Review

The biology of Australian weeds
50. *Lantana montevidensis* (Spreng.) Briq.

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Name

The origin of the genus name *Lantana* is obscure. The specific epithet *montevidensis* indicates that the species originated from Montevideo, Uruguay.

There are two botanical synonyms used for *L. montevidensis*, these being *Lantana sellowiana* Link & Otto and *Lippia montevidensis* Spreng. (White 1929, Stanley and Ross 1986, Shepherd *et al.* 2001). *Lantana montevidensis* was known as *L. sellowiana* from its introduction into Australia until the 1930s and thereafter plants formerly identified as *L. sellowiana* were classified as *L. montevidensis* (Swarbrick 1986). Other species names that have been used in the literature include *L. sellowii*, *L. selowiana* and *L. delicatissima* (Anon. 1857, O'Donnell 2002). These latter names have not been recorded in the Australian Plant Names Index (Australian Plant Names Index 2007).

There are a number of common names used for *Lantana montevidensis* (Spreng.) Briq. in Australia. These include creeping lantana, lantana, polecat geranium, purple lantana, Sellow's lantana, small lantana, trailing lantana, weeping lantana and wild verbena (Moldenke and Moldenke 1983, Shepherd *et al.* 2001).

Description

Lantana montevidensis is a shrub with horizontally growing stems that may root at the nodes (Moldenke and Moldenke 1983, Conn 1992, Munir 1996). The stems also trail over rocks, banks and climb along tree branches for support (White 1929, Everist 1981, Conn 1992). The young stems are 1–2 mm wide, square in cross-section and with age, up to 5 mm in diameter, becoming rounded as they mature (White 1929, Everist 1981, Auld and Medd 1987, Parsons and Cuthbertson 2001, Figure 1). Stems may grow up to 40 mm in diameter at the base (Moldenke and Moldenke 1983). The stems grow from 1–4 m in length but rarely attain more than 0.5 m in height, with the ends of stems growing upwards (Moldenke and Moldenke 1983, Munir 1996, Parsons and Cuthbertson 2001, Cooperative Research Centre for Australian Weed Management 2003).

The stems of the plant form low dense thickets or mats and are frequently trimmed to form hedges over existing structures (Stanley and Ross 1986, Swarbrick 1986, Cooperative Research Centre for Australian Weed Management 2003). The stems are rough to touch, have no prickles, may or may not have short, rigid hairs and are often glandular on the younger parts (Conn 1992).

The bright green leaves of *L. montevidensis* are borne opposite each other, are oval-shaped, and are generally 8–35 mm long, 5–16 mm wide, on petioles 20–40 mm long (Moldenke and Moldenke 1983, Conn 1992). Leaves may be variable in size and either larger, with leaves of ornamental varieties from 25–40 mm long and 6–18 mm wide (White 1929, Everist 1981), or significantly smaller, with leaves of dwarf forms or water stressed plants of the weedy variety up to 6 mm long and 3 mm wide (Moldenke and Moldenke 1983). The leaf bases may be rounded or truncate (cut off in appearance) while the leaf margins are toothed (Stanley and Ross 1986, Conn 1992). The upper surface of the leaves is wrinkled and covered in sharp rigid hairs while the lower surface may or may not be covered in short soft white hairs and is commonly slightly paler (Everist 1981, Conn 1992). The lower leaf surface has yellow and orange glands on it. The leaves are strongly aromatic when crushed and this is most marked in the weedy variety (Everist 1981, Auld and Medd 1987, Parsons and Cuthbertson 2001).

The flower heads of this species are 10–40 mm in diameter while the peduncle is 15–100 mm long and borne in the leaf stalk (Kleinschmidt and Johnson 1977, Conn 1992, Munir 1996, Figure 1). There are up to 20 florets in each head although the weedy variety has fewer florets (Everist 1981, Parsons and Cuthbertson 2001). Broadly oval-shaped bracts are present underneath each flower head and are 4–7 mm long. Each corolla (floret) is 8–12 mm long and 4–10 mm in diameter (Conn 1992, Munir 1996, Parsons and Cuthbertson 2001). The florets are generally pale purple, mauve or lilac with a pale yellow or white centre when young, becoming purple on maturity (White 1929, Everist 1981, Auld and Medd 1987, Conn 1992, Parsons and Cuthbertson 2001, O'Donnell 2002). Other workers have stated that florets of *L. montevidensis* are also lavender, violet, pink, rose or magenta (Moldenke and Moldenke 1983). Ornamental varieties of *L. montevidensis* have lilac and white florets and are more compact plants with smaller leaves (van Oosterhout 2004). Although yellow-flowering varieties appear to be common in cultivation (Munir 1996), these are misnamed as they are hybrids of *L. camara* L. and *L. depressa* Small.

The ellipsoid fruit of *L. montevidensis* is a drupe (incorrectly known as a berry), green at first, 2–8 mm in diameter and purple/black or reddish/brown when mature (White 1929, Everist 1981, Conn 1992, Munir 1996, Conn 1999, Parsons and Cuthbertson 2001). Several authors noted that only the weedy variety of this species produced fruit whereas the ornamental varieties rarely, if ever, produced fruit (Everist 1981, Auld and Medd 1987, Swarbrick 1986, O'Donnell 2002). It should be noted that ornamental varieties do set seed if pollinated by the weedy variety (Neal 1999). Each fruit has up to two seeds (O'Donnell and Panetta 2000). Seeds are a pale straw colour and up to 4 mm long (Parsons and Cuthbertson 2001).

