LIPPIA

Lippia

(Phyla canescens) in Queensland

PEST STATUS REVIEW SERIES – LAND PROTECTION

by
Catherine Leigh
C.S. Walton

Queensland Government
Natural Resources and Mines

Acknowledgments

The authors wish to thank the many people who provided information for this assessment, especially the Land Protection Officers from across the state who replied to requests for information on the species. Greg Dight, Gary Zerner, Jodie Garton are thanked for attending and coordinating field trips to view the species. Figures 1, 2 and 3 were provided courtesy of the State Herbarium of South Australia. Moya Calvert prepared the splined distribution maps, Figures 4, 5 and 6. Marc Bryant is thanked for developing the soil /climate prediction overlay system used for Figure 6.

Photographic credits:
Natural Resources, Mines and Energy staff

Editing, design and proofreading:

Web and Publishing Services
Department of Natural Resources, Mines and Energy

QNRME04184

ISBN 1 920920 80 3

July 2004

Land Protection
Department of Natural Resources, Mines and Energy
GPO Box 2454, Brisbane Q 4000

#16913 07/04

Contents

1. Summary

Lippia is one of two species in the genus *Phyla* present in Australia. It is known to have been in this country from the 1920s, introduced as a lawn ornamental. It has established a good foothold in the floodplains of south-east Australia, including the Murray–Darling system, and may have the potential to grow in more tropical areas of Queensland given the right soil and moisture availability. Lippia is an environmental and economic weed in some parts of Queensland and is already a significant problem in New South Wales.

Lippia is a prostrate (growing along the ground) perennial plant that spreads both vegetatively and by seed, enabling it to spread to vast areas of land. Vegetative material breaks off the main plant during flooding events and can remain dormant until suitable environmental conditions present. It appears to be particularly adapted to floodplain clay soils but has been found occurring on lighter soils and in non-flood-prone environments.

The spreading nature and deep rooting system of lippia are some of the main concerns with this plant. Both characteristics are associated with stream bank and soil erosion, structural damage to roads, and high control costs. Lippia probably imposes its most long-reaching impact on primary production in grazing country. It appears to be either unpalatable to stock and/or too short to be easily consumed. Stock avoidance thus contributes to its spread as they may more heavily graze other areas creating more bare areas. Reduced stocking rates and productivity loss on grazing land, as well as reduced land values, are all associated with lippia infestations.

Control of lippia involves long-term commitment and integrated management practices aimed at both reducing bare soil and increasing competition by other plants. A combination of pasture improvement, herbicide use and grazing management appears to be the best approach to control currently available. Whether such commitment and monitoring can be achieved in all areas and by all landholders is currently questionable. It may also be economically unfeasible at some sites.

There is much concern over lippia in south-east Queensland among local governments and landholders. It is currently undeclared as a weed in the State of Queensland. Further research into methods of control and extension of management practices may help contain the spread of lippia throughout the state. Eradication is unfeasible at this point, but controls on sale and awareness of control methods is possible.

2. Taxonomic status

Lippia, *Phyla canescens* (Kunth) Greene (1899), is a member of the family Verbenaceae. This family contains about 75 genera with about 3000 species worldwide, mainly in tropical and subtropical regions. Australia has 17 genera of Verbenaceae with about 16 species occurring in all states. Other weed species, such as creeping and common lantana (*Lantana montevidensis* and *L. camara*), badhara bush (*Gmelina asiatica*), snakeweeds (*Stachytarpheta* spp.) and Maynes pest (*Verbena tenuisecta*) are also members of the family Verbenaceae. There are eleven species in the genus *Phyla* (Mabberley 1997).

Members of the genus *Phyla* in Australia underwent a full taxonomic revision by the South Australian Herbarium (Munir 1993) after many years of attempted revision. Following this revision, there are now two distinct species of the genus recognised as occurring in Australia. These are *P. canescens* (common name: lippia) and *P. nodiflora* (common name: phyla weed). The two species have historically been considered synonyms. In confirmation of this, a study conducted in 1987 isolated and identified certain flavonoids, flavone aglycones and flavone sulphates in the aerial parts of *Lippia nodiflora* (known now as *Phyla nodiflora*) (Tomas-Barberan et al. 1987). Analysis of *L. canescens* (*P. canescens*) showed a very similar flavonoid pattern to that of *P. nodiflora*, and it was concluded that this offered support for the close morphological relationship between the two species.

According to Munir, the species are now separated on the basis of their different environmental requirements in terms of climatic and soil type adaptations as well as their morphology. Munir also notes that the plant exhibits a number of variable forms (differently sized leaves and other features) in the field. This could blur the difference between the two species in Queensland and raises questions over the validity of the split. A number of taxonomic characters are provided below to differentiate the two species, and this document will treat the species as separate in accordance with the taxonomic revision. The authors of this report consider, however, that genetic studies are required to confirm that these species deserve to be separated. Taxonomic studies could also confirm the native origin of *Phyla canescens,* if it is a separate species.

Many of the reports prior to 1993 of lippia in Australia are very likely to be about *P. canescens*, rather than *P. nodiflora,* as stated in the literature of the time (Lucy et al. 1995; S Cshures 2003, pers. comm. January). In fact, Munir (1993) states that all prior recordings of *P. nodiflora* specimens for South Australia and Victoria are now recognised as *P. canescens*. Therefore, any information regarding lippia prior to and surrounding the 1993 taxonomic revision must be interpreted in light of the current taxonomic classification. There may be overlap in the habitat of these two species. The species have been recorded to occur together at sites in the New South Wales central coast, Tasmania and Western Australia.

Synonyms of *P. canescens* include: *Lippia canescens* Kunth; *L. filiformis* Schrad.; *L. nodiflora* (auct. non) (L.) Michaux: Ewart; *L. nodiflora* (L.) Michaux f. *canescens* (Kunth) Kuntze; *L. nodiflora* (L.) Michaux var. *rose*a (Don) Macbr.; *L. nodiflora* var. *repens* auct. non (Bertol.) Schauer: Ewart.; *L. nodiflora* var. *sarmentosa* auct. non (Willd.) Schauer: Ewart.; *L. repens* Spreng.; *L. uncinuligera* Nees ex Walp.; *Phyla nodiflora* (auct. non) (L.) Greene: sensu Bailey.; *P. nodiflora* (L.) Greene var. *canescens* (Kunth) Moldenke.; *P. nodiflora* var. *pusilla* (Briq.) Moldenke.; *P. nodiflora* var. *rose*a (Don) Moldenke.; *Zapania canescens* (Kunth) Gilbert. and *Z. nodiflora* (L.) Lam. var. *rosea* Don. (Munir 1993; PNP 1999; Randall 2002; USDA 2003).

The various common names of this species include lippia, carpet weed, Condamine couch, Condamine curse, fog fruit, frog fruit, mat grass and no-mow grass.

2.1 Description

Lippia is a fast-growing, mat-forming and prostrate perennial plant. When in competition with other species, it can grow to a height of 20–30 cm, and dominate other plants. Once dominance is established, lippia tends to become more prostrate and lower growing. Its life form is described as a running herb (Lazarides et al. 1997) and an aquatic herb (Batianoff & Butler 2002), that is, 'one that tends to inhabit wet areas' (D Butler 2003, pers. comm. February).

Stems of lippia are green to purple in colour when young and can become somewhat grey and woody with age. Young stems are 2–3 mm thick and can be between 30–95 cm long. Roots are produced from leaf axils along stems and consist of a central taproot, usually 50–60 cm in length, but thought to extend up to 2 m (NWWCC 2002). An extensive fibrous root system extends from the taproot. Lippia also produces fibrous roots from some stem nodes.

Leaves arise in pairs at stem nodes and are rounded (10–20 mm long and 3–7 mm wide), entire or bluntly toothed at the tip (Figure 3), and narrow towards the petiole (2–5 mm) at the leaf base (Munir 1993). Leaves can be somewhat canescent, that is, having a greyish-green appearance due to a covering of fine hairs on their surface (hence the botanical name) (Figure 1).

White to purple flowers are produced in heads (10 mm in diameter) on long peduncles (15–45 mm) arising from leaf axils. As they mature, individual flowers become tubular at their bases, ending in a 2-lipped calyx and surrounded by longer broad overlapping bracts (McCosker 1994). The lower lip (2-lobed and yellow towards the base) is twice as long as the upper lip (3-lobed) (McCosker 1994). Dehiscent fruits (1–1.5 mm in diameter) release two tiny brown, oval, flattened seeds at maturity (Lucy et al. 1995). Seeds are barely visible to the naked eye.

Lippia has a C_3 photosynthetic pathway (Veeranjaneyulu & Das 1984), enabling it to perform well in temperate areas. It has the ability to remain dormant when moisture reserves become depleted, and can withstand long dry periods. It can also regrow quickly after rain events, allowing it to compete with other species.

2.2 Distinguishing characters

The use of different common names, variation in leaf shape and flower colour within the genus *Phyla* has caused confusion relating to the knowledge of lippia in Australia. This confusion, especially regarding the information on lippia's exact distribution, has been recognised in the literature of other countries as far back as 1972 (Tutin et al. 1972). In Australia, distributional distinctions of the two species are now used to distinguish them from one another. The major occurrences of *P. nodiflora* are in the higher rainfall, more humid coastal regions, and the species appears to be adapted to lighter, sandy soils. *P. canescens* is found in the lower, more temperate regions of Australia and appears well adapted to heavier clay soils, particularly in floodplain environments (Lucy et al. 1995).

According to Munir, *P. canescens* may be distinguished from *P. nodiflora* var. *nodiflora* by its canescent stems and leaves, and blunt short teeth on its leaf tips (figures 1 and 2). The leaf serration and bracts are also noted to differ (Figure 3). These characters accepted by the authors of this assessment as differentiating the two species.

Stanley & Ross (1986) record only one species of *Phyla* in Australia with two varieties: *P. nodiflora* var. *longifolia* and *P. nodiflora* var. *nodiflora*. It appears that the *nodiflora* variety may be the currently acknowledged *P. canescens*, as Stanley and Ross (1986) indicate it occurs on clay soils away from the coast. However, this is not confirmed, as Munir (1993) recognises this variety as separate to *P. canescens*. Stanley and Ross (1986) do indicate that the observable difference between these two plants is in leaf length, which is less than 15 mm for the *nodiflora* variety (possibly lippia) and over 15 mm for the *longifolia* variety (recognised as a long-leaved form of *P. nodiflora* by Munir).

Infestations of lippia around the Condamine River near Warwick, south-east Queensland, display leaf lengths between 5 and 20 mm, indicating that this weedy species is *P. canescens*. Greg Dight, Pest Management Officer, Warwick Shire Council, has observed a similar but more robust-looking species growing in coastal situations at Caloundra, south-east Queensland, with leaf lengths well over 15 mm (G Dight 2003, pers. comm., February), which may be *P. nodiflora*. These differences are obviously confusing and/or questionable, so field identification may need to rely on where the plant occurs rather than measurements of leaf length, or by using the other characters noted in figures 1 and 2.

