NSW DPI

# Review of the declaration of *Lantana* species in New South Wales

NSW DEPARTMENT OF
**PRIMARY INDUSTRIES**

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# *Lantana* species

in New South Wales

New South Wales
Department of Primary Industries
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**Frontispiece.**
*A flowering and fruiting branch of the common pink variety of* Lantana camara, *near Copmanhurst (NSW north coast, October 2005) (Source: S. Johnson, NSW DPI).*



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**Disclaimer: The information contained in this publication is based on knowledge and understanding at the time of writing (December 2007). However, because of advances in knowledge, users are reminded of the need to ensure that information upon which they rely is up to date and to check currency of the information with the appropriate officer of New South Wales Department of Primary Industries or the user's independent adviser.**
**Job number 7262**

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**Figure 1.**
*White and purple flowering varieties of the ornamental* Lantana montevidensis *planted in a median strip, Griffith (south western NSW, September 2005) (Source: S. Johnson, NSW DPI).*

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# APPENDICES

Appendix 1 Declarations of *Lantana* species across Australia.
Appendix 2 Recommendations for declarations of *Lantana* species in NSW.

# ABBREVIATIONS

| | |
|---|---|
| ACT | Australian Capital Territory |
| NSW | New South Wales |
| NT | Northern Territory |
| Qld | Queensland |
| SA | South Australia |
| Vic | Victoria |
| WA | Western Australia |

# ACKNOWLEDGMENTS

This review has benefited greatly from information and comments provided by staff from NSW Department of Primary Industries, Biosecurity Queensland, the University of Queensland and the Botanic Gardens Trust.

**Figure 2.**
*A red and yellow flowering ornamental* Lantana *hybrid planted in a median strip, Griffith (south western NSW, September 2005) (Source: S. Johnson, NSW DPI).*

# EXECUTIVE SUMMARY

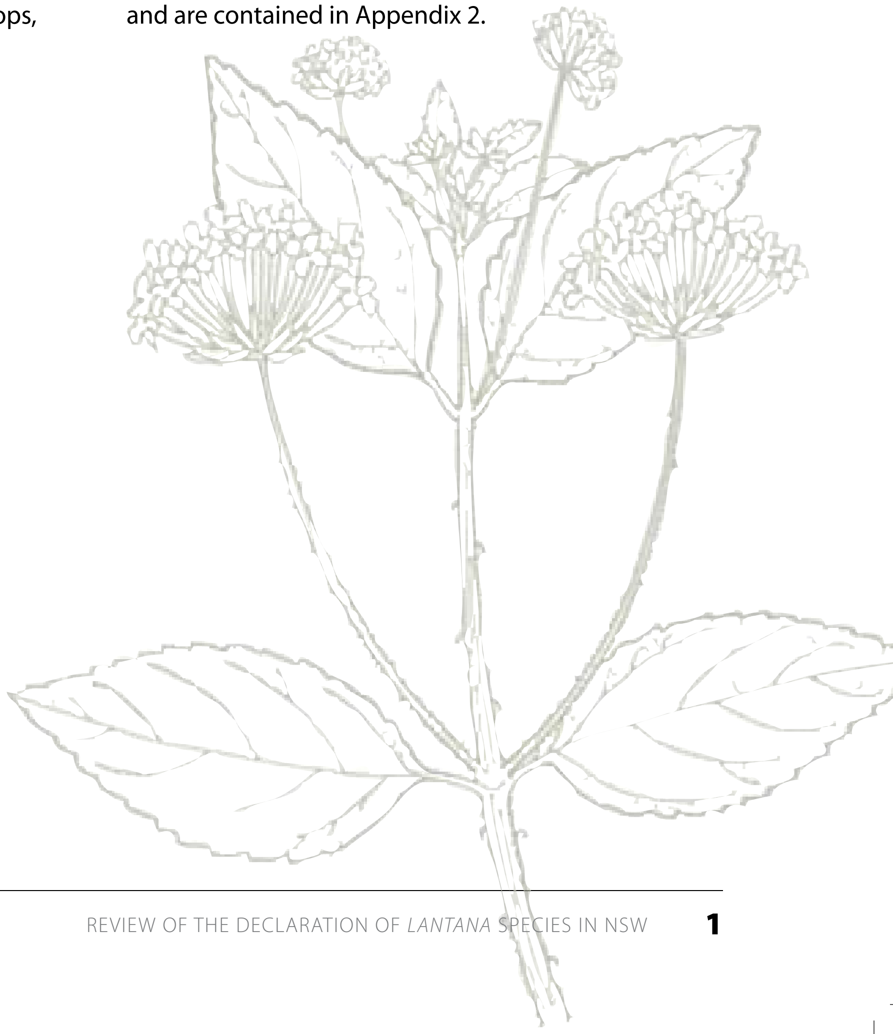
This document examined the basic biology and management of *Lantana* species in NSW.  Two species have naturalised, these being *L. camara* (lantana), a polyploid species aggregate composed of at least 29 different weedy and ornamental varieties and *L. montevidensis* (creeping lantana) of which one weedy and at least several ornamental varieties are present. Varieties of *L. camara* respond differently to a range of environmental and management conditions and practises.  Species of *Lantana* are able to hybridise and many such hybrids are grown for horticultural purposes.  Despite claims to the contrary, all varieties are fertile to some extent.  Although there is extensive spread of both species in eastern Australia, further spread is likely in both clean and infested areas.

Both species form dense, multi-branched thickets making access and management difficult.  Flowering and fruit set may occur all year round with dispersal of fruit by a range of birds and animals.  Both species are able to spread vegetatively to some degree.

*Lantana* species invade pastures, a wide range of natural ecosystems, forestry and plantation crops, as well as other areas reducing plant and animal biomass, abundance and biodiversity, generally causing livestock toxicity if eaten, often preventing regeneration of natural areas, and affecting tourism, recreational and aesthetic values.  Alternatively, both species have been widely planted as ornamental and hedge plants, and as amenity plantings.  Plants may provide alternative habitat for animals and provide a source of essential oils.

*Lantana camara* is a Weed of National Significance and has been banned from trade and distribution in all states and territories in Australia.  Varieties of *L. camara* are declared noxious in parts of coastal NSW, while both species are declared in Qld and the NT.  Management of both *Lantana* species is difficult with integrated control programs needed including preventative, chemical, mechanical and biological measures while fire, ploughing, hand pulling, revegetation and grazing management are useful tools.

Recommendations arising from this document have been made to the Noxious Weeds Advisory Committee and are contained in Appendix 2.



# SCOPE OF THIS REVIEW

This document outlines the basic biology and management of species of the genus *Lantana* that are present in New South Wales. The review was undertaken to ascertain if the current declaration of the noxious weed species *Lantana camara* was appropriate. An assessment of *Lantana montevidensis* and the large number of ornamental *Lantana* varieties was also made to determine if new declarations were appropriate.

Information from the literature has been grouped into the following general areas throughout this document: - nomenclature, species descriptions, taxonomy, origin, lifecycle, dispersal, growth and development, habitat, distribution, importance, legislation, control and recommendations. Further research needs and information required from consultation have been highlighted.

**Figure 3.**
*A flowering plant of the red variety of* Lantana camara, *near Seeview (Grafton, NSW north coast, October 2005) (Source: S. Johnson, NSW DPI).*

# REVIEW OF THE DECLARATION OF *LANTANA* SPECIES IN NSW

## NOMENCLATURE

### *Lantana camara*

There are a variety of common names used for *Lantana camara* L. in Australia. These include: Lantana, Common lantana, Kamara lantana, Large-leaf lantana, Red-flowered sage, White sage and Wild sage (Shepherd *et al.* 2001).

International common names include: Ach mann (Cambodia), Bahug-bahug (Philippines), Bands (India), Boenga pagar (Indonesia), Bunga tahi ayam (Malaysia), Cambara de espinto (Brazil), Cariaquillo (Puerto Rico), Chiponiwe (Zimbabwe), Cuasquito (Nicaragua), Guphul (India), Kauboica (Fiji), Kembang satik and Kembang telek (Indonesia), Largeleaf lantana (USA), Latora moa (Tahiti), Nagaairi (India), Pha-ka-krong (Thailand), Phullaki (India), Prickly lantana (Malaysia), Putus (India), Red-flowered sage (Barbados, Thailand and Trinidad), Saliara (Indonesia), Sapinit (Philippines), Tahi agam (Indonesia), Tantbi (India), Tatura moa (Tahiti), Telekan (Indonesia), Thom oi (Vietnam), Tick berry (eastern Africa and Zimbabwe), Vieille fille (Mauritius), Wild sage (Jamaica) and White sage (Thailand and Trinidad).

Synonyms that are used to describe the species include: - *Camara vulgaris* Benth., *Lantana aculeata* L., *Lantana camara* subsp. *aculeata* (L.) R.W.Sanders, *Lantana camara* var. *aculeata* (L.) Moldenke, *Lantana camara* L. var. *camara*, *Lantana camara* var. *crocea* (Jacq.) L.H.Bailey, *Lantana camara* var. *sanguinea* L.H.Bailey (pink-edged red flowering variety), *Lantana camara* var. *splendens* Moldenke, *Lantana crocea* Jacq. (pink-edged red flowering variety), *Lantana tiliifolia* Cham. and *Lantana scabrida* Sol. (Holm *et al.* 1977; Everist 1981; Jessop and Toelken 1986; Parsons and Cuthbertson 2001; APNI 2007).

A brief discussion of the validity of the taxonomic revision of *L. camara* to *L. strigocamara* is contained in the taxonomy section (Sanders 2006). This document uses the taxonomic name *L. camara* to describe this aggregate species.

### *Lantana montevidensis*

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 (Shepherd *et al.* 2001; O'Donnell 2002).

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

These two *Lantana* species are the only species recorded as being naturalised in NSW. They have been referred to by scientific name throughout this document.

## SPECIES DESCRIPTIONS

### *Lantana camara*

*Lantana camara* plants are multi-branched shrubs that generally grow from 2-4 m in height (Auld and Medd 1987; Conn 1992, Figures 3-5 and 14). The branches climb over each other, forming dense thickets (Conn 1992), to 15 m in height if supported by surrounding vegetation (Swarbrick *et al*. 1998). The branches are square in cross-section and 2-4 mm in diameter when young, becoming more rounded, grey/brown and up to 150 mm in diameter when mature (Swarbrick *et al*. 1998; Parsons and Cuthbertson 2001). The young stems of the weedy varieties are hairy and have short recurved prickles while those on the non-weedy varieties are rounder, more slender and do not have prickles (Swarbrick *et al.* 1998). The branches may be woody or brittle and often have pithy centres (Everist 1981; Swarbrick *et al*. 1998; Parsons and Cuthbertson 2001; van Oosterhout 2004).

The oval-shaped leaves are borne opposite each other, are 20-120 mm long and 15-80 mm wide, on petioles 5-30 mm long (Holm *et al*. 1977; Stanley and Ross 1986; Conn 1992; Munir 1996; Swarbrick *et al.* 1998; Parsons and Cuthbertson 2001). The leaf bases are rounded, pointed or heart-shaped while the margins are roundly toothed (Conn 1992; Swarbrick *et al*. 1998). The leaves of the pink flowering variety of *L. camara* are pale green while those of the red flowering variety are darker (Auld and Medd 1987). Leaf size and shape is dependant on the variety of *L. camara* and the availability of moisture (van Oosterhout 2004). The leaves may sometimes be glossy (Parsons and Cuthbertson 2001). The upper surface of the leaves is often wrinkled and covered in sharp, rigid hairs while the lower surface may or may not be covered in short, soft hairs (Conn 1992). The leaf veins are prominent on the lower surface while the upper surface contains very few stomata (Swarbrick *et al*. 1998). The leaves have a strong odour when crushed (Swarbrick *et al*. 1998).

The flat topped to dome-shaped flower heads are produced in pairs in the axils of opposite young leaves (Swarbrick *et al*. 1998; Day *et al.* 2003; Figure 4) and are 10-30 mm in diameter, while the peduncle or flower head stem is 20-95 mm long (Jessop and Toelken 1986; Conn 1992; Munir 1996; Swarbrick *et al.* 1998). Lance-shaped bracts are present underneath each flower and are 3-8 mm long (Munir 1996). There are 20-40 stalkless, tubular flowers in each head with each corolla (flower) 9-14 mm long with four spreading rounded lobes (Auld and Medd 1987; Conn 1992; Swarbrick *et al*. 1998). The flower buds are angular and tightly packed, opening initially from the outside of the flower head and moving inwards towards the centre (Swarbrick *et al*. 1998). Newly opened flowers normally have yellow throats with flower heads coloured in combinations of white, cream, yellow, orange, red, purple and pink. These colours tend to change with age (Conn 1992; Swarbrick *et al*. 1998; Parsons and Cuthbertson 2001). The most common variety of *L. camara* in NSW has flower heads to 25mm wide and individual flowers that are pale cream to dark yellow at first, changing to pink and lilac or purple (Auld and Medd 1987). There are a number of flower colours in ornamental varieties. Ornamental varieties are generally more compact plants with smaller leaves (van Oosterhout 2004).

The fruit of *L. camara* is a drupe (incorrectly known as a berry), 4-8 mm in diameter, green and hard when immature, turning a shiny purple/black when ripe (Auld and Medd 1987; Parsons and Cuthbertson 2001; Figure 5). Fruit are borne in clusters of up to 20 with each fruit containing one 'seed' that is pear-shaped and pale straw in colour, hard and 1.5-4 mm long and wide (Holm *et al*. 1977; Swarbrick *et al*. 1998; Parsons and Cuthbertson 2001). This seed is in fact two fused pyrenes each with a single embryo, both of which are viable (Swarbrick *et al*. 1998; Vivian-Smith *et al*. 2006). Swarbrick *et al*. (1998) further noted that non-weedy varieties of *L. camara* tend to retain their flowers longer after pollination in contrast to the flowers of weedy varieties which darken in colour after pollination, losing their yellow centre and then fall from the plant. Non-weedy varieties produce very few fruit, mostly failing to set seed after pollination.

**Figure 4.**

Lantana camara *shoot showing leaf and flower head morphology (Source: Botanic Gardens Trust (2007), used with permission).*

**Figure 5.**

*A branch with flowers, green and mature fruit of the common pink variety of* Lantana camara, *near Copmanhurst (NSW north coast, October 2005) (Source: S. Johnson, NSW DPI).*

The root system of *L. camara* is brown and woody and has a short taproot with many shallow lateral branches (Swarbrick *et al*. 1998; Parsons and Cuthbertson 2001). These laterals divide repeatedly to form a dense root mat (Swarbrick *et al*. 1998). *Lantana camara* is able to vigorously regrow from the base of the stem, from the plant crown if defoliated by fire or herbicide, or after drought or frost damage, from lateral root fragments when broken and slowly from rooted horizontal stems that come into contact with moist soil (Saint-Smith 1964; Swarbrick 1982; Waterhouse and Norris 1987; Swarbrick *et al*. 1998; Parsons and Cuthbertson 2001).

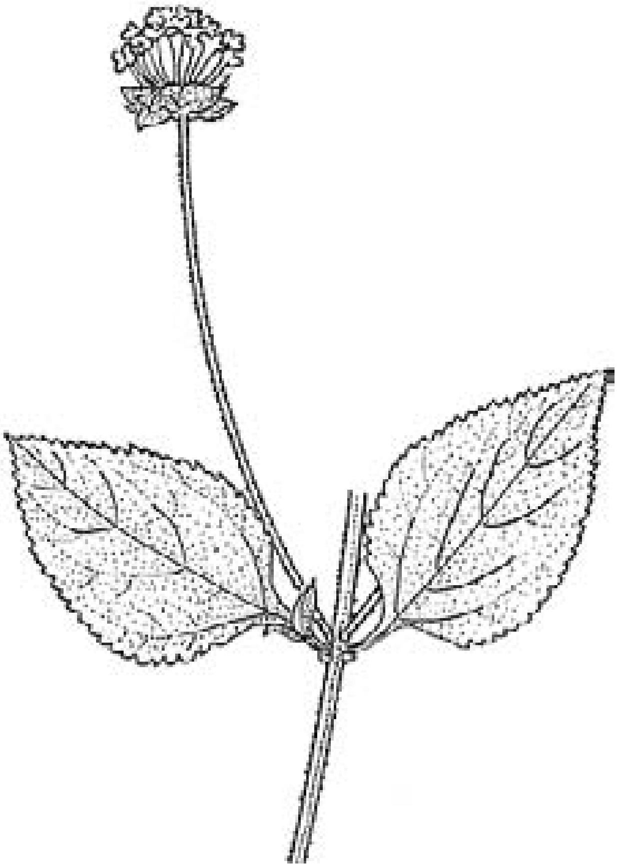
## *Lantana montevidensis*

*Lantana montevidensis* is a shrub with horizontally growing branches that may root at the nodes (Conn 1992; Munir 1996, Figures 1, 6, 13 and 15). The branches also trail over rocks, banks and climb along tree branches for support (White 1929; Everist 1981; Conn 1992). The young branches 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). The stems grow from 1-4 m in length but rarely gain more than 0.5 metres in height with the ends of branches growing upwards (Munir 1996; Parsons and Cuthbertson 2001; Cooperative Research Centre for Australian Weed Management 2003).

**Figure 6.**
Lantana montevidensis *shoots showing leaf and flower head morphology (Source: S Johnson NSW DPI. Line drawing source: Botanic Gardens Trust (2007), used with permission.).*

These branches 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 branches are also rough to touch with short rigid hairs, have no prickles, may or may not have 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, generally 8-30 mm long, 5-16 mm wide, on petioles 20-40 mm long (Conn 1992), although occasionally larger (White 1929). The leaves of the ornamental varieties of this species may be slightly larger, from 25-40 mm long and 6-18 mm wide (Everist 1981). 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 (Auld and Medd 1987; Parsons and Cuthbertson 2001), and this is most marked in the weedy variety (Everist 1981).



The flower heads of this species is 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). There are up to 20 flowers in each head although the weedy variety has fewer flowers (Everist 1981; Parsons and Cuthbertson 2001). Broadly oval-shaped bracts are present underneath each flower head and are 4-7 mm long. Each corolla (flower) is 8-12 mm long and 4-10 mm in diameter (Conn 1992; Munir 1996; Parsons and Cuthbertson 2001). The flowers are pale purple, mauve or lilac in colour 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). Munir (1996) stated that flowers of *L. montevidensis* are also pink, rose or magenta. Ornamental varieties of *L. montevidensis* have lilac and white flowers and are more compact plants with smaller leaves (van Oosterhout 2004). Munir (1996) also stated that yellow flowering varieties were common in cultivation but these are misnamed as they are a hybnd of *L.camara x L.depressa*

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 note that only the weedy variety of this species produced fruit whereas the ornamental varieties rarely, if ever, produced fruit (Auld and Medd 1987; Everist 1981; Swarbrick 1986; O'Donnell 2002). O'Donnell and Panetta (2000) indicated that each fruit has up to two seeds. The seeds of this species are a pale straw colour and up to 4 mm long (Parsons and Cuthbertson 2001). This species has 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 it acts as a carbohydrate storage organ allowing the species to resist fire, drought and herbicide damage (O'Donnell and Panetta 2000).

The two species are easily differentiated with *L. montevidensis* having a horizontal growth habit, branches that readily root at the nodes, purplish flowers, leaves that are less then 25 mm long and the lower leaf surface that has yellow to orange glands. *Lantana camara* does not have any of these characteristics.

# TAXONOMY

## Family Verbenaceae

The Verbenaceae family includes around 75 genera and 3000 species of herbs, shrubs and trees of tropical and subtropical parts of the world (Conn 1992). Conn (1992) recorded the presence of 17 genera and 62 species in Australia and nine genera and 19 species are found in NSW. Hosking (in prep.) recognised one additional genus and at least five more species. Aside from *Lantana*, there are a number of Australian genera that contain weedy species including *Phyla* (lippia), *Verbena* (purpletop/verbena) and *Stachytarpheta* (snakeweed) (Parsons and Cuthbertson 2001).

