006) estimated that savings of close to $140 million in control costs would accrue over a 30 year period. The benefit to cost ratio was 59 to 1, excluding lost production costs, hence the full cost is underestimated.

All parts of the plant, but particularly the berries are toxic to animals. Toxic alkaloids within the berries combine with sugars to form glycoalkaloids which are hydrolysed within the gastrointestinal tract. The result is the release of toxic nerve poisons (Boyd et al., 1984). Typical symptoms of poisoning include rapid, laboured breathing, nasal discharge, salivation and slobbering and trembling of the muscles. However, the palatability to stock is undecided. In NSW it is only moderately palatable (Kidston et al., 2007), and is generally avoided by stock in Victoria (Heap & Carter, 1999). In South Australia, mature and green berries were eaten by sheep between January and April, when alternative feed supplies were low (Heap & Honan, 1993). Others claim the berries are readily eaten by livestock (Boyd et al., 1984) but foliage is thought only to be eaten when no other feed is available, and palatability is further reduced when flowering (Heap & Carter, 1999). Although some stock have been lost through poisoning, mortality rates are extremely rare (Snell, 2003).

Cattle appear more susceptible to poisoning than sheep (Boyd et al., 1984), although cross-bred sheep are at greater risk than Merinos due to eating preferences (Snell, 2003). However, in a feeding trial in Victoria, sheep that were fed stems, fruits and leaves failed to be poisoned (Molnar 1982 cited in Heap & Carter, 1999). Goats could consume up to 10 times that of cattle with no impact from toxicity (Buck et al., 1960), and in range conditions in the United States, goats will readily select and consume silverleaf nightshade (Mellado et al., 2008). Although a source of protein, it disqualifies as a high energy forage (Mellado et al., 2008).

Silverleaf nightshade is an alternative host for phytophagous insects and plant diseases (Heap & Carter, 1999) such as root rot *Rhizoctonia solani* Kuehn, wilt *Verticillium albo-atrum* Reinke and Berth, and the tomato thrips *Franklienella schultzei* (Schellhorn et al., 2010).

The alkaloids present in the plant have been shown to have allelopathic potential on the germination of other plants. Bothma (2006) found cotton and lettuce germination were inhibited with water infusions of silverleaf nightshade foliage. In India, the steroidal alkaloid solasodine has been extracted from the plant for use in contraceptive and corticosteroid drugs (Maiti 1967). Of solanum species studied, silverleaf nightshade has been found to have the most promising source of solasodine with a 3.2% dry weight yield (Kwong, 2006). Recent studies also suggest that plant extracts can have a cancer inhibiting effect (Anonymous, 2007). Native Americans of the southwestern United States used berries in making cheese and the seed was used in a mixture to tan hides (Boyd et al., 1984). Silverleaf nightshade has no recognised ornamental value and introductions worldwide appear to have been unintentional (Anonymous, 2007).

7 Legislative requirements

In South Australia, the Natural Resources Management Act 2004 is the governing legislation for weed control. Under this Act, silverleaf nightshade is a declared class 2a weed, which means that the following provisions apply to the movement, sale and control of silverleaf nightshade for the whole of the State. However, the declaration was raised as an issue at the workshop, especially section 180, which states it is notifiable across the state. Many landholders are not aware that silverleaf nightshade is notifiable, and in areas where the weed is widespread notification provides little benefit. Thus, it is recommended that the legislation, in particular section 180, is reviewed to increase the efficacy of legislative measures.

175- **Movement of animals or plants**

(2) Subject to this act, a person must not bring an animal or plant of a class to which this subsection applies, or cause or permit an animal or plant of a class to which this subsection applies to be brought, into a control area for that class of animal or plants

177- **Sale of animal or plants, or produce or goods carrying plants**

(1) Subject to this Act, a person must not sell an animal or plant to which this subsection applies

(2) Subject to this Act, a person must not sell any animal, plant, soil, vehicle, farming implement or other produce, goods material or thing carrying a plant of a class to which this subsection applies.

180- **Notification of presence of animals or plants**

(1) If an owner of land within a control area for a class of animal or plants to which this section applies becomes aware of the presence of an animal or plant of that class on that land, the owner must, within the prescribed period, notify the NRM group for the area in which the land is situated of the species of animal or plant and the locality in which it was seen or is to be found.

182- **Owner of land to take action to destroy or control animals and plants**

(2) Subject to this section, an owner of land to within a control area for a class of animals or plants to which this subsection applies must control and keep controlled all animals or plants of that class on that land.

(3) An owner of land to within a control area for a class of animals or plants to which this subsection applies must-

a) take any measures prescribed by the regulation or specified by a relevant authority in the prescribed manner for the control of all animals or plants of that class that are, or may be, on that land

b) take any measures prescribed by the regulation or specified by a relevant authority in the prescribed manner requiring that the land, or anything present on the land, be subjected to specified treatment.

185- **NRM authorities may recover certain costs from owners of land adjoining roadside reserves**
(1) If an NRM authority carries out on road reserves measures for the destruction or control of animals or plants of a class to which this section applies, the NRM authority may, within 3 months, give notice in writing to each owner of land adjoining the road reserve requiring the owner to pay to the NRM authority an amount specified in the notice within a period in the notice, being not less than 28 days from the date of the notice.

8 Best practice management

As with most invasive species, and particularly with a difficult to control species such as this one, an integrated approach to control will maximise successful outcomes. Thus, it is best practice to incorporate more than one of the following control methods where possible. Management strategies should be adapted depending on level of infestation:

- Clean properties with neighbouring infestations should concentrate on regular paddock inspections and hygiene practices
- Those with isolated infestations should spot spray (where appropriate), adopt good hygiene to prevent spread and regularly inspect paddocks for new infestations
- Where established infestations exist, management should focus on containment, prevention of seed set and spread through herbicide application and regular monitoring

Preventing spread through livestock movement, feed and vehicles is the most important method of control

As it is such a challenging weed to control once established, it is vital to prevent infestation of clean areas. Paddock inspections should be regularly conducted in mid summer when plants are flowering and most conspicuous. If new plants are found, it is important to start control in the first season. Control of a spreading weed is greatly improved by destroying satellite infestations.

Stock from infested areas must be quarantined for at least 14 days to allow seed to pass through the digestive tract, although low numbers of seeds may still be excreted by sheep after 31 days (Heap & Honan, 1993). Ideally, quarantine areas should be easily accessible for monitoring and control purposes, and able to exclude stock if infestations are found the following season. Infested areas should have stock excluded while the weed is in fruit. Imported hay should be checked for berries to prevent spread. Keeping machinery clean is also important, especially when moving from infested to clean areas. Always clean machinery in the same spot and inspect regularly for any subsequent germination. Monitoring infestations is essential; mark all known infestations for later reference, and record details of control techniques to help evaluate the most successful methods.

8.1 Mechanical control

Although some research has had success with mechanical control, under South Australian conditions, cultivation and slashing are not regarded as best practice and are not recommended. In the USA, regular cultivations at weekly, fortnightly or monthly intervals eradicated the weed after 3 seasons (Heap & Carter, 1999), and continuous pruning for 2 months exhausted food reserves and killed the plant in trials in India (Babu et al., 1995). However, machinery used in cultivation can aid spread of the weed, and the frequency of cultivation is expensive and damaging to soil structures (Heap et al., 1997).