Plants have a brown woody taproot, strong lateral roots and fine white roots (Parsons and Cuthbertson 2001). This large lignified taproot is also known as a xylopodium and acts as a carbohydrate storage

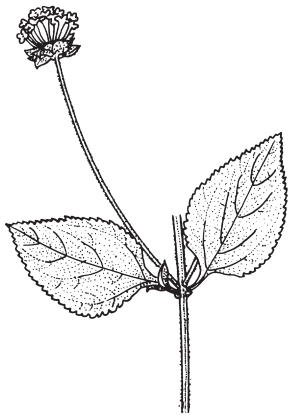

Figure 1. *Lantana montevidensis* shoot showing leaf and flower head morphology. No scale is given for the original. Source: Botanic Gardens Trust (2007), used with permission.

organ, allowing the species to resist fire, drought and herbicide damage (Moldenke and Moldenke 1983, O'Donnell and Panetta 2000).

This species is easily differentiated from the species aggregate *L. camara* because *L. montevidensis* has a horizontal growth habit, stems that readily root at the nodes, often has purplish florets, leaves that are less than 25 mm long and lower leaf surfaces bearing yellow to orange glands. *Lantana camara* does not have any of these characteristics.

Taxonomy

Verbenaceae

The Verbenaceae family includes around 75 genera and 3000 species of herbs, shrubs and trees of tropical and subtropical parts of the world, with 17 genera and around 62 species in Australia (Conn 1992). Aside from *Lantana*, there are a number of Australian Verbenaceae genera that contain weedy species, including *Phyla* (lippia), *Verbena* (purpletop/verbena) and *Stachytarpheta* (snakeweed) (Parsons and Cuthbertson 2001).

Lantana genus

The complex taxonomy inherent in the family Verbenaceae and genus *Lantana* has been summarized elsewhere (Day *et al.* 2003). *Lantana* is composed of 150 herb and shrub species, native to tropical America with several native to Africa and Asia (Conn 1992, Day *et al.* 2003). Nine of these species have been recorded as weeds in various tropical and subtropical areas (Holm *et al.* 1979). Four distinct sections in the genus *Lantana* are recognized (Munir 1996). *Lantana montevidensis* belongs to section *Calliorheas* and has a haploid chromosome number of $n = 12$ (Henderson 1969, Munir 1996, Day *et al.* 2003), although there is one record of $n = 11$ (Chatha and Bir 1988).

Varieties of L. montevidensis in Australia

A previous study recorded that two varieties of *L. montevidensis* occurred in Australia, each with a different ploidy (Henderson 1969). The common garden variety tested was a triploid ($2n = 36$) while the weedy variety was a tetraploid ($2n = 48$). It is not known if further introduction of *L. montevidensis* varieties into Australia has increased the number of ploidy levels.

A much later study indicated that there were a number of ornamental varieties of *L. montevidensis* available for sale in Australia (van Oosterhout 2004). Although widespread propagation of ornamental varieties occurs, the weedy purple-flowered variety has also been grown in gardens as an ornamental (Neal 1999, van Oosterhout 2004). In Table 1 some differences between the weedy and two ornamental varieties of *L. montevidensis*, one with lilac florets and the other with white florets, are outlined in comparison with the common pink-flowered weedy variety of *L. camara*. Further, Neal (1999) indicated that crosses between *L. montevidensis* ornamental varieties may have occurred in Australia. A variegated leaf form of *L. montevidensis* with lilac florets is also cultivated in the new Botanic Gardens in Brisbane (Swarbrick 1986).

History

Both species of *Lantana* naturalized in Australia, *L. montevidensis* and *L. camara*, are native to tropical South America. Although most authors generally agree that the native range of *L. montevidensis* includes southern Brazil, there is some conjecture as to whether the range also includes Uruguay (Everist 1981), Paraguay and/or northern Argentina (Moldenke and Moldenke 1983, Day *et al.* 1999). The species was introduced into Europe from Montevideo in 1822 (Swarbrick 1986), and to Australia by 1851 (Shepherd 1851, Johnson 1872, both cited in Swarbrick 1986, Munir 1996). *Lantana sellowii* was recorded in cultivation in south west Sydney in 1857 (Anon. 1857). Although one earlier reference indicates that *L. montevidensis* was recorded as a weed in Australia (Holm *et al.* 1979) and perhaps in Florida (Bailey 1963), the species is thought to be weedy in other countries, including Africa and parts of India (Day *et al.* 2003). Other references refer to naturalization of the species, but not to weediness, in subtropical and tropical areas of the world including in Sri Lanka, and in New Zealand (Everist 1981, Moldenke and Moldenke 1983, Webb *et al.* 1988, van Oosterhout 2004). These authors also indicated the widespread planting of the species as an ornamental.

After introduction, *L. montevidensis* was widely dispersed in Australia, appearing in the Melbourne Botanic Gardens in 1852 and then in many botanic gardens and nursery catalogues (Swarbrick 1986). That author stated that the species was first found in Adelaide in 1859 and Brisbane in 1875. The first mention of *L. montevidensis* as either a garden escape or weed is by Bailey and Tenison-Woods (1879) who recorded the species in the Brisbane River area.