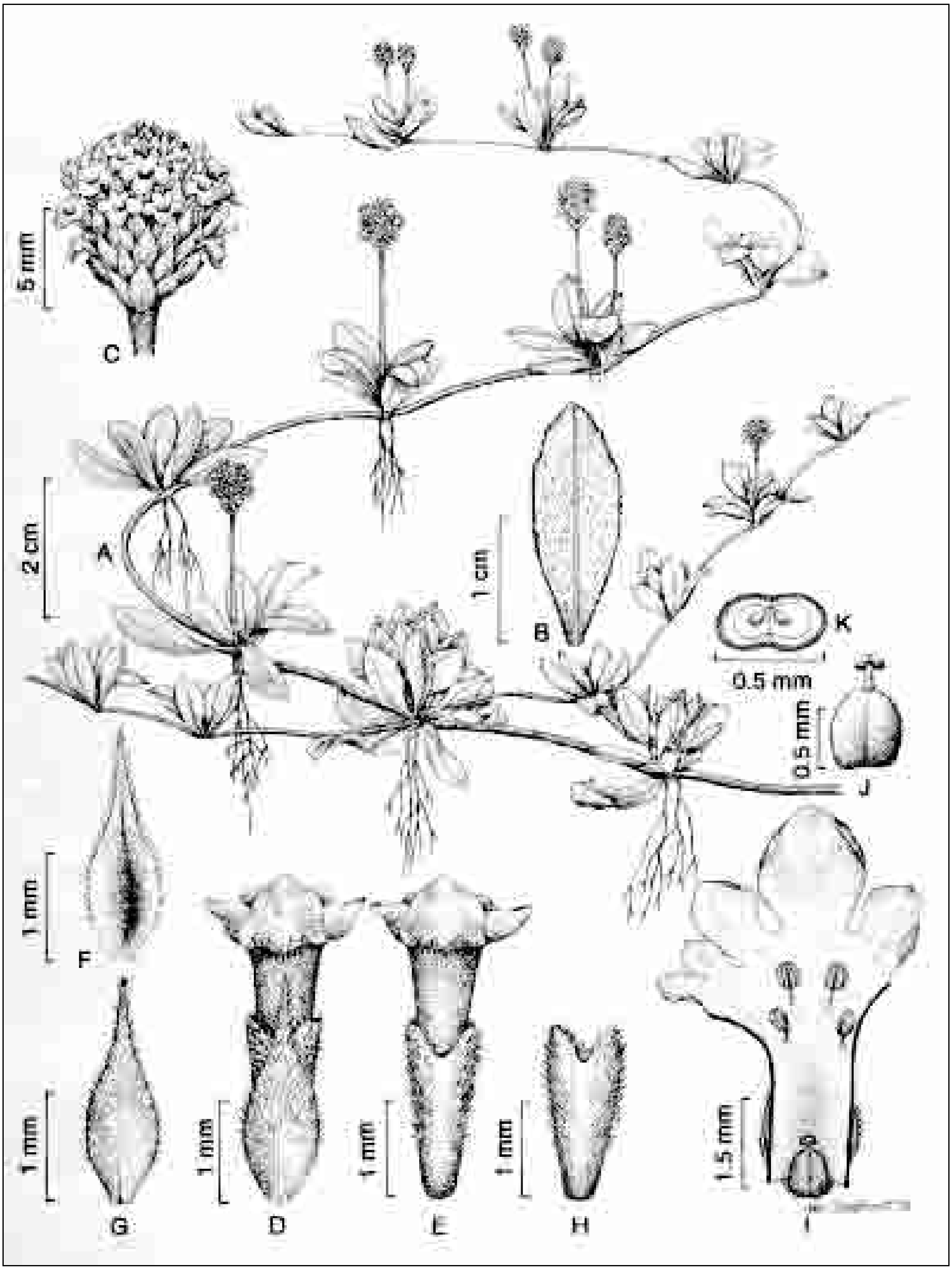

Fig. 1. *Phyla canescens.* A, habit sketch of a flowering branch; B, leaf with almost entire margin; C, globose spike; D, flower with bract; E, flower without bract; F, bract showing adaxial (inside) view; G, bract showing abaxial (outside) view; H, calyx with short lobes; I, flower longitudinally cut open showing androecium and gynoecium and glabrous inside; J, ovary; K, transverse section of ovary. Reproduced courtesy of the State Herbarium of South Australia from Munir (1993).

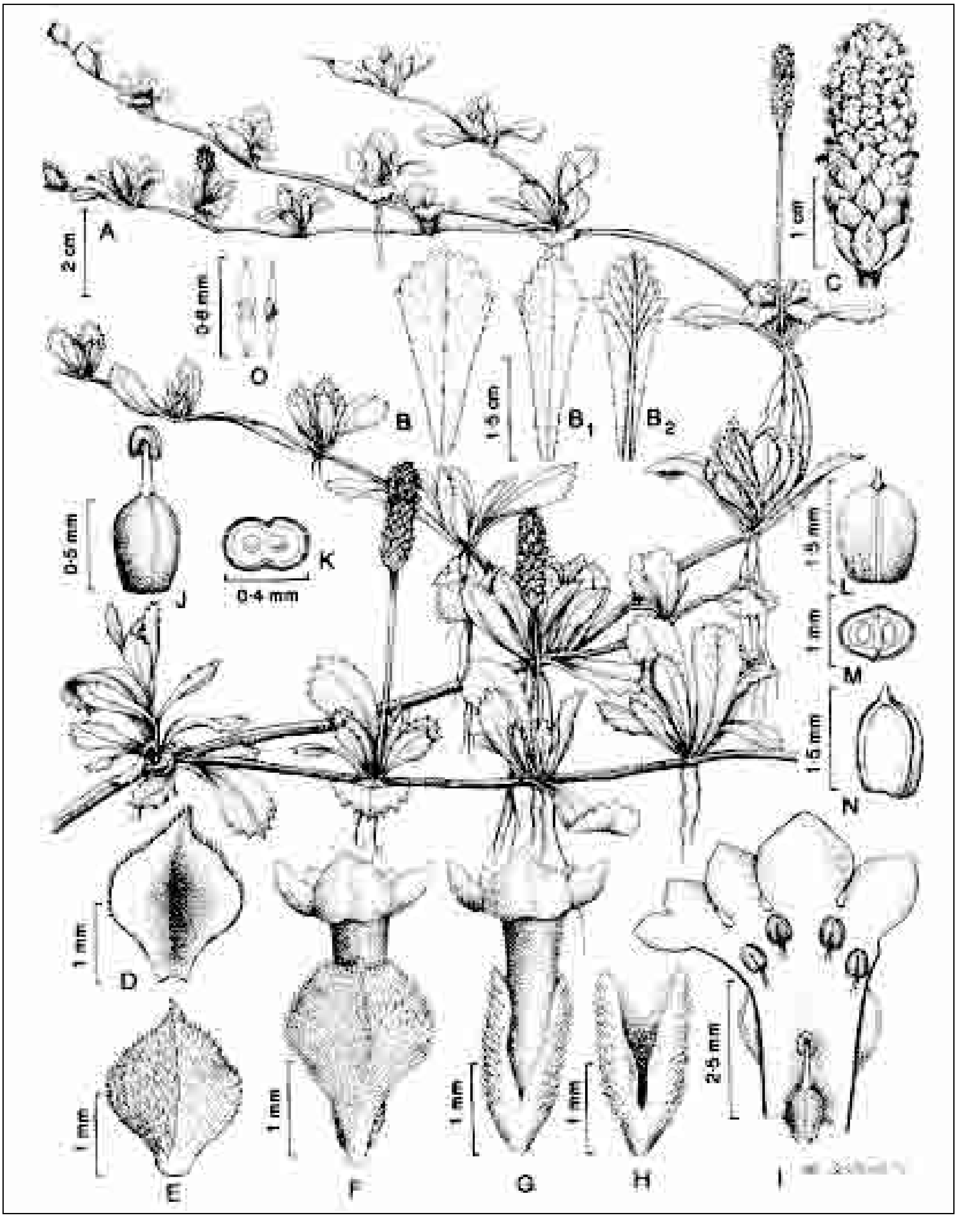

Fig. 2. *Phyla nodiflora.* A, habit sketch of a flowering branch; B and B1, leaves showing adaxial (upper) view; B2, leaf showing abaxial (lower) view; C, cylindrical spike; D, bract showing adaxial view' E, bract showing abaxial view; F, flower with bract; G, flower with deeply lobed calyx; H, calyx lobed almost to base; I, flower longitudinally cut open showing androecium and gynoecium and glabrous inner surface; J, ovary; K, transverse section of ovary; L, fruit; M, transverse section of fruit; N, fruitlet; O, medifixed or malpighiaceous hairs. Reproduced courtesy of the State Herbarium of South Australia from Munir (1993).

Tutin and co-workers (1972) note that lippia has woody stem bases and heavily pubescent outer corollas with unequal lobes compared to phyla weed, which has a sparsely pubescent corolla with sub equal lobes. Munir (1993) contests this, as contemporary findings indicated that the corolla of *P. canescens* is entirely glabrous (non-hairy) except for a thin band on the outer edge of lobe bases. Leaves of *P. nodiflora* are said to be non-canescent, whereas those of *P. canescens* are (Munir 1993), although field observations of *P. canescens* leaves in Warwick appear green rather than grey. Therefore, apart from woody stems, such morphological differences between the two species may not be very applicable in field a situation which again poses the question of the validity of the species separation.

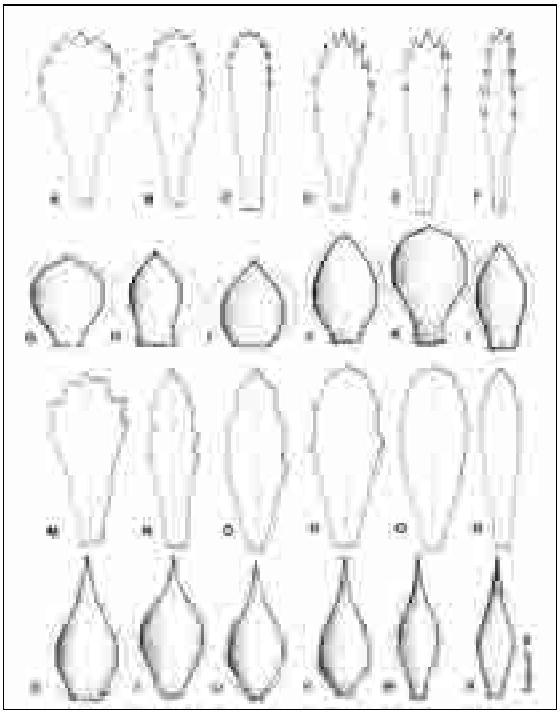

Fig. 3. Range of variation in shape of leaves (A–F, M–R) and bracts (G–L, S–X) of *Phyla nodiflora var. nodiflora* (A–L) and *Phyla canescens* (M–X). Reproduced courtesy of the State Herbarium of South Australia from Munir (1993).

