

Taxonomy

Phyla canescens was reported in Australia for the first time by Munir (1993) who published a taxonomic revision of *Phyla* in 1993. Although Lucy *et al.* (1995) cite the first official recording as Lake Torrens Adelaide SA in 1927 and in Queensland at Tummaville in 1944. The species was referred to most commonly as *Phyla nodiflora* until at least that time. e.g. in surveys of the Condamine River catchment by Mann in 1960 and Csurhes in 1989 (Lucy *et al.*, 1995). Other synonyms include:- *Phyla nodiflora* var *canescens*, *Lippia canescens*, *Lippia nodiflora*, *Lippia nodiflora* var *rosea*, *Zapania canescens*, *Zapania nodiflora* var *rosea*.

There is some conjecture over the native status of *Phyla nodiflora*. The first collections of *Phyla nodiflora* were made in 1802, and the first published record of *Zapania* was in 1810, all recent records until at least 1993, refer to *Phyla nodiflora* (Munir, 1993).

The earliest record of 19 specimens of *Phyla canescens* listed on the Royal Botanic Gardens, Sydney, database was 1949 from Burrumbuttock on the SW slopes of NSW. The Royal Botanic Gardens, Melbourne, list 30 specimens of *Phyla canescens* on its database with the earliest collections from Williamstown, a suburb of Melbourne, in 1914 (Table 7).

Table 7. Specimens of *Phyla canescens* held at (a) The Royal Botanic Gardens Herbarium, Sydney, (b) The National Herbarium, Canberra and (c) The Royal Botanic Gardens Herbarium, Melbourne, the location and date of collection are also listed.

(a)		(b)	
Location	Date	Location	Date
Hay	2002	Deakin, Canberra	1994
Moulamein	2000	Macquarie Marshes, Quambone	1980
Hay	2000	Macquarie Marshes	1980
Mildura	2000	Breeza	2001
Deakin, Canberra	1994	Westmar, Qld.	1959
Mannum SA.	1986	Brookstead, Qld.	1981
Jemalong Weir	1983	Chinchilla	1993
Moree	1981	Queens Bend, Murray River, SA.	1980
Balranald	1981	Martins Bend, Murray River, SA.	1983
Deniliquin	1977	Clare	1965
Central Coast	1976	Adelaide	1960
Wentworth	1976	Glandore, Adelaide	1984
Moree	1974	Fleurieu Peninsula	1984
Broken Hill	1971	Victor Harbour	1981
Angledool	1970	Zadow's Landing, Lwr Murray SA.	1987
Deniliquin	1964	Mildura	1960
Wentworth	1959	Kerang	1977
Wentworth	1955	Murray Valley	1988
Burrumbuttock	1949		

Table 7c. Specimens of *Phyla canescens* held at The Royal Botanic Gardens Herbarium, Melbourne, including location and date of collection.

(c)

Location	Date
Swan Hill	1998
Lake Keepit	1994
Swan Hill	1997
Wimmera	1997
Murray Mallee	1970
Kerang	1977
Swan Hill	1977
Riverina	1977
Williamstown	1937
Wimmera	1986
Williamstown	1950
Riverina	1985
Williamstown	1914
Shepparton	1981
Vinifera	1988
Birchip	1967
Murray Mallee	1983
Benalla	1985
Wimmera	1981
Kensington	1977
Williamstown	1917
Lake Boort	1985
Wannon	1984
Mildura	1965
Piamble SF, Murray Mallee	1982
Murray Valley	1988
Nyah SF	1977
Murray Mallee	2000
Williamstown	1991

Phyla nodiflora is thought to be common in coastal areas from NSW, Qld. NT and WA, whereas *Phyla canescens* is the species rapidly overtaking and continuing to spread throughout the inland floodplain region.

There appears to be some degree of overlap in the habitat of *Phyla canescens* and *Phyla nodiflora*. A specimen of *Phyla canescens* held by the Royal Botanic Gardens Herbarium, Sydney was collected from the NSW Central Coast in 1976 and at least two specimens collected over the duration of this study are thought to be *Phyla nodiflora*, this however this remains to be confirmed. Both species have been reported as occurring in Tasmania and Western Australia.