There are a number of observations of *L. montevidensis* in south-eastern Queensland from 1883–1909, generally of plants that were garden escapes from nearby towns into neighbouring pastures (Swarbrick 1986). That author noted that rapid spread of the weed occurred in coastal Queensland after 1900, with herbarium records from Gayndah in 1913 and 1917, near Cairns in 1918 and at Rockhampton in 1925. The 1917 Gayndah record is significant because the species is described as a 'very common weed' (O'Donnell 2002). By the 1950s and 1960s *L. montevidensis* had become widespread throughout coastal and sub-coastal Queensland, especially in the Burnett district (O'Donnell *et al.* 1999). Furthermore, O'Donnell (2002) recorded that by the 1980s and 1990s the species had reached levels where the ongoing viability of grazing enterprises was significantly affected in some areas of Queensland.

It is presently unclear when *L. montevidensis* was first noted as a weed problem in New South Wales. Records at the Royal Botanic Gardens in Sydney indicated that infestations of the species were present as early as 1952 near Concord in Sydney and around 1963 near Casino on the North Coast. In contrast to the widespread distribution of *L. montevidensis* in Queensland, only limited naturalizations of the species have occurred in New South Wales.

Table 1. Distinguishing floral and leaf characteristics of *Lantana montevidensis* varieties and the common pink-flowering weedy variety of *L. camara*, summarized from van Oosterhout (2004).

		Floral characteristics			
Species	Variety	Bud	Middle floral ring	Outer floral ring	Leaf characteristics
L. montevidensis	**Purple** (weed)	Purple	White throat Purple petals	White throat Purple petals	Smaller than *L. camara*
L. montevidensis	**Lilac** (ornamental)	Lilac	White to yellow throat Lilac petals	White to yellow throat Lilac petals	Larger than weedy variety of the species
L. montevidensis	**White** (ornamental)	White to cream	Yellow throat White petals	Pale yellow throat White petals	Larger than weedy variety of the species
L. camara	**Pink** (weed)	Pink	Yellow throat Pale yellow petals	Orange throat Pale or dark pink petals	Large, pale green

A number of authors indicated that only one variety of *L. montevidensis* has been introduced into Australia as an ornamental (Auld and Medd 1987, Conn 1992, Parsons and Cuthbertson 2001). In contrast, van Oosterhout (2004) outlined that both ornamental lilac and white varieties as well as the common purple-flowered weedy variety were used (Table 1, Figure 2).

Lantana camara × *L. montevidensis* hybrids appear to have been developed for use in horticulture. For example, Howard (1969) stated that the *L. montevidensis* has been used to produce such hybrids since the early 19th century and Hammer (2004) indicated that this practice continues. In particular, *L. montevidensis* is commonly used to achieve new horticultural varieties with low, mounding and trailing growth habits. Furthermore, a number of authors noted the hybridization of both previously geographically separated species when grown in the same location (Sanders 1989, in Day *et al.* 2003).

Distribution

Current distribution

Suitable habitats for the species generally occur in sub-humid and semi-arid regions of the tropics and subtropics (Everist 1981, Parsons and Cuthbertson 2001).

Naturalized populations of *L. montevidensis* can be found in coastal and sub-coastal areas of Australia (Figure 3). Along the east coast of Australia, the species can be found from Nowra 34°53'S in southern New South Wales to Cairns 16°55'S in northern Queensland (Munir 1996, Neal 1999). A number of authors indicated that *L. montevidensis* can be found on the north coast (around Casino, Murwillumbah and Byron Bay) and central coast of New South Wales north from Sydney (Everist 1981, Swarbrick 1986, Auld and Medd 1987, Conn 1992, O'Donnell 2002). The species is also found on the north-western slopes of New South Wales around Tamworth and south of Sydney (Conn 1992, Australia's Virtual Herbarium 2007).

Lantana montevidensis is common in south-eastern Queensland, mainly from Rockhampton to the New South Wales/Queensland border, again in coastal and sub-coastal areas such as the Moreton, Wide Bay, Burnett and Port Curtis pastoral districts (Seawright 1965, Kleinschmidt and Johnson 1977, Everist 1981, Auld and Medd 1987, Day *et al.* 1999, O'Donnell *et al.* 1999, O'Donnell 2002). Records show naturalization in the coastal pastoral districts of South Kennedy, North Kennedy (around Townsville) and Cook (around Cairns) and the inland district of Leichhardt (Hnatiuk 1990, Munir 1996, Australia's Virtual Herbarium 2007).

The species has been recorded as a weed in other situations in Darwin (Jeffrey and Ready 1999). In addition, there are two herbarium records of *L. montevidensis* in

Figure 2. White- (foreground) and purple-flowering (background) varieties of the ornamental *Lantana montevidensis* planted in a median strip at Griffith (south-western New South Wales, September 2005).