## *Lantana* genus

Day *et al*. (2003) summarised the complex taxonomy inherent in the family Verbenaceae and genus *Lantana*. The *Lantana* genera 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). Holm *et al*. (1979) recorded that nine of these species are weeds in various tropical and subtropical areas. Four distinct sections in the genus *Lantana* are recognised (Munir 1996). Two of these are section *Calliorheas* which includes *L. montevidensis* and section *Camara* which includes *L. camara*. The haploid chromosome numbers for the section *Calliorheas* are n = 12 while those in the section *Camara* are n = 11.

## The *Lantana camara* species aggregate

The aggregate species known as *L. camara* is a "variable polyploid complex of interbreeding taxa" (Day *et al*. 2003; Sanders 2006). It contains a wide diversity of varieties arising from horticultural and natural hybridisation, selection and somatic mutation (Swarbrick *et al*. 1998; Day *et al*. 2003, e.g. Figure 2). It has been widely stated that the species *L. camara* arose from hybridisation of a number of similar or closely related but spatially distinct tropical American species, or indeed from complexes derived from these species. For example, RAPD (Random Amplified Polymorphic DNA) studies on 30 different populations of the pink variety of *L. camara* from the east coast of Australia (16.9-35.4°S) indicated that these populations probably arose from *L. urticifolia* (Scott *et al*. 2002). It is likely that varieties of *L. camara* in other countries have different origins.

In reviewing the situation outlined, Sanders (2006) stated that "current usage of *L. camara* includes a widely cultivated and naturalised cultigen species of hybrid origin that is taxonomically distinct from *L. camara*". That author described the weedy material he examined belonging to this cultigen as a new species *Lantana strigocamara*. It is important to note that this does not imply that "all weedy *Lantana* in all countries is *L. strigocamara* due to the multiple importations of Lantana to each country" (W. Palmer pers. comm.). Palmer further states that over 250 Australian Lantana specimens have been sent to Dr Sanders to ascertain the correct species name of this material. In lieu of that work, this document uses the name *L. camara*.

The aggregate species *L. camara* freely hybridises within the species itself producing fertile hybrids that may exhibit some morphological differences when compared to the adult plants (Spies 1984a). Members of this species can also hybridise back to the parent species that the complex was derived from (Swarbrick *et al*. 1998). The taxa that have resulted from this hybridisation have been given species, form, cultivar, biotype, subspecies and varietal status (Day *et al*. 2003). Despite the fact that the botanical rank varietas (variety) has been overused for plants that are actually cultivars and that varietal names are somewhat misapplied (Sanders 2006), this review uses the word variety to denote differences in *L. camara*.

The large numbers of varieties of *L. camara* found throughout the world vary in terms of ploidy, bush shape, flower colour, prickliness, leaf shape, response to environmental conditions, natural enemies, herbicides, chemical composition and toxicity to animals (Swarbrick *et al*. 1998; Day *et al*. 2003). Everist (1981) recorded that most weedy varieties of *L. camara* in Australia were tetraploids (2n = 44), but that several were triploids (2n = 33), one was a diploid (2n = 22), while another was a pentaploid (2n = 55). Swarbrick *et al*. (1998) concluded that most weedy varieties in South Africa and India were tetraploids while most ornamental or non-weedy varieties were triploids, and concluded that this was probably also the case in Australia. Hexaploid varieties of *L. camara* have also been recorded (Natarajan and Ahuja 1957; Spies 1984a, b; Swarbrick *et al*. 1998). Those authors summarise information indicating that these ploidy levels arise from a breeding system that is sexual, semi-sexual and asexual or apomictic (not involving the fusion of male and female gametes in reproduction), (Khoshoo and Mahal 1967) and from both auto- and allo-polyploidy within *L. camara* and other *Lantana* species (Natarajan and Ahuja 1957). Auto-polyploidy arises from having two or more sets of chromosomes derived from the same species while allo-polyploidy arises from having two or more sets of chromosomes derived from different species.

Some authors have indicated that there appeared to be no direct relationship between ploidy level or morphology, flower colour and seed set (Swarbrick *et al*. 1998). In contrast, Tandon and Bali (1955) noted that triploid varieties were more vigorous, had larger, thicker and darker leaves and produced larger and more numerous flowers in contrast to the diploid varieties they examined. Spies (1984a) also stated that increases in seed mass were also observed as ploidy level increased from diploid to pentaploid. In contrast, Swarbrick *et al*. (1998) compared the morphology of 13 weedy and ornamental varieties from south east Qld and found similarity in the weedy varieties which all had larger bushes, longer internode lengths and leaf blades, prickly stems and high levels of fruit production. Five of the six ornamental varieties had smaller bushes, shorter internode lengths and leaves, lacked prickles and while they produced similar flower numbers, they set very few fruit. The sixth ornamental variety Drap d 'or had much larger bushes, internodes and leaves but lacked prickles and had little seed production indicating it was derived from a different source to the ornamental and weedy varieties examined.

Branches of certain *L. camara* plants occasionally morphologically revert to other varieties and bred true to that variety when cuttings are taken (Smith and Smith 1982; Day *et al*. 2003). The reasons why these somatic mutations occur are poorly understood even though the branches have been recognised as a reversion to parent varieties that the plant was derived from (Smith and Smith 1982). Day *et al*. (2003) postulated that environmental switches changed the expression of chromosomes in these branches and that since these changes had important implications in successful biological control and toxicity management, that they needed to be investigated.

The continued sale of supposedly sterile triploid ornamental varieties of *L. camara* will further complicate the taxonomy of this species wherever weedy varieties are also present (Day *et al*. 2003). For example, there is evidence to suggest that these sterile varieties are capable of hybridising with fertile weedy varieties in Australia and South Africa (Spies and du Plessis 1987; Neal 1999). The rate at which these new gene combinations are integrated into weedy populations is not known (Neal 1999; Day *et al*. 2003).

## Varieties of *L. camara* in Australia

Although Smith and Smith (1982) recorded at least 29 different varieties of *L. camara* had naturalised in Australia, it is highly likely that this number has long ago been exceeded. While naturalised varieties can be partially differentiated by flower colour, complete differentiation relies on a range of characteristics including flower colour and size, flower limb morphology and other vegetative characteristics such as the size, shape and colour of the leaves, the structure of leaf hairs, thorniness and the length of bracts (Everist 1981; Smith and Smith 1982; Parsons and Cuthbertson 2001; van Oosterhout 2004). Swarbrick (1986) noted that most weedy varieties of *L. camara* in Australia had long, rambling, thorny stems and freely set seed while the ornamental varieties at that time tended to be thornless or nearly so and set comparatively little seed.

Four or five major groups of *L. camara* can be separated via their flower colour as follows: -

- **red flowered varieties** that are orange or yellow after opening but change to a shade of red when mature. There are two subgroups within these varieties, those with pink edges and those that are dark red. Everist (1981) and van Oosterhout (2004) give these two subgroups variety status, that is the **red** and **pink-edged red varieties**;
- **pink flowered varieties** that are divided into two subgroups based on flower size that is small and large flower varieties. The typical weedy variety of *L. camara* is a small flower variety, with flowers starting as pale yellow or white and maturing into pink (a different colour to that outlined above);
- **white or pale-pink flowered varieties**; and
- **orange flowered varieties** with flowers that remain deep yellow (similar to Figure 7) to orange throughout their life.

These varieties have been documented in van Oosterhout (2004), pg. 6. A summary of the most distinguishing characteristics is outlined in Table 1 and Figure 8.

Ensbey (2003) outlines four of the most common *L. camara* varieties that occur in NSW. These include the:-

- **common pink flowered variety** that is spread throughout NSW (included in the pink flowering varieties above);
- **common pink-edged red flowering variety** (e.g. Figure 3) that is found on the north coast, around Kempsey, Dorrigo, Bellingen, Coffs Harbour and Grafton and on the central coast (included in the red flowering varieties above); and
- **round red** and **Stafford red varieties** that are found on the north coast, around Kempsey, Bellingen, Coffs Harbour (again included in the red-flowered varieties above).

**Figure 7.**
*A yellow flowering ornamental hybrid variety of* Lantana camara *planted in a median strip, Griffith (south western NSW, September 2005) (Source: S. Johnson, NSW DPI).*

**Table 1.** Distinguishing floral and leaf characteristics of *L. camara* and *L. montevidensis* varieties outlined by van Oosterhout (2004). The flower heads of the weedy varieties of *L. camara* are illustrated in Figure 8. Although there are ornamental varieties of *L. camara* with other flower colours, only the yellow variety has been outlined here (similar to Figure 7). Information from Everist (1981) has also been included in this table.

| Species | Variety | Bud | Floral characteristics<br>Middle floral ring | Outer floral ring | Size and Colour of Leaves |
|---|---|---|---|---|---|
| *L. camara* | **Pink**<br>(weed) | Pink | Yellow throat,<br>Pale yellow petals | Orange throat,<br>Pale or dark pink petals | Large<br>Pale green |
| *L. camara* | **White**<br>(weed) | Cream | Yellow throat<br>Pale yellow petals | Orange or yellow throat<br>Lilac petals | Small |
| *L. camara* | **Pink-edged Red**<br>(weed) | Pink to dull red | Orange throat<br>Pale yellow to orange petals | Orange throat<br>Two-toned pink to red colour petals (inner darker than outer) | Small<br>Darker than pink *L. camara* |
| *L. camara* | **Red**<br>(weed) | Blood red | Yellow throat<br>Pale yellow petals | Red throat<br>Red petals | Large<br>Dark green |
| *L. camara* | **Orange**<br>(weed) | Orange | Yellow to orange throat<br>Yellow petals | Orange throat<br>Orange petals | Small<br>Pale green |
| *L. camara* | **Yellow**<br>(ornamental) | Green yellow | Bright yellow throat<br>Bright yellow petals | Bright yellow throat<br>Bright yellow petals | Smaller than weedy varieties |
| *L. montevidensis* | **Purple**<br>(weed) | Purple | White throat<br>Purple petals | White throat<br>Purple petals | Smaller than *L. camara* |
| *L. montevidensis* | **Lilac**<br>(ornamental) | Lilac | White to yellow throat<br>Lilac petals | White to yellow throat<br>Lilac petals | Larger than weedy variety of the species |
| *L. montevidensis* | **White**<br>(ornamental) | White to cream | Yellow throat<br>White petals | Pale yellow throat<br>White petals | Larger than weedy variety of the species |

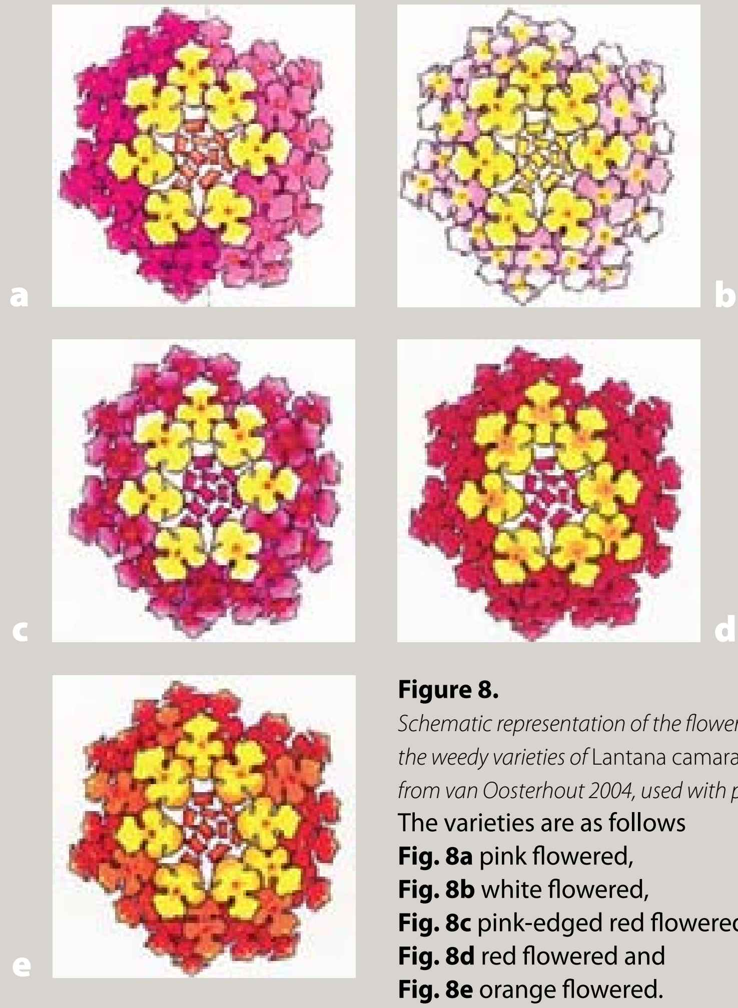



**Figure 8.**

*Schematic representation of the flower heads of the weedy varieties of* Lantana camara *(extracted from van Oosterhout 2004, used with permission).*

The varieties are as follows

**Fig. 8a** pink flowered,

**Fig. 8b** white flowered,

**Fig. 8c** pink-edged red flowered,

**Fig. 8d** red flowered and

**Fig. 8e** orange flowered.

Smith and Smith (1982) also recorded three other varieties of *L. camara* in NSW. The first is a red flowered variety known as pale Stafford red around Kempsey, the second an orange-red variety known as oblong red west of Grafton along the Gwydir highway (apparently not abundant or widespread but perhaps found elsewhere in the area) and the third, an orange-flowered variety known as true orange that is occasional near Palm Beach, north of Sydney. This last variety is commonly cultivated.

The value of categorisation of varieties of *L. camara* into broad flower-colour groups has been questioned by a number of authors for various reasons. These reasons include wide variability in colour within and between taxa making differentiation difficult (Day *et al*. 2003; Sanders 2006). In addition, there are differences between same coloured varieties in their toxicity to livestock and their susceptibility to biological control agents or herbicides between different regions (Diatloff and Haseler 1965; Seawright 1965; Everist 1981; Day *et al*. 2003). Furthermore, different varieties of *L. camara* survive in different climatic zones and ecosystems in Australia (Clark *et al*. 2004).

Scott *et al*. (1997) analysed the genetic relationship between pink and pink-edged red weedy varieties of *L. camara* from four regions along the east coast of Australia and found that geographical proximity was more important than flower colour in defining genetic similarity between populations. While there was some genetic isolation between varieties within a region, flower colour had little phylogenetic significance between regions. The overall level of differentiation in *L. camara* varieties makes it difficult for many land managers and scientists alike to manage this weed and to promote consistent weed management messages.

### Varieties of *L. montevidensis* in Australia

Henderson (1969) recorded that two varieties of *L. montevidensis* occurred in Australia, each with a different ploidy. The common garden variety tested was a triploid (2n = 36) while the weedy variety was a tetraploid (2n = 48). It is not known if the further introduction of *L. montevidensis* varieties into Australia has increased the number of ploidy levels. Some differences between the weedy and two ornamental varieties of *L. montevidensis*, one with lilac flowers and the other with white flowers, are outlined (Table 1). Further, Neal (1999) indicated that crosses between *L. montevidensis* ornamental varieties may have occurred in Australia. A variegated leaf variety of *L. montevidensis* with lilac flowers is also cultivated in the new Botanic Gardens in Brisbane (Swarbrick 1986).

## ORIGIN

The two species of *Lantana* naturalised in Australia, *L. camara* and *L. montevidensis* are both native to tropical South America. *Lantana camara* was initially introduced into Europe from Brazil as an ornamental around 1636 (Howard 1969). Further introductions into Europe continued throughout the 17th, 18th and especially the 19th centuries where introductions, ensuing hybridisation and vegetative reproduction of somatic mutations resulted in the registration of 397 new varietal names in nursery catalogues from 1850 to 1900 (Howard 1969; Swarbrick 1986). In excess of 630 varieties (not 650 as claimed by many authors) of *Lantana* have been developed for horticulture world wide as a result of hybridisation (Howard 1969), although a number of these names may be misspellings and synonyms because detailed botanical descriptions are generally unavailable.

From Europe, *L. camara* was introduced into a number of countries that were formerly part of colonial empires. The species can now be found growing as a weed in at least 60 countries or island groups including the United States of America, many countries in South America, around the western Mediterranean, throughout Africa, central and south east Asia and various countries around the Pacific ocean including New Zealand and Australia (Holm *et al*. 1979; Webb *et al*. 1988; Day *et al*. 2003). Although *L. camara* is widely grown as an ornamental in other countries, suitable terrestrial habitats for the weed only occur throughout tropical, subtropical and warm temperate areas (Figure 9).

The first record of *L. camara* in Australia was in 1841 in the old Adelaide Botanic Gardens (Bailey 1841). *Lantana camara* was first recorded in cultivation in NSW in 1843 near Sydney (Anon. 1843, in Michael 1972). The species quickly spread northwards and was recorded as naturalised in the 1850's, in Brisbane in 1861, and in the Hastings and Clarence catchments of NSW in the late 1860's (Swarbrick 1986). Bailey (1897) described *L. camara* as "a huge rambling prickly bush ... it has spread to an alarming extent, and forms impenetrable thicket on the banks of streams, deserted farms, and the edges of scrubs" in the Port Jackson and Brisbane areas. Similarly, concern over *L. camara* resulted in it being listed as one of the ten worst weeds in NSW in 1895 (Maiden 1895) and 1920 (Maiden 1920).

*Lantana camara* has been grown in Vic since 1852 and WA since 1875, but may have only been introduced to the NT during the 1930's or 1940's (Swarbrick 1986). Further expansion into previously uninfested areas is likely to still be occurring, often as a result of land clearing and other human disturbance (Humphries and Stanton 1992; Swarbrick *et al*. 1998).

Numerous further introductions of *L. camara* have occurred in Australia as garden plants in eastern Australia (Smith and Smith 1982), and probably in the NT and WA (Swarbrick *et al*. 1998). Smith and Smith (1982) considered that 19 varieties were sufficiently common in eastern Australia to be considered problematic weeds or toxic plants. Both nursery stock and seeds of *Lantana* species were, until late 2006, still permitted for import into Australia (Australian Quarantine and Inspection Service 2007).

*Lantana montevidensis* was also widely distributed by man in the 19th century (White 1929; Swarbrick 1986). Although most authors generally agree that the native range of *L. montevidensis* includes southern Brazil, there is some conjecture if the range also includes Uruguay (Everist 1981) and/or northern Argentina (Day *et al*. 1999).

Swarbrick (1986) recorded that the species was introduced into Europe from Montevideo in 1822 and to Australia by 1851 (Johnson 1872; Shepherd 1851, both in Swarbrick 1986; Munir 1996). The species (*L. sellowii*) was recorded in cultivation in south west Sydney in 1857 (Anon. 1857). Holm *et al*. (1979) indicated that *L. montevidensis* has only been recorded as a weed in Australia, and perhaps in Florida (Bailey 1963) even though it is widely planted as an ornamental or has naturalised in various parts of the world including Australia, New Zealand, Africa and parts of India (Everist 1981; Webb *et al*. 1988; Day *et al*. 2003; van Oosterhout 2004). Suitable terrestrial habitats for the species generally occur in subhumid and semi-arid regions of the tropics and subtropics (Everist 1981; Parsons and Cuthbertson 2001).

*Lantana 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. Swarbrick (1986) also noted a Brisbane herbarium specimen that indicated that *L. montevidensis* had naturalised near Ipswich in 1888.