Preliminary results from a study in South Australia, indicate that grazing and spray grazing may be useful in reducing the size and number of shoots as well as suppressing flowering and seed set (Hawker et al., 2004). However, a major reduction in density may take numerous years due to the extensive root system and existing seedbank, and soil erosion can result as an unwanted side effect.

8.2 Chemical control

There is currently no single effective chemical treatment for silverleaf nightshade control. The information provided in the sections below is a summary of the latest research, however conflicting results prevent any general recommendations. Local successes through trial and error may provide the best guidance for each particular situation.

For effective control, it is essential to kill all parts of the root system that can regenerate, and with such an extensive root system, herbicide efficacy can vary greatly. Seedlings and small patches (1-5 shoots) are the most susceptible stage of plant growth to control measures, as smaller root systems allow chemicals to be easily translocated. Picloram or glyphosate will provide some success for spot spraying treatments (especially patches smaller than $1m^2$) but generally need to be repeated over several applications to provide satisfactory control (Anonymous, 2007, Westerman & Murray, 1994). Seedlings need to be controlled immediately after harvest of winter crops or senescence of winter pastures (Kidston et al., 2007). For larger infestations, a suitable herbicide that eradicates the plants is not yet available. The dry summers in southern Australia may inhibit effective chemical control, due to lack of moisture and active growth of plants (Heap, 1992). With chemical control it is important to understand the aim of control; the focus should be on seed reduction or root reduction. Depending on the focus, spray timing will be different, i.e. before flowering to reduce seed and after flowering to reduce root growth (Snell, 2003).

With established colonies, timing of application is very important to ensure roots are killed. However, the research presents conflicting results, and local results from herbicide application may be the best indicator of success. Spraying before flowering occasionally requires at least one follow up application, and less translocation of chemical to the roots occurs after berries start to develop (Snell, 2003). Moisture conditions may be more important than growth stage as both (Stubblefield & Sosebee, 1986) and (Snell, 2003) agree moisture conditions, and active growth are the most effective periods for herbicide application. Wet summers may provide the best conditions to achieve maximum control of infestations. Recent research from NSW has shown that chemical application just prior to leaf loss (i.e. early autumn) is more effective than early summer applications, although this needs to be tested under South Australian conditions (R. Stanton pers. comm.). Morning provides optimal conditions to apply herbicides via boom sprays and follow up control is best completed within a month of the previous spray (Snell, 2003). The ability of silverleaf nightshade to recover from herbicide means that assessment of applications should not occur too early as growth may merely be delayed.

Glyphosate

Control with glyphosate can vary widely, from 0-98%. Only (Westerman & Murray, 1994) found a single application of glyphosate at a rate of 7.2 g acid equivalent/L seven weeks after crop emergence controlled the weed. Under Australian dry mallee conditions glyphosate was not effective (Heap & Carter, 1999).

Applying glyphosate at the end of summer can enhance control as carbohydrates and nutrients are being moved into the root system at this time (Kidston et al., 2007). However, (Choudhary & Bordovsky, 2006) found applying glyphosate late in the season didn't effectively control the population. Instead, early season applications of glyphosate controlled populations and increased yield, although numerous applications over the season provided the most effective control. In South Australia, glasshouse trials found seasonal timing was the major factor influencing absorption and translocation rates (Greenfield 2003). Application in

February recorded the highest rates of absorption and translocation at 70 and 60% respectively, application in October and November recorded about 50% and spraying in December and January had the lowest uptake rates of 0-40%.

Research has also provided varying results on the best stage of growth to apply glyphosate. In Australia (Heap, 1992) states the plants are more susceptible at berry stage than full bloom, and intensive applications in Texas at berry stage had eradicated it from some areas. In Morocco however, (Bouhache et al., 1996) found silverleaf nightshade was more susceptible at full bloom than at the green berry stage. In Greece, (Eleftherohorinos et al., 1993) found no difference in control between applications at full bloom or the berry stage. For control in SA, successful local results may be the best guide for timing application.

Reductions in glyphosate efficacy of 46% and 78% occurred when plants hadn't been watered and when foliage was covered with dust prior to application (Bouhache et al., 1996). Coating the plants with dust after herbicide application also resulted in reduced efficacy by 50%. In South Australia, drought stress was not found to affect glyphosate absorption or translocation (Greenfield 2003). Glyphosate toxicity was also reduced by the hardness (i.e. mineral content) of the spray water and the presence of calcium cations (Bouhache et al., 1996). The use of good quality water or an adjuvant will help increase glyphosate efficacy under these conditions. Using higher dosages is not advised as it burns the plants too quickly and doesn't allow the chemical to be distributed to the roots (Snell, 2003).

The use of a rope wick applicator to apply glyphosate controlled 95% or more of mature silverleaf nightshade in the USA (Abernathy and Keeling in Westerman), and was as effective as traditional spraying in NSW, but used only a fraction of the product (at a 1:3 glyphosate to water concentration) (Lemerle, 1982). A blanket wiper has been used in the mid north of SA and on the Eyre Peninsula. In the mid north, one application of amine provided some success, although some plants did regrow in the same season (G. Roberts pers. comm.). However, unlike the rope applicator where product rates were reduced, the main advantage of using the wiper in the mid north was the prevention of spray drift in an area with active growing vines. On the Eyre Peninsula, the blanket wiper used less chemical than boom spraying but the application cost was more expensive and the long term results were of little difference (Honan pers. comm.).

Picloram

Eleftherohorinos et al. (1993) found picloram consistently restricted growth to less than 5%, whereas regrowth from glyphosate application varied between 0 and 69%. However, successive yearly applications of picloram are still needed to kill the root system. (Molnar & McKenzie, 1976) found two successive annual sprays at 1:100 killed the roots to a depth of 120 cm. Timing of application may be less important than with glyphosate for example, but plants treated in November can regrow in the same season whereas plants treated in February did not (Heap & Carter, 1999). Spraying both the shoots and the soil for a radius of 2 m provided more effective control (Heap et al., 1997). Use of picloram can have a severe impact on legumes and may prevent other sensitive broad leaved plants from growing for 2-3 years after application, but grasses are likely to be unaffected (Heap et al., 1997).

Picloram is rapidly translocated and found throughout the root system after 24 hours. Almost half of the applied herbicide was absorbed only 6 hours after treatment and 75% of the applied herbicide had been absorbed after 72 hours when uptake ceased (Richardson, 1979). The top 20 cm of the root system contained much more herbicide than roots below 20 cm, suggesting that the herbicide is exuded or redistributed by the plant, thereby reducing herbicide to non-toxic levels (Richardson, 1979). A combination of picloram and metsulfuron methyl can also be effective (Stanton pers. comm. 2008), although consideration needs to be given to possible impacts on plantings planned for the following year. However, other experiments over six years have failed to achieve eradication with picloram (Heap & Carter, 1999). Heavy cereal stubbles can prevent picloram from leaching through the soil (Heap & Carter, 1999).