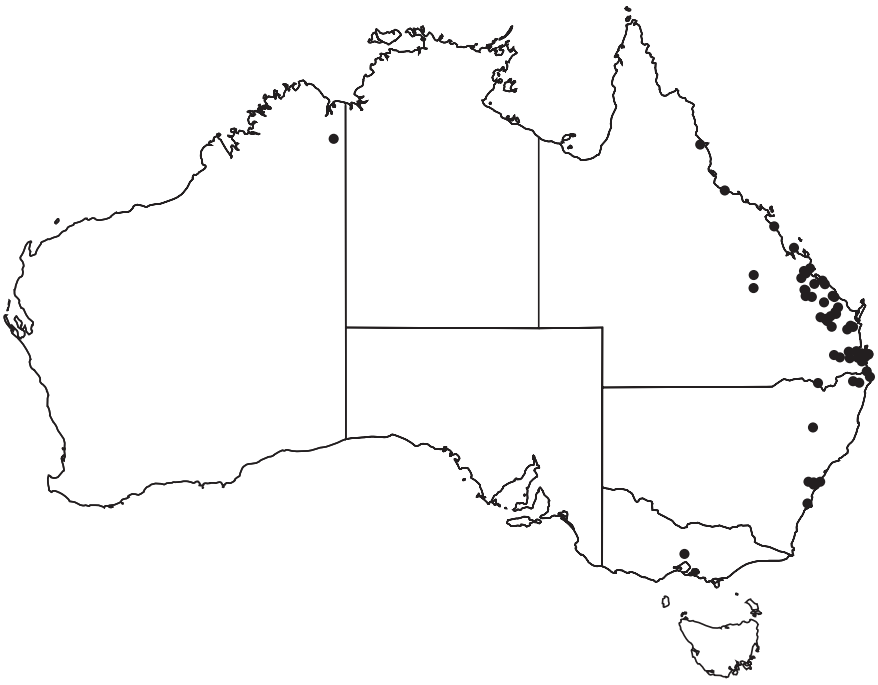

Figure 3. The current distribution of *Lantana montevidensis* in Australia (Australia's Virtual Herbarium 2007).

Australia, one from Kununurra (Western Australia) and the other north of Melbourne (Australia's Virtual Herbarium 2007). In support of the Melbourne record, Conn (1999) indicated that the species has become weakly established away from gardens in Victoria.

The species has been planted as an ornamental in Australia in the past, especially in the Northern Territory (Munir 1996, Parsons and Cuthbertson 2001), Queensland, New South Wales, South Australia, Victoria and Western Australia (O'Donnell 2002, R. Randall personal communication).

Potential distribution

Lantana montevidensis is in the early stages of spread in Australia (Neal 1999). She mapped the potential distribution of *L. montevidensis* via CLIMEX and concluded that at least 30% of Queensland and 10% of New South Wales were at threat of serious invasion. It has been noted that since ornamental varieties of *L. montevidensis* appear to have similar climatic preferences to that of the weedy variety, the species could spread beyond its present range in Australia (O'Donnell 2002). It is important to note, however, that the ecological limitations of the species are not known and require further investigation.

Given the current sparse distribution, it would be reasonable to expect that the species will continue to invade coastal and sub-coastal areas of New South Wales and Queensland, particularly in the areas where it currently occurs. Expansion on the Darling Downs in Queensland and in the north and central western plains of New South Wales may be possible, as may further expansion of the species in southern New South Wales and Victoria, since the species seems to be tolerant of cooler temperatures than *L. camara* in New Zealand (Webb *et al.* 1988). Having said this, one researcher has questioned whether southern Australian occurrences of the species are able to set seed (M. Day personal communication).

Habitat

Specific observations of the habitat of *L. montevidensis* have not been recorded in the literature. As mentioned above, Webb *et al.* (1988) indicated that while both *L. camara* and *L. montevidensis* occurred in the northern New Zealand, *L. montevidensis* was more tolerant of cold and hence is grown further south as an ornamental plant.

Lantana montevidensis appears to grow on a range of soil types, from shallow, stony soils in sloping areas that tend to dry out, to well drained alluvial or loam soils (Kleinschmidt and Johnson 1977, Munir 1996, O'Donnell 2002, M. Day personal communication, Figure 4).

Growth and development

Morphology and perennation

Much of the basic biological research conducted on *L. montevidensis* is centred on the reproductive biology of the species (discussed below). The early growth of *L. montevidensis* is slow while the taproot and lateral roots are developed (Parsons and Cuthbertson 2001, O'Donnell 2002). High mortality of *L. montevidensis* seedlings occurred via a wide range of factors including moisture stress, physical disturbance, fire, herbicides, cattle trampling and perhaps grazing (O'Donnell 2002). Seedlings established more readily in protected areas such as stony outcrops and areas protected from cattle, underneath fences and fallen timber, within tussocks of grasses that were not eaten and in pastures that were not subject to hot fires. Seedlings may grow at rates of only 1 cm per month (O'Donnell 2002).

Although glasshouse plants of *L. montevidensis* have been shown to produce seeds within a year of germination, seedling development is much slower in the field (Parsons and Cuthbertson 2001, O'Donnell 2002). This results in vegetative plants becoming dormant over winter, reshooting in the following spring and starting to flower in late spring.

Plants of *L. montevidensis* may survive for at least five years and persist under periods of extended drought (O'Donnell 2002). Plants are able to grow and reproduce in situations from full sunlight to shade (O'Donnell 2002). Although the drought persistence of this species is well established, evidence suggests that the species grows and spreads at a faster rate under wetter conditions (O'Donnell 2002).

Reproduction

Floral biology

Established plants of *L. montevidensis* flower most of the year in Australia and New Zealand (Conn 1992, Webb *et al.* 1988, Parsons and Cuthbertson 2001). More specifically, O'Donnell (2002) recorded that *L. montevidensis* flowered in response to rainfall, with heaviest flowering after a protracted dry period, for example after the first spring rainfall break.

Pollen viability of approximately 65% has been recorded in the weedy variety of *L. montevidensis*, in contrast to the ornamental variety which had less than 6% viability (Henderson 1969). Similarly, Neal (1999) indicated pollen viabilities of 82% from the weedy populations of *L. montevidensis* she assessed and 14–16% from the populations of white and purple ornamental *L. montevidensis* varieties. The differences between the studies are likely to be due to the restricted number of populations collected by Henderson.