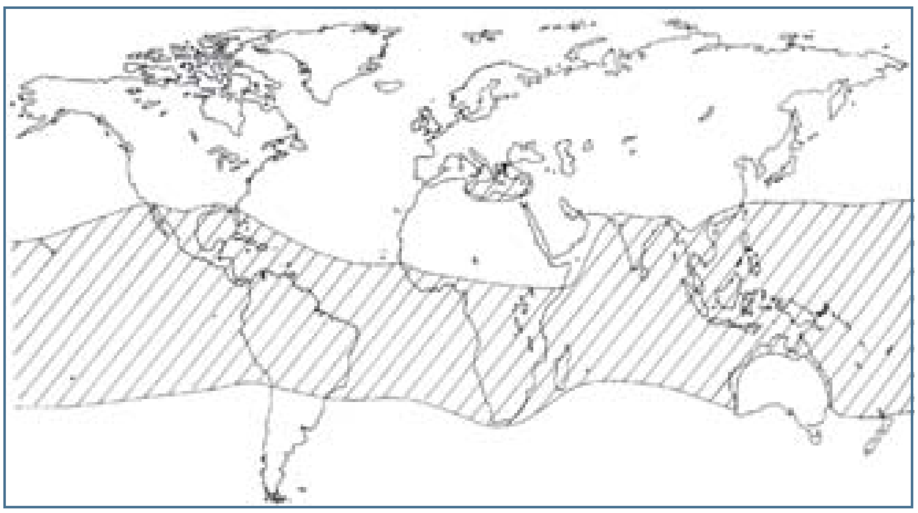


**Figure 9.**

*Suitable terrestrial habitats for* L. camara *throughout the world. (Source: Swarbrick* et al. *(1998), used with permission).*

Swarbrick (1986) recorded a number of observations of *L. montevidensis* in south eastern Qld from 1883-1909, generally of plants that were garden escapes from nearby towns into neighbouring pastures. Swarbrick (1986) noted that rapid spread of the weed in coastal Qld occurred 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 1950's and 1960's *L. montevidensis* had become widespread throughout coastal and subcoastal Qld, especially in the Burnett district (O'Donnell *et al*. 1999). O'Donnell (2002) records that by the 1980's and 1990's the species had reached levels where the ongoing viability of grazing enterprises in some areas of Qld was significantly affected.

It is presently unclear when *L. montevidensis* was first noted as a weed problem in NSW. 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 Qld, only limited naturalisations of the species have occurred in NSW and these were generally restricted to the Sydney basin, around Casino and Murwillumbah on the north coast and to Tamworth.

Although a number of authors indicate 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), van Oosterhout (2004) recorded ornamental lilac and white varieties as well as the common purple flowered weedy variety (Table 1; Figure 1).

*Lantana camara* x *L. montevidensis* hybrids 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 hybridisation of both previously geographically separated species (Sanders 1989, in Day *et al*. 2003) and varieties (Spies 1984b; Day *et al*. 2003) when grown in the same location.

# LIFECYCLE

Seeds of *L. camara* and *L. montevidensis* germinate at any time of the year provided that there is sufficient soil moisture (Parsons and Cuthbertson 2001; O'Donnell 2002). *Lantana camara* seeds need high light conditions for germination and early growth (Gentle and Duggin 1997b; Duggin and Gentle 1998; Stock 2004) with seedlings unlikely to survive beneath dense infestations.

The largest seedling flushes of *L. camara* occur after initial summer storms, particularly in higher rainfall areas (Parsons and Cuthbertson 2001; van Oosterhout 2004). van Oosterhout (2004) indicated that increases in light intensity and temperature are also important for germination. These factors may occur as a result of human disturbance e.g. clearing, burning, or pest animal activity such as pig rooting or rabbit burrowing. Germination from these events will occur if soaking rains follow, especially in areas that have higher soil moisture, for example around creeks, rivers, gullies and dams (van Oosterhout 2004).

Field germination rates range between 4 and 63% (Gentle and Duggin 1997b; Day *et al.* 2003). Germination is likely to be increased through an increase in nutrients via burning, and by biomass removal and soil scarification associated with grazing and fire (Gentle and Duggin 1997b; Duggin and Gentle 1998).

Specific studies on the conditions required for the germination of *L. camara* seeds are somewhat limited. One notable exception is the study of Vivian-Smith *et al*. (2006) which indicated that temperature regimes between 15 and 25°C were suitable for germination of pink and pink edged-red varieties of *L. camara*. Those authors found that the seed feeding fly *Ophiomyia lantanae* damaged the seed of pink edged-red varieties resulting in reduced germination and seedling emergence. In contrast, the emergence of the more common pink variety was increased, possibly a result of the damage reducing dormancy in this variety.

O'Donnell and Panetta (2000) indicated that seeds of *L. montevidensis* required light to germinate and that seed buried to 1-2 cm did not germinate. O'Donnell (2002) presented some evidence to suggest germination flushes occurred when good soil moisture conditions coincided with cold night temperatures close to or below freezing. That author also found that exposure to smoke from pasture fires for 5 to 15 minutes also 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 early growth of both *L. camara* and *L. montevidensis* is slow while the taproot and lateral roots are developed (Parsons and Cuthbertson 2001; O'Donnell 2002), for example, seedlings of *L. montevidensis* may only grow at rates of 1 cm/month (O'Donnell 2002). Studies by Stock and Wild (2006) found that seedlings of *L. camara* grow taller and wider under the relative open canopy of the weed as opposed to those growing underneath the canopy of number of sub-tropical rainforest species. Seedling growth was most limited under rainforest tree species that formed the original or 'old growth' forests.

Although Sahu and Panda (1998) noted low rates of seedling and mature plant mortality in *L. camara,* similar studies do not appear to have been repeated under Australian conditions. O'Donnell (2002) indicated that mortality of *L. montevidensis* seedlings occurred via a wide range of factors including moisture stress, physical disturbance, fire, herbicides, cattle trampling and perhaps grazing. Seedlings thus 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.

The stems of *L. camara* plants begin to entwine forming thickets within their first season of growth but they do not produce flowers within this season. The onset of winter either reduces or stops growth and development. Although glasshouse plants of a *L. camara* x *L. depressa* hybrid and *L. montevidensis* have been shown to produce seeds within a year (Neal 1999; O'Donnell 2002), the development of seedlings of *L. camara* and *L. montevidensis* is much slower in the field (Parsons and Cuthbertson 2001; O'Donnell 2002). Dormant seedlings reshoot in the following spring and start to flower in late spring (*L. montevidensis*) or early summer (*L. camara*) in the second season of growth. Parsons and Cuthbertson (2001) recorded that established plants of *L. camara* flower throughout summer and then until March or April. Plants of *L. camara* were reported as flowering between September - October through to March - April in ensuing years in temperate areas from southern Vic to northern NSW (van Oosterhout).

Swarbrick *et al*. (1998) summarised various literature that stated that flowering in *L. camara* can occur year round under conditions of high available soil moisture, air humidity and temperature and when plants grew in well lit situations. This generally results in flowering and fruit set all year in coastal areas of Qld and northern NSW, that is in subtropical and tropical areas (van Oosterhout 2004). In contrast, Webb *et al*. (1988) indicated that *L. camara* can flower all year in New Zealand. Distinct flushes of flowering four to six weeks after rainfall events exceeding 25 mm followed by fruit set are more common in drier inland areas (Swarbrick *et al*. 1998; van Oosterhout 2004).

A number of authors record that 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 following a protracted dry period, for example after the first spring rainfall break.

Newly opened flowers of *L. camara* attract a range of insect pollinators which result in self- and cross-pollination. These insects include butterflies, moths, bumble, honey and other types of bees, and thrips (Dronamraju 1958; Schemske 1976; Kugler 1980 in Swarbrick *et al*. 1998; Clemson 1985; Mathur and Mohan Ram 1986). Khoshoo and Mahal (1967) stated that both pollen and seed viability resulted from open-pollination of plants of all ploidy levels they examined (diploids - pentaploids). They suggested that normal sexual union was responsible in diploids but that apomixis (reproduction without fertilisation of gametes) was responsible in plants of other ploidy levels. However this is unlikely to be the case as the review of literature by Stirton (1977) found no evidence for apomixis. Instead, Spies and Stirton (1982) found normal sexual embryos in diploid, triploid and tetraploid plants but no normal sexual embryos in either pentaploid or hexaploid varieties. There are conflicting reports about the ability of *L. camara* to self pollinate (Day *et al*. 2003).

Spies (1984a) recorded differences in pollen viability when studying diploid, triploid and tetraploid plants in South Africa. For example, the average and range in pollen viabilities for diploid plants was 59.95 % (30.85-85.25 %), for triploid plants was 36.21 % (27.30-44.38 %) and for tetraploid plants was 63.3 % (16.01-83.22 %). Neal (1999) recorded that 65 % of pollen from the weedy common pink variety of *L. camara* was viable in contrast to the 2 % of pollen from a *L. camara* x *L. depressa* hybrid.

In summarising several references and other observations, Swarbrick *et al*. (1998) stated that an average of 36.7-48 % fruit set occurred in open-pollinated *L. camara* inflorescences, with each averaging 32.6 flowers. Because there are usually two inflorescences per node, the total number of fruit produced under good growing conditions may be as high as several thousand per metre. Data from the Philippines indicated that 24 fruits were produced per inflorescence and that there were 511 inflorescences per plant resulting in 12,264 fruits per plant. The number of fruit that have fully formed embryos may be as little as 36 % however (Graaff 1987). While there have been few specific studies on the influence of the fruit pulp on the germination of *L. camara* seeds, both Graaff (1987) and Swarbrick *et al*. (1998) present evidence that a delay or inhibition mechanism occurs. Neal (1999) also indicated that 0.16 - 2 % of florets produced seeds in the supposedly sterile *L. camara* x *L. depressa* hybrid she examined.

The seed bank densities of *L. camara* have been the subject of limited research. While Gentle and Duggin (1997b, 1998) indicated that low densities of 1.4 - 3.4 seeds/$m^2$ were found, much larger densities of 599 - 3674 seeds/$m^2$ have been determined from another study (Vivian-Smith *et al*. 2006). It is important to note that only a small proportion of these seeds (6-16 %) were viable as either germinable or dormant seeds.

van Oosterhout (2004) summarised research that indicated up to 50 % of *L. camara* seed will remain viable under dry conditions for up to two years after dispersal while other studies have indicated that viable seed may persist for up to five years (G. Vivian-Smith pers. comm.). Despite these studies, Day *et al*. (2003) indicated that very little was known about the seed bank dynamics of *L. camara*. These studies are important as they place a time frame for ongoing control following the removal of dense infestations.

O'Donnell and Panetta (2000) indicated that the viability of *L. montevidensis* seeds decreased 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 (2002) added that all surface sown seed was dead after two years but that up to 20 % of buried seed was still viable. These results indicate that the seed of *L. montevidensis* is relatively short lived in the soil. In addition, the seed pulp or mesocarp inhibited seed germination 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). A proportion of seeds will germinate with the pulp surrounding them however.

Plants grow rapidly under favourable conditions of soil, humidity, temperature and light and may grow year round under these conditions. In many areas *L. camara* is seasonally defoliated by biological control agents but plants recover once cool weather results in a wane in insect numbers (Day and Hannan-Jones 1999; Day *et al*. 2003). *Lantana camara* is a perennial plant shooting or regrowing vigorously from dormant basal buds if shoots are removed by fire, herbicide, physical removal, drought or if frosted off. In these cases plants can flower within several months under favourable conditions (Swarbrick *et al*. 1998). Plants of *L. camara* plants are very long lived with constant renewal of stems from the plant base, especially if rainfall occurs after stem death (van Oosterhout 2004).

Plants will die under prolonged stressful conditions, for example, intense or prolonged drought, or from shading (Swarbrick *et al*. 1998). Parsons and Cuthbertson (2001) stated that new canes of *L. camara* are produced from the crown of existing plants, from lateral roots in early spring and that shallow laterals sucker if damaged or broken. Suckering may occur after plants are physically removed, often by bulldozing, with large pieces of lateral roots reshooting, especially under good soil moisture conditions (Saint-Smith 1964; Swarbrick 1982; Waterhouse and Norris 1987; Parsons and Cuthbertson 2001). One estimate places the number of new shoots found after clearing a site in sclerophyll woodland in northern NSW that arose from suckering at 30 % (B. Johnson pers. comm.). These observations are in contrast to Swarbrick *et al*. (1998) who stated that no suckering has been observed by those authors. Furthermore they indicated that prostrate stems with adventitious roots may have been mistaken for root suckers after they had produced vigorous shoots from the nodes. Given the divergence of opinion on the role of suckering from lateral roots, further research is required. *Lantana camara* can be propagated from stem tip or hardwood stem cuttings or even leaf material if planted into moist rooting media or soil (Swarbrick *et al*. 1998; Neal 1999).

*Lantana montevidensis* reproduces by seed and by layering - rooting at the stem nodes when covered in moist leaf litter or soil (Parsons and Cuthbertson 2001). Henderson (1969) recorded a pollen viability of approximately 65 % in *L. montevidensis* in contrast to the ornamental variety Henderson (1969) examined which was less than 6 %. Similarly, Neal (1999) indicated that pollen viabilities of 82 % from the weedy variety populations of *L. montevidensis* she assessed and 14 - 16 % from the populations of two ornamental *L. montevidensis* varieties. The differences between the studies are likely to be due to the restricted number of populations collected by the Henderson study.

Plants of *L. montevidensis* are able to flower and set fruit throughout the year, generally from early summer - mid winter in Qld (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* have a high production of fertile seed. For example, O'Donnell (2002) found that yearly seed production varied between 4,965 and 5,175 seeds/$m^2$ and while each drupe had two seeds, generally only 30 % of drupes produced a second seedling. Attwater (1980) reported that the woody seed coat of *L. montevidensis* was impermeable to certain gasses and chemicals and hence prevented seed germination.

Henderson (1969) and Webb *et al*. (1988) recorded that ornamental varieties of *L. montevidensis* did not produce fruit in Australia and New Zealand respectively. In contrast, Neal (1999) demonstrated that 0.42-1 % of florets of the purple flowering ornamental variety she examined produced fruit while leaf material of both ornamental and weedy varieties of *L. montevidensis* was able to give rise to new plants. Populations producing fruit were generally in close proximity to weedy populations of *L. camara* and/or *L. montevidensis.*

It is not known how long individual plants of *L. camara* may live (van Oosterhout 2004) but O'Donnell (2002) suggested that plants of *L. montevidensis* may survive for at least five years.

# DISPERSAL

Parsons and Cuthbertson (2001) noted that *L. camara* is dispersed by seeds and by suckers. Suckering and seedling growth increases the size and density of existing infestations within and on the edges of thickets. Seeds are important in long distance dispersal of this weed, especially after bird and mammal ingestion (Swarbrick *et al.* 1998; Parsons and Cuthbertson 2001). A large number of native and exotic birds have been recorded as feeding on *L. camara* fruits in Australia. These included species such as the brown pigeon, crow, cuckoo and emerald doves, emu, figbird, fruit doves, Indian mynah, Lewin's honeyeater, little wattlebird, pied currawong, purple-crowned pigeon, rainbow lorikeet, red-crowned pigeon, regent and satin bowerbird, silver-eye, sparrow, spiny-cheeked honeyeater, starling, varied triller and wonga pigeon (Liddy 1985; Loyn and French 1991; Swarbrick *et al*. 1998; Carter 2000; Stansbury and Vivian-Smith 2003; van Oosterhout 2004). Some authors indicated that ingestion increased the germination of *L. camara* seeds once they had been excreted (van Oosterhout 2004). Initial infestations from bird-dispersed seeds are common under perching, roosting and shelter trees, fence lines and other perch sites (Swarbrick *et al*. 1998). These isolated plants form the foci of later invasions of the weed.

*Lantana camara* seeds are probably spread by a wide range of other animals in Australia including rodents, cattle, sheep, goats, horses, foxes, pigs, kangaroos and lizards (Swarbrick *et al*. 1998; Day *et al*. 2003; Stock 2004). While ingestion aided spread is generally localised, distances of up to 1 km or more are possible (Swarbrick *et al*. 1998).

Studies regarding the role of birds in dispersing *L. camara* seeds are needed, in particular studies on behaviour and feeding preferences and the distances different birds travel after eating (Day *et al*. 2003). One notable exception is the study by Willson and Crome (1989) which found that seeds of many internally vertebrate-dispersed species such as *Lantana* were found dispersed up to 85 metres into rainforest. Another study by Vivian-Smith *et al*. (2006) indicated that the seed feeding fly *O. lantanae* damaged the fruit and seed of *L. camara* ensuring that less seed was spread by birds.

Ensbey (2003) recorded that *L. camara* can be spread in water, in contaminated soil and on machinery, as well as accidentally on people. New plants arise via vegetative reproduction from garden waste containing plant material of either *L. camara* or *L. montevidensis* when it is not disposed of properly (Neal 1999; Ensbey 2003). The trade of nursery plants has, and continues to be responsible for the spread of this species.

The seeds of *L. montevidensis* are dispersed by a number of means. Parsons and Cuthbertson (2001) noted that the seeds are widely spread by fruit-eating animals and birds, by water flowing across the soil especially after heavy rain and in mud attached to hooves, boots and machinery. O'Donnell (2002) also noted that *L. montevidensis* seeds float and that gullies and watercourses were susceptible to infestation as a result. In particular, O'Donnell and Panetta (2000) recorded that parrots, currawongs, white cockatoos, crows and emus ate the ripe fruit of the species. Pale headed rosellas have also been observed eating the fruit of this species (S. Csurhes pers. comm.). Initial infestations from birds were common under nesting and roosting sites, especially around trees and fences (O'Donnell 2002). O'Donnell (2002) further indicated that ants transport and bury *L. montevidensis* seeds in their nests. The presence of pulp surrounding seeds does not preclude the germination of *L. montevidensis* seeds indicating that prior bird ingestion is not a requirement for successful germination (O'Donnell and Panetta 2000). *Lantana montevidensis* is also spread when viable seeds pass through the digestive tracts of grazing cattle (O'Donnell 2002).

Swarbrick (1986) noted that the weedy variety of *L. montevidensis* may also reproduce by stem cuttings and by the division of established plants. In contrast, the ornamental varieties of *L. montevidensis* appear to have only been propagated and spread by stem cuttings (Swarbrick 1986). The size and density of existing colonies of *L. montevidensis* increases as stems root at the nodes and as seedlings develop within and near existing thickets.

# GROWTH AND DEVELOPMENT

The following information has been extracted from Swarbrick *et al*. (1998) unless otherwise noted. *Lantana camara* is very plastic in its response to light intensity. Seedling densities range from less than one to several per square metre with plants at lower density producing rounded plants while those at higher density producing more upright plants that compete for light. Plants tend to dominate several square metres as adults, growing through and over other plants, often producing impenetrable thickets, shading out other plants and out-competing any *L. camara* seedlings that may emerge. van Oosterhout (2004) indicated that *L. camara* will tolerate partial but not complete shading. New shoots emerge from the base of healthy plants while older shaded stems lose vigour and die. Prostrate stems may root at the nodes if covered by moist debris, sometimes developing into vigorous daughter plants.

*Lantana montevidensis* is able to persist under periods of extended drought and has the ability 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).

# HABITAT

## Climatic requirements

*Lantana camara* grows well in a range of warmer areas of the world, particularly temperate, subtropical and tropical areas (Swarbrick *et al*. 1998). Growth does not occur below 5°C and the plant is frost sensitive (Thaman 1974; Stirton 1977; Winder 1980, in Swarbrick *et al.* 1998) with severe frosts killing the leaves and stems (van Oosterhout 2004). Stirton (1977) noted that *L. camara* seldom occurred where the mean annual surface temperature was below 12.5°C in South Africa, while Graaff (1986) recorded that some varieties could withstand minor frosts so long as these were infrequent. The upper temperature limit for growth for *L. camara* has not been investigated.

Populations of *L. camara* cover a wide geographic and climatic range in Australia from Darwin in the north to Orbost in the south (van Oosterhout 2004) and from areas receiving more than 3,500 mm (Day and Hannan-Jones 1999) to areas receiving 650 mm mean annual rainfall (Bartholomew and Armstrong 1978). *Lantana camara* grows best under conditions of constant rainfall or soil moisture, particularly in areas which receive in excess of 900 mm of rain (Swarbrick *et al*. 1998; Ensbey 2003). The 650 mm isohyet is probably the limit of the species west of which low temperatures and dry soil independently restrict the growth of the species (Swarbrick *et al*. 1998). Swarbrick *et al*. (1998) postulated that both of these factors were responsible for limiting the distribution of this species to areas west of the Great Dividing Range. While these factors are likely to contribute to the restricted distribution of the weed further westwards, low temperatures and dry soil are factors that are common in the eastern parts of the Great Dividing Range and in coastal areas. Furthermore, *L. camara* can to tolerate both dry to humid climates (Parsons and Cuthbertson 2001), although flowering generally occurs under conditions of high soil moisture and air humidity (Swarbrick *et al*. 1998). It is therefore likely that other factors are responsible for its current distribution in Australia and these factors need to be quantified before the potential distribution of this species can be validated.