Other species in the family Verbenaceae within south-east Queensland may be distinguished from lippia. Lippia commonly has white flowers, and leaves always have serrate (saw-like) margins above their midpoint (Stanley & Ross 1986). *Lantana spp*. commonly has heads of many more flowers than *Phyla spp*. Many *Verbena spp.* (snakeweed) have blue, purple or pink flowers, and those that are white, like lippia, have leaves that are pinnatifid (cleft into leaflets that are not entirely separate) rather than serrate (Stanley & Ross 1986). A more obvious feature distinguishing some related species such as badhara bush, lantana and some snakeweeds from lippia is that they are shrubs rather than prostrate herbs. Besides confusion with phyla weed, lippia is easily recognised from other local plants. Its distinct growth form and flowers are quite unique although, from a distance, dense infestations of lippia in flower may appear similar to flowering clover.

3. Ecology and biology

3.1 Habitat

Lippia grows best on bared ground in periodically moist sites (heavy rainfall, flooding or opening of springs) that also undergo periods of water stress (Richardson 1994) and with apparently poor soil structure. It is found mostly on high-moisture-holding clay to clay-loam soils in floodplains or wetlands. Other features of the Australian sites where lippia has taken hold, noted by Richardson (1994), include some heavy frosting in winter (except from Rockhampton northwards), warm to hot summers, low organic matter, and human disturbance such as from grazing and land clearing.

Lippia is well adapted to moist clay soils in riverine and floodplain environments (Lucy et al. 1995; Lazarides et al. 1997; Dellow et al. 2001; Fensham 1998) and has been observed to grow most prolifically on sites which experience periodic flooding of short duration (McCosker 1994). Floodplain catchments with summer rainfall and/or regular spring-summer flooding appear to be the most susceptible to lippia invasion (Lucy et al. 1995). The deep rooting system of lippia allows it to take advantage of intermittent rainfall faster than perennial pasture grasses, as the clay soils maintain moisture to considerable depths (Richardson 1994). These conditions are present in the more eastern and northerly catchments within the Murray–Darling Basin.

In the Condamine river system, lippia appears to prefer the black, heavy clay soils in areas that experience occasional flooding or poor drainage (Csurhes 1989). It can inhabit lighter flood-free soils such as sandy loams found adjacent to floodplains (McCosker 1994; Lucy et al. 1995), and has been observed growing on higher ridge country above wetter channel areas (Jenson 2002; G Dight 2003, pers. comm., February). Lippia also occurs in spring-fed basalt country such as north-west of Charters Towers, an area not flooded by major rivers (Richardson 1994). Around Warwick, lippia will grow on any soil type, providing it has means of access to these new environments through such avenues as gullies adjoined to dams and other infested areas; waterfowl which typically graze along river banks clearing patches of vegetation, leaving them ripe for invasion; and disturbance from humans, vehicles or stock movement (G Dight 2003, pers. comm., February).

Lippia tolerates frequent and occasional inundation but it will also survive drier conditions by becoming dormant for sustained periods of time. Its tolerance towards inundation seems dependent on the length of time it is flooded and the turbidity of the water. It can tolerate extended periods of waterlogged soil; however, four to eight weeks of turbid water inundation may be enough to kill most individuals (Inglis 1994 in Lucy et al. 1995) and up to three months inundation may be intolerable (Dellow et al. 2001). The length of time that

Lippia will survive dry conditions appears to be unknown. It is often referred to as being drought tolerant (Lucy et al. 1995; Dellow et al. 2001) and able to re-establish quickly when moist conditions return (Lucy et al. 1995). Lippia also appears to be quite frost hardy (Mann 1960, in Lucy et al. 1995; Dellow et al. 2001), as dormant nodes will re-shoot in warmer weather, following heavy frosts.

Although lippia grows well in disturbed sites it will also grow in some relatively undisturbed sites. Lippia can overrun a site in the complete absence of livestock as shown in its occurrence on roadsides, ungrazed reserves and lightly grazed woodlands.

3.2 Phenology and floral biology

Lippia flowers anytime in the spring-summer-autumn period given favourable soil moisture conditions (Lucy et al. 1995; Dellow et al. 2001). Flowering can be triggered by rain or flooding at any time during this period (Lucy et al. 1995). During colder months, no flowers have been observed amongst lippia growing around the Condamine River near Warwick in south-east Queensland (G Zerner 2003, pers. comm., February).

Lippia can self- and cross-pollinate (McCosker 1994) resulting in a high percentage seed set and maintenance of sufficient genetic variation to adapt and rapidly colonise new environments (Kumar & Dutt 1989). However, there may be a lack of suitable pollinators in Australia, given the small flower size (McCosker 1994), and it has been suggested that only tiny flies or ants may act as pollinators of these small flowers (Kumar & Dutt 1989). The possibility that seed set may be low in Australia has been supported by research conducted in the Gingham Watercourse where very low seeds banks of less than 1200 per metre square were found after a year (McCosker 1994). While honey bees are noted as frequent visitors of lippia flowers (G Dight 2003, pers. comm., February), it is unlikely that they facilitate pollination and seed set. Further investigations may be required to understand the full extent of lippia’s fertilisation and seed set capabilities in Australia. Studies on the size of the seed bank and longevity of lippia seeds in the soil are also required. Seed bank studies give an indication of the number of years after initial treatment required to exhaust the seeds in the soil.

Germination can occur under a wide range of conditions, and a viable seed bank remains around a parent plant even after the plant’s removal (McCosker 1994; Lucy et al. 1995). Research suggest that seeds of lippia may possess an effective drought survival mechanism involving enhanced germination from the seed bank as a result of alternate drying and wetting (McCosker 1994).

3.3 Dispersal

Lippia is thought to produce copious seed and it has very effective means of dispersal (McCosker 1994), but both the quantity of seed produced and seed viability in Queensland is currently unknown. Seeds are initially dispersed below the parent plant with secondary dispersal via floodwaters, probably by floating on the water surface, and germinate when they are deposited in silt by the declining waters (McCosker 1994). Other suggested dispersal agents include ants (McCosker 1994) and possibly birds (SQDNR 2000). However, deliberate bird dispersal is doubtful, due to the small seed size, but spread of small plant fragments or seeds stuck in mud is possible (McCosker 1994).

Vegetative reproduction occurs via production of roots at stem nodes, and can occur while the plant grows under water (McCosker 1994). In this way, individual plants spread out and can rapidly colonise large areas (McCosker 1994). When inundated with shallow floodwaters, lippia stems grow towards the water surface and become shortened in their stem sections, which then break off as the nodes weaken. The detatched fragments float and can remain dormant before becoming established on suitable soils again when floodwaters recede (McCosker 1994). Estimations of the viable period of stem fragment dormancy varies from at least six to eight weeks (Inglis 1994, in Lucy et al. 1995) up to three months (Dellow et al. 2001).

Vegetative dispersal may be assisted via the displacement of plant material (e.g. muddy stem fragments stuck on the feet of animals) by machinery, cattle, sheep and birds, and is especially likely to occur in wet conditions (McCosker 1994). Such movement of plant material, particularly by stock and waterfowl, has been suggested as a possible pathway for the establishment of lippia above the floodplain (Lucy et al. 1995; SQDNR 2000; G Dight 2003, pers. comm., February).

Another potential means of spread is associated with possible contamination of lucerne pasture by lippia. Lucerne is grown as a high-profit pasture alternative to grain crops by many landholders (G Dight 2003, pers. comm., February). As lucerne is grown throughout the floodplain areas of the Condamine River, it is likely that lippia may contaminate these pastures. Lippia's spread may be increased through sale of contaminated lucerne seed or in the distribution of lucerne as fodder.

Humans may assist the spread of *Phyla* species through use as a garden ornamental and lawn plant. An Internet search of nursery catalogues has shown that lippia is still available for sale in some parts of the world. It appears to have been removed from sale within Australia, though plants under the name *P. nodiflora* are still sold.

4. History of introduction and spread

The first Australian records of *Phyla* (now known as *P. canescens)* were from Victoria in 1930, based on collections from Williamstown in 1914, and from South Australia in 1929, where the plant was collected from around Lake Torrens, Adelaide (Munir 1993). Its introduction is likely to have been for use as an ornamental or lawn plant during the second half of the nineteenth century (Richardson 1994). This usage has been attributed to the widespread distribution of lippia in Australia, as the plant is believed to have escaped from these original sites and subsequently spread throughout river systems (Richardson 1994). Lippia's prostrate growth habit, root system, means of reproduction and dispersal, competitive growth rate, salt tolerance, and soil and water conservation abilities all contribute to its success as a weed species in Australia (Richardson 1994).

In New South Wales, the first official records of lippia are from Wentworth in the west of the state (Lucy et al. 1995) in the 1950s, and it has spread rapidly in this state. Flooding events of the past are suggested to have contributed to the spread of lippia through New South Wales river systems, for example, after floods in 1966 and 1974 (Richardson 1994). It has been recorded that following floods in 1990, the amount of lippia along the Lachlan River (between Forbes and Condobolin) and in the Macquarie Marshes substantially increased (Richardson 1994, Earl 2003). Similar patterns of increased coverage after flooding events have been observed in the Namoi and Gwydir valleys (G Dight 2003, pers. comm., February).

Changes in the water balance within the Murray–Darling Basin ecosystem are postulated to have contributed to the spread of lippia throughout this system (Lucy et al. 1995). Reduced frequency and length of natural flooding periods in native pastures, resulting from such activities as dam construction and extensive irrigation development (McCosker 1994), may favour the invasion of the Murray–Darling river system by weeds such as lippia. Copeton Dam in the upper Gwydir River, which regulates flooding events, provides an example of this effect. It is suggested in this area that less flooding may cause alternative pasture grasses such as water couch to lose their competitive advantage over lippia, thus encouraging its spread (Richardson 1994). At the same time changes in land use, salt levels and other management activities may have increased lippia's competitive viability. McCosker (1994) states, for example, that the distribution of lippia in the Murray-Darling Basin correlates closely with irrigation development in the basin, and that in early development stages the NSW Department of Water Resources planted lippia on irrigation canal banks and around weir sites to encourage soil stability and prevent erosion. Selective cattle grazing may also affect grass species competition, encouraging lippia growth.

In Queensland, the first official recording of lippia was in 1944 at Tummaville, about 60 km south-west of Toowoomba and adjacent to the Condamine River (Lucy et al. 1995). Lippia appears to have been spreading in the Murray–Darling Basin from around the 1930s and was reported as a weed threat in 1953 by the Lands Department in Queensland (Lucy et al. 1995). Landholders in the Condamine River area first expressed concerns about the invasion of lippia on low lying flats along the river in the early 1960s (McCosker 1994).

Surveys in 1960 and 1989 reported that 40 000 and 60 000 hectares respectively in the Upper Condamine catchment were affected by lippia, noted at the time as *P. nodiflora* (Mann 1960; Csurhes 1989). A more recent survey has conservatively estimated 80 000 hectares of land in this region to be affected by lippia (Powell 1992 in Lucy et al. 1995), and in 1994 it was concluded that at least 300 000 hectares of floodplain grazing country were moderately to severely affected with lippia (Richardson 1994). Lucy and co-workers (1995) estimate that this figure can be expanded to 600 000 hectares when all minor tributaries feeding into the main rivers of the Murray–Darling Basin are taken into account. The most recent survey of lippia (Earl 2003) found the species in varying density within each of the 19 catchments in the Murray–Darling Basin. This study estimated that lippia covers an area in the order of 5.3 million hectares.