Seed production and dispersal

Plants of *L. montevidensis* are able to set fruit throughout the year, generally from early summer to mid winter in Queensland (O'Donnell 2002). Seed production in *L. montevidensis* generally occurs five weeks after flowering (O'Donnell 2002). Various authors, including Henderson (1969), stated that the weedy variety of *L. montevidensis* produce a high proportion of fertile seed. For example, yearly seed production varied between 4965 and 5175 seeds m^{-2}. While each drupe had two seeds, generally only 30% of drupes produced a second seedling (O'Donnell 2002).

At least two authors have recorded that ornamental varieties of *L. montevidensis* did not produce fruit in Australia (Henderson 1969) and New Zealand (Webb *et al.* 1988). In contrast, later research demonstrated that 0.42–1% of florets of the purple-flowering ornamental variety examined produced fruit and that these populations were generally found growing in close proximity to weedy populations of *L. camara* and/or *L. montevidensis* (Neal 1999). That study also indicated that pollen from the weedy variety that was used in cultivation resulted in 6% of florets producing seed in another supposedly sterile

Figure 4. Some infestations of *Lantana montevidensis* occur on shallow, stony soils in sloping areas.

L. camara × *L. depressa* hybrid. It was suggested that it is only when ornamental varieties of *L. montevidensis* occur in isolation that very little seed production occurred.

The seeds of *L. montevidensis* are dispersed by a number of means. Dispersal commonly occurs via fruit-eating animals (Parsons and Cuthbertson 2001), including viable seeds passing through the digestive tracts of grazing cattle (O'Donnell 2002) and occasionally kangaroos (Day and McAndrew 2002).

A number of bird species feed on ripe fruit including the *Cacatua* species (white cockatoos), *Corvus species* (crows), *Dromaius novaehollandiae* (Latham 1790) (emus), *Platycercus adscitus* (Latham 1790) (pale-headed rosella) and *Strepera* species (currawongs) (O'Donnell and Panetta 2000, S. Csurhes personal communication). Initial infestations arising from bird-dispersal are common under nesting and roosting sites, especially around trees and fences (O'Donnell 2002, e.g. Figure 5).

Dispersal of seeds also occurs in mud attached to hooves, boots and machinery, by ants transporting and burying seeds in their nests and by water flowing across the soil, especially after heavy rain (Parsons and Cuthbertson 2001, O'Donnell 2002). As a consequence, gullies and watercourses are particularly susceptible to infestation. The trade of nursery plants has been responsible for the spread of this species, and still continues despite legislative restrictions in some states and territories in Australia.

Figure 5. Although initial infestations of *Lantana montevidensis* often occur under roosting sites near fences (similar to that pictured) these plants near Oxley Lookout at Tamworth have spread from intentional roadside plantings.

Germination

Seeds of *L. montevidensis* germinate at any time of the year provided that there is sufficient soil moisture and light (O'Donnell and Panetta 2000, Parsons and Cuthbertson 2001, O'Donnell 2002). Seed buried to 1–2 cm did not germinate however (O'Donnell and Panetta 2000). Despite this, there is some evidence to suggest germination flushes occurred when good soil moisture conditions coincided with night temperatures close to or below freezing (O'Donnell 2002). That research also found that exposure to smoke from pasture fires for 5 to 15 minutes stimulated the germination of *L. montevidensis* seeds 6–15 times. Germination and subsequent growth was enhanced in pasture gaps ranging from 5–40 cm (O'Donnell 2002).

The viability of *L. montevidensis* seeds decreased from 100% to between 30–44% after one year of burial at 1–2 cm of depth, while those planted on the soil surface had only 10–18% viability after a similar time (O'Donnell and Panetta 2000). Further research indicated that after two years all surface sown seed was dead but that up to 20% of buried seed was still viable (O'Donnell 2002). These results indicated that the seed of *L. montevidensis* was relatively short lived in the soil. In addition, the seed pulp or mesocarp inhibited germination for up to 100 days after sowing but had no impact after one year, probably as a result of natural decay (O'Donnell and Panetta 2000).

The woody seed coat of *L. montevidensis* is impermeable to certain gases and chemicals and hence may prevent seed germination (Attwater 1980). The presence of pulp surrounding seeds does not preclude germination, indicating that prior bird ingestion is not a requirement for successful germination (O'Donnell and Panetta 2000).

Vegetative reproduction

Vegetative reproduction of *L. montevidensis* occurs from stem and leaf material. For example, the size and density of existing colonies of *L. montevidensis* increased as stems rooted at the nodes and as seedlings developed within and near existing thickets (Parsons and Cuthbertson 2001). Other research indicated that the weedy variety of *L. montevidensis* reproduced by stem cuttings and by the division of established plants, while ornamental varieties appeared only to be propagated and spread by stem cuttings and not by seed (Swarbrick 1986).

In contrast, leaf material of both ornamental and weedy varieties of *L. montevidensis* was found to give rise to new plants (Neal 1999). In particular, 42% and 34% of ornamental white and purple *L. montevidensis* varieties, respectively, produced root material after five weeks, with 2% and 4% also producing shoots. The weedy variety of *L. montevidensis* had 12% root production from leaves after five weeks.

These results indicate that there is considerable potential for vegetative production and that new plants are likely to arise from garden waste that has not been disposed of properly (Neal 1999).