There are two contrasting theories as to why *L. camara* has not become widely naturalised in Vic and southern Australia. Several authors indicated that the limiting factor may be more regular frosts or lower temperatures (Conn 1999; Parsons and Cuthbertson 2001; Day *et al*. 2003). By way of contrast, Carr (1993) stated that in Vic neither temperature nor moisture were limiting to the growth, flowering and fruiting of established *L. camara* plants, but that seed germination and seedling establishment rarely occurred because sufficient moisture was not available when summer temperatures were sufficient for germination. Those authors stated that outside of garden situations only one naturalised population was known in a situation receiving run off from roads. Other weakly naturalised populations in Vic appear to have been found more recently as outlined in Munir (1996) and Conn (1999). Either temperature or moisture may explain why the species is not more widely naturalised in WA although a lack of suitable moisture to ensure plant establishment is the more likely.

Day *et al*. (2003) outlined that there was some difference in the environmental tolerances of different varieties in Australia with the common pink weedy variety found at higher altitudes and latitudes whereas the pink-edged red variety was restricted to warmer areas. In contrast, Ensbey (2005) indicated that the pink weedy variety of *L. camara* was found throughout the entire range of the species throughout NSW, but that the pink-edged red varieties were relatively common in north eastern NSW and were rarely found south of the mid north coast and Hunter areas. Furthermore, Ensbey (2005) noted that true red varieties of the species were restricted to the north coast of NSW (Clarence, Coffs Harbour, Bellinger, Nambucca and Kempsey council areas) but had the potential to spread further north and south. The orange and white varieties of *L. camara* found in Qld were relatively rare in NSW (A. Clark pers. comm.)

*Lantana camara* grows from sea level to 1000 metres in elevation in eastern Australia and up to 2000 m in other places (Thaman 1974; Munir 1996; Swarbrick *et al*. 1998; Parsons and Cuthbertson 2001). Swarbrick *et al*. (1998) noted that although most areas susceptible to infestation probably already had the species present, that further spread of this species could be expected within these areas, particularly along the fringes of existing infestations and into the river systems on the Gulf of Carpentaria, the NT and WA. 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 is grown further south as a garden plant.

## Soils

While *L. camara* grows best on rich organic soils it will grow on a range of soil types including stony hillsides and nearly pure sand so long as there is a source of soil moisture (Winder 1980, in Swarbrick *et al.* 1998; Humphries and Stanton 1992; Munir 1996). The species grows well on deeper, well drained clay soils of basaltic, metamorphic or granitic origin (Humphries and Stanton 1992). Thaman (1974) summarised evidence that the roots of this species tended to rot in waterlogged soils and that it had a very low tolerance to soil salinity.

Kleinschmidt and Johnson (1977) indicated that *L. montevidensis* is common on shallow, stony soils in sloping areas that tended to dry out. In contrast, Munir (1996) stated that *L. montevidensis* grew in well drained alluvial or loam soils, an observation also made by O'Donnell (2002).

# DISTRIBUTION IN AUSTRALIA

## Current distribution

### *Lantana camara*

*Lantana camara* can be found in coastal and subcoastal areas of Australia (Figure 10). Along the east coast of Australia, the species can generally be found from Eden 37°04' S in southern NSW to Cape Melville (north of Cooktown) 14°12' S in Qld. This northern most record is likely to include only large infestations because Munir (1996) stated that herbarium records of *L. camara* have been collected from the tip of Cape York Peninsula and from the Torres Strait. While Clark *et al.* (2004) reported that infestations of *L. camara* can be found on the NSW/ Vic border, other information suggests that very few infestations are found south of the Eurobodalla and Mount Dromedary areas near Narooma (36°13' S, Harding 2005; M. Michelmore pers. comm.). These infestations are around Bermagui, Tathra, Pambula and Eden. The southern most infestation on the east coast of Australia is probably near Orbost (37°42' S) in coastal Vic (van Oosterhout 2004). *Lantana camara* appears to have become weakly established as a garden escape in other parts of Vic (Conn 1999) and has been recorded near Frankston (38°09' S; Munir 1996).

In NSW, Conn (1992) records the presence of *L. camara* on the north, central and south coast, Lord Howe and Norfolk Islands. The species was probably introduced to these islands in the mid to late 1800's (Swarbrick 1986). The pink flowering variety of *L. camara* is the most widespread along the NSW and Qld coast while the red flowering variety is common on the mid and far north coast of NSW (Ensbey 2005). A red flowering variety is common in the Richmond and Kurrajong area, north west of Sydney (Auld and Medd 1987; McMillan 1989; pers. obs.).

In Qld, *L. camara* can be chiefly found in all coastal areas north to Cooktown (Figure 10) and often beyond. In addition, the species has been recorded on several islands along the Great Barrier Reef (Munir 1996). Seawright (1965) indicated that red flowered varieties were common in far north Queensland around Cairns and between Keppel Bay and Broad Sound in Central Queensland. The remainder of coastal Qld areas had pink flowering varieties with the exception of the white variety that occurred in the eastern slopes of the Great Dividing Range in south eastern Qld. A number of authors including Seawright (1965) have noted the presence of an orange yellow variety found growing around Townsville but not elsewhere. van Oosterhout (2004) also indicated that the weed is present in Emerald (central Qld) and Weipa on Cape York Peninsula while Clark (2006) indicated the species has been found at various places in inland Qld including Surat (Warroo shire, southern Qld), in Belyando and Jericho shires in central Qld and in Etheridge shire in northern Qld. Scattered infestations of *L. camara* can be found in the Torres Strait Islands (Munir 1996; Swarbrick *et al*. 1998, van Oosterhout 2004).

*Lantana camara* can be found in the NT, especially around Darwin, Maningrida (north coastal), on the Gove Peninsula, Adelaide river and on Melville Island (Munir 1996; Jeffrey and Ready 1999; van Oosterhout 2004). Isolated occurrences also occur in other states of Australia (Parsons and Cuthbertson 2001). For example, *L. camara* can be found in south west WA, especially in wetter areas around Perth, Fremantle Manjimup and Albany, around Brome and Geraldton

**Figure 10.**
*The current distribution of* L. camara *in Australia (Source: van Oosterhout (2004)).*

and south of Kununurra (Munir 1996; Hussey *et al*. 1997; van Oosterhout 2004, Clark 2006). In contrast, Hussey *et al*. (1997) indicated that the Kununurra infestation was eradicated in 1995. Scattered infestations of *L. camara* can also be found in the SA, especially around Adelaide (Jessop and Toelken 1986; Swarbrick *et al.* 1998; Blood 2001; van Oosterhout 2004). Swarbrick (1986) cited personal communication that indicated that although *Lantana* species have been widely grown in gardens in Tasmania, they have never escaped from cultivation.

### *Lantana montevidensis*

*Lantana montevidensis* can also be found in coastal and subcoastal areas of Australia (Figure 11). Along the east coast of Australia, the species can be found from Nowra 34°53' S in southern NSW to Cairns 16°55' S in northern Qld (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 NSW 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 (Tamworth) and south of Sydney (Conn 1992; Australia's Virtual Herbarium 2007).

*Lantana montevidensis* is common in south east Qld, mainly from Rockhampton to the NSW/Qld border, again in coastal and subcoastal 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; O'Donnell *et al.* 1999; O'Donnell 2002). For example, Seawright (1965) indicated that *L. montevidensis* grew thickly in paddocks around Beenleigh and Ipswich in south eastern Qld, O'Donnell (2002) recorded the problems the species caused in the Burnett while Day *et al*. (1999) recorded the weed was a severe problem in central Qld. Records show naturalisation 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).

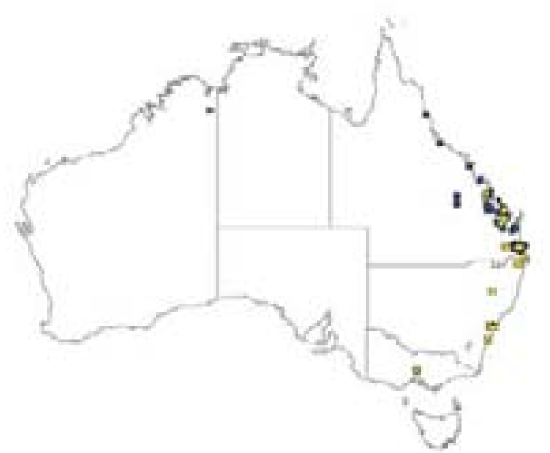


**Figure 11.**

*The current distribution of* L. montevidensis *in Australia (Source: Australia's Virtual Herbarium (2007)).*

The species is used as an ornamental in some towns in the NT (Munir 1996; Parsons and Cuthbertson 2001) and has been recorded as a weed in other situations in Darwin (Jeffrey and Ready 1999). O'Donnell (2002) noted that ornamental varieties of the species can be found from Torres Strait to Sydney, in Melbourne and Adelaide.

There are two other herbarium records of *L. montevidensis* in Australia, one in Kununurra (WA) and the other north of Melbourne (Vic) (Australia's Virtual Herbarium 2007). In addition, Conn (1999) indicated that the species has become weakly established away from gardens in Vic.

## Potential distribution

*Lantana camara* has the potential to spread further within Australia. It is probable that further spread within the current distribution of this weed will occur as uninfested areas are invaded and as increases in density occur within infested areas. In the broadest sense, Day *et al*. (2003) stated that *L. camara* can be found between the latitudes 35°N and S, even though it is most commonly found in tropical, subtropical and temperate areas. In comparison, Australia stretches from approximately 10°30' S on Cape York to 43°30' S at the bottom of Tasmania.

The ecological limitations of *L. camara* are not well understood and need to be investigated. Two references indicated that *L. camara* is now present at the head waters of the major western-flowing rivers after westwards expansion in south eastern Qld during wet years in the 1970's (A&RMCA&NZ, A&NZE&CCFM 2001; van Oosterhout 2004). Personal communication indicated that these infestations are present in the upper Condamine catchment but there is some doubt as to the further spread of the species westward (P. Blackmore pers. comm.; A. Clark pers. comm.). The spread of the weed into western NSW has been postulated along riparian corridors and as a result of poor land management decisions (van Oosterhout 2004). Furthermore, Ensbey (2003) noted that *L. camara* has the potential to spread into Vic while the Cooperative Research Centre for Australian Weed Management (2003) considered that the species is able to spread west of the Great Dividing Range expanding its range into southern Vic, SA and south western WA. Hussey *et al*. (1997) further indicated that *L. camara* has the potential to become naturalised in WA.

Figure 12 outlines the potential distribution of *L. camara* based on temperature, rainfall, seasonal extremes, burning regimes and soil moisture. This modelled data shows that *L. camara* may be able to spread across Cape York Peninsula, and throughout the northern parts of the NT, the Kimberley region, further in south west WA and Vic as well as further inland in southern and eastern Australia. Although the species has not yet spread into these areas its potential as a sleeper weed may allow it to spread some time in the future.

Neal (1999) indicated that *L. montevidensis* is in the early stages of spread in Australia. That author mapped the potential distribution of *L. montevidensis* via CLIMEX and concluded that at least 30 % of Qld and 10 % of NSW were at threat of serious invasion. O'Donnell (2002) noted that since weedy and ornamental varieties of *L. montevidensis* have similar climatic preferences that the weedy variety of the species could be expected to spread beyond its present range in Australia. It is important to note however that the ecological limitations of the species are not known and require further research attention. Hence given the current sparse distribution it would be reasonable to expect that the species will continue to invade coastal and subcoastal areas of NSW and Qld, particularly around areas where it currently occurs. Expansion on the Darling Downs in Qld and in the north and central western plains of NSW may be possible, as may be further expansion of the species in southern NSW and Vic since the species seems more cold tolerant than *L. camara* in New Zealand (Webb *et al*. 1988).

# IMPORTANCE

## Detrimental

Since the introduction of *L. camara* to Australia, infestations have expanded to over at least four million hectares, 2.5 million of this in Qld and 1.5 million hectares in NSW (Culvenor 1985; Ensbey 2005). The costs of these infestations have been conservatively estimated at $2.2 million per annum (Culvenor 1985), although it is likely that this estimate does not account for the weeds many environmental impacts. A more up-to-date estimate on the cost of controlling *L. camara* by primary industries based in Qld is $10 million per annum (A&RMCA&NZ, A&NZE&CCFM 2001).

The weedy varieties of *L. camara* are widespread weeds, especially near habitation, in pastures and arable land, in disturbed grasslands, woodlands, sclerophyll forests and rainforest, along roadsides and fence lines, along waterways and in wasteland (Auld and Medd 1987; Conn 1992; Vranjic 2000; Parsons and Cuthbertson 2001).

In contrast, Day *et al.* (1999) outlined evidence suggesting that *L. montevidensis* infested hundreds of thousands of hectares throughout central Qld. Infestations of *L. montevidensis* currently vary in their severity and impact. One of the most severally affected areas is the North Burnett where severe infestations have decreased grazing animal carrying capacities so as to threaten the viability of these enterprises resulting in decreases in land values (O'Donnell 2002). Neal (1999) also stated that infestations of this species have resulted in significant land devaluation and loss of income.

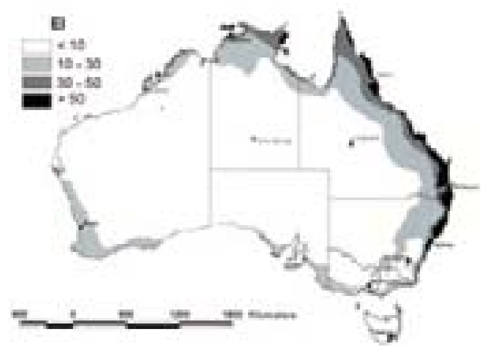


**Figure 12.**
*The potential distribution of* L. camara *in Australia (Source: van Oosterhout (2004)).*

*Lantana montevidensis* is an increasingly prominent weed near habitation, in pastures and degraded grasslands, in woodlands and sclerophyll forests and on alluvial plains, in roadside cuttings, along fence lines and riverbanks and on rocky outcrops (Swarbrick 1986; Munir 1996; O'Donnell and Panetta 2000; J. Hosking pers. comm.). It is important to note that infestations of *L. montevidensis* often occur in inaccessible terrain and that this inaccessibility results in limited weed management options (O'Donnell 2002). The impact of both species will be examined in more detail below.

## Pastures

*Lantana camara* is a troublesome weed of pasture throughout many countries throughout the Pacific and Indian ocean areas (Holm *et al*. 1977). Much of the four million ha outlined above is pasture country in eastern Australia. In many instances the weed has over run pasture ecosystems, shading out more desirable species and reducing their production, often producing pure stands that are inaccessible to people and livestock. These traits are also shared by the related species *L. montevidensis*, which in 1997 had infested around 150,000 ha of pasture land with potential for further exponential spread (Flannery 1997, in O'Donnell 2002). Both species have been consistently recognised as causing significant economic cost to grazing industries (Grice 2002; Barker *et al*. 2006).

*Lantana camara* is generally unpalatable to livestock and all but three of the varieties present in Australia are toxic to cattle and sheep (Everist 1981; Parsons and Cuthbertson 2001). In particular, Everist (1981) stated that all red flowered varieties with the exception of one from Mackay have been found to be toxic. Other red-flowered varieties from north Qld are less toxic than varieties from central and southern Qld and NSW. Only two small-flowered pink varieties were shown to be non toxic, these being the common weedy pink variety and a similar variety found around Bundaberg. All large flowering pink varieties were toxic. Everist (1981) presented further information that indicated the toxicity of *L. camara* in particular areas may be a result of genetic factors not environmental factors and that the random introduction of horticultural varieties was the most probable explanation for the regional distribution of various varieties. Day *et al*. (2003) also summarised evidence of toxicity to other animals including goats, horses, dogs, buffalo, red kangaroos and guinea pigs.

Ingesting plant material of toxic varieties of *L. camara* will cause a range of symptoms often starting within 24 hours of a single feeding event (Everist 1981). Symptoms include depression, a loss of appetite, sluggishness, constipation, frequent urination, diarrhoea and jaundice in the early stages developing into photosensitisation, inflammation of the muzzle and mouth, damage to the liver, kidneys, stomach and intestines, unthriftiness, internal paralysis and often death in one to four weeks (Seawright and Hrdlicka 1977; Everist 1981). Severe facial itching can result in injury and blindness after rubbing. Lamp and Collet (1989) indicated that white-faced cattle are more susceptible to poisoning than others, perhaps as result of increased photosensitisation. Estimates of cattle poisoning due to *L. camara* vary widely from at least 1500 cattle affected per annum in Qld (Culvenor 1985) to an estimated 500-600 affected per annum in one northern NSW coastal Rural Lands Protection Board area alone, Grafton, (Officer 2002).

Since grazing of *L. camara* in quantity only occurs in situations of low feed availability or when new and/or young cattle are introduced to grazing land where the species is present, poisoning can usually be avoided by providing adequate feed and spelling new cattle in *L. camara* free areas after purchase. In addition, the smell of herbicide treated *L. camara* may attract grazing from livestock when pasture is scarce (van Oosterhout 2004). Livestock that are bred in areas infested with the weed generally avoid grazing the species but limited test feeding may occur at times and this does not appear to result in poisoning (Everist 1981; van Oosterhout 2004; B. Johnson pers. comm.).

As well as out-competing many pasture species, *L. camara* also impedes the movement of livestock during watering and mustering (Swarbrick *et al*. 1998). Culvenor (1985) estimated that the annual cost of *L. camara* to pastures to be $7.7 million made up of 1500 cattle deaths ($0.5 million), 4.5 % reduced performance ($2 million), 7.3 % pasture loss ($3 million) and $2.2 million in control costs. These estimates have undoubtedly been surpassed.

While *L. montevidensis* grows on shallow and often stony soils, it can become an aggressive weed in pasture situations (O'Donnell and Panetta 2000; Bray 2002). O'Donnell (2002) stated that while the abundance of *L. montevidensis* is often linked with overgrazing, evidence suggested that the species more readily established in undisturbed or under light to medium grazed conditions. Only after *L. montevidensis* is established does over-grazing appear favour its spread (O'Donnell 2002). A number of authors indicated that *L. montevidensis* spreads in native and unimproved pastures when these are weakened under drought conditions (Everist 1981; Auld and Medd 1987; Conn 1992; O'Donnell *et al.* 1999; O'Donnell 2002). Parsons and Cuthbertson (2001) indicated that *L. montevidensis* is a competitive weed that reduced available grazing areas and hence pasture productivity.

Although some authors indicated that *L. montevidensis* is also toxic to grazing animals (Auld and Medd 1987; Conn 1992; Cooperative Research Centre for Australian Weed Management 2003), others indicated that the species is not toxic (Seawright 1965; Dowling and McKenzie 1993). O'Donnell (2002) postulated that if cattle had been grazing pasture infested with *L. montevidensis* since birth then resistance or immunity may have developed whereas introduced cattle may not have this resistance. Everist (1981) noted that the toxicity of the species required further study.