5. Current and predicted distribution

5.1 Distribution overseas

Lippia is widely distributed throughout the more temperate to subtropical regions of the world. According to most literature, lippia is native to the South American countries listed below (Richardson 1994, USDA 2003), and naturalised elsewhere. However, as a widely cultivated species, the origins of this species are not clear. For example, lippia (*P. canescens*) has recently been recorded as having only a tropical to subtropical world distribution (Dellow et al. 2001) but this is not confirmed by its current distribution across a large range of climatic types.

Lippia has been recorded as *P. canescens*, as well as its synonyms, in southern Africa (Orange Free State and Cape regions of South Africa, Botswana and Swaziland), south America (Argentina, Bolivia, Brazil, Chile, Paraguay, Peru, Uruguay), central America (Cuba, Ecuador, Mexico), USA (Hawaii, California, Utah, Nevada and North Carolina), south-west Europe (France [including Corsica], Italy [including Sardinia], Portugal and Spain [including the Balearics]), Egypt, Ethiopia, Israel, Saudi Arabia, Senegal, Algeria, Mauritius, southern India, Malaysia and Afghanistan (Tutin et al. 1972; Karadge et al. 1983; Tomas-Barberan et al. 1987; Arnold & De Wet 1993; Munir 1993; Richardson 1994; Lucy et al. 1995; Earl 2003, USDA 2003). Munir (1993) states that unlike *P. nodiflora* Lippia has not been recorded from the Pacific Islands; however, Earl (2003) quotes a study by Kennedy who records its presence in both New Zealand and Guam. It is likely that these are records of cultivation.

5.2 Weed history overseas

P. canescens is listed in a global weed compendium (Randall 2002) with six records of citations as a weed throughout the world, including Australia, Argentina, Chile, and South America in general. It has also been recorded (under its synonym *Lippia nodiflora*) as a common weed of banks along the Ganges and various other water bodies and flood-prone environments in India (Kumar & Dutt 1989). However, there is limited literature available indicating the effect of lippia and related *Phyla* species throughout the world. This may indicate that lippia exerts only a minor effect in countries other than Australia.

5.3 Distribution in Australia

Lippia occurs in South Australia, Victoria, New South Wales, Western Australia and Queensland. It is not found in the Northern Territory, Tasmania, or in the more northern parts of Queensland and Western Australia (Lucy et al. 1995; Lazarides et al. 1997).

The Australian National Herbarium holds eighteen specimen records for *P. canescens* (Australian National Herbarium 2003). They are all from within the Murray–Darling catchment except for one record in South Australia north-east of Clare. There are seven other records for South Australia, and three each for Victoria, New South Wales and Queensland. Two of the specimens from South Australia were previously determined as *P. nodiflora* and have since been updated to *P. canescens*.

Lippia is widely distributed across the more temperate, floodplain regions of the Murray–Darling Basin. It is adapted to heavier clay soils, such as the floodplain vertisol soils within the Murray–Darling river system, which range from grey clays (30% clay) to black earths (up to 75% clay) (Lucy et al. 1995). The dense distribution of lippia in this river system appears to extend from the Murray–Goulburn, along the Murray valley and into the lower reaches of the catchment (R Edwards 2001, pers. comm., August).

In New South Wales, lippia has established along the Lachlan River and floodplain system west of Forbes, the Murrumbidgee River floodplains in the Hay area, in the Macquarie Marshes, and throughout the lower Gwydir, McIntyre and Namoi valleys in the north (Dellow et al. 2001).

P. nodiflora, in contrast, is recorded from the Northern Territory, Kakadu National Park, Daly River, Oenpelli and sites south of Darwin including the Coastal Plains Research Station. It is also recorded in coastal sites in Western Australia and New South Wales. In Queensland it is recorded at the Southport Spit and Coolum Beach in the south-east, Georgiana Flooplain near Proserpine, and Lake Moondarra near Mt Isa (Australian National Herbarium 2003).

5.4 Distribution in Queensland

Lippia is well established throughout the Murray–Darling Basin in Queensland. Lippia occurs throughout the Condamine River, from its source near Killarney, to the Balonne River junction (McCosker 1994). A review by Phillips and Moller (1995) found that 33 per cent of sites within the Condamine River catchment contained lippia as part of the riparian vegetation understorey and ground cover. Lippia has been found in Myall Creek, Oakey Creek, Ashall and Fourteen Mile creeks, Condamine River, Hodgson Creek, Kings Creek, Dalrymple Creek and Southwest Creek sub-catchments (Phillips and Moller 1995). A recent survey (Earl 2003) found lippia present in the four catchments of the Murray–Darling Basin in Queensland; Border Rivers, Condamine, Maranoa–Balonne and Warrego–Paroo. The area covered by lippia was recorded as 1 million hectares from a total catchment of 2.5 million in the Condamine catchment, and 1.16 million hectares of the Border Rivers catchment (both NSW and Queensland). Lippia was found in a number of townsites and along both the Maranoa and Balonne rivers. Only individual plants were found along the Warrego River.

Lippia is also present on higher ground adjacent to floodplains (Dellow et al. 2001), table drains, and in paddocks at some distances from the Condamine River (SQDNR 2000).

One such paddock, remembered as good pasture in the early 1970s, is now completely overgrown with lippia and has been abandoned as a grazing pasture (G Dight 2003, pers. comm., February). In the Border Rivers catchment, isolated clumps have been observed on banks of the MacIntyre and Dumeresq rivers (BRFMP 1999).

Lippia also occurs in other areas of Queensland. It has been observed in more northerly regions such as near Charters Towers (Richardson 1994), although it has not been sighted in recent times. Infestations have been found on the Yeppen Flood Plain of the Fitzroy River near Rockhampton (P Hinchcliffe 2003, pers comm., April), although this may be phyla weed. Lippia was noted in the riparian zone and on the higher banks of Barambah Creek, just south-west of Murgon (Jodie Garton 2003, pers. comm. February). It is present in Longreach Shire as ornamental plantings (C Magnussen 2003, pers comm., April).

5.5 Potential distribution in Australia

Richardson (1994) suggests that much of Australia's best grazing land fits the preferred habitat criteria of lippia—that is, high clay content soils (McCosker 1994; Powell 1992 in Lucy et al. 1995) together with waterways, floodplains and damp areas. Lippia has specific climate and soil adaptation requirements, indicating that the main river catchments of the Murray–Darling Basin currently affected or potentially at risk include the Condamine, Moonie, Gwydir, Namoi, Macquarie and Upper Lachlan catchments (Lucy et al. 1995), with the possibility of spread to the Barwon and Darling system in New South Wales and Warrego–Paroo in wet seasons (Earl 2003). Lippia also has the potential to affect areas adjacent to floodplains on lighter sandy loam soils, especially if a series of wet seasons is experienced (Lucy et al. 1995).

Based on the known distribution of lippia in South America, and various ecoclimatic preferences of the plant, CLIMEX (Skarratt et al. 1995) was used to model the potential distribution of lippia in Australia (Figure 4) and Queensland (Figure 5). The irrigation scenario (simulating 10 mm of rainfall per week) was incorporated into the model in order to fully represent the potential habitats available to lippia in Australia, particularly within the Murray–Darling Basin.

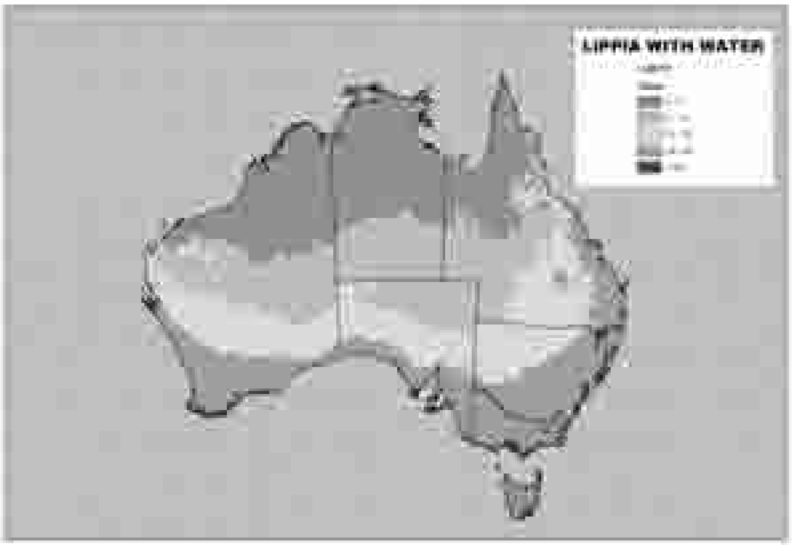

Fig. 4. The potential distribution of *Phyla canescens* in Australia. Data is shown on the national half degree grid from a CLIMEX prediction (EI = Ecoclimatic index: EI<10 potential for permanent population low, EI>50 potential very high).

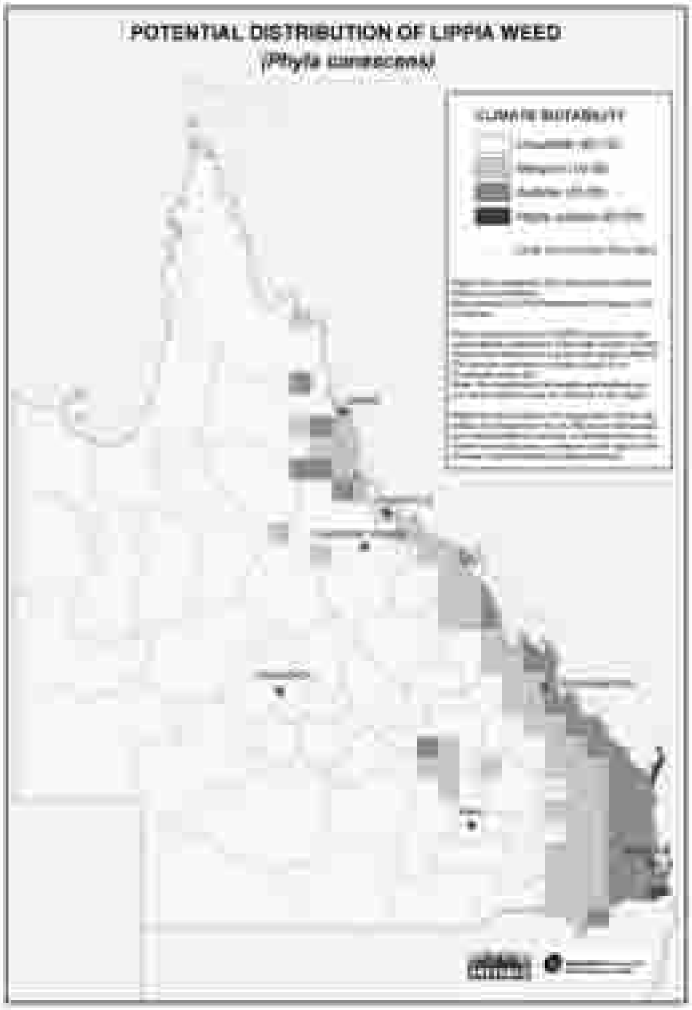

Fig. 5. The potential distribution of *Phyla canescens* in Queensland

As lippia is strongly influenced by soil, adding a soils layer enhanced the climate prediction for this species. The Northcote Soils of Australia vector data layer was converted into a raster format that matched the existing output of the CLIMEX raster dataset. Each dataset was then reclassified to a consistent scale, that is, eight classes, where the soils were assigned a suitability value for lippia growth. Finally, a linear calculation was performed where both soils and CLIMEX datasets were given a weighted index of 50 per cent (M Bryant 2003, pers comm., September). The resultant spatial model is shown in Figure 6.