2,4-D formulations

Recent restrictions on the use of high volatile esters (2,4-D ethyl, butyl and iso-butyl esters) during the summer months mean that only low and non-volatile esters are available when silverleaf nightshade infestations require treatment. Research with high-volatile esters before the restrictions indicates that 2,4-D was less successful than picloram or glyphosate. The toxicity of 2,4-D to root fragments is less than that of picloram and the ratio of aerial growth to root system makes it difficult to get sufficient quantities of herbicide into the plant. 2,4-D will kill top growth but insufficient chemical is translocated to the roots to kill them (Richardson & McKenzie, 1981).

Recent trials have shown a combination of triclopyr, picloram and 2,4-D amine to provide good results although the residual nature of the chemicals can cause further problems (R. Stanton pers. comm.). Experiments in Victoria identified picloram and 2,4-D as giving the most consistent long-term control (Heap et al., 1997) through rapid control of the shoots and long term control of the roots. Further research is required with low and non-volatile formulations to determine their viability as a control option. The application of phenoxy herbicides such as

2,4-D increases the palatability of plants and may provide another control option in conjunction with grazing (see Section 8).

Other formulations

Many other chemicals have been trialled, although most are not suitable control options. Some formulations that have had some success include:

- Tebuthiuron: application at 4 kg active ingredient per ha gave over 99% control in sandy soils, six years after application in Australia (Heap et al., 1997), and experiments at Keith have demonstrated control for 8-9 years after a single application (Heap, 2000). This chemical does have proven leaching and off-target effects though and the half life in arid environments can be up to 60 months (Snell, 2003). Not currently registered for use in SA.
- Fluroxypyr: used in Victoria at 1.5 L/ha with a wetting agent had some success (Snell, 2003).
- Bromacil: can be effective for treating small patches but it is a soil sterilant, and is recommended only for industrial land uses, not agricultural production systems (Parsons & Cuthbertson, 2001).

8.3 Biological control

The control techniques described above can be quite labour and cost intensive especially where large dense infestations occur. Biological control options are being investigated as a desirable tool for management. In its native range, silverleaf nightshade supports diverse insect herbivorous fauna (Goeden, 1971), however many of these are not suitable for climate or specificity reasons in Australia (Kwong et al., 2008) and none have been found that attack roots. There are eleven species from Argentina that may be suitable but very little is known about the biology, host range and impact of the insects, and further research is required (Kwong et al., 2008). Biological control options are limited by the large number of important agronomic crops in the Solanaceae family cultivated in Australia, as well as 87 native Solanum species that are endemic to Australia (Kwong, 2006). Efficacy and specificity of biocontrol is also unknown as it is not known where Australian populations of silverleaf nightshade originated from. Mismatches between biotypes of the host plant in the native range and the target weed in the introduced range can affect success of agents.

One of the eleven species, the gelechiid moth (*Symmetrischema ardeola*) has undergone preliminary testing in Argentina, which has indicated that it might be specific to silverleaf nightshade (Kwong et al., 2008). The larvae of *S. ardeola* feed on flower buds, stamens and pistils and could reduce seed production. A survey of Chilean populations has not occurred, thus a knowledge gap of silverleaf nightshade and its associated fauna still exists (Kwong, 2006). Genetic studies on the origin of Australia's populations of silverleaf nightshade are also required. Once the source of our populations is confirmed, surveys for biocontrol agents can be targeted to the area of origin.

In South Africa, two leaf-feeding beetles *Leptinotarsa texana* and *Leptinotarsa defecta* were tested for host-specificity but were found to feed on cultivated eggplant. Further research determined any risk would be minimal (Olckers & Hulley, 1994). These beetles were released in 1992 and have established populations, although only *L. texana* causes considerable damage to silverleaf nightshade (Hoffmann et al., 1998). This is the first time that biological control agents have been released successfully against a plant in the Solanaceae. The parasitic nematode *Ditylenchus phyllobius* is one of the commonest and most damaging organisms on silverleaf nightshade in Mexico, but relies on rainfall, moist soils and high humidities. It was identified as a potential biological control agent in 1986 (Parker, 1986), however, the lack of moisture over summer in Australia would prevent it from completing its life cycle (Wapshere, 1988) and it attacks some native Solanums and eggplant (Field et al., 2009) .

Recent studies by (Stanton et al., 2008a) have shown that compounds in Eucalyptus leaves exhibit a phytotoxic effect on silverleaf nightshade germination. Four Eucalyptus species were tested; *E. spathulata, E. salubris, E. brockwayii*, and *E. dundasii* and all four species reduced germination to less than 5%. Further research is being undertaken to determine if similar phytotoxic effects are found on root stock regeneration. A new herbicide, Callisto ™ has been developed from these allelopathic compounds (Stanton, 2008).

New pathogens such as the tobacco mild green mosaic virus are also currently being evaluated as potential bioherbicide control (Stanton, 2008). This virus is highly efficient against *Solanum viarum*, and results in the plant destroying itself to fight off the virus. Numerous native insects in Australia have been reported to cause some damage to plants over the years but none of these have had lasting or widespread effects (Heap et al., 1997).

The use of pastures as a competitive control option is not clear. Establishment of dense stands of *Medicago sativa* may have the potential to suppress silverleaf nightshade (Anonymous, 2007), however, under dryland conditions in South Africa, oats and lucerne provided no suppressive effect (Viljoen & Wassermann, 2004). Research is currently being undertaken to identify a range of summer pasture species that can help suppress silverleaf nightshade populations in Australia (Stanton et al., 2008b). Some pasture species have shown to delay the emergence of silverleaf nightshade but they don't prevent the plants from growing (R. Stanton pers. comm.).

9 Key stakeholders and responsibilities

For the effective management of silverleaf nightshade across the State, the following stakeholders are integral in implementing the actions and strategies identified in this plan. Land managers are critical for the successful implementation of this plan. Without their involvement, silverleaf nightshade has potential to dramatically increase its range and further cost the community.

<u>NRM Boards</u>

The NRM Boards should aim to ensure impacts of silverleaf nightshade are kept to a minimum throughout the area by:

- Ensuring representatives of all stakeholders engage in strategic control activities
- Liaising with government departments, other NRM Boards and community groups to undertake control
- Administering and enforcing the provisions of the Natural Resource Management Act 2004
- Allocating resources for control
- Coordinating integrated control activities

While enforcement activities are generally viewed as a last resort in obtaining stakeholder cooperation in undertaking pest management, there will be instances where these powers are required. Board members and staff require a clear understanding of their role to ensure that compliance and enforcement activities can be applied appropriately, consistently and preferably with community support.

<u>Private landholders</u>

Under provisions of the *Natural Resources Management Act* (2004), landholders are required to control and manage silverleaf nightshade on their own lands (see section 7 of this plan for more detail). This *may* include the;

- Development of property management plans
- Implementation of best practice management
- Eradication of strategically important infestations in conjunction with their regional NRMB
- Implementation of good hygiene practices to prevent spread
- Ability to identify silverleaf nightshade

Land managers may play a role in:

- Detection and reporting of new occurrences
- Understanding the impacts of silverleaf nightshade on their property and supporting and promoting sustainable practises to minimise these impacts

- Applying their knowledge and skills to improve management and jointly plan and coordinate management activities with their neighbours

Department of Environment and Natural Resources (DENR)

DENR has the lead role in implementing the State Natural Resources Management Plan which includes (Goal 4) ‘Integrated management of biological threats to minimise risks to natural systems, communities and industry’.