## Natural ecosystems

*Lantana camara*, and to a lesser extent *L. montevidensis,* pose a significant threat to the conservation of a number of ecosystems found on the east coast of Australia (Sindel 2000; Randall 2001). For example, Batianoff and Butler (2001) ranked *L. camara* as the most invasive and frequent weed on natural areas in south-east Queensland, while *L. montevidensis* was ranked 18th. Ecosystems threatened by *L. camara* include frontal dune and nearby community types such as mangroves, sedge and heath lands, woodlands associated with melaleucas, banksias and casuarinas, as well open woodland and forest communities (Benson and Howell 1994; Stock and Wild 2002; van Oosterhout 2004). In particular, *L. camara* is considered a serious invader of disturbed ecosystems throughout Australia and around the world (Swarbrick *et al*. 1998). Furthermore, the species is a serious threat to several World-Heritage listed areas including the Wet Tropics of northern Qld, Fraser Island and the Greater Blue Mountains region (Cooperative Research Centre for Australian Weed Management 2003).

The capacity of *L. camara* to invade Australian forest ecosystems has been the subject of considerable debate. On reviewing the available evidence, Stock and Wild (2002) concluded that there was "little evidence of its capacity to displace forests in the absence of external disturbances". Indeed, the converse appeared to be true in that it was likely that rainforest species actually suppressed the further expansion of *L. camara* from isolated canopy gaps, in particular by dense canopy shading (Stock 2004). This would particularly be the case in tropical rainforest in northern Qld where *L. camara* persists along the edges (including roadsides and creeks) and in canopy openings (Humphries and Stanton 1992), and in subtropical rainforests in south east Qld, both high rainfall environments (Stock 2004). van Oosterhout (2004) noted that *L. camara* thrives along water ways because of the increased availability of soil moisture and light.

Disturbance appears to be one of the key aspects in the introduction and establishment of *L. camara* in forests that receive less rainfall, for example dry rainforest (Fensham *et al*. 1994; Gentle and Duggin 1997b), warm temperate rainforests, wet sclerophyll forest, and eucalypt forests and woodland (Lamb 1988; Humphries and Stanton 1992; Benson and Hager 1993; Gentle and Duggin 1998; Duggin and Gentle 1998). For example, Fensham *et al*. (1994) correlated *L. camara* invasion with soil disturbance caused by feral pigs. This disturbance killed trees, opening the overstorey canopy with increased light penetration occurring. This increased light level favoured *L. camara* growth resulting in two outcomes, the first that pigs then avoided these dense infestations causing further disturbance, and the second it resulted in an increase in fire intensity due to increased fuel loads. These more intense fires then kill the remaining rainforest canopy. Stock and Wild (2002) further postulated that all stages of the lifecycle of *L. camara* including germination, survival and early seedling growth were strongly positively correlated with the intensity of disturbance, which is in turn was positively correlated with resource availability (Duggin and Gentle 1998) and in particular to light.

There has been some debate on the ability of plant species to germinate and grow through *L. camara* infestations (Stock and Wild 2002), for example, competitive species such as broad-leaf privet (*Ligustrum lucidum*) will grow through infestations shading them out (Swarbrick *et al*. 1998). Studies by

Stock (2004) showed that while the germination of rainforest species under *L. camara* canopies was significantly reduced when compared to germination under rainforest canopies, the survival and growth of rainforest seedlings under *L. camara* canopies was not suppressed. This appears to be broadly consistent with the observations of Humphries and Stanton (1992) that rainforest species will eventually establish through *L. camara* infestations but that the rate of regeneration is likely to be a function of soil, rainfall and repeated disturbance with regeneration favoured in areas of higher rainfall and deeper soils. Overall, *L. camara* appears to have the potential to block succession, displace native species and reduce biodiversity (Lamb 1991; Loyn and French 1991; Benson and Hager 1993; Fensham *et al.* 1994; Day *et al*. 2003; Stock 2004; Vidler 2004; Coutts-Smith and Downey 2006).

Stocker and Mott (1981) showed that *L. camara* can slow down or block grass invasion of disturbed rainforest. Gentle and Duggin (1998) indicated that *L. camara* was a very effective competitor against native colonisers under high light, soil moisture and soil nutrient conditions. Lamb (1988) also showed that the competitive nature of *L. camara* will result in an alteration to many of the processes that occur naturally in eucalypt woodland, in particular that native trees lost vigour and that nitrogen cycling was altered in favour of *L. camara*. Regeneration of these communities after clearing *L. camara* may be slow because few native plant propagules from which regeneration can occur may be left (Swarbrick *et al*. 1998).

Reductions in biodiversity with *L. camara* infestations are common, particularly that of threatened biodiversity. In their comprehensive study, Coutts-Smith and Downey (2006) found that *L. camara* was a threat 83 threatened plant species, two threatened animal species (a butterfly and bird) and 11 threatened ecological communities in NSW, whereas 15 threatened ecological communities are listed in the Final determination of *L. camara* as a Key Threatening Process (Department of Environment and Conservation 2006). The threatened ecological communities include rainforest, *Eucalyptus* and floodplain forests and woodlands, and *Banksia* scrub.

A national study on the impact of the species on biodiversity will undoubtedly identify further threats (P. Turner pers. comm.). In contrast, earlier biodiversity studies outlined 20 endangered or threatened flora species which were threatened by *L. camara* infestations in the upper north coast of NSW (van Oosterhout 2004), while 80 species and communities were identified as threatened in the Northern Rivers Catchment Management Authority which encompassed this area (Coutts-Smith and Downey 2006). Sixty plant and animal species of conservation significance were estimated as threatened in Qld (A&RMCA&NZ, A&NZE&CCFM 2001).

Although less commonly recorded, it is also likely that *L. camara* infestations reduce the numbers of non-threatened flora and fauna in infested areas. For example Cummings (2004) reported that several functional groups of ants were reduced in *Lantana* infested areas when compared to nearby rainforest and sclerophyll vegetation. Again, Fernandes *et al*. (2001) indicated that arbuscular mycorrhiza fungi are reduced when rainforest ecosystems in Madagascar are cleared and replaced by introduced weeds such as *L. camara*.

There is some evidence to suggest that *L. camara* infestations alter fire regimes in natural ecosystems (Humphries and Stanton 1992; Fensham *et a*l. 1994; Swarbrick *et al*. 1998). In particular, *L. camara* increased the fuel loads in grassy woodlands and forests on rainforest margins allowing intense fire to penetrate into rainforests (Humphries and Stanton 1992; Fensham *et al.* 1994). In contrast, Humphries and Stanton (1992) recorded evidence that *L. camara* acted as a protective barrier to mild fires. Aside from the situations outlined above, *L. camara* may restrict access to specific areas including forests and other natural ecosystems thereby restricting eco-tourism and recreation activities (Clark *et al*. 2004).

*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). It is a common weed of open woodland and dry sclerophyll forest in south eastern Qld and disturbed areas behind mangroves (Munir 1996; O'Donnell 2002). There is some evidence to suggest that *L. montevidensis* reduced plant and animal biodiversity in these and other ecosystems where it occurred (Munir 1996; O'Donnell 2002; S. Csurhes pers. comm.).

## Forestry

*Lantana camara* is a major weed of timber plantations including hoop pine (*Araucaria cunninghamii*) and may be problematic in the early plantation stages of exotic pine species (radiata and slash pine, *Pinus radiata* and *P. elliottii* respectively) in Australia (Wells 1984; Swarbrick *et al.* 1998; Hall 2000; van Oosterhout 2004). The costs of controlling *L. camara* in hoop pine plantations exceeded $200,000 in 1970 (Waterhouse 1970, in Day *et al*. 2003) and are now undoubtedly much higher. For example, one estimate placed these costs in excess of $500,000 (A&RMCA&NZ, A&NZE&CCFM 2001). In particular *L. camara* varieties form impenetrable thickets under the forest canopy, competing strongly with young trees for light, moisture and nutrients, decreasing growth rates, limiting access to the stands thereby increasing both management costs and fire hazards (Swarbrick *et al*. 1998; Hall 2000; Day *et al*. 2003). In contrast, Swarbrick *et al*. (1998) recorded that *L. camara* is rarely a problem in established exotic pine plantations because it is shaded out whereas light penetration is much higher in hoop pine plantations (van Oosterhout 2004).

van Oosterhout (2004) also recorded *L. camara* as a serious weed of hardwood and cabinet timber (rainforest species) plantations where the species becomes a prolific understorey monoculture in high light situations.

## Plantation and other crops

*Lantana camara* has been reported as a weed of at least 14 crops throughout the world (Holm *et al*. 1977). It is an important weed of banana, coconut, coffee, copra, citrus, oil palm, pineapple, rubber and tea crops particularly in south east Asia, the Pacific and Australia, but also in other countries such as India, Nigeria and Trinidad (Holm *et al*. 1977; Waterhouse and Norris 1987; Singh and Achhireddy 1987; Swarbrick *et al*. 1998; Parsons and Cuthbertson 2001; van Oosterhout 2004). van Oosterhout (2004) also recorded *L. camara* as a weed of almond, avocado, grape, guava, kiwifruit, lychee, macadamia, mango, nut, olive, papaya, pecan, pistachios, pome fruit, stone fruit and walnut crops. Holm *et al*. (1977) and van Oosterhout (2004) noted that *L. camara* is a weed of cotton in Turkey and Nicaragua, rice in Indonesia, sugar cane in Australia, India and South Africa and peanut and soybean crops.

## Railway and service providers

*Lantana camara* is one of the most troublesome weeds that affect railways and railway corridors due to its size, and the rapid rate of spread of the species (Mahoney 1967; van Oosterhout 2004). The weed is also problematic along cleared easements for electricity lines, and road ways (Swarbrick *et al*. 1998; van Oosterhout 2004).

## Allelopathy

Several authors have summarised studies which illustrate the ability of *L. camara* to produce chemicals that inhibit the germination and growth of certain crops e.g. wheat and soybean and ryegrass and annual weeds under laboratory conditions (Gentle and Duggin 1997a; Swarbrick *et al*. 1998; Stock 2004). These interactions have not been examined further because they are of limited importance to this discussion.

Gentle and Duggin (1997a) found evidence that *L. camara* "is capable of interrupting regeneration processes by decreasing germination, reducing early growth rates and increasing mortality" of native Australian tree species that the weed co-occurs with. Singh and Achhireddy (1987) have shown the *L. camara* is allelopathic to citrus in Florida. Swarbrick *et al*. (1998) outlined further unpublished data that suggested that *L. camara* is allelopathic towards many endemic Australian plants. Further research is needed to better understand the allelopathic interactions that *L. camara* has with various native and crop plants.

## Hosts for other pests

*Lantana camara* thickets provide refugia for pest animals and other plant pathogens and pests in Australia and around the world (Holm *et al*. 1977; Swarbrick *et al*. 1998; Parsons and Cuthbertson 2001; Day *et al*. 2003; van Oosterhout 2004).

### Human effects

Aside from the nuisance aspects of *L. camara* restricting access to certain areas and impacting on other human and farming activities, the fruit of *L. camara* may also poison humans if ingested, occasionally resulting in death (Everist 1981; Swarbrick *et al.* 1998). Shepherd (2004) also indicated that the leaves of *L. camara* were poisonous. Infestations of *L. camara* reduce the overall visual amenity of various areas (Ensbey 2003).

## Beneficial

### Ornamental

Both weedy and non-weedy varieties of *L. camara* are widely planted as ornamental plants in gardens, in particular as hedges (Swarbrick 1986). The non-prickly triploid varieties that produce little seed are better ornamental plants than the prickly fruiting varieties because of their shorter, denser plant habits and because the flowers last longer since they largely fail to fertilise (Swarbrick *et al*. 1998). Both *Lantana* species 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). Everist (1981) and Webb *et al*. (1988) indicated that *L. montevidensis* 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.

### Other human uses

Much of the following information has been summarised from Munir (1996) and Day *et al.* (2003), which are themselves reviews of a wide range of information. Extracts from *L. camara* are used as herbal medicines, especially in India, with extracts from the leaves showing antimicrobial, fungicidal, insecticidal and nematicidal activity, but not antiviral activity. Investigations are continuing as to whether extracts are also useful as herbicides and nematicides. *Lantana montevidensis* is used in herbal medicine in South America.

The essential oils present in *L. camara* flowers and leaves can be extracted for use in perfumes. Products containing these essential oils are available for purchase on the world wide web. The twigs and stems of *L. camara* are widely used as firewood in developing countries.

### Alternative food and habitat sources for wildlife

Swarbrick *et al.* (1998) reviewed evidence that *L. camara* was beneficial to wildlife providing feeding sites for seed-, leaf- and litter-feeding insects and shelter for small birds and mammals. The results of that review were not conclusive however. Both Low (2001) and van Oosterhout (2004) contended that *L. camara* thickets provided suitable habitat for birds such as brush turkeys, quail, whipbirds and wrens, terrestrial animals such as bandicoots and wallabies, frogs and reptiles such as snakes, and insects such as birdwing butterflies and reed bees where this weed had displaced native vegetation. In many places *L. camara* infestations provided important replacement habitat when natural habitat was not available (Day *et al*. 2003). Clemson (1985) noted that *L. camara* was rarely attractive to bees because they obtained very little nectar and pollen from the flowers.

### Other benefits

*Lantana camara* is seen as useful in preventing soil compaction and soil erosion in steep riverine situations in some agricultural situations (Swarbrick 1986; Waterhouse and Norris 1987; van Oosterhout 2004). Infestations of *L. camara* may also be a valuable source of organic mater for pasture improvement and increase nutrient mobility in eucalypt forests and other situations (Munir 1996; Day *et al.* 2003; van Oosterhout 2004). van Oosterhout (2004) indicated that *L. camara* can also be used to provide barriers or buffers against further disturbance of various areas by humans, livestock and other weeds, to provide interim buffers on rainforest edges while infestations inside are managed, and to restrict access to ecologically sensitive areas e.g. caves where bats breed. These infestations need to be managed to prevent further spread however. The use of *L. camara* fruit as a stockfeed has been investigated in India (Lall *et al*. 1983 a, b). *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).

## The sale of ornamental *Lantana* species

The potential sale of the largely sterile triploid varieties of *L. camara* in South Africa has been criticised by Spies and du Plessis (1987). Those authors showed that the triploid varieties were capable of producing fertile pollen (27.3-44.4 %) and viable seeds thus hybridising with diploid varieties of the plant. Neal (1999) indicated that between 2 and 16 % of pollen from ornamental varieties of *L. montevidensis* and a *L. camara* x *L. depressa* hybrid, all supposedly sterile, was in fact viable. Furthermore 20 % of Brisbane gardens sites surveyed that contained the ornamental *L. camara* x *L. depressa* hybrid and the purple ornamental variety of *L. montevidensis* had 0.16-2 % seed production/floret. Pollination studies by Neal (1999) indicated pollen from weedy varieties of *L. camara* and *L. montevidensis* resulted in 26 % and 6 % of florets respectively producing seed in supposedly sterile *L. camara* x *L. depressa* plants. Those results suggested that when an ornamental variety of *Lantana* occurs in isolation, very little seed production occurred. Seed production does occur when ornamental varieties are found adjacent to weedy *L. camara* and/or *L. montevidensis* plants.

In addition Neal (1999) demonstrated considerable potential for vegetative reproduction from various *Lantana* species and varieties. For example, 24 % of transplanted leaves from the ornamental *L. camara* x *L. depressa* hybrid produced root material after five weeks while 4 % also produced shoots. One plant even produced flowers and seed after ten weeks. A total of 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. In contrast, the weedy varieties of *L. camara* and *L. montevidensis* had 8 % and 12 % root production from leaves after five weeks. Those results indicated that there is considerable potential for vegetative production, indicating that these varieties have considerable weedy potential quite apart from any that occurs from sexual reproduction and dispersal.

One of the key aims of the Weed of National Significance national strategy for *L. camara* is the phase out of sale and distribution of all non-sterile varieties of the species (A&RMCA&NZ, A&NZE&CCFM 2001). The trade and distribution of *L. camara* is banned in all states and territories in Australia (van Oosterhout 2004; Appendix 1). Despite this, van Oosterhout (2004) indicated that ornamental *L. camara* varieties were still being planted in gardens and landscaping in states and territories of Australia, particularly in WA (D. Collopy pers. comm.). The trade and planting of these varieties is gradually decreasing however.

van Oosterhout (2004) indicated that a number of ornamental varieties of *L. montevidensis* were available for sale in Australia. In other cases, the weedy purple flowered variety was grown in gardens as an ornamental. While the weedy variety produces fertile pollen and seed, the ornamental varieties are largely sterile, flowering profusely and rarely producing seed (Henderson 1969; Everist 1981). Unfortunately pollen from weedy varieties can pollinate ornamental varieties resulting in viable seed set. This adds to the genetic diversity of *L. montevidensis*. In addition, Hammer (2004) indicated that *L. montevidensis* is able to cross with *L. camara*.

Any sale of ornamental varieties of *L. camara* and *L. montevidensis* has the potential to add genetic diversity to the weedy varieties already present in Australia. It is likely that further genetic diversity will help both species to expand their distribution into new environments and to make control using herbicides and biological agents far more difficult (van Oosterhout 2004). Because of the diverse genetic background of *L. camara* (e.g. Day *et al*. 2003), this document recommends the removal of all *Lantana* species from sale in NSW. In addition, all plants and seeds supplied by nurseries, wholesalers, other plant marketers e.g. large supermarket chains and from garden club exchanges should be banned from entry into the state and an information program conducted to alert and inform these plant trade industries/bodies and the general public of these reasons.

van Oosterhout (2004) recommended the removal of all plantings of *L. camara* and *L. montevidensis* from private and public gardens and amenity areas so that genetic material did not move further into the environment. While this recommendation is sound it is probably not practical under current NSW legislation. Instead the information campaign should encourage all government and private land managers to remove all ornamental plantings of both species, to ensure they are properly killed (solarisation under or in plastic has been suggested), to replant the areas with native species (or less preferably non-invasive exotic species) that are low maintenance and that do not have the potential to become weedy in the area followed by monitoring of any seedlings or regrowth (A&RMCA&NZ, A&NZE&CCFM 2001; van Oosterhout 2004).

### Negative impacts of the removal from sale of *Lantana* species

There are likely to be a number of minor negative impacts associated with the removal of sale of *Lantana* species. The first is the commercial impacts that such a ban will have on the nursery industry and other plant suppliers. Ensbey (2005) indicated that *Lantana* species only fill a small market niche and that this niche could be replaced by native or non-weedy exotic species that fulfilled a similar function e.g. species that were hardy, low growing, required low maintenance levels, were drought tolerant and were similarly colourful. A regulatory impact statement associated with the declaration and prohibition from sale of *Lantana* species in Qld in 2003 indicated that the market for the species was valued at $75,000/annum (Ensbey 2005). The costs of controlling *Lantana* species and associated impacts from the weeds far outweighed the minor potential losses to the nursery industry. There has only been one issue that has arisen in Qld after the six month moratorium used to remove stocks of *Lantana* species ended, this being where a large retail chain store offered plants for sale which were sourced from outside Qld (A. Clark pers. comm.).

# LEGISLATION

## State declaration

Prior to March 2006, *L. camara* was declared as a noxious weed through the north, mid north and south coast areas of NSW and in the Sydney area (Appendix 1; New South Wales Department of Primary Industries 2005). Depending on the local government area and the variety of the plant (pink or red flowered), *L. camara* was declared as a W2 weed in most cases meaning that it was to be fully and continuously suppressed and destroyed. Less commonly *L. camara* was declared as a W3 plant which meant that it needed to be prevented from spreading and its numbers and distribution reduced. The recommendations for declaration of *Lantana* species that arise from this review are outlined in Appendix 2.

In summarising the information contained in Appendix 1, Ensbey (2005) noted that only the red flowered variety of *L. camara* was declared as a W2 or W3 weed on the north and mid north coasts of NSW, mainly due to its toxicity to livestock. The pink flowered variety, although widespread was not declared in these areas even though it was controlled by land holders and managers as resources allowed. Moving further south, with the exception of the Cessnock council, *L. camara* was not declared in the Hunter and central coast areas whereas both red and pink flowering varieties were declared as W2 weeds throughout Sydney. Again, *L. camara* was not declared south of Sydney with the exception of the pink flowering variety in Eurobodalla. Bega valley had an active monitoring and eradication program for the species even though it was not declared.