Interestingly, this map shows that the sites with the highest value correspond quite strongly to the Murray and Darling river systems. Consistent with the climate prediction map, other parts of Queensland such as the central Queensland coast and the central highlands appear to be suitable for this species. Of concern is the prediction of potential growth in more inland and generally drier sites near Longreach and the Lake Eyre Basin, which may be at risk in occasional high-rainfall seasons or in irrigated situations. Although the predicted climate maps include the more tropical areas of Queensland, lippia may not necessarily perform well in these regions due to the soil types. This appears to be confirmed by Richardson (1994) who notes that lippia has only occurred in limited patches in tropical Queensland with no significant spread. In less flood-prone areas of western Queensland, the climate may be too dry and soils too unfavourable to allow the spread of lippia from gardens and lawns (Richardson 1994). Being a C3 plant, lippia is able to tolerate shady conditions and has therefore been recommended as a lawn and garden plant, particularly for shady areas. It has not appeared to spread much from these areas (Richardson 1994).

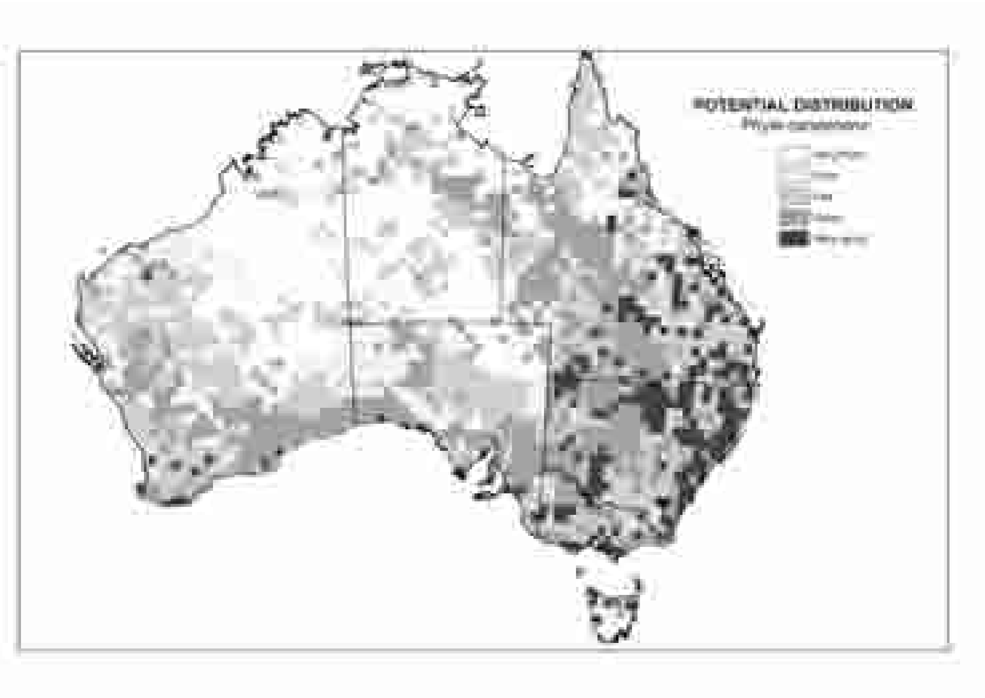

Fig. 6. Potential distribution of *Phyla canescens.* Predicted using a compilation of the Northcote Soils of Australia and CLIMEX climate output.

6. Current and potential impacts

6.1 Impact on primary industry

6.1.1 Costs

Most of the information on the impact of lippia is derived from studies in New South Wales. The possible economic cost of lippia includes: reduction in pasture productivity leading to reduced stocking rates and land values; metallic wool in sheep; reduction in lucerne production; reduced crop production due to competition; and erosion. A recent study has suggested these impacts in the whole Murray–Darling Basin to be worth $38 million per annum in lost production (Earl 2003).

Lippia may dominate pastures resulting in reduced stocking rates or productivity of grazing land, by as much as 90 per cent on severely affected grazing lands (Lucy et al. 1995; Csurhes 1989, Richardson 1994). Livestock productivity is reduced on lippia-affected pasture, in comparison with alternative pasture grasses, since it is associated with reductions in available feed supply (Lucy et al. 1995). A Parkes landholder observed that weight gains of cattle grazing on lippia were approximately seven months behind those grazing on other pasture (G Dight 2003, pers. comm., February). More research is required on the conditions that lead to these high densities, including studies into grazing management, without better pasture management it is unlikely that lippia control will result in long-term improvement to affected grazing lands. A survey by the Namoi/Gwydir Noxious Weeds Advisory Committee estimated that the average producer within the Moree Rural Land Protection Board experienced on their properties a $39 728 per year loss of productivity due to lippia (White 2002).

In a survey of the Condamine River, Csurhes (1989) states that lippia poses the greatest threat to landholders grazing stock on native pastures along black-soil flats adjacent to the river, but is not a problem on land that can be cultivated as it can be controlled by herbicides. A producer survey conducted by Earl (2003), mostly in the Condamine, Border Rivers and Gwydir catchments, confirmed this with 70 percent of the lippia-affected areas on or adjacent to waterways and 57 per cent in flood-prone areas

The land value of lippia-infested properties, and possibly of adjoining property, may be affected by potential buyers regarding such land to be of reduced sale value. Such reductions would be due to perceived costs of control and reduced productivity of the land, which are associated with lippia infestation (Lucy et al. 1995). Lippia has been estimated to cost the Moree Shire $A12 million in reduced land values (BRCMLC 2002).

Annual reduced livestock productivity losses from lippia, based on hypothetical farm budgets (Richardson & Powell in Lucy et al. 1995) of lippia-infested farms in the Pittsworth and Tara districts of Queensland and the Forbes district of New South Wales, resulted in an estimated annual loss to the Australian economy of at least $17 million due to reduced livestock productivity (Lucy et al. 1995). This used the 1995 figure of 300 000 hectares for the extent of the Murray–Darling Basin floodplain grazing land seriously affected by lippia. As mentioned above, this figure has now been calculated to be $38 million for the whole river system (Earl 2003).

Pasture productivity may be affected as a result of the induced copper deficiency that develops in sheep grazing on lippia (SQDNR 2000). This phenomenon is related to 'metallic' wool, as has been noted in the Rosenthal and Allora shires in Queensland (Richardson 1994).

Lippia may reduce seed set in commercial crops via pollinator competition. It has been claimed by some lucerne growers in the Forbes district of New South Wales that bees prefer lippia to lucerne flowers, and that this is having a negative effect on the pollination of their commercial crop and seed production (Lucy et al. 1995).

Lippia is suggested by some farmers to reduce water availability for crops. Farmers in the Forbes district have indicated that there is a need for deep sowing if early oats are planted after a dry autumn, due to reduced available water in lippia-infested sites (Richardson 1994). Further studies are required to confirm the impact of lippia on water relations in cropping lands.

Some research suggests that lippia has allelopathic effects on other plant species (McCosker 1994). One study showed that lippia leachate inhibited the growth of lettuce seedlings, and the researchers correlated this by the presence of potential allelopathic compounds that have been isolated from the plant (Elakovich & Stevens 1985). Field observations (McCosker 1994) have noted areas of bare ground surrounding dense swards of lippia, which have been attributed to the plant's allelopathic ability. Pasture failures, linked to an allelopathic affect, have been reported in the Darling Downs when sowing followed the cultivation of pasture previously dominated by lippia (Lucy et al. 1995). It may be possible, however, that the presence of a dense lippia root sward is responsible for this reduction in pasture growth since it make take months for the remaining root mass to rot to a point where other plant roots can grow. Other workers also question the attributing of this bare ground to allelopathy. For example, there are many other sites where other species grow within close proximity of lippia without any apparent allelopathic affect. The evidence for this allelopathic effect is largely anecdotal.

Sheet erosion (erosion caused by a sheet of water that flows over the surface transporting with it the surface soil) may be accelerated by lippia. Its low growth habit is linked to an associated increase in the speed of floodwaters over this vegetation (Lucy et al. 1995). In some areas, change of land use from grazing to cotton production has also helped to increase the rate of surface water flow. As cultivation of lippia-infested country may be a cost-effective control method, there is also concern that cultivation on traditional grazing country may significantly increase sheet erosion during overland flooding events (Lucy et al. 1995).

6.1.2 Benefits

Possible economic benefits of lippia include: reduced fire risk; use in the nursery trade; noxious weed control via its superior competitiveness; honey production; and its capacity to be an important feed supply for stock in some seasons (Lucy et al. 1995).

The NSW State Forestry Service (Forbes) does not consider lippia a problem since in forestry areas it reduces fire hazards due to the low fuel loads. Lippia is also found to act as an effective control for burrs (*Xanthium* spp.) on this land (Richardson 1994).

Lippia has been sold as a lawn and garden ornamental in the nursery industry and it is sold as shade-loving lawn replacement species. It is probable that most of this plant material is *P. nodiflora* and not *P. canescens* (Lucy et al. 1995). However, plants that appear to be lippia have been planted as an ornamental as far inland as Longreach. It was not possible within this assessment to value this industry in Queensland or in Australia.

Lippia produces many flowers that are very attractive to bees. Bees are able to extract large quantities of nectar from lippia flowers, which is said to produce a pleasant tasting honey (Richardson 1994). Because of this, and the fact that lippia is very easy to grow, the plant is favoured by honey producers (Richardson 1994; P Warhurst 2003, pers. comm., February). This plant is also favoured because changes in the composition of the native and introduced plant flora has meant that other good flower sources have been lost from some regions. If lippia infestations were to be controlled, new pollen sources would be required for apiarists in the Upper Condamine.

Lippia may be the only available feed at certain times of year (Csurhes 1989) due to its frost and drought resistance. While it has been regarded as unpalatable to stock, this may be a misconception based on the observed selectivity (Lucy et al. 1995) of grazing cattle towards it. Csurhes (1989) states that the plant is palatable to stock but is generally too short for cattle to eat because of its prostrate growth form; however, stock that do feed solely on lippia can scour very badly.

6.2 Impacts on the environment

The possible environmental cost of lippia includes impacts on stream banks, competition with other plants, and impacts on ecosystem biodiversity. Lucy and co-workers identified lippia as a weed of environmental significance in the inland river systems of southern Queensland and New South Wales (Lucy et al. 1995) and a major threat to watercourses, floodplains and native pasture areas (Dellow et al. 2001). In many cases, however, the effects of lippia have not been separated from the impact of changed land use and stock grazing at the same sites. Lippia is not ranked a high environmental threat in all regions. Based on an assessment invasiveness by weed scientists, with weeds ranked between 3 (moderate) and 5 (high), lippia scored an invasiveness score of 4.2 for south-east Queensland (Batianoff & Butler 2002). However, it was only ranked 54th in the resulting list of the 200 most invasive species; as it had only been recorded in four sites in south-east Queensland.