Rate of increase of *Lippia*

Clearly the distribution of *Lippia* has increased significantly over the past 10-20 years but to talk of a consistent rate of increase is misleading. *Lippia*, as for every other plant species, is susceptible to environmental fluctuations and has the potential to take advantage of conditions which are particularly favourable for its growth. The potential for a species to increase or decrease in density depends on environmental influences and interactions with other species growing in association.

The spread of *Lippia* appears to be clearly related to flood events. Many farmers, particularly south of the Queensland border, stated that *Lippia* has become a problem since specific flood events. In the Gwydir region the *Lippia* population increased markedly following the 1996 flood and again after the 1998 floods. In the Lachlan a significant increase in *Lippia* followed the floods of 1990. A comment attached to a specimen collected from the King's Billabong on the Murray River in 1965 reads "Before the 1956 flood this plant was unknown on the river flats. Now it's everywhere".

The long term data from McCosker's survey sites (Table 5) shows the fluctuation in *Lippia* population density over time. At two of these sites (1 & 5) *Lippia* was not recorded prior to the 1998 flood event. At sites 2 & 3 *Lippia* was present at the initial survey in 1992 providing less than 10% cover at that time. The population at both sites has fluctuated markedly over the 10 year duration of the study. At the final site, site 4, *Lippia* has been a dominant component of the vegetation over the period and peaked at 99% cover at the measurement following the 1998 flood.

A common feature of these data is that at all sites litter/bare ground is the other dominant component of cover. In April 2003 *Lippia* provided approximately 25-35% cover at all sites. In light of the severity of the current drought conditions being experienced over inland Australia at the time of the study the area occupied by *Lippia* is likely to be a small fraction of its potential given adequate soil moisture. The average area of bare ground at each of these sites was greater than 50%.

Under conditions of adequate soil moisture it would not be unexpected to achieve very close to 100% cover by *Lippia* at each of these sites within 3-4 weeks following rainfall sufficient to saturate the soil profile and provide suitable growth conditions. This growth potential is enhanced by the absence, or suppression, of other species with the ability to effectively compete with *Lippia* for space, moisture or nutrients and eventually light. Such an event would equate to a 400% increase in a matter of 4 weeks. The conditions recorded by McCosker at these 5 sites during April 2003 were typical of many thousand hectares of land across the Murray Darling Basin. A 400% increase in *Lippia* cover over much of the area in a matter of weeks is a very real possibility.

The distribution, in terms of the area occupied by *Lippia* throughout the Murray Darling Basin has increased markedly since estimates by McCosker (1994a) and Lucy *et al.* (1995). Of equal importance is that over the last decade the density of *Lippia* at some sites has increased significantly. The current relatively low levels of cover of *Lippia* present at many locations is predominantly a function of low soil moisture inhibiting growth. However, in the majority of locations where *Lippia* does occur, there was little other perennial groundcover vegetation present to effectively compete with *Lippia* when favourable growth conditions return.

Potential distribution

As mentioned in the previous section, as soon as favourable soil moisture conditions return the area occupied by Lippia will, in all probability, increase significantly in a matter of weeks. In many areas the current and continuing drought has suppressed the growth of Lippia but the conditions, in combination with continual grazing of areas by livestock, has suppressed the growth of all other species growing in association to a much greater extent. This particularly applies to the perennial grass component of pastures.

There are vast areas of the Murray Darling Basin currently devoid of groundcover and with Lippia the only species present retaining any amount of green leaf. The ability of Lippia to regenerate and grow rapidly under suitable growth conditions has it well placed to quickly dominate any area where it currently is extant. A period of significant rainfall will result in an 'explosion' in the Lippia population similar to that observed throughout many catchments during the 1990s.

It is unlikely the actual area of distribution will alter greatly until the next major flood event. Taking the Namoi as an example, Lippia appeared to progress further down the catchment with each successive flood event throughout the 1990s. Thought to originate in Cox's Creek it rapidly progressed down the catchment to Boggabri and Narrabri in the early 90s then following the 1998 flood and wetter conditions through 2000 Lippia was identified as widespread in Wee Waa and Burren Junction. In the Condamine and many other areas, Lippia has demonstrated an ability to adapt to conditions where it is not frequently inundated and is reportedly spreading throughout the higher hilly areas.

The presence and success of Lippia in establishing in the relatively lower rainfall areas of the Lowbidgee, Lower Murray and SA MDB would suggest it is only a matter of time before Lippia extends further west along the Barwon and Darling Rivers of NSW and the Warrego Paroo system in Queensland. Its current sporadic occurrence in these areas would suggest it has the ability to adapt and persist in relatively drier environments.