Ensbey (2005) recorded that the north, mid north and south coast, as well as the Tablelands Regional Weed Advisory Committees have developed and are implementing regional control programs for *L. camara*. The south coast plan included priority areas with containment zones and buffer areas to prevent the spread of the species further south.

All *Lantana* species including *L. camara* and *L. montevidensis* are declared as Class 3 pest plants across Qld (QNRW 2007). A Class 3 pest plant is one that is common throughout Qld but that may pose an environmental, social or economic threat in, or adjacent to an environmentally significant area. This classification means that landholders needed to control this plant if they lived next to 'environmentally significant areas' such as national parks and reserves, but only if these were free from the weed. Certain local government areas in Qld have also declared both weeds requiring control in areas that are not in or adjacent to environmentally significant areas (Appendix 1). Plants of both species could not be sold. Landholders were also required by law to reduce infestations of both species in some areas of the NT (van Oosterhout 2004).

The trade and distribution of both *L. camara* and *L. montevidensis* is restricted in many states.

## A Weed of National Significance (WoNS)

*Lantana camara* has been declared a Weed of National Significance (WoNS) because of its widespread distribution and impact on primary industries, conservation and biodiversity areas (van Oosterhout 2004). A major national control program has been launched focussing on preventing its introduction and spread (Ensbey 2003). Continuing declaration of this weed within NSW will give valuable support to these efforts.

## Benefits that may accrue from continued legislative control

There are a number of other benefits that will accrue from ongoing legislative control of *L. camara* and the implementation of legislation to control all *Lantana* species. While Ensbey (2005) outlined a number of reasons, these have been expanded with information contained in this document as follows: -

- preventing the further distribution of *L. camara* and *L. montevidensis*. There is some contention as to whether *L. camara* has spread to its maximum geographic range or not. On reviewing the evidence this document outlines evidence that further spread may occur, especially if new genetic material moves into the existing population. In contrast, it is highly unlikely that *L. montevidensis* has spread to its maximum geographic range at this time;
- preventing the further spread of *L. camara* within current distribution areas. While *L. camara* is widely distributed in NSW, there are a number of areas within the limits of its current geographic spread that are not infested. Continued management via legislative control may help to reduce the in-filling of such areas;
- a reduction in the negative impacts caused by both species including pasture, forestry, crop and natural ecosystem invasion and a reduction in livestock and human poisoning; and
- prevention of further genetic movement from ornamental varieties into the environment. Stabilisation of the genome of this species should aid in the future success of biological control agents.

# CONTROL

There are a number of excellent reviews available examining the management of *L. camara*, particularly van Oosterhout (2004) and Swarbrick *et al*. (1998). O'Donnell (2002) also produced an excellent review on the management of *L. montevidensis*. The purpose of this section is to highlight the basic principles of management of these species in Australia and information has been drawn from these references. In general the principles outlined for *L. camara* will be effective for *L. montevidensis* unless otherwise mentioned. It is important to note that the control of *L. montevidensis* is often more difficult than that for *L. camara* (O'Donnell 2002). Constant vigilance is required for the successful management of both species (Day *et al.* 2003).

There are a number of reasons why infestations of *L. camara* and *L. montevidensis* can be difficult to control including the size of infestations, poor access to invaded areas, the low values of invaded land and the cost of the ongoing control that is needed (Day *et al*. 1999; Day *et al.* 2003; Ensbey 2003). An integrated management strategy is likely to provide the most economic, efficient and practical means of managing this weed (Ensbey 2003). Such a strategy will include both physical and chemical control, follow up, ongoing monitoring and revegetation (Parsons and Cuthbertson 2001; Clark *et al*. 2004; van Oosterhout 2004) and needs to be tailored to each situation. A summary review of integrated weed management strategies will follow the initial discussion of various tools that may form these strategies.

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). In cases where extensive and dense infestations exist, initial control measures are used to either promote access to the site or to encourage regrowth so that future control is easier (van Oosterhout 2004). Before this though, it is always easiest to prevent a weed from entering an area.

## Prevention

Prevention of the spread of *L. camara* and *L. montevidensis* into uninfested areas is probably the best means of control (Cooperative Research Centre for Australian Weed Management 2003). There are three main means by which this can occur: -

- strategic control of existing infestations so that they do not spread further (to enable this see the discussion below);
- restricting the sale and use of both *Lantana* species as garden plants because these plants can act as sources of new infestations and introduce new genetic material into areas where existing infestations occur making control more difficult (Randall 2001; van Oosterhout 2004). Non invasive native or exotic species could be recommended in place of these species; and
- restricting the further importation of any *Lantana* species into NSW, not only *L. camara* and *L. montevidensis*. This will eventually result in the prevention of any new varieties or species escaping from cultivation, naturalising and hybridising with the existing *Lantana* species.

While *L. camara* is relatively widespread, efforts to prevent it spreading to currently uninfested areas are still useful. In contrast, *L. montevidensis* is not widespread in NSW and some areas of Qld and various hygiene measures should be observed (O'Donnell 2002). These include fodder inspection and refusal of suspect fodder, including the inspection of feeding sites after periods of drought to ensure the species has not been spread. Quarantining cattle that have been grazing on plants that have ripe fruit before moving them from infested to clean pastures for five to six days 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 spread of this species. The use of buffer strips between infested and uninfested areas will also help prevent the vegetative spread of the *L. montevidensis*.

## Herbicides

The current herbicide recommendations for *L. camara* control in NSW include 2,4-D amine, dichlorprop, fluroxypyr, glyphosate, metsulfuron-methyl, tebuthiuron and triclopyr, and mixtures of fluroxypyr and aminopyralid, glyphosate and metsulfuron-methyl, picloram and 2,4-D amine and triclopyr and picloram (Australian Pesticides and Veterinary Medicines Authority 2007). Aside from triclopyr and triclopyr/picloram mixtures, these herbicides work best by thoroughly wetting actively growing foliage (Ensbey 2004; QNRM 2004). Products containing triclopyr are useful for cut stump or basal applications and need to be applied to each stem to achieve effective control. The best results from cut stump applications occur when the stump is cut no higher than 15 cm from the ground and the herbicide is applied to the stump within 15 seconds (van Oosterhout 2004). The following discussion focuses on foliar herbicides unless otherwise noted.

There are a number of factors affecting the efficacy of the foliar herbicides outlined above. Swarbrick *et al*. (1998) summarised a range of Australian and international herbicide trials on *L. camara*. The following list of registered herbicides was derived and are listed in order of decreasing effectiveness: - fluroxypyr; glyphosate; picloram mixtures; dichlorprop; metsulfuron-methyl; and 2,4-D amine. These herbicides were effective against the common pink and less common red flowering variety as well as the 'Helidon White' variety that commonly occurs in south east Queensland. Herbicides containing dicamba (not registered) and fosamine (now withdrawn from sale) were moderately effective.

High volume foliar applications of fluroxypyr were more effective than low volume applications, especially when surfactants are added (Love 1989). Ground applications of 2,4-D amine, glyphosate, dichlorprop and picloram were more effective than aerial applications (Armstrong *et al*. 1987).

There was a marked seasonality in the effectiveness of herbicide control. In particular, fluroxypyr, glyphosate, picloram, dichlorprop, metsulfuron-methyl and 2,4-D amine were more effective when applied between December and April (Hannan-Jones 1998; Swarbrick *et al.* 1998). Of these, the action of the growth regulating hormonal herbicides (all herbicides except glyphosate and metsulfuron-methyl) was linked to the growth activity of the plant and may possibly be linked to increased translocation of the herbicide. In summarising others research, Swarbrick *et al*. (1998)

indicated that water-stress and reduced foliage cover resulted in reduced control during autumn, although cold weather may also be linked to this reduction. The best results from herbicide applications were generally achieved six weeks after good rains (rainfall exceeding 35 mm) and when temperatures exceeded 15ºC (Hannan-Jones 1998). The resulting growth flush resulted in a greater amount of herbicide being deposited on younger leaf tissue.

Graaff (1986) and Hannan-Jones (1998) both postulated that the variable response of *L. camara* to similar herbicide treatments may be due to the large variability within the species. For example, there was a variable response of three different varieties to 2,4-D amine in south east Qld in that pink and white flowered varieties died within four months but that red flowered varieties recovered within six weeks and kept growing despite the fact that there were no differences in leaf wetability and spray retention (Diatloff and Haseler 1965). Variable herbicide responses to 2,4-D amine and fluroxypyr were also observed in different varieties found in north Qld (Vitelli and Dorney 1991).

Glyphosate appeared to give decreasing control as plant size increased (Wells 1984). McMillan (1991) showed that the volume of herbicide applied needed to be proportional to the volume of the plant rather than the leaf area. van Oosterhout (2004) indicated that *L. camara* regrowth from 30 to 100 cm high after drought or frost events (or even after burning, cutting, slashing or dozing) was ideally treated with foliar herbicides because it was actively growing, access was often easier and the reduced surface area of the plant required less herbicide.

There are a number of other important considerations when applying herbicides to *L. camara* (Ensbey 2003). In particular the cost of the initial treatments and follow-up herbicide applications (or cost of other treatments) on regrowth and on new seedlings that have emerged needs to be factored in as a cost of an ongoing control program. Herbicides are likely to be an expensive option to treat large, dense infestations (van Oosterhout 2004) and while aerial applications by helicopter may be feasible for large infestations that are inaccessible to other machinery or cannot be burnt, these are still not cost-effective. Herbicide choice also needs to minimise potential off-target impacts on desirable native and pasture species, and waterways where relevant (Day *et al.* 2003; van Oosterhout 2004). It is always important to read and follow label instructions with the use of any herbicides.

O'Donnell (2002) recorded that fluroxypyr gave the best overall control of *L. montevidensis* and that while glyphosate also gave good results in autumn it did not achieve good results in spring. 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).

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

O'Donnell (2002) recorded that regrowth occurred from plants that had been apparently dead for periods of over two years with all herbicide treatments used and that no herbicide achieved 100 % control. Regrowth stimulated from a burning event did not improve the performance of *L. montevidensis* control over unburnt areas (O'Donnell 2002).

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 *L. montevidensis* (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.

## Other management

### Fire

Although the use of fire has been widely recommended in the past (Goodchild 1951; Saint-Smith 1964; Bartholomew and Armstrong 1978), Swarbrick *et al.* (1998) commented that very little information was available on the effects of seasonality, meteorological conditions during or after the burn, fuel loads, the type of fire (ground or crown fire) and the timing of the reintroduction of livestock if applicable. While agreeing with these sentiments, van Oosterhout (2004) outlined certain considerations that are required for the use of fire to help manage *L. camara* in natural and pasture ecosystems.

The best results with fire appeared to be obtained when the fires were hot and the weed was actively growing, in early summer in south eastern Qld and in late winter and spring in NSW (Cooperative Research Centre for Australian Weed Management 2003). Exclusion of grazing livestock before a fire was planned helped build up fuel loads. Burning was not recommended near rainforest areas as these ecosystems are highly sensitive to fire and the resulting burn could provide further opportunities for *L. camara* to invade canopy gaps, or may promote the regrowth of sclerophyll species instead of more desirable rainforest species (Vranjic *et al.* 2000; Cooperative Research Centre for Australian Weed Management 2003). Fire may also damage plantation timber or other tree crops e.g. coconuts if used (Day *et al*. 2003).

Fire is a useful tool in the management of *L. camara* clearing dense thickets and reducing the number of plants when combined in an integrated management program (Parsons and Cuthbertson 2001), particularly prior to, or as follow up to treatments for mechanical or chemical control (Cooperative Research Centre for Australian Weed Management 2003). The dangers of fire escaping and damaging property and people need to be carefully assessed and fire permits may need to be obtained (Cooperative Research Centre for Australian Weed Management 2003; van Oosterhout 2004).

Fire can be useful in two ways in managing *L. montevidensis* seedlings (O'Donnell 2002). Burning trials have indicated that surface seed is killed by hot pasture fires but that buried seed (especially in ant nests) escapes. Any seed that escapes a fire was more likely to germinate via smoke stimulus and these plants could be easily controlled by herbicides and/or trampling as seedlings. Adult plants are not killed by fire because regrowth occurs soon after, and while seed set may be delayed, observations suggested that flower and seed numbers may be higher on previously burnt plants.

## Mechanical clearing

A number of authors have recommended the use of mechanical clearing to remove *L. camara* in pastures (Goodchild 1951; Saint-Smith 1964; Bartholomew and Armstrong 1978). This can be easily performed using bulldozers, slashers, stick rakers or with chain pulling where the terrain permits and where erosion risks would be minimised (Ensbey 2003; van Oosterhout 2004). O'Donnell (2002) indicated that bulldozing to a depth of 15 cm gave reasonable control of *L. montevidensis*. It was important to follow up any such clearing with spot herbicide applications or hand pulling of regrowth from existing plants, any new seedlings, or any other weeds that emerged due to soil disturbance (O'Donnell 2002; Ensbey 2003; Cooperative Research Centre for Australian Weed Management 2003; van Oosterhout 2004). It was also important to consider that reshooting from broken stems after pushing or stick raking was also likely and that this regrowth needed control (van Oosterhout 2004). A combined mulcher/harvester has been built to clear woody weeds including *L. camara* within hoop pine plantations in Qld (Swarbrick *et al*. 1998).

## Cultivation

While cultivation, generally disc ploughing, gives very effective control of *L. camara*, it is important to plant competitive pastures to prevent reestablishment of the weed (Saint-Smith 1964; Swarbrick *et al*. 1998; van Oosterhout 2004). Various fodder plants have been suggested including glycine (*Neonotonia wightii*), kikuyu (*Pennisetum clandestinum*), leucaena (*Leucaena leucocephala*) and Guinea and Rhodes grass (*Panicum maximum* and *Chloris gayana* respectively), (Saint-Smith 1964; Swarbrick *et al.* 1998; A&RMCA&NZ, A&NZE&CCFM 2001). It is important to account for the potential weediness of any new species introduced to ensure that the introduced species does not become a weed (e.g. Randall 2001; Walton 2003). It may be necessary to obtain a permit if native vegetation is also cleared by these management methods. Mechanical grubbing of individual plants in scattered infestations may also be useful, especially if revegetation is carried out immediately (van Oosterhout 2004).

O'Donnell (2002) recorded that more effective control of *L. montevidensis* occurred with offset discs rather than chisel ploughs but noted that multiple passes may be needed. Chisel ploughing caused fragmentation of *L. montevidensis* material with an increase in plant numbers resulting.

## Hand removal and flame weeding

*Lantana camara* is widely removed by hand-grubbing in areas identified for regeneration after which selected tree species may be planted and tended until a canopy has formed that shades out any further invasions of the weed (Swarbrick *et al*. 1998). Hand grubbing can occur with a mattock or hoe, while a 'lantana lever' is under development in Qld (van Oosterhout 2004). Hand cutting using a brush cutter, brush hook or machete is popular, as is the use of large secateurs and hedging tools, and even chainsaws. Hand cutting allows access to the plant base for grubbing or for the cut stump to be painted with herbicide (van Oosterhout 2004). Hand pulling of seedlings or even larger plants after rainfall is popular in smaller infestations (Saint-Smith 1964). Flame weeding also controlled small *L. camara* seedlings. It is important to minimise soil and desirable vegetation disturbance with such activities to reduce the risk of further *L. camara* seed germinating (van Oosterhout 2004).

The management of very small areas of *L. montevidensis* may be achieved via 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).

## Grazing management

Grazing management as a means of managing *Lantana* species has often been overlooked by a number of reviews. Ensbey (2003) noted that proper grazing management is a useful preventative means of management for many pasture weeds, not only *L. camara*. Conversely, the removal of excessive pasture biomass through overstocking and grazing will lead to pasture degradation and the invasion of weeds like *L. camara*. Replanting of desirable pasture species may help reverse any overstocking (as mentioned above). A vigorous pasture sward as opposed to grass tussocks will help prevent the establishment and growth of seedlings of *L. montevidensis* (O'Donnell 2002).

## Revegetation

The replanting of desirable native species along with continual maintenance of these areas is a similar means of preventing the regrowth of *L. camara* in environmentally sensitive areas (Saint-Smith 1964; Cooperative Research Centre for Australian Weed Management 2003; Ensbey 2003). Revegetation, along with monitoring and follow up control measures, will help ensure that sites are kept free of reinfestation (van Oosterhout 2004). After studying the response of *L. camara* to shading, Stock (2004) recommended that tree canopy densities of 75% prevented further encroachment by the weed. Revegetation may include resowing of pastures after mechanical disturbance and either the active planting of local native plant species, or allowing these to regenerate naturally. Regeneration will be more successful if the native vegetation is intact and if infestations by the weed are more recent. This is because many more propagules of desirable species are likely to remain. If remnant vegetation is present, regeneration can be encouraged by removing *L. camara* on the interfaces and then extending these interfaces progressively into the infestations over time (van Oosterhout 2004) combined with the planting of fast growing tree species if appropriate (Stock 2004).

## Biological control

There has been widespread interest and activity in the biological control of *L. camara* for several reasons including the cost of treating large infestations, the inaccessibility of doing so, the need for ongoing treatment and that infestations are generally on land of low economic value (Day *et al.* 2003).

The first biological control agents were introduced into Qld in 1914 (Tyron 1914) and a number of other insects have been introduced since. Although 29 insect species have been trialled and released for the control of *L. camara* in Australia, most of these biological control agents have provided, at best, only minor or seasonal control (Tomley and Riding 2002; Day *et al*. 2003; Walton 2004). Four species have made the most significant impact of those that have established, these being a sap sucking bug *Teleonemia scrupulosa*, two leaf mining beetles *Uroplata girardi* and *Octotoma scabripennis* and a seed feeding fly *O. lantanae* (Day *et al*. 2003). Further information on the range of biological control agents released in Australia and around the world for use on *L. camara* is available elsewhere (Day *et al*. 2003).

It is important to remember that biological control is only one tool that may be used as part of an integrated management program against *L. camara,* and that biological control agents may only be effective at certain times of the year (van Oosterhout 2004). The wide geographic and climatic range over which *L. camara* occurs in Australia also makes the establishment of populations of biological control agents that are adapted to these variable conditions difficult (Swarbrick *et al*. 1998; Day and Hannan-Jones 1999; Day *et al*. 2003). There is increasing evidence that insect biological control agents may show a preference for some varieties of *L. camara* over others (Harley *et al*. 1979; Cilliers 1987; Waterhouse and Norris 1987; Swarbrick *et al*. 1998; Day and Hannan-Jones 1999; Day *et al*. 2003). The largest problem with the development and release of new ornamental varieties of *L. camara* is the increase in the genetic diversity that inevitably results in weedy varieties making potential future biological control even more difficult. In other cases, plant taxonomy may be the confounding issue. For example, the strong affinity between populations of the five weedy varieties of *L. camara* in Australia (Table 1), and in Fiji and Vanuatu indicated that these populations share *L. urticifolia* as a progenitor (an originator of these lines of descent), in contrast to populations from the Solomon Islands and Maui (Hawaii), (Scott *et al.* 2002; Day *et al*. 2003). This knowledge has now been integrated into the continuing search for effective biological control agents, particularly agents that have some specificity for *L. urticifolia* (Day *et al*. 2003). Day *et al.* (2003) suggested further research was needed into the classification and identification of weedy varieties of *L. camara* in Australia and around the world to support these efforts. In contrast, the rust *Prospodium tuberculatum* which was released in 2001 may have better efficacy against many pink flowered varieties of this weed (Tomley and Riding 2002).

Care needs to be taken in the release of any biological control agent into the environment, not only to ensure its efficacy, but also to minimise non-target effects. Non-target effects have been caused by the insect *Aconophora compressa* (released against *L. camara* in 1995) to the exotic ornamental Verbenaceae species fiddlewood, (*Citharexylum spinosum*) and duranta (*Duranta erecta*)*,* and a number of other common garden species including jacaranda (*Jacaranda mimosifolia*) and yellow bells (*Tecoma stans*) (Maher *et al.* 2004; Palmer *et al.* 2004, 2005).