Importance

Detrimental

Lantana montevidensis is an increasingly prominent weed in agricultural and environmental situations. For example, the species is a weed in pastures and degraded grasslands, in woodland and sclerophyll forests, and in roadside cuttings, along fence lines, riparian areas and on rocky outcrops (Swarbrick 1986, Munir 1996, O'Donnell and Panetta 2000, J. Hosking personal communication). The various impacts of this species will be examined in more detail below.

Pastures *Lantana montevidensis* has the potential to overrun pasture ecosystems, shading out more desirable species and reducing biomass production (O'Donnell and Panetta 2000, Parsons and Cuthbertson 2001, Bray 2002). In particular, dense infestations decrease grazing animal carrying capacities and threaten the viability of grazing systems, resulting in decreases in land values (O'Donnell 2002). The most severe pastoral impacts occur in central Queensland with an estimated 150 000 ha of pasture land infested in 1997, with potential for further exponential spread (Flannery 1997, in O'Donnell 2002). Other work has also suggested that the species is a significant weed in grazing industries (Grice 2002, Barker *et al.* 2006).

Although O'Donnell (2002) stated that the abundance of *L. montevidensis* is often linked to overgrazing, evidence suggested that the species established more readily in undisturbed or under light to medium grazed conditions. Only after *L. montevidensis* was established did over-grazing favour its spread (O'Donnell 2002). A number of authors have also indicated that *L. montevidensis* spreads in native and unimproved pasture grasses when these are weakened under drought conditions (Everist 1981, Auld and Medd 1987, Conn 1992, O'Donnell *et al.* 1999, O'Donnell 2002).

There is some disagreement as to the toxicity of *L. montevidensis* to grazing animals, with toxicity reported by some (Auld and Medd 1987, Conn 1992, Cooperative Research Centre for Australian Weed Management 2003), but not by others (Seawright 1965, Dowling and McKenzie 1993). While it has also been postulated that cattle grazing pasture infested with *L. montevidensis* from birth develop resistance or immunity to any toxins present (O'Donnell 2002), the toxicity of the species requires further study (Everist 1981).

Natural ecosystems *Lantana montevidensis* is considered a weed of natural ecosystems, and in particular national parks, because it is an efficient pioneer species that displaces native vegetation (Flannery 1997, in O'Donnell 2002, Bray 2002, Cooperative Research Centre for Australian Weed Management 2003). As the 18th most invasive and frequent weed on natural areas in south-eastern Queensland (Batianoff and Butler 2001), it is commonly found in open woodland, dry sclerophyll forest and disturbed areas behind mangroves (Munir 1996, O'Donnell 2002).

There is some evidence to suggest that *L. montevidensis* reduces plant and animal biodiversity in these and other ecosystems where it occurs (Munir 1996, O'Donnell 2002, S. Csurhes personal communication).

Beneficial

Ornamental *Lantana* species have been widely planted as ornamental plants in gardens, in particular as hedges in Australia (Swarbrick 1986) and around the world in the past (Moldenke and Moldenke 1983). These plantings include ornamental and weedy varieties of *Lantana montevidensis*, and hybrids of *L. montevidensis* with other *Lantana* species (Neal 1999, Hammer 2004). *Lantana montevidensis* plants are widely used in landscape design, public and private gardens, in parks, on roundabouts, in median strips, in roadside cuttings and beside footpaths because they are colourful, require little maintenance and have some drought tolerance (Neal 1999, van Oosterhout 2004). The species is commonly grown in rock gardens and used as a ground-cover plant on retaining walls and banks in New Zealand, and in other parts of the world (Everist 1981, Webb *et al.* 1988), while the species, or its hybrids are also used in hanging baskets and window boxes (Moldenke and Moldenke 1983).

Ornamental varieties of *L. montevidensis* have been widely sold in Australia as 'sterile'. Indeed, it has been stated that while the weedy variety produces fertile pollen and seed, ornamental varieties are largely sterile, flowering profusely and rarely producing seed (Henderson 1969, Everist 1981). These claims are incorrect (see *Seed production and dispersal*).

Other uses or benefits *Lantana montevidensis* is used in herbal medicine in South America (Moldenke and Moldenke 1983). The species contains camphor, menthol and bornyl acetate and is employed to treat broncho-pulmonary diseases, headaches, sunstroke and fevers.

Lantana montevidensis may also prevent erosion of steep slopes, although this is only because it has replaced more desirable species that formerly provided soil coverage (O'Donnell 2002).

Legislation

In recognition of the threats posed by *L. montevidensis*, declaration has occurred throughout New South Wales, the Northern Territory and Western Australia and in parts of Queensland. Details of these declarations are outlined. The species has not been declared in other states and territories of Australia.

New South Wales

All *Lantana* species have been declared as Class 5 weeds in all local government areas in New South Wales under the *Noxious Weeds Act 1993* (New South Wales Department of Primary Industries 2007). A Class 5 declaration applies to 'plants that are likely, by their sale or the sale of their seeds or movement within the state or an area of the state, to spread in the state or outside the state'. This declaration was applied to prevent the trade and distribution of all *Lantana* species so that further movement of genetic material from ornamental *Lantana* plantings into the environment did not occur.

In addition, all *Lantana* species are declared as either Class 3 or Class 4 weeds in a number of eastern local government areas in New South Wales. A Class 3 weed poses a serious threat to primary production or the environment, is not widely distributed and is likely to spread. Class 3 weeds must be fully and continuously suppressed and destroyed. The declaration applies to the Eurobodalla and Bega areas to support management efforts to reduce *Lantana* species in the Southern containment zone for *Lantana* in New South Wales (Harding 2005). Lord Howe Island also has a Class 3 declaration to support control efforts.