6.2.1 Stream bank instability and soil erosion

Riparian areas often support high diversity of plants and animals and given previous land practices often harbour endangered and vulnerable species. Floodplain soils are also particularly susceptible to stream bank and tunnel soil erosion (Richardson 1994). Lippia thrives in riparian areas and is thought to affect the stability of these areas.

Lippia has a deep root system that dries out floodplain clay soils. This is said to contrast to native perennial grasses which have an extensive but fine fibrous root system. Soils crack as a result of drying out caused by the lippia root system, which can cause stream bank instability in areas overtaken by this plant, especially if no other vegetation, particularly tree cover, is present. Following flooding, long aprons of lippia mats are often seen hanging over banks of the Condamine River, the soil having been eroded from underneath by floodwaters (G Dight 2003, pers. comm., February). This erosion is believed to be increased in lippia-infested areas.

At some sites, however, such as on the Condamine River in Warwick (see cover photograph), lippia is virtually the only plant on the riverbank. In these places it is offering a tenuous stability to these river banks. Unless suitable replacement vegetation and alternative bank stabilisation work can be achieved, it will be best to let lippia remain in these areas. Removal of lippia would result in considerable erosion.

Gully erosion is associated with overland flows tunnelling under lippia during floods (Lucy et al. 1995). This erosion is because increased runoff, with regard to both volumes and velocity of water, is a typical problem in cleared areas, compared to uncleared or ungrazed areas. The low height of lippia will increase this erosion, compared to areas covered with taller grasses, due to faster water flows.

6.2.2 Competition and impacts on ecosystem biodiversity

Lippia competes effectively with other plants for moisture due to its deep and extensive root system. As a result, lippia is able to completely dominate ground layer vegetation. It has even been known to dominate in areas previously covered by robust and weedy grasses such as Johnson's grass (*Sorghum halepense*) (G Dight 2003, pers. comm., February). Native herb and grassland communities have been displaced as ephemeral wetland, and riparian plant communities in the Macquarie, Gwydir and Condamine valleys have become heavily infested with lippia (McCosker 1994). It is also considered a serious threat to the natural integrity of the flood-prone Darling Downs grassy communities due to this competitive ability (Fensham 1998).

Fensham states that although there are relatively few exotic species that may be able to displace native plants without the aid of mechanical disturbance, a notable exception in flood-prone habitats is lippia (Fensham 1998). This may have serious long-term ecological consequences for riparian and floodplain zones such as the upper floodplain areas of the Condamine and Balonne river systems (McCosker 1996). Lippia is likely to be an aggressive competitor with many native seedlings for light, moisture and nutrients. It is suggested that this competition contributes to the decline in natural eucalypt regeneration in many riparian forests in Queensland (Lucy et al. 1995). The ability of lippia to effectively dry out soil profiles has been postulated as having negative effects on the establishment of eucalypt seedlings, such as the river red gums (*Eucalyptus camaldulensis*), along the Condamine River (Richardson 1994).

A number of ecologically threatened communities and species occur in areas within the area threatened by lippia (Earl 2003). The ecosystems are: the Bluegrass (*Dicanthium* spp.) grasslands of the Brigalow Belt bioregions, Brigalow communities (*Acacia harpophylla*), Buloke Woodlands of the Riverina and Murray–Darling Depression bioregions and the Grassy White Box Woodlands of New South Wales. Threatened species include *Echinochloa inundata* (which occurs in the Macquarie Marshes) and various herbaceous grasses and forbs. Lippia’s direct impact on these species, however, has not been assessed, and this needs to occur to determine the true environmental impact of this species. For example, the loss of wildlife habitat has been observed in the Macquarie Marshes, including the reduced availability of waterbird nesting sites, as a result of the conversion of water couch communities to lippia (Richardson 1994). What is not recorded is whether other land management factors have also contributed to this change in plant community or if lippia is the main reason for this change.

Lucy et al. (1995) notes that increased soil erosion may result in increased stream nutrient loading and increased water turbidity. This may affect the habitat of the fish and other aquatic plants and animals. A flow-on effect may also be subsequent eutrophication of the river systems due to the increased levels of nutrients resulting in algal blooms or increases in aquatic weeds such as water lettuce (*Pistia stratiotes*).

Lippia has been observed growing up the base of eucalypt trunks growing along stream banks in southern Queensland (Lucy et al. 1995). The impact and extent of this is not clear; it may be a sign of an ecologically stressed environment or perhaps it attests to the extremely invasive nature of lippia. It is possible that herbicide treatment of lippia in such situations may affect surrounding vegetation.

6.3 Impacts on society

Lippia can have a small but important impact on people's enjoyment of the place in which they live as well as societal impacts that are more substantial economically.

A small number of stakeholders in south-east Queensland have indicated in a recent survey (Elliot 2001) that lippia detracts from the enjoyment gained from the land, partly in terms of impacts on recreation and partly through its mere presence. Lippia causes the surfaces of playing fields to become slippery and can therefore be potentially dangerous for sporting activities (G Dight 2003, pers. comm., February). This, combined with the large numbers of bees that visit lippia when in flower, increases the potential for injury and possible litigation on both council lands and private property.

Lippia's potential impacts on society include damaging roads, diversion banks and other infrastructure. Its deep rooting system may actively damage roadsides and the increased rate of water flow over lippia may cause erosion around diversion banks or roads. Lippia can be observed growing right up to road edges from infested floodplain areas in the Warwick Shire (see cover photograph). However, it is suspected that road damage from lippia probably only occurs in areas where black cracking clay soils are found (G Zerner 2003, pers. comm., February). Lucy et al. (1995) estimated that lippia may be responsible for over one million dollars of additional road maintenance costs per year in the Darling Downs area alone. Additional costs to councils come from the cost of management, such as herbicides. These figures could not be confirmed during this study, but this damage may increase the total cost of this species to the community.

6.4 Potential impacts of related species

Lippia's close relative, *P. nodiflora,* is thought to be Asian in origin, although it may be endemic to the South Pacific region (Munir 1993). While there is some conjecture over whether this species is native to Australia, it is likely that it was introduced into Australia in the 1800s. It is not commonly recognised as a problem plant but it occurs widely in moist coastal sites around Australia. *P. nodiflora* is listed as a weed in Guam by one website (PIER 2004). All members of the genus *Phyla* appear to be weeds of uncultivated, moist environments. They are all listed in Randall's Global Compendium of Weeds (Randall 2002).

Close relatives of lippia include other introduced hard to control weeds: lantana (*Lantana camara* complex), common verbena (*Verbena officinalis*) and Mayne's pest (*Verbena tenuisecta*). Other members of the Family Verbenaceae can be expected to cause similar problems if permitted entry into Queensland.

7. Current control methods

Long-term control of lippia is best achieved through an integrated approach involving use of herbicides, mechanical control, pasture improvement and grazing management (Motley et al. 2001). However, it may be difficult to implement control strategies in some cases, as there are many situations where conventional control methods are either uneconomic or impractical (Lucy et al. 1995). Although the species has been subject to years of trials by landholders and researchers, a comprehensive manual of treatment methods for all situations has not been developed. There are no biological control agents currently available for lippia, and to date it has not been targeted for research. It will be important to understand the native origins of the material in Queensland before a search of agents can commence in the native range. Conflicts may arise if the species also impacts on *P. nodiflora* if this species is still used commercially.

7.1 Chemical control

As lippia is a broadleaved weed that is often found in grasslands, it can be controlled or at least reduced in vigour by the use of herbicides without affecting competitive grasses. Land managers have had variable success with the registered herbicides; many have not been able to control the species with regrowth after common treatments. Registration of one of these herbicides has recently lapsed, decreasing the available options. Lippia suppression by herbicides, as an alternative to complete kills, may give other pasture species a competitive chance (SQDNR 2000).

Three herbicides, 2,4-D Amine, Glyphosate and Metsulfuron, are currently registered by the National Registration Authority, for the suppression of lippia in pasture and fallow floodplains in both New South Wales and Queensland (APVMA 2004). Originally registered for New South Wales, this permit was extended to Queensland in July 2003 and will last until July 2008. The salient recommendations for use of these herbicides are, firstly, that multiple herbicide applications within a season can give better results than single applications in controlling the emergence of seedlings from the seed bank, particularly following drought-breaking rains (McCosker 1994). Secondly, application of herbicides should be carried out during the active growing stage of lippia when plants are starting to flower and there is good soil moisture availability (Dellow et al. 2001; Motley et al. 2001).

Trials conducted by the Department of Lands in Queensland in the 1960s led to the department's 1973 recommendations for the use of the potassium salt of 2,4-dichloprop, or DP-600, in lippia control. This chemical is the active constituent of the product Nufarm Lantana DP-600 Herbicide, and was effective on all members of the Family Verbenaceae. The product was used in boom spraying or to target plants directly. Best results will be achieved if spraying is conducted during flowering and avoided during conditions of drought, extreme cold, or when rain is imminent, as the plant will not be actively growing at such times (Nufarm 2003). There is a withholding period of seven days for livestock on treated pasture.

Landholders in the upper Condamine have reported successful control with DP-600 used on scattered infestations growing in previously 'clean' areas (Csurhes 1989). More recently, local grazers in the Granite Belt region south of Warwick, south-east Queensland, have reportedly maintained successful control of lippia for the past few years using DP-600 (G Dight 2003, pers. communication). However, Csurhes (1989) commented that this control method was time consuming and had to be conducted regularly, and that such control became uneconomic and impractical when infestations moved beyond the scattered stage. DP-600 has been considered an expensive lippia control agent (SQDNR 2000; White 2002) with the recommended 5-litre application rate costing around $45 per hectare (Lucy et al. 1995). However, trials with spray machinery may increase the accuracy of this control technique. Unfortunately, this permit expired in September 2003 and to date has not been renewed (APVMA 2004).

Possible limitations of chemical control of lippia include:

1. the potential for stream and water pollution of the aquatic environments where lippia grows (Lucy et al. 1995; Dellow et al. 2001)
2. limited application on Gilgai soils and because of poor accessibility resulting from trees and steep grades of stream banks (SQDNR 2000)
3. the proximity of other susceptible crops (SQDNR 2000) and possible effects of herbicides on native vegetation
4. costs and the need for persistence in application, even in cases of small invasions on residential properties where costs of herbicide control may seem unwarranted (G Dight 2003, pers. comm., February)
5. suppression being temporary only as lippia can overcome short-term setbacks from herbicide application due to its high reinfestation potential (Motley et al. 2001)
6. limitation of herbicide use by legislation
7. lack of full suite of herbicide registration in all states.

7.2 Mechanical/physical control

Ploughing is an effective method of lippia control (SQDNR 2000; Csurhes 1989). Clearing land for cultivation to control lippia costs from $300 to $410 per hectare (Earl 2003). This method is not practical, however, if lippia grows in inaccessible areas such as creek banks, riparian zones and certain pasture areas.

In general lippia is not a pest of cultivated lands. Cropping practices on suitable land, including strip cropping, stubble retention, minimum tillage and catchment management, may be successful in controlling lippia (Lucy et al. 1995). Success has been achieved in the eastern Darling Downs and in the Gwydir Watercourse using these methods (McCosker 1994). Re-infestation may occur after cultivated land is replaced by native or introduced pastures (McCosker 1994). In addition, it has been suggested that farmers commonly experience re-invasion of lippia into areas kept clean for at least two years, following just one wet summer (Dellow et al. 2001).