One biological control agent for *L. montevidensis*, the leaf feeding beetle *Charidotis pygmaea* was released in 1994 (Day *et al.* 1999). Populations of this agent are not sustained on *L. camara.* Unfortunately this biological control agent has had no impact on *L. montevidensis* (Walton 2004). Day *et al.* (1999) noted that three other agents released for the control of *L. camara* also attacked *L. montevidensis.* These agents are a leaf feeding insect *Hypena laceratalis,* a leaf blotching fly *Calycomyza lantanae* and a flower feeding moth *Lantanophaga pusillidactyla* but again, the impact of these agents is limited.

## Integrated management of *L. camara*

An integrated management program for *L. camara* will require a range of strategies including prevention, physical and chemical control tools, follow up, monitoring, revegetation and perhaps biological control agents where present (Parsons and Cuthbertson 2001; van Oosterhout 2004). The use of various tools will depend on a large number of factors including the size and location of infestations, and the time, money and other resources available. Any integrated management strategy needs to be specific to the situation encountered.

### Pasture situations

Physical control of small numbers of plants may involve digging plants up before flowering by hand, hand pulling seedlings or clearing with machinery (often a tractor and chain) and burning (Parsons and Cuthbertson 2001; van Oosterhout 2004). Care is needed with this approach to ensure that as much lateral root material is removed as possible to prevent reshooting. The spot spraying of herbicides is generally effective in small but dense infestations (van Oosterhout 2004) while cut stump and basal bark spraying are effective on small scattered infestations.

On a larger scale, excluding livestock prior to a burning event, bulldozing or slashing and then stickraking weedy material together can add to fuel loads (Cooperative Research Centre for Australian Weed Management 2003). Slashing can be used reduce the height and density of plants and to create access so that trampling by livestock or machinery can occur, as well as encouraging regrowth (van Oosterhout 2004). It is important to remember that regrowth from live stems can occur when contact is made with moist soil even if these stems are chopped up, (van Oosterhout 2004). Biological control agents may be useful in suppressing *L. camara* growth when present leading to improved access and management (van Oosterhout 2004).

Burning followed by discing on arable terrain and the immediate establishment of a vigorous grass and legume pasture has enabled suitable control in areas suitable for grazing (Goodchild 1951; Saint-Smith 1964; Bartholomew and Armstrong 1978; Parsons and Cuthbertson 2001). For example, Goodchild (1951) and Bartholomew and Armstrong (1978) recommended the use of green panic (*P. maximum* var. *trichoglume*) or guinea grass (*P. maximum*) and siratro (*Macroptilium atropurpureum*) mixtures. This mixture ensures that season round ground coverage is achieved, siratro increases soil nitrogen fertility, which is important for subsequent grass growth, and both species provide dry material for subsequent burning if necessary. Both Bartholomew and Armstrong (1978) and van Oosterhout (2004) noted that pasture needed to be resown at above-normal rates before rainfall to ensure good establishment. The application of superphosphate fertiliser, or other fertilisers may be necessary for several years along with light grazing management within the first 18 months to allow good pasture establishment (Bartholomew and Armstrong 1978). If burning is continued then it is important to resow pastures after each burn and that livestock are excluded until the pasture is established (Bartholomew and Armstrong 1978).

### Natural ecosystems

Management of *L. camara* in natural ecosystems and conservation areas will require a slightly different approach to the strategies outlined for pasture situations above. Much of the following discussion has been drawn from van Oosterhout (2004). In most cases chemical application is not appropriate and when used care is required to avoid off-target impacts. Cut stump and limited foliar spraying may be useful, as may hand grubbing. Slashing may also be appropriate around forest edges whereas mechanical disturbance is not useful in most situations. For large dense infestations under the canopy where access is restricted, fire and biological control may be the only practical means of management. *Lantana camara* can create hotter fires which may threaten rainforest vegetation and structure making it an inappropriate tool. Fire should not be used to manage *L. camara* in dry vine scrub vegetation which also has a limited tolerance to fire. *Eucalyptus* forests and woodlands are more adapted to fire of varying intensity and frequency such that fire may be used as a tool to promote regrowth management. Any means of management needs to be followed by revegetation, either by natural means from the germination of propagules in the soil or by active replanting after *L. camara* removal. Monitoring bird roosting sites should also continue accompanied by the hand pulling of any seedlings, while disturbance should be minimised. If *L. camara* is providing alternative habitat or stabilising soil then sections rather than entire areas need to be progressively controlled and revegetated.

### Controlling regrowth

*Lantana camara* regrowth is best spot-sprayed in summer and autumn, especially after good rainfall. This is best done when it is vigorously growing and between 30 and 100 cm tall (Parsons and Cuthbertson 2001; QNRM 2004; van Oosterhout 2004). Various herbicides give effective control including 2,4-D amine, 2,4-D amine and picloram mixtures, dichlorprop, glyphosate and picloram. Alternatively, 2,4-D amine or triclopyr applied as a basal bark spray or as a dressing on a cut stump are effective. In addition, fluroxypyr applied to the foliage (Parsons and Cuthbertson 2001) and tebuthiuron applied to the soil at the base of the plant are also effective (Gillett and Wells 1999; Parsons and Cuthbertson 2001). When spot spraying is combined with several years of annual burning, infestations can be reduced to levels where hand removal becomes economically feasible. Follow up management combined with a program of continual monitoring needs to occur not only for *L. camara* but also for other weeds and may be necessary for at least two years (van Oosterhout 2004).

### Identifying the causes of infestation

Finally, it is important to try and identify the cause of the infestations of *L. camara*. For example, weed infestations are often symptomatic of other problems including disturbance, over grazing, inappropriate burning and clearing (van Oosterhout 2004). Reducing the causes of infestations will help reduce the infestations themselves.

## Integrated management of *L. montevidensis*

Although adult plants of *L. montevidensis* are very resilient to fire, drought, mechanical disturbance and some herbicides, an integrated weed management program for *L. montevidensis* involving many of the same principles as outlined above will be successful (O'Donnell 2002). Much of the following discussion has been extracted from O'Donnell *et al*. (1999), O'Donnell and Panetta (2000), Parsons and Cuthbertson (2001) and O'Donnell (2002), unless otherwise noted.

Control of *L. montevidensis* is best achieved by the physical removal of adult plants and the use of herbicides. Small infestations of the weed can be removed by physically digging them up to remove the plants and by cultivation. Subsequent to offset discing, planting competitive pastures composed of grass species such as Indian bluegrass (*Bothriochloa pertusa*) and woolly finger grass (*Digitaria eriantha*) will provide good grass biomass and some suppression of *L. montevidensis* (O'Donnell 2002). Other species such as creeping bluegrass (*Bothriochloa insculpta*) provided good biomass but gave no suppression whereas buffel grass (*Cenchrus ciliaris*) competed effectively with the weed. Fewer *L. montevidensis* plants eventuated when pasture species were sown in combination with the legume wynn cassia (*Chamaecrista rotundifolia*), which 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 germination, seed burial via ploughing should also reduce seedling emergence. Seed viability falls by up to 70 % in the first year of burial and 80 % in the second year.

Where cultivation is not practicable, repeated herbicide applications on actively growing plants in late summer and autumn should be used where necessary. Registered herbicides for the control of this species have been outlined above. Alternatively the native black speargrass *(Heteropogon contortus)* 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.*

Day *et al*. (1999) outlined that while repeated herbicide application on *L. montevidensis* regrowth and the planting of perennial pasture species was a useful means of control, the cost per unit area often made this an unfeasible option. Burning was also ineffective because there was generally inadequate fuel loads to maintain a hot enough fire to kill the roots (Day *et al*. 1999; Parsons and Cuthbertson 2001).

# SOCIAL LIMITATIONS TO CONTROL

## The widespread acceptance of *L. camara*

In the past, the community has widely accepted *L. camara* as being 'part of the landscape' (Clark *et al.* 2004; van Oosterhout 2004). In efforts to increase the motivation for managing this weed, as well as providing information, management tools and directions to assist with management, Clark *et al.* (2004) outlined four needs to ensure that increased management occurs, these being: -

- "a re-evaluation of attitudes to *Lantana* species to ensure renewed diligence;
- improved awareness and exchange of information;
- integration of control methods and prioritisation of actions to achieve better control results; and
- strategically coordinated management to secure on-ground results."

There are a number of factors that have resulted in the widespread acceptance of *L. camara* by the community (Clark *et al.* 2004). These include the large size of infestations confronting land managers, the inaccessibility of many such infestations to conventional methods of management, the confusion about the continued sale of ornamental varieties and the widespread planting of these varieties by gardeners, councils and businesses. The size and inaccessibility of infestations generally reduces the impetus for land managers to both start and continue managing such infestations on an ongoing basis.

## Issues involved with the sale of *Lantana* species

There are a number of issues that arise from the continued sale of *Lantana* varieties. It has been argued that because of the widespread nature of *Lantana* varieties in eastern Australia, the continued sale of these varieties in these areas is likely to have a minor impact on the further spread of the species outside of its current range. This argument can not be sustained on a number of grounds.

Firstly, it is well known that the species *Lantana camara* is composed of a number of genetically variable varieties and that these varieties easily hybridise with one another (Spies 1984 a,b; Spies and du Plessis 1987; Neal 1999; Day *et al.* 2003). Any further additions to the genetic diversity of the species are likely to result in more difficult management in the long term, especially for potential biological and chemical control (Ensbey 2003; Clark *et al.* 2004), but may also increase the adaptability of new hybrids of the species to new environments (A&RMCA&NZ, A&NZE&CCFM 2001). Ensbey (2003) stated this as a reason as to why it was necessary to limit new introductions of *L. camara* to non-invasive varieties.

While the introduction of non-invasive varieties, if enacted, would be helpful, it would not entirely solve the problem. Such non-invasive varieties are still likely to produce a small proportion of viable pollen and seed, adding to the current gene pool in the environment (Neal 1999; QNRM 2004). In addition, these varieties upon crossing with plants in the existing gene pool will result in hybrids that may or may not retain the non-invasive character of one of their parents. It is much safer instead to recommend the use of alternative native plants that offer similar growing and ornamental features (Ensbey 2003), but only if the non-invasive nature of these native species has been well established. This is important because there are a number of examples of native plants from one area of Australia that are invasive in another and thus considered as serious environmental weeds, for example Cootamundra wattle *(Acacia baileyana)* among many other *Acacia* species, as well as sweet pittosporum *(Pittosporum undulatum)* (Bennett and Virtue 2004).

Secondly, the widespread distribution of this species across a number of climatic, ecosystem, rainfall, topographic, elevation and rainfall zones indicates that this species is highly adaptive to a broad range of climatic conditions (Swarbrick *et a*l. 1998; Day *et al*. 2003; van Oosterhout 2004). A number of authors postulate that this species may spread further outside its current range, particularly into the warmer tropical northern Australian coastline areas and perhaps into cooler southern NSW and Vic coastal areas. The intentional sale of this species into these areas is likely to produce further genetic material from which weed populations can establish.

The third issue that arises is that the sale of these varieties is likely to provide for continued spread of the species. Even if *L. camara* has reached the limits of its potential range in NSW, continued introductions will result in the species invading new habitats and increasing in density within this range (Ensbey 2003). This will contribute to increased management needed for the control of the species.

The fourth issue is uniformity of legislation. For example, if *Lantana* species are not removed from sale in every state then trade and movement of the species from states that have the species for sale can still occur into areas where they are restricted from sale. This will result in continued spread of the species.

The fifth issue is one of perception. While the varieties sold may not be 'weedy' varieties of *L. camara* or *L. montevidensis,* land managers are unlikely to either recognise this or, if they do, to place this knowledge aside when they consider management of infestations of *L. camara* on their land. Rather, land managers will perceive that there is little point to managing *Lantana* species if gardeners, councils and business can plant it, thereby spreading plants to the land managers' lands when various animals eat and spread it. Again, there is a perceived conflict of interest if councils continue to plant *Lantana* varieties and then enforce the management of weedy varieties on private or public lands. This conflict of interest extends to councils permitting the sale of *Lantana* varieties to the wider community while enforcing control on other parts of the community.

Even if land managers recognise that there are some differences between the varieties for sale (despite the fact that these varieties will result in some spread and gene flow) and those that are weedy, they are likely to set this knowledge aside. This may be because they are not convinced of the truths of these claims or they conveniently ignore them because they do not wish to spend the money to control existing infestations. These actions may provide suitable excuses to land holders that claim a potential conflict of interest with local government (as outlined above).

**Figure 13.**
*Purple flowering variety of the ornamental* Lantana montevidensis *planted in a median strip, Griffith (south western NSW, September 2005) (Source: S. Johnson, NSW DPI).*

## Constraints to managing *L. camara*

After surveying 1021 land holders and managers in 2003, van Oosterhout (2004) indicated that time and cost were the two largest factors constraining *L. camara* control. These factors were followed by the difficulty in accessing *L. camara* infestations particularly due to the terrain. Economies of scale were achieved on larger properties such that the average cost per hectare on properties smaller than 100 ha was $31.70, decreasing to $8.40/ha for properties 500-1000 ha and $0.86 for properties larger than 10,000 ha. It was encouraging to note that knowledge of potential management options was considered a very minor factor limiting control and that the vast majority of respondents had ongoing follow up at intervals. In general however, land holders and managers needed to trial more integrated management strategies instead of relying on a single control method such as a manual, mechanical or chemical removal.

## Motivating land managers to undertake management

In considering how to motivate all landholders to undertake management, Clark *et al.* (2004) noted that there were a number of positive and negative factors influencing the management of this species and summarised these under six broad categories.

- Available information. Land managers may be more motivated to manage *Lantana* species when they have sound information available to them. This information would include best management practice and an integrated program of control combining management and monitoring. Such information should help prevent single control methods and ad-hoc management which are often ineffective.
- Resource availability. Various resources including time, money, equipment and personnel were needed to manage this weed. Positive motivation may arise from favourable cost/benefit ratios in grazing systems, incentives from local government for landholders to undertake control and the availability of public funding to preserve important areas. Few resources are devoted to unused and vacant land creating little active control and a lack of motivation for management.
- Access. Management is easier in readily accessible areas whereas it may be hampered in relatively inaccessible areas such as steep hillsides or other dense areas.
- Active land management. Agricultural land and natural areas that are actively managed are likely to be actively managed for *Lantana* species because removal will increase productivity, conservation and biodiversity values. In contrast, neglected areas are likely to attract lesser attention.
- Committed environmental attitude and priority. The management of *Lantana* species is likely to arise from those who have an increased environmental awareness, for example, land managers who wish to farm in a sustainable way and land holders and environmental volunteers who are trying to restore blocks of land to a more 'natural' species composition. The priorities of these people will result in increased control of environmental weeds adding to the conservation value and community perception of these lands.
- Legislation and compliance. While legislation can be used as a powerful tool to encourage good stewardship of land, it is important to encourage land managers to voluntarily abide by regulations, and on the other hand for government bodies to enforce the legislation where it is appropriate. Good stewardship of the land may not be practiced without enforced compliance.

# RECOMMENDATIONS

Recommendations from this document have been made to the Noxious Weeds Advisory Committee. These are outlined in Appendix 2.

# FURTHER RESEARCH NEEDS

There are a number of further research needs. These have been briefly mentioned below.

- An accurate assessment of the number of varieties of *L. camara* and *L. montevidensis* in Australia, their identification and possible toxicities combined with accurate information on the best management of each of these varieties. This may partially involve further DNA analysis via RAPD techniques.
- The rate at which genetic flow from existing ornamental varieties of *Lantana* species occurs into naturalised populations. This may occur via spread of pollen, seed or vegetative material. This has important implications in the continued management of weedy varieties of both *L. camara* and *L. montevidensis*.
- Further quantification of the factors responsible for *L. camara* and *L. montevidensis* germination, seedling recruitment and mortality. In particular, no specific studies have determined the influence of fruit pulp on the germination of *L. camara* seeds while further studies on the seed bank dynamics of this species are needed. These studies are important to accurately place a timeframe on ongoing monitoring once the removal of infestations has occurred.
- Further studies into the breeding system of *Lantana* species, in particular, the ability of *L. camara* to self pollinate.
- Studies regarding the role of birds in dispersing *Lantana* seeds are needed, in particular behaviour and feeding preferences and the distances different birds travel after eating.
- An assessment of the ability of lateral shoots of *L. camara* to produce new shoots once broken or damaged in the soil. Mechanical or hand removal produces a high number of broken lateral roots and some evidence suggests that these roots may give rise to new plants under suitable growing conditions.
- A better understanding of the factors that result in occasional branches of *L. camara* reverting back to parental varieties via somatic mutation. Such changes have important implications in successful biological control and toxicity management.
- Investigations into the ecological limitations of both *Lantana* species. In particular, studies should investigate the influence of low temperatures/frosts and soil moisture as there is some disagreement about the importance of these factors as they relate to the current distribution of both species.
- Quantification of the factors responsible for the regeneration of rainforest and other forest species through *Lantana* infestations. An understanding of these factors will be important to ensure revegetation can occur.
- Accurate assessments on the impact of *Lantana* infestations on threatened plant and animal species. The potential of *L. camara* to provide alternative food and shelter to insects and other animals requires further study.
- More accurate assessment of the impact of *L. camara* on fire regimes in various natural ecosystems. Given that fire is a useful tool in some situations this research needs to focus on the effects 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 livestock on the control of both species.
- The continued assessment of potential biological control agents against both *Lantana* species.
- Further assessment on the toxicity, or otherwise of *L. montevidensis*.
- Further proof of allelopathic affects of *L. camara* on other plants under field conditions.
- A more up-to-date assessment of the economic impact of both *L. camara* and *L. montevidensis* on primary production and the environment in Australia.
- Collation of existing information and research on alternative ornamental species, growth habits and requirements including likely sources of such planting material.

# INFORMATION REQUIRED FROM CONSULTATION

The impacts of the recommendations outlined in this report need to be evaluated via consultation with various stakeholders. In particular this consultation needs to evaluate the following: -

- an accurate assessment of the economic impact on the removal from sale of all *Lantana* species to the nursery industry and the community;
- the affects of both *Lantana* species on pastures and animal production. Impacts such as reduction in pasture biomass and species abundance, the impacts of *Lantana* toxicity on grazing animals and the impedance on livestock and husbandry movements need to be accurately assessed;
- the affects of both *Lantana* species on the integrity of natural ecosystems with particular reference to flora and fauna biodiversity and abundance, conservation and amenity values and feral animal control;
- the impact of *L. camara* on commercial forestry and other plantation crops including banana, citrus, pineapple, and various fruit and nut crops in Australia;
- the costs incurred by *Lantana* invasion into railway, electricity and road corridors;
- information on the toxicity or otherwise medicinal value of *Lantana* species on human beings. The extent that *L. camara* is used as a medicinal oil source in Australia also needs to be explored. A ban on the sale of *Lantana* material may also result in a ban on the production processes and end products associated with essential oils from *Lantana* species unless an exemption is made for these processes and products; and
- the intent of local government to continue to manage *L. camara* and undertake control of *L. montevidensis*.

# CONCLUSIONS

There are two naturalised species of *Lantana* in NSW, *L. camara* (lantana) and *L. montevidensis* (creeping lantana). Both species have a number of ornamental and weedy varieties.

*Lantana camara* is a multi-branched, perennial shrub that has the ability to form dense thickets. If damaged, shoots regrow vigorously from the plant crown and from damaged stems. The species may also have the ability to reshoot from broken lateral roots. In contrast *L. montevidensis* is a creeping perennial species rooting at the stem nodes and producing low but dense thickets. This species has a large lignified taproot that allows the plant to resist shoot damage. Ornamental varieties may produce fewer fruit than weedy varieties. The thicket forming nature of these species makes management of infestations difficult. The apparent lower fecundity of ornamental varieties may reduce their weed potential in some situations.

The species *Lantana camara* is a variable polyploid species aggregate composed of at least 29 different varieties in Australia. Existing varieties freely hybridise resulting in difficulty in correctly ascertaining their origin and hence potential biological control agents. Although some ornamental varieties are supposedly sterile, recent studies in South Africa and Australia indicate that this is not the case.