A Class 4 weed poses a threat to primary production, the environment or human health, is widely distributed and is likely to spread. The growth and the spread of a Class 4 weed must be controlled according to the measures specified in a management plan published by the local control authority. A Class 4 declaration applies to 54 local government areas, covering much of coastal New South Wales (New South Wales Department of Primary Industries 2007).

Northern Territory

Lantana montevidensis is declared in the Northern Territory under the *Weeds Management Act 2001* under two classes (Northern Territory Natural Resources, Environment and the Arts 2007). These are as a Class B Noxious weed (a regional declaration), such that growth and spread are controlled outside town areas, and as a Class C Noxious weed to prevent the introduction of this species into the Northern Territory. Declared weeds are restricted from sale.

Queensland
All *Lantana* species are declared Class 3 pests in Queensland under the *Land Protection (Pest and Stock Route Management) Act 2002* (Queensland Natural Resources and Water 2007). Class 3 pests, in this case weeds, are defined as weeds that have established in Queensland and have, or could have, adverse economic, environmental and social effects (including in other states). It is an offence to introduce, release, give away, sell or otherwise supply a Class 3 pest. Land holders may be required to control a Class 3 pest if it is an environmental, social or economic threat in or adjacent to an environmentally significant area such as a national park or reserve, but only if these are free from the weed.

Certain local government areas have also declared *L. montevidensis* and *L. camara* under local law, requiring control in areas not in or adjacent to environmentally significant areas including Bowen, Cardwell, Charters Towers, Dalby, Eacham, Gayndah, Johnstone, Kilkivan, Kingaroy, Maroochy, Maryborough, Mirani, Murgon, Pittsworth, Rockhampton, Sarina, Tara and Townsville.

Western Australia
Lantana montevidensis is declared as a P1 plant in Western Australia under the *Agricultural and Related Resources Protection Act 1976*. This declaration means it is prohibited to import, move and trade this species into and within WA.

Weed management

An integrated weed management program for *L. montevidensis* can be successful despite the resilience of *L. montevidensis* plants to fire, drought, mechanical disturbance and some herbicides when used as sole means of control (O'Donnell 2002). There are a number of management tools available including chemical and physical control, the use of fire, grazing management and regeneration and prevention of further infestations. Each control method will be reviewed separately but combinations need to be tailored as part of an integrated program. Much of the information in this section has been drawn from an excellent review of the management of this species (O'Donnell 2002), with additional information from O'Donnell *et al.* (1999), O'Donnell and Panetta (2000) and Parsons and Cuthbertson (2001).

There are a number of reasons why infestations of *L. montevidensis* can be difficult to control. In particular, individual plants have a large lignified taproot that aids in plant regrowth; infestations occur in inaccessible terrain, resulting in limited weed management options; many infestations are of large size; land values of the invaded land are low; and the large costs of ongoing control that are needed (Day *et al.* 1999, O'Donnell 2002, Day *et al.* 2003). It is also important to note that the control of *L. montevidensis* is often more difficult than that for *L. camara* (O'Donnell 2002) and that constant vigilance is needed (Day *et al.* 2003).

Despite this, two general principles of management still apply. The first is that it is always easiest to work from areas where light infestations occur towards those with heavier infestations, if possible (Cooperative Research Centre for Australian Weed Management 2003). Secondly, in cases where extensive and dense infestations exist, initial control measures should be used either to promote access to the site or to encourage regrowth so that future control is easier (van Oosterhout 2004).

Herbicides
Fluroxypyr gave the best overall control of *L. montevidensis* and while glyphosate also gave good results in autumn, it did not achieve good results in spring (O'Donnell 2002). Wetting agents did not improve the efficacy of fluroxypyr or glyphosate treatments. In addition, the use of fluroxypyr allowed grass production within three months of treatment (O'Donnell 2002).

The use of dichlorprop for the control of *L. montevidensis* has been recommended by some, although thorough coverage is needed for actively growing plants (Kleinschmidt and Johnson 1977). Other research has shown that while this chemical achieved control of plants for two years, significant regrowth occurred after this time (O'Donnell 2002). Herbicides containing 2,4-D amine salts and picloram/2,4-D mixtures were less effective on *L. montevidensis* than those already mentioned.

In some trials, with all herbicide treatments used, regrowth occurred from plants that had been apparently dead for periods of over two years; no herbicide achieved 100% control (O'Donnell 2002). Herbicides applied to plant regrowth stimulated from a burning event did not improve the ultimate control of *L. montevidensis* over unburnt areas (O'Donnell 2002).

In areas where cultivation is not practicable, repeated herbicide applications on actively growing plants in late summer and autumn should be used where necessary. While repeated herbicide applications on *L. montevidensis* regrowth and the planting of perennial pasture species is a useful means of control, the cost per unit area often makes this option unfeasible (Day *et al.* 1999).

In addition to those herbicides outlined above, herbicides containing metsulfuron-methyl, tebuthiuron, triclopyr and mixtures of fluroxypyr and aminopyralid, glyphosate and metsulfuron methyl and triclopyr and picloram are all registered for the control of this weed (Australian Pesticides and Veterinary Medicines Authority 2007). Herbicides containing glufosinate and imazapyr have been shown to be effective against *L. montevidensis* in research trials but are not registered against this weed.