Machinery can easily spread lippia. Therefore, the cleaning down of equipment, vehicles and footwear after use in areas known to contain lippia may help to contain the spread of this species. This issue may become more important as contract headers are being increasingly employed by landholders to reduce costs (G Dight 2003, pers. comm., February). Hence, contractor equipment is therefore likely to be used across large areas of land, thus assisting the spread of lippia if it is not inspected and cleaned between contracts.

7.3 Land management

Lippia will colonise land that has been put at risk by overgrazing, flood or disturbance. It can be reduced by adoption of grazing strategies to assist degraded pastures to repair and become competitive, planting of improved pastures, or use of pondage in areas that can be managed in these ways. A dense stand of perennial vegetation has the ability to resist invasion by lippia.

7.3.1 Pastures

Pastures in good condition can suppress lippia. However, overgrazing or selective grazing by stock of desirable pasture plants can allow the invasion of lippia into pastures, as it is able to expand into exposed areas (Dellow et al. 2001). The spread of lippia into these areas may also be assisted by grazing activities of waterfowl. Good grazing management will maintain or improve pasture condition, increasing resistance to lippia establishment and improving livestock production. A sensible grazing pressure takes into account the ‘body of feed’ available, rather than the traditional ‘acres per animal’ stocking rate. It should ensure that animals avoid overgrazing, desirable grasses are setting seed each season, and pasture use matches seasonal grass production.

Lippia is considered an aggressive competitor, particularly with other pasture species that it is able to dominate (Lucy et al. 1995). However, sowing and maintenance of introduced pasture species, for example, rhodes grass (*Chloris gayana*) or kikuyu (*Pennisetum clandestinum*), may out-compete lippia effectively as long as the vigour of the new pasture is maintained (Csurhes 1989). Other species suggested for pasture improvement are paspalum (*Paspalum dilatatum*), water couch (*Paspalum distichum*), Makarikari grass cv Bambatsi (*Panicum coloratum* var. *makarikariense*), purple pigeon grass cv Inverell (*Setaria incrassata*), silk sorghum, bluegrass cv Floren (*Dicanthium aristatum*), pangola (*Digitaria eriantha*) and African star grass (*Cynodon nlemfluensis*) (Lucy et al. 1995). The native species, *Sporobolus mitcheli,i* was found to be able to maintain cover relative to lippia if the initial cover was greater than 25 per cent (Taylor 2003 in Earl 2003).

Floren bluegrass, Bambatsi grass and purple pigeon grasses have all been recommended for inclusion as long-term components of improved pasture (Illing 2000). Floren bluegrass produces mulch on the ground, impeding lippia growth (Dellow et al. 2001). This grass has also been recommended for use in lippia-infested country around Warwick (G Dight 2003, pers. comm., February). Bambatsi and purple pigeon grasses display good waterlogging tolerance, which has been confirmed by Sands (1983); however, purple pigeon grass did not demonstrate good flood tolerance.

Phalaris (*Phalaris arundinacea*), balansa (*Trifolium michelianum*) and hard-seeded persian clover varieties (*T. resupinatum*), strawberry clover (*T. fragiferum*), barrel medic (*Medicago truncatula*) varieties and naturalised burr medic (*M. polymorpha*) have recently been recommended as pasture improvement species for the floodplain soils of southern New South Wales (Dellow et al. 2001). These areas experience conditions favourable for rapid growth (good rainfall and mild to warm weather), mainly between October and April, compared with the ten months of good conditions experienced in the north of this state. Therefore, their application in south-east Queensland may not be successful. Incorporation of legumes that do well in wet areas, such as strawberry clover, can improve nitrogen availability and help maintain a strong pasture (Illing 2000).

Principles for re-establishing pasture include preparing a fine moist seed bed with high soil moisture content; timely sowing to avoid effects of residual allelopathic chemicals; accurate seed placement; and weed and grazing control during early growth periods (Lucy et al. 1995). Battering down or levelling deep washouts and gutters in preparation for new pasture will reduce the risk of out-competition by lippia, and sowing at up to double the normal planting rate will help to ensure adequate establishment and ground cover to suppress the emergence of lippia seedlings (Illing 2000). The addition of nitrogen by top dressing may increase pasture condition and success (Lucy et al. 1995).

Re-invasion of lippia in established pastures must be monitored and can be checked with herbicide treatment (Lucy et al. 1995). For example, a field previously infested with lippia has been successfully reclaimed as a turf-covered sports oval by a school in Warwick, by complete resurfacing. Good management has prevented regrowth and re-invasion from neighbouring lippia-infested property and adjacent banks of the Condamine River for approximately two years since reclamation (G Dight 2003, pers. comm., February). It may be interesting to monitor this success in years to come, considering that two years may be the point at which control becomes more difficult.

7.3.2 Riparian areas

Grazing management to limit lippia may require reduction or cessation of grazing on high productivity river flats or river frontages, especially in dry seasons when this feed is most valuable. While many producers may not consider this feasible, flooded pastures need adequate rest from grazing to regain their competitive edge over weeds such as lippia. Over the long term lippia infestations will totally reduce carrying capacity in these areas, and failure to take action will result in lippia-dominated pasture. It is known that stock watering points are points of constant and very high grazing pressure, which commonly have low numbers of grass tussocks and lack pasture competition. Flooding also kills grass and lippia fragments or seeds may be carried into flooded areas increasing the level of infestation on bare soil. To overcome high grazing pressure points, it is important to establish several stock watering points per paddock and to rotate stock by alternating water points in use. Planned grazing management has been an effective weed management option for producers, especially in the central highlands of Queensland for reducing the impacts of parthenium weed.

Rehabilitation of riverbanks is likely to be an important way of decreasing reinvasion with lippia; plant species including native *Casuarina* species and introduced willows (*Salix* spp.) have been shown to suppress growth of lippia (Lucy et al. 1995). Fencing along watercourses is likely to be required to assist in grazing management and vegetation rehabilitation. If the edges of the river are densely vegetated, this may catch stray seeds and fragments before they are able to spread out onto the river flats in slow rising floodwaters. Revegetation of creek and riverbanks will also decrease the erosion threat; many lippia-infested riverbanks currently have little other vegetation including understorey and trees and so the banks are easily undercut.

7.3.3 Ponded pastures

Lippia is intolerant to extended periods of inundation; for example, in Gilgai soils country it will only grow on the raised mounds, as the cracking areas are too wet. Ponded pasture systems may therefore be a valuable control method. These systems, with seasonally inundated dams planted with waterlogging tolerant pasture species, can control the length of time a pasture is inundated for, particularly in areas where low intensity and/or non-regular flooding events occur (Lucy et al. 1995). Ponded pastures are used in central and northern Queensland for dry-season pasture for beef cattle. Inundating pasture for at least a month during summer (without rain) with 20–30 cm water may seriously weaken lippia and re-establish the competitive advantage in favour of grasses tolerant of these conditions, such as water couch (McCosker 1994; Lucy et al. 1995). Ponding may be a spread risk, however, as under flooded conditions, lippia is known to disperse dormant stem sections, which are able to re-establish in favourable conditions. Local topography and water supply may also limit the use of this control method (SQDNR 2000). The development of ponded pastures in Queensland is controlled by a government policy. This policy should be referred to before this technique is considered (Anon 2001).

8. Management approaches

Lippia is a rising problem in Queensland and New South Wales and there is a need to review management approaches to this species. Legislation resulting in obligatory control by landholders is not currently a viable tool for lippia. Until research provides effective methods of control for all situations and more is known about the mode of spread then compliance with legislation is unlikely. Lessons can be learned from managing other weeds in Queensland such as parthenium and the weedy Sporobolus grasses. The management approaches for lippia are also linked to the need to improve the overall health of the Murray–Darling Basin system. Recommendations for further action include the need for research on the species, its control, and the production of extension products.

8.1 Legislation

8.1.1 Present status in Australia

Lippia is only declared in New South Wales and Western Australia. In New South Wales, both *P. canescens* and *P. nodiflora* are categorised as W4cp noxious weeds under the Noxious Weeds Act 1993 (NWSEC 2001). The 'W4' category prohibits specific actions being undertaken in respect of the weed. The 'cp' subcategory requires the weeds not to be sold, propagated or knowingly distributed, and to be prevented from spreading to adjoining properties. This declaration applies to a small number of local council areas in New South Wales including the Central Northern County Council (Manilla, Murrurundi, Nundle, Parry, Quirindi and Tamworth council areas) as well as Gunnedah and Moree Plains control areas (NWSEC 2001). Western Australia uses a Permitted and Prohibited list for plant entry control. *P. nodiflora* is included in the 'Permitted' list (R Randall 2003, pers. comm., March) while *P. canescens* is 'Unassessed'. This means that although the plant has not been assessed at this stage, its entry into Western Australia is prohibited due to its declaration in New South Wales (NWSEC 2001).

8.1.2 Present status in Queensland

Lippia was declared under local law in the Warwick Shire, following a council resolution in November 1997. This action was intended to increase awareness of lippia in the shire and to highlight the extent of invasion to the state government (G Dight 2003 pers. comm., February). However, the plant may be undeclared at the next council review due to lack of means of enforcing the declaration (G Dight 2003, pers. comm., February). This is the only known case of declaration in Queensland. Lippia is currently mentioned in the pest management plans of only five local governments.

8.1.3 Demand for declaration in Queensland

Although there is concern over the spread and current/potential impact of lippia in Queensland, this has not resulted in nomination for declaration of the plant. The general view is that if the plant cannot be adequately controlled due to its widespread distribution or lack of adequate control methods, state declaration will only place an unacceptable burden on local governments and landholders (G Dight 2003, pers. comm., February; Anon 2003). The only possible benefit of legislation may be if it prompts research into alternative and successful control methods, such as biocontrol agents. Government assistance regarding research into biocontrol of lippia has been requested by landholders and shire councils (Illing 2000; G Dight 2003, pers. comm., February). Research can also occur without declaration; a project on biological control is currently being investigated by CSIRO and another project of the ecology of the species is being funded by the Cooperative Research Centre for Weed Management.

Six community and stakeholder groups in south-east Queensland have rated lippia as being among their top five 'weeds of high priority' (Elliot 2001). All organisations recognised current and/or potential impacts of lippia on the environment, economy and social/cultural values. Research (particularly chemical control) and extension were rated as the highest level of importance in terms of strategic directions taken by the Department of Natural Resources, Mines and Energy in its future weed management activities.

A community-based group has been founded to help the development of improved management and control methods for lippia and to minimise the spread and impact of this plant. The Murray–Darling Basin Lippia Working Group was established out of Moree in New South Wales in 2002, and includes landholders and representatives from state government agencies, local governments, research bodies and industry groups from Queensland and New South Wales (T Woods 2002, pers. comm., February). Their work is of a continuing nature and may contribute to the ultimate management of lippia in Queensland and other states.