Biosecurity SA

NRM Biosecurity within Biosecurity SA will continue to support research and provide technical advice on silverleaf nightshade issues to the NRM Boards and implement some functions of the Chief Officer under the NRM Act. As the lead agency for weed management in the State, Biosecurity SA are responsible for developing State policies and providing legislative recommendations to the Minister.

10 Implementing the plan

10.1 Principles

The principles underpinning this plan are those identified in the National Weeds Strategy:

1. Weed management is an essential and integral part of sustainable management of the natural resources and the environment and requires an integrated, multi disciplinary approach.
2. Prevention and early intervention are the most cost effective techniques that can be deployed against weeds
3. Successful weed management requires a coordinated national approach which involves all levels of government in establishing appropriate legislative, educational and coordination frameworks in partnership with industry, landholders and the community
4. The primary responsibility for weed management rests with landholders/ land managers but collective action is necessary where the problem transcends the capacity of the individual landholder/ land manager to address it adequately.

10.2 Links to other strategies

This plan has been established to provide a co-ordinated framework for the management of silverleaf nightshade on a Statewide level. This strategy contributes to targets at the national level, has direct links to other State level plans, is supported by regional targets where identified, and seeks to compliment property management plans (illustrated below).

Scope/ scale	Plan title
National	National Weeds Strategy
State	State NRM Plan

State Silverleaf Nightshade Management Plan

Regional	Relevant NRM Plans
	Regional Pest Management Strategies: SAAL Pest management strategy SA MDB Regional pest management plan SE Pest Management Strategy (in prep) AMLR Draft pest management strategy EP NRM Biosecurity strategy
Local	Property management plans

10.3 Goals and objectives

The vision for silverleaf nightshade management in SA is:

Silverleaf nightshade effectively managed to prevent spread; protecting urban areas and maintaining agricultural production across the State

This plan identifies three goals to work towards achieving this vision. Each goal is supported by numerous objectives as outlined below:

1. Understanding is continually improved

1.1 SLN network established
1.2 Land managers and the community can identify silverleaf nightshade
1.3 Land managers are aware of impacts
1.4 Research needs are supported

2. No new infestations are established

2.1 Legislation is appropriate to prevent spread
2.2 Distribution of SLN is known
2.3 Strategic planning guides management
2.4 Priority areas are protected

3. Existing infestations are effectively managed

3.1 Larger infestations are contained
3.2 Smaller infestations are controlled with a view to eradication
3.3 Land managers are aware of best practice management and have the capacity to implement it
3.4 Infestations are regularly monitored for adaptive management

The difficulty of controlling this weed once established necessitates preventing further spread of this weed. Objectives focus on preventing spread from existing infestations through timely control and hygiene protocols to prevent accidental spread from transported seed. Monitoring is another important objective to curtail spread and ensure control efforts are effective.

10.4 Actions

A summary of the actions and responsibilities to meet these goals and objectives are outlined in Table 2 below. These actions are recommended as necessary for the successful management across the State. However, it is recognised that each NRM region has different infestation levels, thus not all of the actions will be relevant for all areas.

Table 2: Summary of objectives and actions and responsible parties

Objectives	Action	Stakeholders
1.1 SLN network established	Contact made with relevant interstate and international agencies, groups and individuals.	Biosecurity SA, EP NRMB
1.2 Land managers and the community can identify SLN	Identification material for SLN is produced where needed and readily available in a variety of media formats	Biosecurity SA, NRMBs, Industry
	Local landholders are utilised as weed champions to increase awareness	NRM Boards
1.3. Land managers are aware of impacts	A variety of media formats including TV, radio, internet, print and face to face (field days and demonstration days) are utilised to raise awareness about SLN	NRM Boards, Industry groups, Biosecurity SA
	NRM Groups and local landholders are utilised as weed champions to increase awareness	NRM Boards
1.4 Research needs are supported	Support continued research into biological and ecological studies of SLN	Biosecurity SA, research orgs.
	Support the investigation into other control measures (chemical, cultural, especially those suited for dense/ large infestations of SLN)	Biosecurity SA, research orgs.
	Support genetic studies into SLN source in Australia	Biosecurity SA, research orgs.
	Source all available funding avenues both public (national, state, regional and local) and private (Industry, private organisations and individuals).	NRM Boards, SLN Network
2.1 Legislation is appropriate to prevent spread	Gather information about regional requirements for effective control and compliance and seek changes to the legislation if required	Biosecurity SA in conjunction with NRM Boards
2.2 Distribution of SLN is known	Survey current distribution to delineate extent	NRM Boards
	Collate, update and maintain a database of SLN distribution and density for SA	Biosecurity SA, NRM Boards
2.3 Strategic planning guides management	Areas are prioritised for management based on distribution results	NRM Boards
	State and regional WRA are periodically undertaken	Biosecurity SA, NRM Boards
2.4 Priority areas are protected	Land managers restrict movement of stock and feed from infested to clean areas	NRM Boards, Landholders
	All land surrounding known infestations (including roadsides) is monitored annually	Biosecurity SA, NRMBs, Landholders
	Priority areas are surveyed at least every five years	Biosecurity SA, NRMBs, Landholders
	Landholders regularly survey their main stock movement routes every two years, or after summer rain events	Biosecurity SA, NRMBs, Landholders
3.1 Larger infestations (e.g. $>10m^2$) are contained	Landholders actively control populations	NRM Boards, Landholders
	Hygiene protocols are implemented for vehicles and machinery exiting infested areas	NRM Boards, Landholders
	Hygiene protocols are implemented for stock and feed travelling from infested areas	NRM Boards, Landholders
3.2 Smaller infestations ($<10m^2$) are controlled with a view to eradication	Small infestations are regularly controlled as appropriate	NRM Boards, Landholders
	Landholders prevent stock from accessing infested areas until controlled	NRM Boards, Landholders
3.3 Land managers are aware of best practice management and have the capacity to implement it	Best practice management information is produced and readily available in a variety of media formats	NRMBs, Industry, Biosecurity SA
	The SLN network is used as a vehicle for regular dissemination of information	Proposed SLN network
	Local success stories are promoted to other landholders	NRM Boards, Biosecurity SA
3.4 Infestations are regularly monitored for adaptive	All control programs are regularly monitored and evaluated	NRM Boards, Landholders
	Management strategies are adapted as required	NRM Boards, Landholders

management	At risk areas are surveyed after unseasonal weather events or land use changes	NRM Boards, Landholders

10.5 Monitoring and Evaluation

Monitoring is important to:

- Assess effectiveness of control measures
- Identify new weed infestations
- Maintain data on current infestations

The success of silverleaf nightshade control is dependent on monitoring and timely follow up control. Monitoring should be undertaken:

- periodically prior to and after control treatments (e.g. 1 month, 6 months and 12 months)
- After a change in conditions, e.g. unseasonal weather events, land use change
- Annually in areas located near known infestations to prevent new plants establishing
- At least every 5 years in priority areas where silverleaf nightshade has not been found
- Regularly in stock movement and holding areas to prevent new plants establishing.