In the event of a significant flood event in any of the MDB catchments the potential is that Lippia could spread rapidly across entire floodplains. If such a flood were followed by a sequence of average or above average rainfall years, under current land management practices, Lippia has the ability to totally cover vast areas of land, including wide areas above the level of flood plains.

Lippia has had relatively less impact on agricultural practices in the Central West (Castlereagh, Macquarie and Bogan) catchment of NSW. The reasons for this are unclear given the extent of development and alteration to water regime that has occurred in the catchment (DWR, 1992). The potential exists for Lippia to successfully extend its range to this catchment unless preventative action is taken immediately.

Given that the climate of the past 5 years has been drier than average over most of the MDB, no major flooding has occurred in any catchment, and Lippia is still reported to be increasing over this time it is highly probable that another significant expansion of Lippia throughout the catchment is imminent. The amount of bare ground present over much of the inland floodplain region of the MDB provides the perfect conditions for the widespread establishment of Lippia following any flood event. The photographs on the following page (Plates 2-4) are typical of vast areas of the MDB and illustrate the urgency of the situation. The estimated extent of the potential distribution of Lippia in the MDB is illustrated in Figure 9.



Plate 2

The extent of bare ground associated with Lippia at a site near Toobeah, Qld. Lippia is the only actively growing species and in the event of favourable soil moisture will be best placed to take advantage of such conditions.



Plate 3

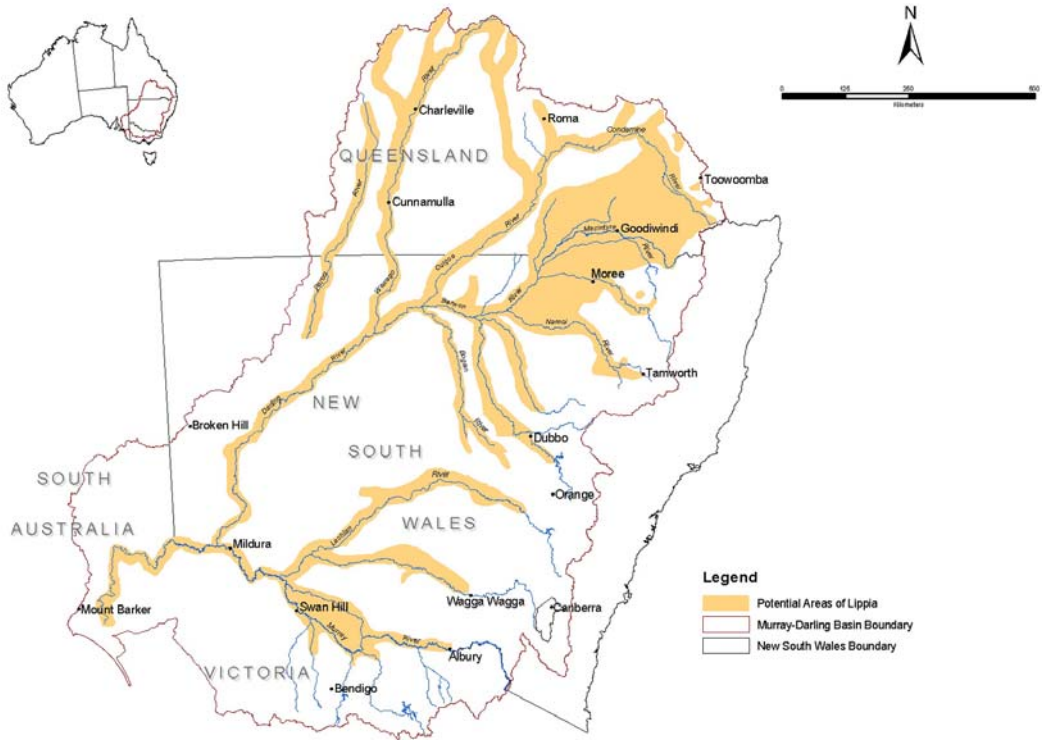
At this site on the Big Leather Watercourse west of Moree, NSW, Lippia provides most of the actively growing groundcover.



Plate 4

On the banks of the Murray River at Swan Hill, Vic, Lippia and bare exposed soil dominate the groundcover.