*Lantana camara* varieties vary in terms of their ploidy levels, plant morphology, response to environmental conditions and natural enemies, chemical composition and toxicity and their response to herbicides. The level of differentiation in *L. camara* varieties also makes it difficult to promote consistent weed management messages. Although it is unclear how many varieties of *L. montevidensis* are present in Australia, studies indicate differences exist in ploidy levels and plant morphology. These differences may also be important in the management of varieties of this species. Studies indicate that different *Lantana* species previously separated by geography hybridise freely and that *L. camara* x *L. montevidensis* hybrids are grown as garden plants.

*Lantana camara* was first introduced into Australia in 1841. The species has spread extensively throughout the eastern coastal areas of NSW and Qld in tropical, subtropical and warm temperate areas. Smaller infestations can be found in the NT, WA, SA and Vic. This indicates that *L. camara* has a wide climatic range in Australia, although spread of this species in areas receiving less than 650 mm of mean annual rainfall has not yet occurred. The ecological limitations responsible for the distribution of this species in Australia are, as yet, poorly understood. There is some disagreement as to whether *L. camara* has reached the limit of its geographic spread in Australia. Further invasion of currently uninfested areas is also still occurring. Although *L. camara* is weedy in over 60 countries, ornamental varieties can be found throughout the world.

*Lantana montevidensis* appears to have been introduced into Australia in 1851, was recorded as weedy in south eastern Qld from the 1880's and has since become a significant problem in subcoastal and coastal areas of Qld. The species was first recorded as a weed in NSW in the 1950's but has not spread significantly in NSW as yet, despite the climatic similarities of NSW with Qld. Small infestations can be found in the NT, Vic and WA. It is likely that *L. montevidensis* will spread beyond its present range in Australia, particularly in coastal and western areas of NSW and Qld, and perhaps into cooler areas in southern NSW and Vic. While *L. montevidensis* is widely planted as an ornamental around the world, it has only been recorded as a weed in Australia, and perhaps Florida. Both nursery stock and seeds of *Lantana* species were permitted import into Australia until late 2006 potentially increasing the genetic diversity of both species.

Although germination of both *Lantana* species occurs throughout the year, seedlings are more likely to establish under high soil moisture, temperature and light conditions, particularly after disturbance. Seedling growth rates are slow and plants generally do not flower in their first year of growth with growth slowed or stopped during winter. The seedling mortality of *L. montevidensis* may be high during this period. The long juvenile period of both species allows for considerable management opportunities.

After spring regrowth, *L. camara* plants flower and set fruit all year round in tropical and subtropical areas, and throughout spring, summer and autumn in more temperate areas, particularly in response to rainfall. Flowering and fruit set in *L. montevidensis* also tends to occur year round. In excess of 12,000 fruit may be produced on large *L. camara* plants while over 2,500 fruit/$m^2$ are produced on *L. montevidensis* plants. Reductions in seed viability of up to 50 % in *L. camara* and 80 % in *L. montevidensis* may occur within two years of seed burial. Plants of both species are perennial with rapid shoot growth occurring after the removal of shoots by fire, herbicide, physical removal, drought or frost. New plants or canes appear to be produced from plant crowns, from intact or damaged lateral roots, and from intact and cut stem material.

Dispersal of both species occurs via a number of means. A large number of native and exotic bird species spread seed, as well as a wide range of feral animals and livestock. Aside from deliberate spread via the trade of ornamental varieties, spread may also occur in water, in soil, on machinery, on people and vegetatively on discarded garden waste. The wide variety of dispersal mechanisms indicates that spread of these species is difficult to contain.

Twenty year old estimates indicate that infestations of *L. camara* covered in excess of 4 million hectares and cost primary production in excess of $10 million/annum (a more recent estimate). The cost of *L. montevidensis* infestations has not been estimated but hundreds of thousands of hectares are affected in Qld.

Both *Lantana* species over run pasture ecosystems, shading out more desirable species and reduce pasture production with infestations reducing access for people and livestock. All but three varieties of *L. camara* are poisonous to grazing livestock and other animals, producing a range of symptoms and often death, for example in up to 1500 cattle per annum in Qld. There is some disagreement as to whether *L. montevidensis* is toxic to livestock. The considerable losses caused to pasture based primary production indicate there is considerable need to continue to manage these species.

*Lantana camara* threatens a large number of ecosystems including frontal dune and nearby community types such as mangroves, sedge and heath lands, woodlands associated with melaleucas, banksias and casuarinas, as well open woodlands, tropical, subtropical, warm temperate and dry rainforests and wet and dry sclerophyll forest communities. There is little evidence to suggest that *L. camara* invades forest ecosystems in the absence of disturbance events such as of the soil, increased light and fire intensity levels. Infestations have the potential to block or slow forest succession, displace native species and reduce biodiversity. There is increasing evidence that *L. camara* has a negative impact on threatened animal and plant species. *Lantana camara* also alters fire regimes, commonly allowing more intense fires to penetrate into rainforests causing extensive and perhaps irreversible damage. Ecotourism, recreational and aesthetic values are affected by *L. camara* invasions. *Lantana montevidensis* is also a weed of woodland, forest and mangrove communities where it displaces native vegetation and reduces plant and animal biodiversity. Although the environmental impacts of *Lantana* species are not well quantified, they represent a serious concern and warrant management in affected ecosystems.

*Lantana camara* is also a major weed of many other crops including forestry, particularly pine, hardwood and rainforest species plantations, and plantations and orchard crops. It is a weed of roadway, railway and utility corridors, provides refugia for pest animals and other plant pathogens and may be allelopathic. Plant material may also be poisonous to humans if ingested but may have some medicinal uses in other instances.

Both *Lantana* species are widely planted as ornamental and hedge plants and are popular in landscape design, public and private gardens, in parks, on roundabouts, in median strips, on roadside cuttings and beside footpaths because they are colourful, require little maintenance and have some drought tolerance. Alternative beneficial uses for *Lantana* species include the harvest of essential oils, use as firewood, the provision of alternative or replacement habitats for animals and in the prevention of erosion.

*Lantana camara* is a Weed of National Significance. One of the strategies to reduce the impacts of these weeds is to ban the sale and distribution of these species. All states and territories within Australia have banned the trade and distribution of this species. Only Qld and the NT have restrictions on the sale and trade of *L. montevidensis*. The continued sale of ornamental varieties of either species has the potential to add genetic diversity to the weedy varieties already present in Australia. It is likely that further genetic diversity will help both species to expand their distribution into new environments and to make control using herbicides and biological agents far more difficult. The negative impacts of removing these species from sale are likely to be limited because alternative species which are hardy, low growing, require low maintenance levels, are drought tolerant and similarly colourful are available. One estimate indicated that the total market value of *Lantana* species in Qld was $75,000/annum.

Various varieties of *L. camara* have been declared noxious in NSW mid and north coastal local government control areas and in Sydney. Declarations do not generally exist in central and southern coastal areas. A regional control plan for the south coast includes containment, buffer and management plans to prevent the spread of *L. camara* further south.

Although the management of both species of *Lantana* is problematic, *L. montevidensis* is generally more difficult to control. The major limiting factors for the control of both species are the size, accessibility and costs of ongoing control of infestations and the low land values that these infestations occur on. These factors often severally limit control directed towards these species. An integrated weed management strategy including the use of many of the following strategies is likely to be successful however.

Prevention of the movement of plants into clean areas via various hygiene practices and a ban on the sale of the species are effective means in preventing outbreaks of either species. A number of effective herbicides are currently registered for the control of both species. These herbicides are either applied to actively growing foliage (including regrowth) or as cut stump or basal applications. Of the foliar herbicides, the following decreasing order of effectiveness is generally correct: fluroxypyr; glyphosate; picloram mixtures; dichlorprop; metsulfuron-methyl; and 2,4-D amine. Climatic and varietal differences may affect herbicide efficacy. Ongoing herbicide applications on regrowth material are needed. It is important to consider off-target effects with some herbicide applications.

Fire is another useful management tool even though a number of factors affecting its performance are not well understood. Fire is useful in clearing dense thickets of *L. camara* and in killing seeds and seedlings of *L. montevidensis*. Fire is also particularly useful when used prior to, or as a follow up to chemical or mechanical clearing. Again, off-target effects need to be considered.

Mechanical clearing using a range of machinery including bulldozers, slashers, stick rakers or with chain pulling equipment is also effective against *L. camara*. Regrowth needs to be controlled with tools such as herbicide applications or with hand pulling. Cultivation, generally disc ploughing followed by the planting of competitive pastures is also useful in a number of situations against both *Lantana* species. There are various methods of removing *L. camara* by hand or treating plants with flame weeding. Both revegetation and proper grazing management are important tools in preventing the reinvasion of both species. Although 31 different biological control agents have been released against *Lantana* species in Australia, these have provided, at best, only minor or seasonal control of the species.

Recommendations arising from this document have been made to the Noxious Weeds Advisory Committee and are contained in Appendix 2. These recommendations consider all *Lantana* species for a number of reasons. The most important of these is that the *L. camara* is a species aggregate and many weedy and ornamental varieties of it exist. The second reason is that it is important to try and reduce the current size of the *L. montevidensis* problem while infestations in NSW are still small. The potential for movement of genetic material from varieties of ornamental *L. camara* or *L. camara* x *L. montevidensis* hybrids is possible if weedy varieties of *L. camara* co-occur. In the same way, genetic movement is possible if ornamental varieties of *L. montevidensis* or *L. camara* x *L. montevidensis* hybrids co-occur with weedy varieties of *L. montevidensis*. The listing of all *Lantana* species also covers the possibility of continued trade of varieties of any *Lantana* species if, at the point of trade or movement, the species name is either not used or not known.

A variety of further research needs were outlined as were information requirements from consultation.

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**Figure 14**

*A flowering and fruiting plant of the common pink variety of* Lantana camara*, near Copmanhurst (NSW north coast, October 2005) (Source: S. Johnson, NSW DPI).*

**Figure 15**

*Vegetative naturalised plants of* Lantana montevidensis *(mid ground), near Oxley Lookout, Tamworth (April 2006) (Source: S. Johnson, NSW DPI).*

# APPENDICES

## APPENDIX 1

### Declarations of *Lantana* species across Australia

### New South Wales

*Lantana camara* is a declared weed under the *Noxious Weeds Act 1993* in NSW. Prior to 2006, two declarations applied to weedy pink and red flowering varieties. These were the W2 Noxious weed declaration which meant that the weed was to be fully and continuously suppressed and destroyed and a W3 Noxious weed declaration which meant that the weed was to be prevented from spreading and its numbers and distribution reduced. The following information was drawn from New South Wales Department of Primary Industries (2005).

The pink and red flowered variety of *L. camara* were declared as W2 weeds in each of the following control areas: - Ashfield; Auburn; Bankstown; Botany; Burwood; Campbelltown; Canada Bay; Canterbury; Cessnock; Fairfield; Holroyd; Hornsby; Hunters Hill; Hurstville; Kogarah; Ku-ring-gai; Lane Cove; Leichhardt; Liverpool; Manly; Marrickville; Mosman; North Sydney; Parramatta; Pittwater; Randwick; Rockdale; Ryde; Strathfield; Sutherland; Sydney; Warringah; Waverley; Willoughby; and Woollahra;

The pink flowering variety of *L. camara* was declared as a W2 weed in the Eurobodalla local control area.

The red flowering variety of *L. camara* was declared as a W2 weed in the following control areas: - Clarence Valley (W2 and W3 declarations applied because this area included the former areas of Copmanhurst, Grafton, Maclean and Pristine Waters, areas which had differing declarations); and Greater Taree, and a W3 weed in the following areas: - Bellingen; Coffs Harbour; Hastings; Kempsey; and Nambucca.

All *Lantana* species were declared as W2 weeds on Lord Howe Island.

All coloured varieties of *L. camara* except the pink flowering variety were declared as W3 weeds in the Far North Coast County Council (included the former areas of Ballina, Byron, Kyogle, Lismore, Richmond valley and Tweed).

### Queensland

All *Lantana* species are declared Class 3 pests in Qld under the *Land Protection (Pest and Stock Route Management) Act 2002*. Class 3 pests, in this case weeds, are defined as weeds that have established in Qld 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. The sale of all *Lantana* species became illegal in November 2003. 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 reserves, but only if these are free from the weed.

Certain local government areas have also declared both weeds under local law requiring control in areas not in or adjacent to environmentally significant areas: - Bowen; Cardwell; Charters Towers; Dalby; Eacham; Gayndah; Johnstone; Kilkivan; Kingaroy; Maroochy; Maryborough; Mirani; Murgon; Pittsworth; Rockhampton; Sarina; Tara; and Townsville.

### Northern Territory

Both *L. camara* and *L. montevidensis* are declared in the NT under the *Weeds Management Act 2001* but under differing levels. These are a Class B Noxious weed (regional declaration) that growth and spread are controlled outside town areas and as a Class C Noxious weed which is not to be introduced into the NT. Declared weeds are restricted from sale in the NT.

### South Australia

*Lantana camara* has been declared as a Class 11 - category 3 plant under the *Natural Resource Management Act 2004*. This declaration means that the species is restricted from sale but that control is not required.

### Tasmania

*Lantana camara* has been prohibited from import and sale in Tasmania under the *Weed Management Act 1999*. The species may not be otherwise supplied. Land holders may be required to control the species on their property if infestations are found.

## Western Australia

*Lantana camara* has been declared in WA under the *Agricultural and Related Resources Protection Act 1976* and the *Plant Diseases Act 1914*. This declaration has resulted in a ban on the import and trade of this species. The declaration does not include *L. montevidensis*.

## Victoria

*Lantana camara* has been declared a noxious weed in Vic under the *Catchment and Land Protection Act 1994*. The trade and distribution of the species is restricted under this declaration.

## Australian Capital Territory

*Lantana camara* has been declared a prohibited pest plant in the ACT under the *Pest Plants and Animals Act 2005*. The species is not able to be supplied or propagated as a result.

## Commonwealth legislation

All *Lantana* species and material including nursery stock, plant parts and seeds were prohibited entry to Australia under the *Quarantine Proclamation 1998* from late 2006.

# APPENDIX 2

## Recommendations for declarations of *Lantana* species in NSW

The recommendations for declarations of *Lantana* species in NSW that arise from this review have been outlined below (see also Figure A1 overleaf). These recommendations were made to the Noxious Weeds Advisory Committee for consideration in Weed Control Order Number 19 of the *Noxious Weeds Act 1993*.

It is recommended that all *Lantana* species be declared as Class 3, Class 4 and Class 5 noxious weeds in NSW. These declarations should apply to local government control areas as follows: -

- a Class 3 declaration in the local government control areas of Bega and Eurobodalla to support management efforts to reduce *Lantana* species in the proposed Southern containment zone in NSW (Harding 2005). A Class 3 declaration is also appropriate for Lord Howe Island to support control efforts;
- a Class 4 declaration in all other local government control areas where either variety of *L. camara* has been declared prior to 2006. These declarations would include the local government control areas of Ashfield; Auburn; Bankstown; Bellingen; Botany; Burwood; Campbelltown; Canada Bay; Canterbury; Cessnock; Clarence Valley; Coffs Harbour; Fairfield; Far North Coast; Greater Taree; Holroyd; Hornsby; Hunters Hill; Hurstville; Kempsey; Kiama; Kogarah; Ku-ring-gai; Lane Cove; Leichhardt; Liverpool; Manly; Marrickville; Mosman; Nambucca; North Sydney; Parramatta; Pittwater; Port Macquarie-Hastings; Randwick; Rockdale; Ryde; Shellharbour; Shoalhaven; South Sydney; Strathfield; Sutherland; Sydney; Warringah; Waverley; Willoughby; Wollongong; and Woollahra. These declarations would ensure that local government areas could continue to manage and reduce the incidence of this species so that further spread and economic impacts are reduced. Management plans need to include an integrated program of management methods as outlined in this document for the varieties of *L. camara* or *L. montevidensis* present; and
- a Class 5 declaration in all local government areas in NSW to prevent trade and distribution of *Lantana* species will prevent the further movement of genetic material into the environment and support the national ban on the WoNS species.

A Class 3 declaration is appropriate for "plants that pose a serious threat to primary production or the environment of an area to which the order applies, are not widely distributed in the area and are likely to spread in the area or to another area".

A Class 4 declaration is appropriate for "plants that pose a threat to primary production, the environment or human health, are widely distributed in the area to which the order applies and are likely to spread in the area or to another area".

A Class 5 declaration is appropriate for "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".

There are a number of operational matters that need to accompany these declarations as follows: -

- the development of regional *Lantana* weed management plans encompassing any local government control areas that have any weedy *Lantana* species outside of ornamental, landscape and/or garden plantings where the species are not declared under Order 19 of the *Noxious Weeds Act 1993;*
- the ongoing surveillance and monitoring of any *Lantana* species in all other local government control areas of NSW (where there are no outbreaks of the weed), whether these areas have any *Lantana* species as ornamental, landscape and/or garden plantings or not; and
- the continued prohibition on the sale or movement of plants, seeds or other plant material of *Lantana* species.

Consideration of a Class 2 declaration for *Lantana* species may be considered for south coast local government control areas after the implementation of the South Coast Regional Lantana Management Plan (Harding 2005) or to Lord Howe Island to support eradication attempts, if appropriate.

Although desirable, it is not feasible to require all local government control areas to remove all amenity plantings of *Lantana* material. A state wide local government and public education campaign should encourage relevant stakeholders to remove such plantings and replace them with alternative plant species that are indigenous to the area. Alternatively, a campaign similar to that encouraged by the Orange city council for the removal of *Ligustrum* (privet) may be appropriate where ever *Lantana* species have been planted, that is, people trading the removed weed for new tube stock material of more desirable ornamental species.

## Postscript

Declarations arising from the Noxious Weeds Advisory Committees recommendations can be found in Weed Control Order Number 19 of the *Noxious Weeds Act 1993*, published in the New South Wales Government Gazette Number 166, pp. 11671-11890.

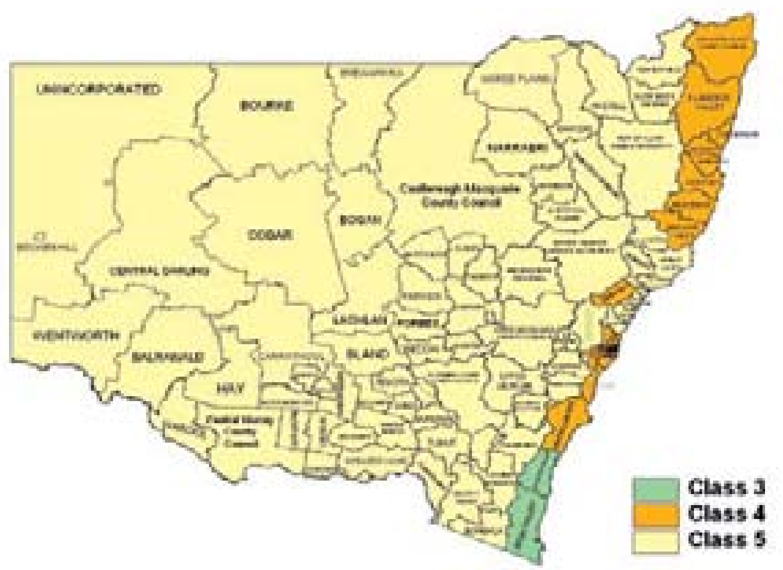


**Figure A1.**

*Declarations of* Lantana *species in mainland NSW recommended to the Noxious Weeds Advisory Committee for consideration in Weed Control Order Number 19 of the* Noxious Weeds Act 1993. Lantana *species on Lord Howe Island are recommended to be declared as Class 3 weeds. Declaration in Class 3 and 4 areas also includes declaration at Class 5* (*Source: A. Maguire, NSW DPI, used with permission*).

NSW DEPARTMENT OF
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