Monitoring methods can include:

- Formal ground surveys of known infestations or priority areas on foot, bike or vehicle
- As part of normal property inspections
- Via photo points

Data collected from monitoring efforts will be at different scales and likely in different formats. The type of information collected will also differ depending on the needs of the user. Ideally, a GPS should be used to record location information, however, if a GPS is not available (e.g. to landholders), information can be digitised from maps. Where possible, when collecting monitoring data it is important to collect some basic information such as:

- Date of collection
- Location
- The name or agency of the person collecting the data
- Species
- Area infested (preferably in ha or m^2)
- Density (% of area covered)
- Reason for collecting data e.g. inspection, treatment, follow up, monitoring.

Standard data collection will allow sharing between different stakeholders and regions. For strategic management across the state, sharing of data is important to understand the scope of distribution. A national standard for the collection of weeds data exists and can be found at http://www.weeds.org.au/mapping.htm.

It is also important that the data are accessible to all relevant stakeholders. In priority areas, NRM Boards may need to access data collected by landholders, and should develop appropriate mechanisms to do so. As no statewide database exists, and some NRM Boards have developed standardised databases, it seems likely that most data will reside at the Board level. NRM Boards and State agencies will need access to the data for management purposes including:

- priority setting at various scales
- monitoring the effectiveness of current management decisions
- identifying distribution
- influencing future management decisions

As well as monitoring control actions, evaluation is needed to determine what methods are working and how to adapt them for improved best practice. Evaluation should focus on effectiveness, appropriateness and efficiencies of the outputs of a control program. Evaluation is only possible if outcomes are measurable and can be compared to previous status. Control programs should define required outcomes (e.g. no further spread from main infestation) prior to the control being undertaken.

11 Appendices

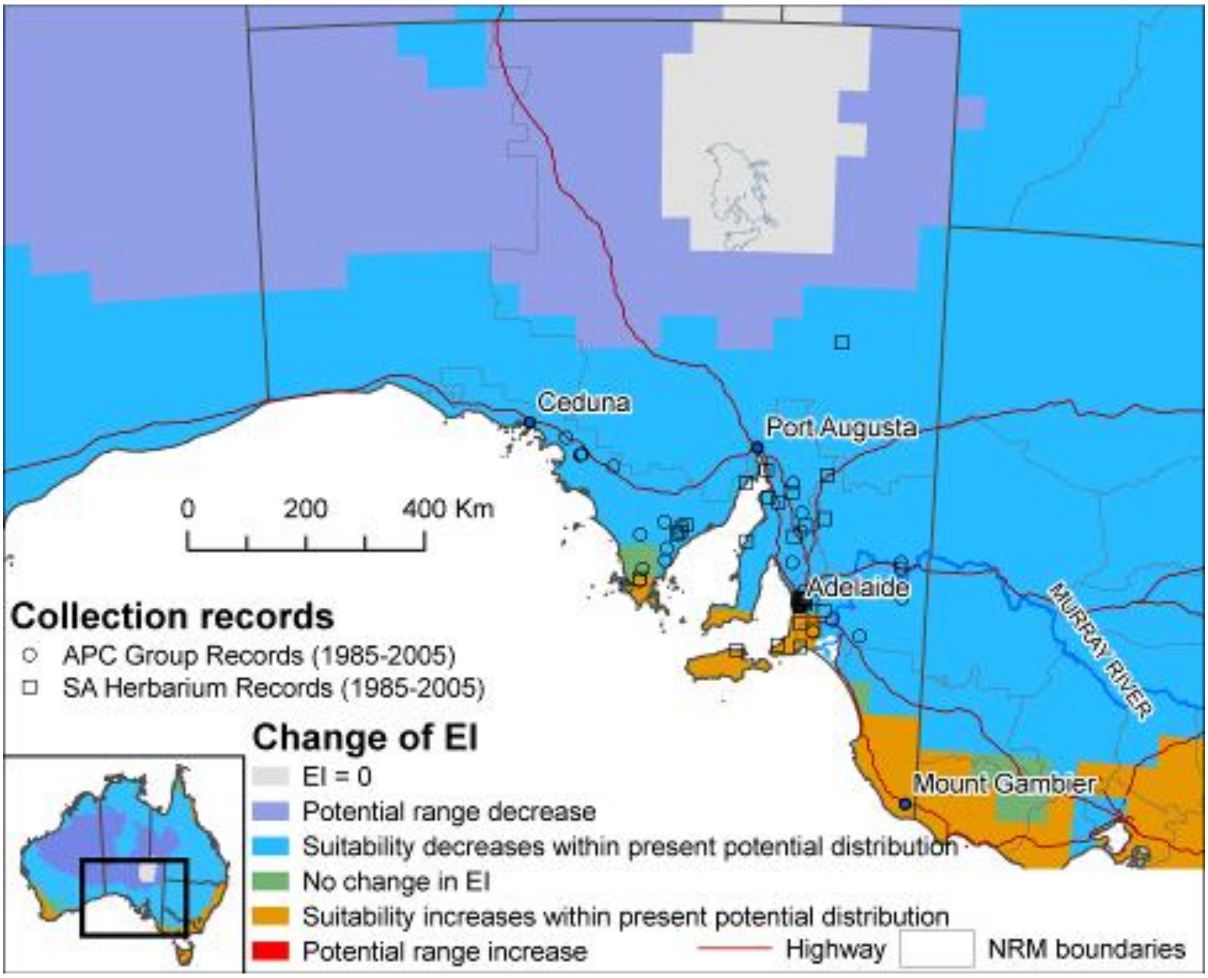
Appendix 1

Results from the regional Weed Risk Assessments for silverleaf nightshade within South Australia are listed below. Kangaroo Island NRM Board is to undertake their WRA soon. The actions have been shaded in the same colours as in the standard WRA results table. Orange, yellow and purple actions indicate high priorities and green and blue are lower priorities because of the low feasibility of control in these situations. The difference amongst these results indicates that uniform legislation across the state may not be the most effective strategy for long term control. In the SAAL, AW, AMLR and SE regions, where the distribution of the weed is fairly isolated, provisions under the legislation may need to be stricter than in areas where the weed is more widespread.