Figure 9 Estimated short-term potential distribution of Lippia throughout MBD.



Farmer survey results

Survey forms were distributed to approximately 2,000 landholders throughout the Murray Darling Basin. A total of 108 forms were returned and included in the analysis, representing a 5.4% response rate. The majority of respondents were from the Condamine, Border Rivers and Gwydir catchment areas indicating the relatively higher level of concern regarding the impact of Lippia in these regions. Although the response rate approximated the 5% average expected survey response, a general lack of awareness of Lippia and the associated problems, particularly in the southern areas of the MDB may have been a contributing factor to more survey forms not being returned. The summary of landholding area, areas affected by Lippia and attempts to suppress Lippia is presented in Table 8.

On average, respondents had been aware of Lippia for 15 years, although this time ranged from 3 months to 50 years, 91% of respondents had Lippia present on their property. There was a strong association between the time when most people observed Lippia on their property and the time when they first became aware of it and the associated issues. The areas affected by Lippia when it was first observed ranged from a number of small patches covering a few square metres in paddocks along bore drains or creek edges to many hectares, generally spreading across floodplains following floods. The average property area covered by Lippia when initially observed was 6%, at the time of the survey the average level of cover across properties was 26%.

Table 8. Summary of survey responses relating to land area, the presence of Lippia and management methods.

Land Areas

Total area of holdings of respondents	155,835 ha.
Respondents average area of holding	2,255 ha.
Range of property size of respondents	73 -16,000 ha.

Total area cultivated.	63,272 ha.	45% of the total area.
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Total area affected by Lippia	42,655 ha.	27% of the total area, 46% of the area not cultivated
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70% of those with Lippia present reported it as occurring on or adjacent to waterways
57% of those with Lippia present reported it as occurring on flood prone areas
56% of those with Lippia present reported it as occurring on areas above flood zones

Control

72% of those who have Lippia present have tried some method of control
41% of those who have attempted suppression of Lippia have not achieved any level of control for any length of time, using any method.

The high percentage of respondents (56%) reporting Lippia as occurring above the reach of floodwaters indicates its ability to adapt and effectively spread to relatively

drier environments (Table 8). Generally, management in these areas will be more difficult.

Of all respondents, 72% reported attempting one or more method to control the spread of Lippia (Table 8). Of these only 41% of those who had attempted to control it reported achieving any level of suppression for any length of time, using any method. A number of respondents had tried more than one method of suppression. Table 9 lists the various methods of management attempted, the percentage of those who had achieved any degree of control and the average length of time respondents considered effective suppression had been achieved.

Table 9. Summary of respondents who have attempted use of any method of control, the percentage of those who reported achieving suppression and for those who reported successful suppression, the average length of time that suppression was achieved.

Method	Respondents	Control achieved	Average length of time
Chemical	62%	15%	5 months
Mechanical	66%	30%	2¼ years
Grazing	35%	18%	8 years

The results presented in Table 9 highlight the inability of the tools that are currently most commonly used to effectively manage Lippia. Clearly, chemical application has had little impact on suppressing the spread of Lippia. Only 15% of those who have tried to control Lippia with herbicide, on average, achieved suppression for 5 months. A 5 month period could be considered suppression of expression of Lippia rather than any 'control' or reduction in its occurrence. Those that had employed cultivation as a means of suppression reported reinvasion of Lippia, on average, within 2¼ years of ceasing the practice. Of the respondents who had attempted control using grazing livestock few individuals had been successful. Each had applied a planned grazing strategy using high-density-short-duration stocking and had, to date, effectively managed the spread of Lippia for 7 and 17 years respectively (ref. Case Study 15).

Lippia presents the greatest problem on clay soils, 95% of respondents reported it as occurring on soils with a high clay content.

Of those that reported Lippia as present 63% nominated Lippia as their worst weed. An economic impact of Lippia on farming practices was reported by 12% of respondents. An increased number of workings was necessary and a greater use of chemical was necessary on cultivated land to suppress Lippia in crops.

The economic impact of the presence of Lippia was much greater on grazed land, 58% of respondents acknowledged an impact on their livestock enterprise, primarily in a reduction of stocking rate. The average stocking rate reduction recorded amongst respondents was 55%, overall changes in stocking rate attributed to Lippia ranged from 0 to 100% destocking. Another effect of Lippia was on the time taken to finish stock.