8.2 Eradication or containment strategies

Eradication is not a feasible management option for lippia in Queensland due to its long establishment and the extent of its spread in the Murray–Darling catchment area. Containment may be possible with a combination of public education, pasture management and commitment to the control of its spread, especially in susceptible parts of central and south-western Queensland. The spread of parthenium weed in Queensland has been slowed by the implementation of roadside control activities and the control of see spread. Restrictions on the sale of lippia as a grass substitute are desirable as a method of slowing the spread of the species although the restrictions on sales of lippia may have economic impacts on the nursery industry. It would also be hoped that the species would no longer be used in stream bank stabilisation activities, as this has obviously been a major means of spread in southern states.

A large number of producers and land mangers are currently unaware of lippia. In light of this, an information sheet on lippia is highly recommended for affected regions or at risk areas. This document would include how to identify the species as well as extension on methods to manage the plant and reduce its spread. A similar document for the giant rats tail grasses has substantially increased community awareness of these species.

Pasture improvement to manage lippia in timbered and riparian lands may conflict with legislation. Rob McCosker, a Brisbane-based ecosystem management consultant, has stated that the most realistic approach to land rehabilitation in these sites is through improved pasture, which may require some strategic clearing (White 2002). In Queensland the *Vegetation Management Act* 1999 may affect the management of lippia. As the species is not currently declared it cannot be used as a reason for clearing for weed management purposes. If such control is limited in both Queensland and New South Wales (where two pieces of legislation are involved), containing the spread of lippia in these states may be harder to achieve. The recent expansion of lippia into non-riparian sites requires study, as these sites demonstrate a new threat to primary production in Queensland. It may be difficult to prevent the spread to these sites as it appears to be linked to movement of seeds in mud and plant material by birds and other animals. These sites may require quite different management methods; for example, planned grazing may be a good option.

The occurrence of lippia in the New South Wales catchments of the Murray–Darling Basin system appears to be strongly linked to changes in both water flows and land use, resulting in increased bare ground. It is unlikely that the treatment of current infestations along much of this river system will be effective in the long term without significant improvements in the management of the riverbanks, river floodplains and flows. Lippia will continue to be carried down the river with floods and bare sites will be re-colonised. Research into practical methods of restoring riparian vegetation is required. Removal of lippia from sites not linked to site restoration is likely to result in riverbank erosion. In the short term efforts must be made to increase the amount of groundcovers (either native or from improved pastures) to further reduce the establishment and spread of lippia. There are currently many sites where lippia is the only species to have survived recent droughts and it is likely that the species will continue to expand after the rainfall events in late 2003.

8.3 Further activities

This review has identified the following knowledge gaps relevant to the pest status of lippia in Queensland:

1. Confirmation of the status of the two species, *Phyla canescens* and *P. nodiflora*, and endemism of the species
2. Economic and environmental impacts of lippia
3. Seed production and seed bank
4. Ecology of invasion in non-riparian areas.

9. References

Anon 2001, *Ponded pastures policy*, available online at <http://www.nrm.qld.gov.au/land/management/pdf/ponded_pasture.pdf>, viewed 24 March 2004.

Anon. 2003, 'Clifton wants answers on weed control', *The Chronicle*, 27 February, p. 7.

Arnold, TH & De Wet, BC 1993. *Plants of southern Africa: names and distribution,* Memoirs of the Botanical Survey of South Africa, no. 62, National Botanical Institute, Pretoria.

Australian National Herbarium 2003, *Australian National Herbarium Specimen Information Register*, available online at <http://www.anbg.gov.au/cgi-bin/anhsir>, viewed 17 January 2003.

Australian Pesticides and Veterinary Medicines Authority (APVMA) Website 2003. Available online at **<**http://www.apvma.gov.au/index.html**>**, viewed 24 March 2004.

Batianoff, GN & Butler, DW 2002, 'Assessment of invasive naturalised plants in south-east Queensland', *Plant Protection Quarterly*, vol. 17, pp. 27–34.

Border Rivers Catchment Management and Landcare Centre (BRCMLC) 2002, Newsletter from the Border Rivers Catchment Management and Landcare Centre, Natural Heritage Trust, Landcare Catchment Management Queensland, and Waterwatch Australia, Goondiwindi, Queensland, available online at <http://www.waggambalandcare.org.au/Publications/Sept_Newsletter.pdf**>**, viewed 28 February 2003.

Border Rivers Flow Management Planning (BRFMP) 1999, *Current ecological condition of streams in the Border Rivers catchment*, Part 1, prepared for the Department of Natural Resources (Queensland) and the Department of Land and Water Conservation (New South Wales), available online at <http://www.nrm.qld.gov.au/wrp/pdf/border/cecr_p1.pdf>, viewed 6 January 2003

Csurhes, SM 1989, *Occurrence of phyla weed (*Phyla nodiflora*) on the Condamine River*, Queensland Lands Department Survey, Allan Fletcher Research Station.

Dellow, JJ, Motley, K, Storrie, A & Spenceley, J 2001, *Lippia*, Agfact P7.6.52, NSW Agriculture.

Earl J 2003, The distribution and impacts of Lippia (*Phyla canescens*) in the Murray Darling System, Agricultural Information and Monitoring Services report for the Lippia Working Group.

Elakovich, SD & Stevens, KL 1985, '*Volatile constituents of* Lippia nodiflora', *Journal of Natural Products*, vol. 48, pp. 504–6.

Elliot, H 2001, 'Southern Queensland priority weed survey: community and stakeholder results', internal report, Department of Natural Resources and Mines, Queensland.

Fensham, RJ 1998, 'The grassy vegetation of the Darling Downs, south-eastern Queensland, Australia: floristics and grazing effects', *Biological Conservation*, vol. 84, no. 3, 301–10.

Illing, D 2000, *Managing lippia: the crucial points*, Pittsworth, Queensland.

Jenson, M 2002, 'From the best to the worst', *The Border News*, 29 April 2002, p. 1.

Karadge, BA, Danawade, LN & Chavan, PD 1983, 'Physiological studies in salt tolerance in *Lippia nodiflora* Michaux. 1. Growth, mineral nutrition and organic constituents', *Biovigyanam*, vol. 9, pp. 47–58.

Kumar, P & Dutt, B 1989, 'Cytogenic basis of breeding system in some Verbenaceous species', *Cytologia*, vol. 54, pp. 347–53.

Lazarides, M, Cowley, KJ & Hohen, P 1997, *CSIRO handbook of Australian weeds*, CSIRO Australia, Collingwood, Victoria.

Lucy, M, Powell, E, McCosker, R, Inglis, G & Richardson, R 1995, *Lippia (*Phyla canescens*): A review of its economic and environmental impact on floodplain ecosystems in the Murray–Darling Basin*, Department of Primary Industries, Brisbane.

Mabberley, DJ 1997, *The plant book: a portable dictionary of the vascular plants*, 2nd edn, Cambridge University Press, Cambridge.

Mann, J 1960, *The occurrence of phyla weed (*Phyla nodiflora*) on the Condamine River*, Queensland Lands Department Survey, Alan Fletcher Research Station, Brisbane.

McCosker, RO 1994, *Lippia (*Phyla nodiflora*): an invasive plant of floodplain systems in the Murray–Darling Basin*, a report on the distribution and ecology of lippia in the lower Gwydir Valley and the Murray–Darling Basin prepared for the Gingham Watercourse Landcare Group, Department of Ecosystem Management, University of New England, Armidale, NSW.

McCosker, RO 1996, *An environmental scan of the Condamine-Balonne River system and associated floodplain*, prepared by RO McCosker, Landmax, Armidale, NSW.

Motley, K, Dellow, J, Storrie, A & Spenceley, J 2001, *Using herbicides in a lippia management program*, Agnote DPI-384, NSW Agriculture.

Munir, AA 1993, 'A taxonomic revision of the genus *Phyla* Lour. (Verbenaceae) in Australia', *Journal of the Adelaide Botanical Gardens*, vol. 15, pp. 109–128.

National Weed Strategy Executive Committee (NWSEC) 2001, *Weeds Australia: national weeds strategy*, National Weed Strategy Executive Committee and National Heritage Trust, available online at <http://www.weeds.org.au/cgi-bin/weednet.cgi>, viewed 3 February 2003.

North West Weeds County Council (NWWCC) 2002, *Lippia*, available online at <http://www.northwestweeds.nsw.gov.au/Lippia.htm>, viewed 5 December 2003.

Nufarm 2003, Nufarm, Australia, <http://www.nufarm.com.au/web/nufarmcomau/nufarmcomauhp.nsf/web/index.html> accessed 24 March 2003.

Pacific Island Ecosystems at Risk (PIER) 2004. *Phyla nodiflora*, available online at <http://www.hear.org/pier/oscinames.htm> , accessed on 22 March 2004.

Phillips, N & Moller, M 1995, *State of the rivers: Upper Condamine River and major tributaries*: an ecological and physical assessment of the conditions of streams in the Upper Condamine River catchment, Department of Primary Industries, Water Resources Branch, Brisbane.

The Plant Names Project (PNP) 1999, *International plant names index*, available online at <http://www.ipni.org>, viewed 15 January 2003.

Randall, RP 2002, *A global compendium of weeds*, RG and FJ Richardson, Melbourne.

Richardson, R 1994, *Lippia (*Phyla nodiflora*): its distribution and impact throughout the eastern mainland states of Australia*, a postgraduate report, Faculty of Applied Science, The University of Queensland, Gatton College, Lawes.

Sands, JW 1983, 'Evaluation of the flood and waterlogging tolerance of a range of tropical grasses, fourth year thesis project, The University of Queensland, Gatton College, Lawes.

Skarratt, DB, Sutherst, RW & Maywald, GF 1995, CLIMEX for Windows Version 1.0: users guide.

Stanley, TD & Ross, EM 1986, *Flora of south-eastern Queensland,* Department of Primary Industries, Queensland.

Department of Natural Resources (DNR) 2000, *Better management practices manual*, Department of Natural Resources, Upper Condamine Floodplain, Natural Heritage Trust and Landcare Queensland, available online at <http://www.nrm.qld.gov.au/community/condaminefp/bmp-manual.htm>, viewed 6 January 2003.

Tomas-Barberan, FA, Harborne, JB & Self, R 1987, Twelve 6-oxygenated flavone sulphates from *Lippia nodiflora* and *L. canescens*, P*hytochemistry*, vol. 26, no. 8, pp. 2281–84.

Tutin, TG, Heywood, VH, Burges, NA, Moore, DM, Valentine, DH, Walters, SM & Webb, DA (eds) 1972, *Flora Europaea*, vol. 3, Cambridge University Press, Cambridge.

USDA, ARS, National Genetic Resources program (USDA) 2003, *Germplasm Resources Information Network*, National Germplasm Resources Laboratory, Beltsville, Maryland, available online at <http://www.ars-grin.gov/cgi-bin/npgs/html/taxon.pl?429348**>**, viewed 14 March 2003.

Veeranjaneyulu, K & Das, VSR 1984, 'Purple pigmentation in leaves of some tropical weed species', *Biologia Plantarum*, vol. 26, pp. 215–20.

White, S 2002, 'Spreading cancer', *The Land*, 2 May 2002, p. 15.

World Wildlife Fund For Nature (WWF) 2002, *Media release: Invasive floodplain weed a costly threat to Murray–Darling Basin*, available online at <http://www.wwf.org.au/default.asp?p+press_gallery.htm>, viewed 19 December 2002.