NRM region	Landuse	Resulting action
South East	Cropping	Contain spread
	Grazing	Destroy infestations
	Irrigated pastures	Contain spread
	Perennial horticulture	Protect sites
Murray Darling Basin	Crop pasture	Protect sites
	Grazing rangelands	Monitor
	Grazing non-arable	Manage sites
AMLR	Cropping	Destroy infestations
	Pasture/grazing	Protect sites
	Horticulture	Manage sites
	Native vegetation	Protect sites
Northern and Yorke	Crop pasture	Contain spread
	Perennial horticulture	Manage sites
Eyre Peninsula	Cropping	Manage weed
	Pasture	Manage sites
	Perennial pasture	Protect sites
	Urban	Protect sites
SA Arid Lands	Broken Hill complex bioregion	Monitor
	Finke bioregion	Monitor
Alinytjara Wilurara	All areas	Monitor

Appendix 2

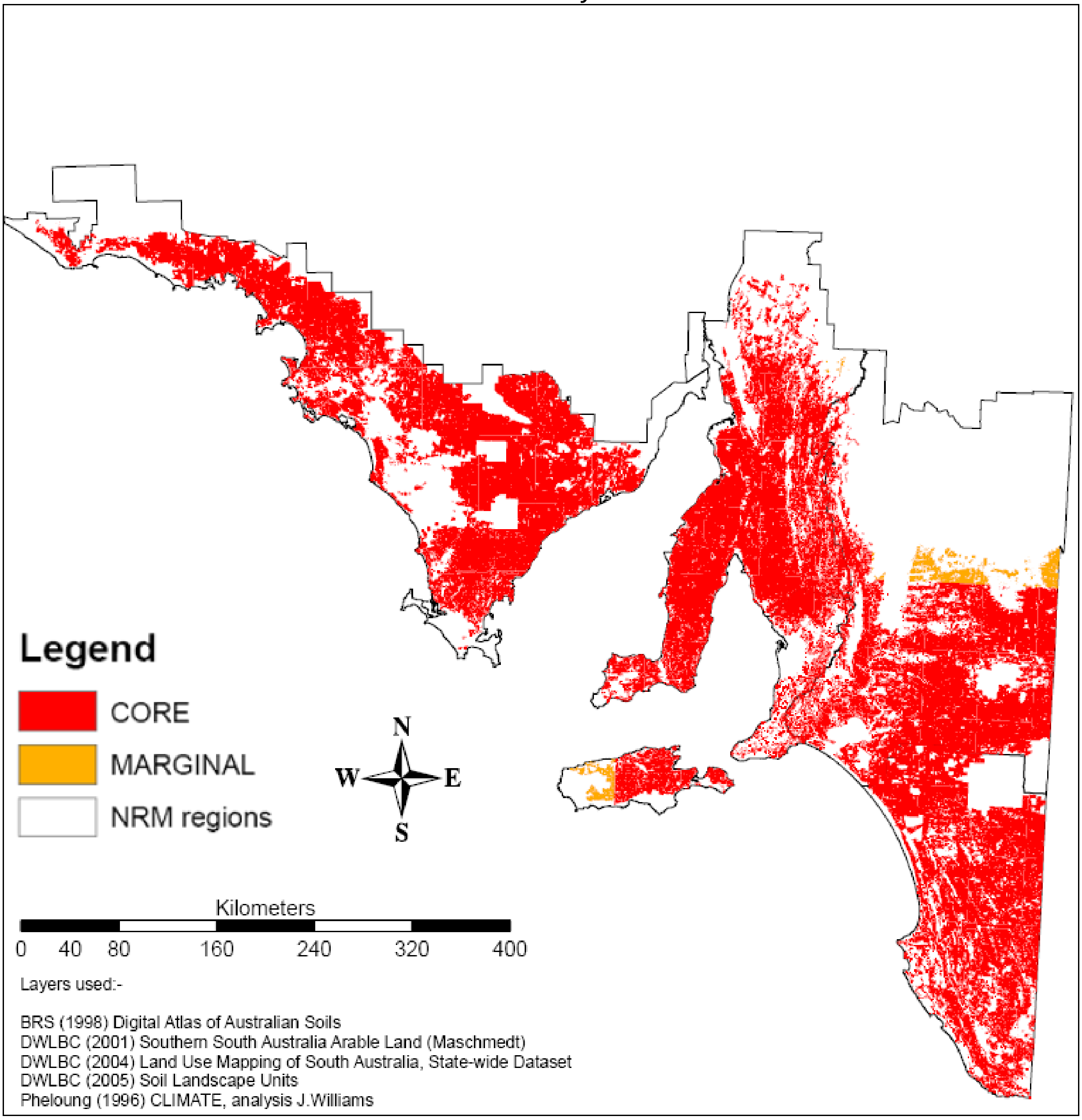
Change in climate suitability for silverleaf nightshade in SA as indicated by the CLIMEX Ecoclimatic Index (EI) using CSIRO Mk3 projections for 2080 based on the A1B SRES emissions scenario. Developed by Darren Kriticos (Kriticos *et al.*, 2010)



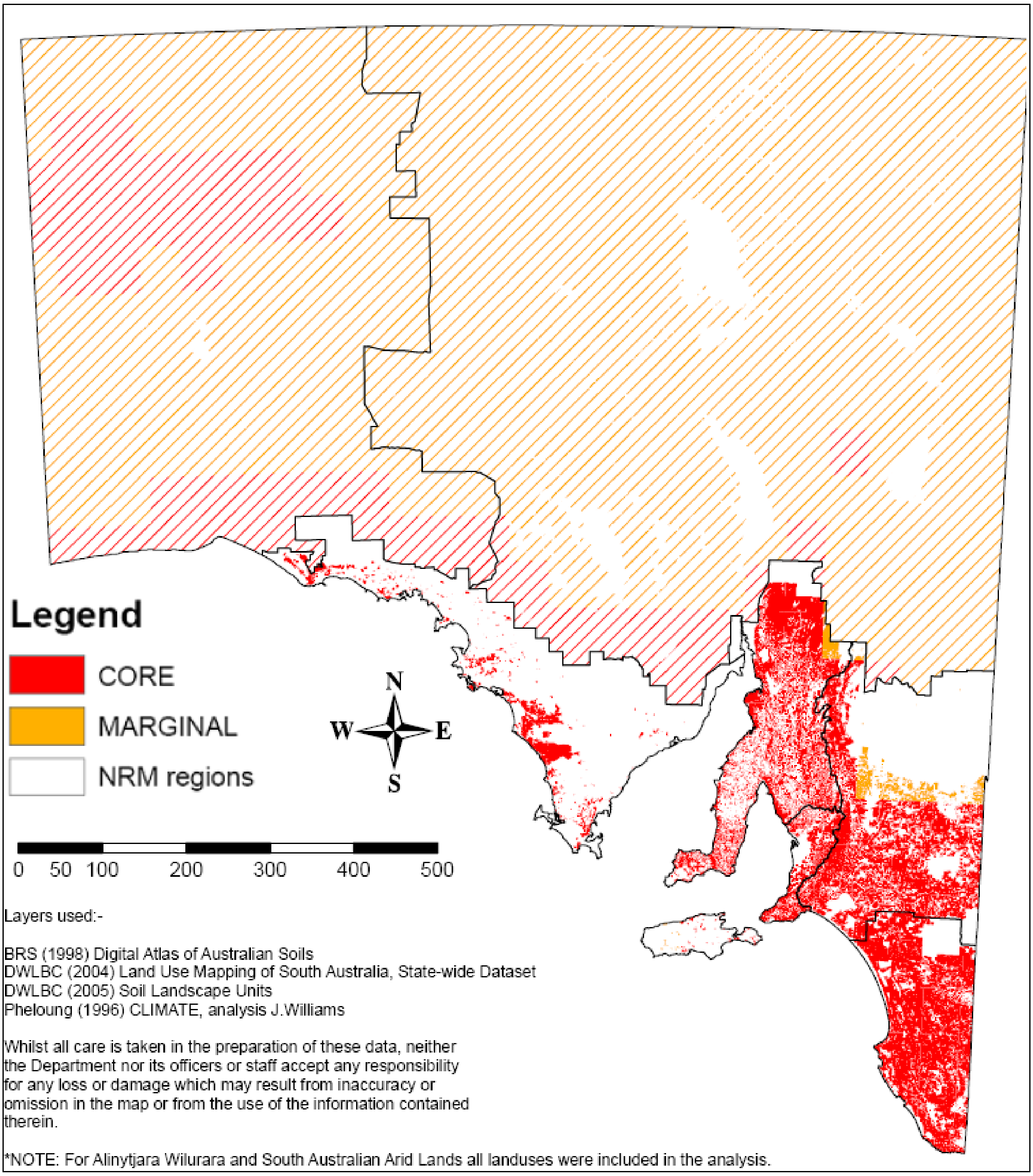
Government of South Australia
Biosecurity SA