On farm costs associated with Lippia

The costs associated with suppress of Lippia on farm, as expected, vary considerably between individuals, regions and catchments depending on the level of infestation and individual attitudes to the presence of Lippia. The costs may be in terms of direct expenditure associated with application of herbicide or costs of clearing land for cultivation. There may be extra costs in additional working of land, one or two more passes with the plough or additional chemical application on cultivated land to suppress Lippia. Less direct impacts are apparent in terms of a gradual reduction in stocking rate or an increase in the time required to finish stock when grazing Lippia infected pastures.

A 2002 survey of landholders in the Tamworth, Narrabri and Moree RLPB districts showed the cost of control varied from 0 to \$400 per hectare (NGNWAC, 2002). These figures are comparable to costs identified by the majority of respondents in the current study, which were found to vary from 0 to \$410 per hectare.

Cultivation

The cost of clearing land for lippia management generally varied from \$200 to \$410 per hectare, although one landholder reported the cost of clearing one area to be \$615 per hectare. In many instances clearing for the purpose of sowing a crop was an activity which would not have been considered other than for the purpose of Lippia suppression. The productive potential of the land was considered to be so poor due to the presence of Lippia that cropping the affected areas was the only option available to generate income. Additional costs associated with this activity and not usually taken into account is the cost of lost production from an area for the period the development is taking place and time out of production between annual crops. There is also a high risk associated with the loss of topsoil that may occur in a flood event particularly in areas located close to waterways.

Herbicides

The cost of herbicide application also varies with the type of chemical used the rate of application and the method of application. Typically the costs of the chemical ranged from \$20 - \$45 per hectare depending on the chemical and rate of application. The costs associated with the activity ranged from \$30 - \$50 per hectare. Total costs associated with spraying were up to \$120 per hectare and affected areas were commonly sprayed twice in a growing season. Many graziers also noted that damage to equipment was also an issue in areas affected by Lippia, because of unevenness in the ground created by its presence and the inaccessibility of machinery to many affected areas.

More difficult to quantify was the economic impact of Lippia on grazing enterprises due to the range of areas affected and variation in the productive potential of the land in different regions. The most common livestock enterprise on the floodplain regions was beef cattle production and the worst affected areas were native or natural pastures of the floodplain region. NSW Agriculture gross margins (June 2003) for an inland early weaner calf production enterprise grazing natural pastures were used to calculate the following costs to the grazing industry. A number of assumptions were used to generate the economic costs. These were estimated from responses to questions included in the farmer survey.

Cost of Lippia to the grazing industry

Assumptions:

Gross Margin for a 100 cow mob	= \$291.21/hd (NSW Dept of Ag. GM June 03)
Average stocking rate	= 1 cow-calf unit/5ha
1 cow/calf unit average annual	= 18 DSE.
Average stocking rate	= 18 DSE / 5 ha
	= 3.6 DSE/ha.

∴ 500 ha is required for 100 cow mob

From survey responses the average reduction in stocking rate was 50% excluding those who had totally destocked.

The GM for an average 500 ha block = $100 \times \$291.21/\text{hd} \div 500 \text{ ha}$
= \$58.24 per ha

A 50% reduction in stocking rate, GM = \$29.12 per ha.

Conservatively, there are 1.3 million hectares of grazing land affected by Lippia.

The value of the industry over this area = \$75,712,000

At an average loss of production of \$29.12/ha the total cost over the area = \$37,856,000

These estimates are considered conservative, although, they are consistent with estimates from other sources such as Lucy *et al.* (1995) and Whalley (2002). In some areas of the Murray Darling Basin average stocking rates in the absence of Lippia approach 20 DSE/ha and the gross margin/ha for some cattle enterprises may be as high as \$700/ha. In such situations a 50% reduction in stocking rate reduces the gross margin by \$350/ha a more than tenfold increase in the estimates used in the calculations above.

Taking an average 500ha area west of Moree affected by Lippia to the extent that carrying capacity is reduced by 50%.

The lost production from this area = \$14,560/yr (based on figures above)

The cost of a single average chemical spray treatment @ \$80/ha, assuming an average of 2 sprays per year are required to suppress Lippia annual cost = \$80,000

The total annual cost of Lippia to the landholder on this 500ha area is of the order of \$95,000.