Physical control
Bulldozing to a depth of 15 cm gave reasonable control of *L. montevidensis* (O'Donnell 2002). He noted that offset discs rather than chisel ploughs were also effective, but that multiple passes were needed. Chisel ploughing caused fragmentation of *L. montevidensis* material, with an increase in plant numbers resulting. It may be necessary to obtain a permit if native vegetation is also cleared by these management methods.

The management of very small areas of *L. montevidensis* may be achieved via several means. These include physically digging up and removing plants or pruning to ground level, because while regrowth occurred after the first two pruning events, plants died after the third (O'Donnell 2002). A similar effect may be achieved by chipping, mowing or slashing. Mulching with hay to a depth of at least 20 cm may also kill adult plants (O'Donnell 2002).

Fire
Fire can be useful in two ways in managing *L. montevidensis* (O'Donnell 2002). Burning trials indicated that surface seed is killed by hot pasture fires but buried seed (especially in ant nests) escapes. Seed that escapes a fire is more likely to germinate via smoke stimuli but the seedlings that arise are easily controlled by herbicides and/or trampling. Adult plants are not killed by fire and regrowth occurs soon after. While seed set may be delayed, observations suggest higher floret and seed numbers on previously burnt plants.

Regarding the use of fire as a management tool for *L. camara*, Swarbrick *et al.* (1998) commented that very little information was available on the effects of seasonality, meteorological conditions during or rainfall after the burn, fuel loads, the type of fire (ground or crown fire) and the timing of the reintroduction of live stock if applicable. Several authors have commented that *L. montevidensis* generally produced inadequate fuel loads to maintain a hot enough fire to kill the roots (Day *et al.* 1999, Parsons and Cuthbertson 2001). Thus, the comments by Swarbrick *et al.* (1998) probably equally apply to the use of fire to manage *L. montevidensis*, despite the information from O'Donnell (2002) outlined above.

Grazing management and regeneration
A vigorous pasture sward will help prevent seedling establishment and growth (O'Donnell 2002). Subsequent to mechanical disturbance, planting competitive pasture grasses such as *Bothriochloa pertusa* (L.) A.Camus (Indian bluegrass) and

Digitaria eriantha Steud. (woolly finger grass) provided good grass biomass and some suppression of *L. montevidensis* (O'Donnell 2002). *Bothriochloa insculpta* (Hochst. ex A.Rich.) A.Camus (creeping bluegrass) provided good biomass but gave no suppression, whereas *Cenchrus ciliaris* L. (buffel grass) competed effectively with the weed. Fewer *L. montevidensis* plants eventuated when pasture species were sown in combination with the legume *Chamaecrista rotundifolia* (Pers.) Greene (wynn cassia). This may be a result of the sprawling habit of the legume, combined with the extra nitrogen released encouraging grass production. Since light appeared to be required for *L. montevidensis* germination, seed burial via ploughing should also reduce seedling emergence.

Alternatively, the native *Heteropogon contortus* (L.) P.Beauv ex Roem. & Schult. (black speargrass) can become established in infestations of *L. montevidensis* without ground preparation, making it useful on steep slopes where cultivation is not possible. Conservative stocking rates, combined with pasture spelling to allow regeneration of desirable grasses and the strategic use of fire, is an effective means of maintaining the vigour and competitive ability of native pastures while reducing the growth of *L. montevidensis*.

Biological control

One biological control agent for *L. montevidensis*, the leaf feeding beetle *Charidotis pygmaea* Klug was released in 1994 (Day *et al.* 1999). Unfortunately this biological control agent has had no impact on *L. montevidensis* (Day and McAndrew 2002). Day *et al.* (1999) also noted that three other agents released for the control of *L. camara* also attack *L. montevidensis*. These agents are a leaf feeding moth *Hypena laceratalis* Walker, a leaf blotching fly *Calycomyza lantanae* Frick and a floret feeding moth *Lantanophaga pusillidactyla* Walker. The impact of these agents is limited.

Prevention of further infestations

Prevention of the spread *L. montevidensis* into uninfested areas is probably the best means of management (Cooperative Research Centre for Australian Weed Management 2003). There are two main means by which this can occur. Strategic control of existing infestations is needed so that they do not spread further, and secondly, restrictions on the sale and use of *Lantana* species and hybrids as garden plants would be best applied to all states and territories. This has now occurred at a Federal level with all *Lantana* species (including nursery stock, plant parts and seeds) now prohibited from entry to Australia under the *Quarantine Proclamation 1998* (Australian Quarantine and Inspection Service 2007). Restrictions on the sale and use of all *Lantana* species across Australia is important because garden plants can act as sources of new infestations, introducing new genetic material into areas where existing infestations occur, making control more difficult (Randall 2001, van Oosterhout 2004). Native or non-weedy exotic species could be recommended in place of these species.

Since *L. montevidensis* is not widespread in New South Wales and some areas of Queensland, various hygiene measures may be important to limit its spread (O'Donnell 2002). These include fodder inspection, the refusal of suspect fodder and the inspection of feeding sites after periods of drought to ensure the species has not been spread. Quarantining for five to six days cattle that have been grazing on plants that have ripe fruit, before moving them from infested to clean pastures, may be an effective way of reducing the spread of viable seeds through the digestive tracts of cattle. Vehicle hygiene to prevent the movement of seeds in mud or vegetative fragments will also help prevent the spread of this species. The use of buffer strips between infested and uninfested areas will help prevent the vegetative spread of the *L. montevidensis*.

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