Appendix 3

Map 1 illustrating the potential distribution of silverleaf nightshade in cropping areas of SA based on CLIMATE software analysis.



Map 2 illustrating the potential distribution of silverleaf nightshade in grazing areas of SA based on CLIMATE software analysis.


Legend
CORE
MARGINAL
NRM regions
N
W
E
S
0 50 100 200 300 400 500
Layers used:-
BRS (1998) Digital Atlas of Australian Soils
DWLBC (2004) Land Use Mapping of South Australia, State-wide Dataset
DWLBC (2005) Soil Landscape Units
Pheloung (1996) CLIMATE, analysis J.Williams
Whilst all care is taken in the preparation of these data, neither the Department nor its officers or staff accept any responsibility for any loss or damage which may result from inaccuracy or omission in the map or from the use of the information contained therein.
*NOTE: For Alinytjara Wilurara and South Australian Arid Lands all landuses were included in the analysis.

12 References

Anonymous (2007) Solanum elaeagnifolium. *Bulletin OEPP,* 37**,** 236-245.

Babu, V.S., Muniyappa, T.V. & Shivakumar, H.R. (1995) Control of silverleaf nightshade (Solanum elaeagnifolium Cav.) through mechanical methods. *World Weeds,* 2**,** 93-98.

Bouhache, M., Laakari, A. & Hilali, S. (1996) Influence of environmental factors on the control of Solanum elaeagnifolium by glyphosate. *Proceedings of the second international weed control congress, Copenhagen, Denmark, 25-28 June 1996: Volumes 1-4.***,** 801-805.

Boyd, J.W. & Murray, D.S. (1981) Environmental factors affecting silverleaf nightshade (*Solanum eleagnifolium*) growth from established perennials. *Proceedings of the 34th annual meeting of the southern weed science society.*

Boyd, J.W. & Murray, D.S. (1982a) Effects of shade on silverleaf nightshade(*Solanum elaeagnifolium*). *Weed Science,* 30**,** 264-269.

Boyd, J.W. & Murray, D.S. (1982b) Growth and development of silverleaf nightshade (*Solanum elaeagnifolium*). *Weed Science,* 30**,** 238-243.

Boyd, J.W., Murray, D.S. & Tyrl, R.J. (1984) Silverleaf nightshade, *Solanum elaeagnifolium*, origin, distribution, and relation to man. *Economic botany,* 38**,** 210-217.

Buck, W.B., Dollahite, J.W. & Allen, T.J. (1960) Solanum elaeagnifolium. silver-leafed nightshade, poisoning in livestock. *Jour Amer Vet Med Assoc,* 137**,** 348-351.

Carter, R.J. (1992) Co-ordinated control of silverleaf nightshade, Solanum elaeagnifolium, reduced its spread rate. *Proceedings of the 1st International Weed Control Congress.***,** 109-112.

Choudhary, M. & Bordovsky, D. (2006) Timing of glyphosate application on control of silverleaf nightshade and glyphosate-resistant cotton yield. *Weed Technology,* 20**,** 198-203.

Cooley, A. & Smith, D. (1972) Seed aspects of two perennials- woolyleaf bursage and silverleaf nightshade. *Proceedings of the Southern Weed Science Society.*

Cuthbertson, E.G. (1976) Morphology of the underground parts of silverleaf nightshade. *5th Australian Weeds Conference.*

Cuthbertson, E.G., Leys, A.R. & McMaster, G. (1976) Silverleaf nightshade - a potential threat to agriculture. *Agricultural Gazette of New South Wales,* 87**,** 11-13.

Eleftherohorinos, I.G., Bell, C.E. & Kotoulasyka, E. (1993) Silverleaf nightshade (*Solanum elaeagnifolium*) control with foliar herbicides. *Weed Technology,* 7**,** 808-811.

Field, R.P., Kwong, R.M. & Sagliocco, J.-L. (2009) Host specificity of *Ditylenchus phyllobius*, a potential biological control agent of silverleaf nightshade (*Solanunm elaeganifolium* Cav.) in Australia. *Plant Protection Quarterly* 24, 141-145.

Goeden, R.D. (1971) Insect Ecology of Silverleaf Nightshade. *Weed Science,* 19**,** 45-51.

Green, J.D., Don, S.M. & Verhalen, L.M. (1987) Full-season interference of silverleaf nightshade (*Solanum elaeagnifolium*) with cotton (*Gossypium hirsutum*). *Weed Science,* 35**,** 813-818.

Green, J.D., Murray, D.S. & Stone, J.F. (1988) Soil-water relations of silverleaf nightshade (*Solanum elaeagnifolium*) with cotton (*Gossypium hirsutum*). *Weed Science,* 36**,** 740-746.

Hawker, V., Preston, C. & Baker, J. (2004) Controlling silverleaf nightshade (*Solanum elaeagnifolium* Cav.), a deep rooted perennial weed, with herbicides and grazing. *Fourteenth Australian Weeds Conference.* Weed Society of NSW.

Hawker, V., Preston, C., Baker, J. (2006) Genetic variation within and among silverleaf nightshade (*Solanum elaeagnifolium* Cav.) populations in South Australia. *Proceedings of the 15th Australian Weeds Conference, Adelaide South Australia***,** 176.

Heap, J. & Honan, I. (1993) Weed seed excretion by sheep- temporal patterns and germinability. *10th Australian Weeds Conference.* Brisbane, Weed Society of Queensland.

Heap, J., Honan, I. & Smith, E. (1997) *Silverleaf nigthshade: A technical handbook for animal and plant control Boards in South Australia,* Adelaide, Animal and Plant Control Commission.

Heap, J. W. (1992) Golden dodder and silverleaf nightshade- Study tour to USA. Adelaide, Department of Agriculture SA.

Heap, J. W. (2000) Future Research Directions for Silverleaf nightshade in South Australia.

Heap, J.W. & Carter, R.J. (1999) The biology of Australian weeds: 35. Solanum elaeagnifolium Cav. *Plant Protection Quarterly,* 14**,** 2-12.