Assuming this paddock was a relatively open area and the landholder decided to clear, cultivate and sow a crop, at an average cost of \$200/ha, the total cost of development of this area would be \$100,000 plus the cost of submission of any required development application.



Plate 5

Lippia regeneration at Quirindi, NSW, 14 days after spraying, April 2003.



Plate 6

Clearing and cultivation are seen as the only effective control where Lippia occurs at high density. The cleared area in the background was in a similar condition to the vegetation to the fore-ground prior to development. Moree, NSW.



Plate 7

Significant production losses have been incurred by the grazing industry. Low density grazing results in a decline in the competitive ability of perennial grasses and enables weeds such as Lippia to dominate the vegetation. Moree, NSW.

Damage to roads and structures

A number of Shire Councils have reported significant damage to road foundations as a result of the ability of the roots of Lippia to extend under road base causing premature deterioration of the road surface. Lucy *et al.* (1995) estimated that Lippia was responsible for in excess of \$1 million additional expenditure by Shire Councils in the Darling Downs region to cover the cost of annual road maintenance costs. Erosion of river banks attributed to Lippia is also reported to be risking the stability of bridge support columns. Other costs to Councils associated with Lippia is the cost of herbicide spray programs to manage the spread of Lippia.



Plate 8

Lippia growth in bitumen along the edge of roadside a Boggabri, NSW.



Plate 9

Lippia growth encroaching across the surface of the road, Boggabri, NSW.

Environmental impacts

Biodiversity

High biodiversity, productivity and habitat heterogeneity are inherent characteristics of natural floodplain (Tockner and Stanford, 2002). Habitat alteration, flood and environmental flow control and species invasion are closely linked and important causes of floodplain degradation, which includes the decline in biodiversity. The low, dense mat forming growth habit of *Lippia* effectively restricts the growth of other species growing in association. The density of growth in many areas is such that it effectively limits light at the soil surface, inhibiting the germination of other species. There is also a suggestion by a number of graziers and researchers of the allelopathic effect of *Lippia* in suppressing the germination and growth of surrounding species (Lucy *et al.* 1995).

For any plants which co-exist in situations where they are subject to environmental stress those which are best able to use the available resources and maintain growth will have the advantage (Taylor, 2003). The ability of *Lippia* to tolerate drought, retain green leaf and ability for rapid growth, gives it an advantage over other species when favourable soil moisture conditions return (Mawhinney, 2002). These characteristics of *Lippia* have a detrimental effect on plant species diversity, with the result that all diversity is suppressed where it occurs at high density.

The primary threat from *Lippia* lies in its direct impact on groundcover in floodplain communities. By preventing recruitment of other floodplain herbaceous species, *Lippia* has the potential to catastrophically reduce the diversity of floodplain herbaceous plants. *Lippia* has the potential to cause significant changes to the structure and diversity of floodplain grasslands, sedgeland, woodlands and forests. Regeneration of floodplain eucalypts such as Coolibah (*Eucalyptus coolabah*) and River Red Gum (*Eucalyptus camaldulensis*) and other woody plants such as lignum (*Muehlenbeckia cunninghamii*) are particularly susceptible. These changes will result not only in a loss of diversity in floodplain groundcover plants but also in loss of diversity in floodplain fauna as a result of changes to habitat structure and resource availability.



Plate 10

Lippia dominates the ground cover along the Gingham Watercourse, a RAMSAR listed wetland of International Significance. The density of *Lippia* restricts the regeneration of many other herbaceous species, effectively reducing biodiversity.

Threatened communities & species

There are at least four threatened ecological communities listed that occur within the area of distribution of *Lippia*. These are the Bluegrass (*Dicanthium* spp.) dominant grasslands of the Brigalow Belt Bioregions (North and South) of Queensland (Fig. 10), Brigalow (*Acacia harpophylla* dominant and co-dominant) of Queensland and northern NSW (Fig.11), Buloke Woodlands of the Riverina and Murray-Darling Depression Bioregions (Fig. 12) and the Grassy White Box Woodlands of NSW (Fig.13). The distribution of these threatened ecological communities are shown on the respective maps.