Hoffmann, J.H., Moran, V.C. & Impson, F.A.C. (1998) Promising results from the first biological control programme against a solanaceous weed (Solanum elaeagnifolium). *Agriculture Ecosystems & Environment,* 70**,** 145-150.

Khanna, K. R. & Singh, S.P. (1987) Studies on variability and association of yield and its components in *Solanum elaeagnifolium* Cav. *Indian Forester,* 113**,** 629-633.

Kidston, J., Thompson, R. & Johnson, A. (2007) Silverleaf nightshade. In industries, N.D.O.P. (Ed.). Orange, NSW Department of Primary Industries.

Kriticos, D., Crossman, N., Ota, N. & Scott, J. (2010) Climate change and invasive plants in South Australia. CSIRO.

Kwong, R.M. (2006) Feasibility study of biological control of solanaceous weeds of temperate Australia, Silverleaf nightshade, Solanum elaeagnifolium Cav. and prairie ground cherry, Physalis viscosa L. Victoria, Department of Primary Industries.

Kwong, R.M., Sagliocco, J. L., Weiss, J., Hunt, T. & Morfe, T. (2008) Feasibility of biological control of silverleaf nightshade in Australia. *Proceedings of the 16th Australian Weeds Conference, Cairns Convention Centre, North Queensland, Australia, 18-22 May, 2008***,** 256-258.

Lemerle, D. (1982) Chemical control of silverleaf nightshade using a ropewick applicator. *Proceedings of the 2nd agronomy conference.*

Lemerle, D. & Leys, A.R. (1991) Control of silverleaf nightshade(*Solanum elaeagnifolium*) increases the grain-yield of wheat. *Australian Journal of Experimental Agriculture,* 31**,** 233-236.

Leys, A.R. & Cuthbertson, E.G. (1977) Solanum elaeagnifolium Cav. (silverleaf nightshade) in Australia. *Proceedings of the 30th Annual Meeting of the Southern Weed Science Society.*, 137-141.

McKenzie, D.N. (1975) Silverleaf nightshade- one method of dispersal. *Australian Weeds Research Newsletter,* 22**,** 13-15.

McLaren, D., Morfe, T., Honan, I. & Holtkamp, R. (2004) Distribution, economic impact and attitudes towards silverleaf nightshade (*Solanum eleagnifolium* Cav.) in Australia. *Fourteenth Australian Weeds Conference.* Weed Society of NSW.

Mellado, M., Garcia, J.E., Arevalo, J.R. & Pittroff, W. (2008) Replacement value of *Solanum elaeagnifolium* for alfalfa hay offered to growing goats. *Journal of Arid Environments,* 72**,** 2034-2039.

Molnar, V.M. & McKenzie, D.N. (1976) Progress report on silverleaf nightshade research. Victoria, Keith Turnbull Research Institute.

Moore, R.M., Parsons, W. T., Strang, J. & Tideman, A.F. (1975) Silverleaf nightshade (*Solanum elaeagnifolium* Cav.). *Australian Weeds Research Newsletter,* 22**,** 5-13.

Olckers, T. & Hulley, P.E. (1994) Resolving ambiguous results of host-specificity tests - the case of 2 *Leptinotarsa* species (Coleoptera, Chrysomelidae) for biological-control of *Solanum elaeagnifolium* Cavanilles (Solanaceae) in South Africa. *African Entomology,* 2**,** 137-144.

Parker, P.E. (1986) Nematode control of silverleaf nightshade (*Solanum elaeagnifolium*) - a biological-control pilot project. *Weed Science,* 34**,** 33-34.

Parsons, W.T. & Cuthbertson, E.G. (2001) *Noxious weeds of Australia,* Victoria, CSIRO Publishing.

Paynter, Q., Hill, R., Bellgard, S. & Dawson, M. (2009) Improving targeting of weed biological control projects in Australia. Canberra, Land and Water Australia.

Richardson, R.G. (1979) Absorption, translocation and toxicity of picloram in silver leaf nightshade (*Solanum elaeagnifolium* Cav.). *Journal of the Australian Institute of Agricultural Science,* 45**,** 263-266.

Richardson, R.G. & McKenzie, D.N. (1981) Regeneration of, and toxicity of 2,4-D to, root fragments of silverleaf nightshade (*Solanum elaeagnifolium* Cav). *Journal of the Australian Institute of Agricultural Science,* 47**,** 48-50.

Rutherford, P.A. (1978) Effect of time immersion in running and still water on germination of silverleaf nightshade. *1st conference of the Australian Weed Science Society.*

Rutherford, P.A. (1979) Distribution and spread of silverleaf nightshade in Western Australia. *Proceedings of the Western Australia Weeds Conference***,** 22-23.

Schellhorn, N.A., Glatz, R.V. & Wood, G.A. (2010, in press). The relative risk of exotic and endemic plants as hosts for four pest thrips (Thysanoptera: Thripinae). *Bulletin of Entomological Research*.

Smith, K.R. (1975) A new system of surveying and its use on liverleaf nightshade. *Journal of Agriculture South Australia,* 78**,** 36-39.

Snell, K. (2003) Integrated Management of Silverleaf Nightshade. *Notes from weed management workshop.* Bendigo Victoria, DPI.

Stanton, R., Wu, H., An, M. & Lemerle, D. (2008a) Home among the gum trees - not necessarily so for silverleaf nightshade. *Proceedings of the 16th*

*Australian Weeds Conference, Cairns Convention Centre, North Queensland, Australia, 18-22 May, 2008***,** 330-332.

Stanton, R., Wu, H., Dear, B. & Lemerle, D. (2008b) Managing perennial summer weeds with competitive pastures. *Proceedings of the 16th Australian Weeds Conference, Cairns Convention Centre, North Queensland, Australia, 18-22 May, 2008***,** 503.

Stanton, R., Wu, H. & Lemerle, D. (2008) Silverleaf nightshade- new approaches to an old problem. *Proceedings of the 1st South Australian Weeds Conference.* Adelaide, Weed Management Society of SA.

Stubblefield, R.E. & Sosebee, R.E. (1986) Herbicidal control of silverleaf nightshade. *Proceedings of the Western Society of Weed Science.***,** 117-118.

Symon, D.E. (1981) A revision of the genus Solanum in Australia. *Journal of the Adelaide Botanical Gardens,* 4**,** 1-367.

Trione, S.O. & Cony, M.A. (1990) Thermoperiodism and other physiological traits of *Solanum elaeagnifolium* seeds in relation to germination. *Seed Science and Technology,* 18**,** 525-539.

Viljoen, B.D. & Wassermann, V.D. (2004) Suppression of silver-leaf bitter apple (Solanum elaeagnifolium Cav.) by cultivated pasture crops under dry-land conditions: a preliminary study. *South African Journal of Plant and Soil,* 21**,** 63-66.

Wapshere, A.J. (1988) Prospects for the biological-control of silverleaf nightshade, *Solanum elaeagnifolium*, in Australia. *Australian Journal of Agricultural Research,* 39**,** 187-197.

Westerman, R.B. & Murray, D.S. (1994) Silverleaf nightshade(*Solanum elaeagnifolium*) control in cotton (*Gossypium hirsutum*) with glyphosate. *Weed Technology,* 8**,** 720-727.