There are many more communities threatened by the presence of *Lippia*. *Lippia* occurs commonly in River Red Gum (*Eucalyptus camaldulensis*) Forests, Coolibah (*Eucalyptus coolabah*) and Black Box (*Eucalyptus largiflorens*) Woodlands, some Poplar Box (*Eucalyptus populnea*) and Belah (*Casuarina cristata*) Woodlands and in Carbeen (*Corymbia tessellaris*) Forests. *Lippia* has also been reported as a serious invader of *Cyperus* and *Bolboschoenus* sedgeland, Water couch (*Paspalum distichum*)/spikerush (*Eleocharis plana*) meadows and lignum swamps, in *Dicanthium* grasslands and in native grasslands of the Liverpool Plains.

Eriochloa inundata is the only threatened species known to occur in the Macquarie Marshes, although at least five other species are expected to be present (Brock, 1997). Indeed, any species that occurs in wetlands, along riparian zones or on floodplains which are affected by *Lippia* could be regarded as potentially threatened because of the extent of the modification of the habitat and the ability of *Lippia* to tolerate such a wide range of environmental extremes.

Herbaceous species listed as threatened under the EPBC Act which occur within the known area of distribution of *Lippia* and may potentially be adversely impacted by *Lippia* include; *Amphibromus fluitans*, *Bothriochloa biloba* (Lobed Blue-grass), *Brachyscome muelleroides*, *Brachyscome papillosa* (Mossgiel Daisy), *Callitriche cyclocarpa* (Western Water-starwort), *Digitaria porrecta* (Finger Panic Grass), *Eleocharis obicis* (a Spikerush), *Eriocaulon australasicum* (Southern Pipewort), *Lepidium monoplocoides* (Winged Peppergrass), *Senecio behrianus* (Stiff Groundsel), *Austrostipa wakoolica* (a speargrass), *Swainsona murrayana* (Slender Darling-pea, Slender Swainson, Murray Swainson-pea), *Swainsona plagiotropis* (Red Darling-pea, Red Swainson-pea).

Species considered to be most at risk to become threatened under the EPBC Act or TSC Act in future as a result of the increased distribution and growth of *Lippia* include; *Desmodium campylocaulon*, *Ipomoea diamentinensis* (Desert Cow Vine), *Phyllanthus lacerosus*, *Phyllanthus lacunarius*, *Sida rohlenae*, *Solanum papaverifolium*, *Aristida leptopoda*, *Asperula charophyton*, *Picris barbarorum*, *Poa fordeana*, *Teucrium* sp. A.. A number of these species have no current status at the Federal level and require further investigation, however, they are virtually all restricted to the same habitat as *Lippia*.

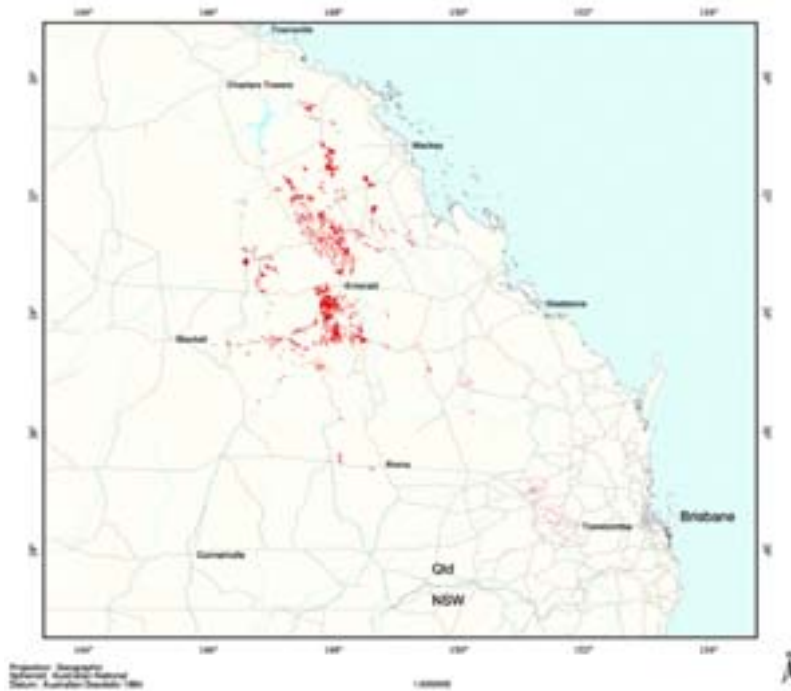


Figure 10. Distribution of the Bluegrass (*Dicanthium* spp.) dominant grasslands of the Brigalow Belt Bioregions (North and South) threatened ecological community.

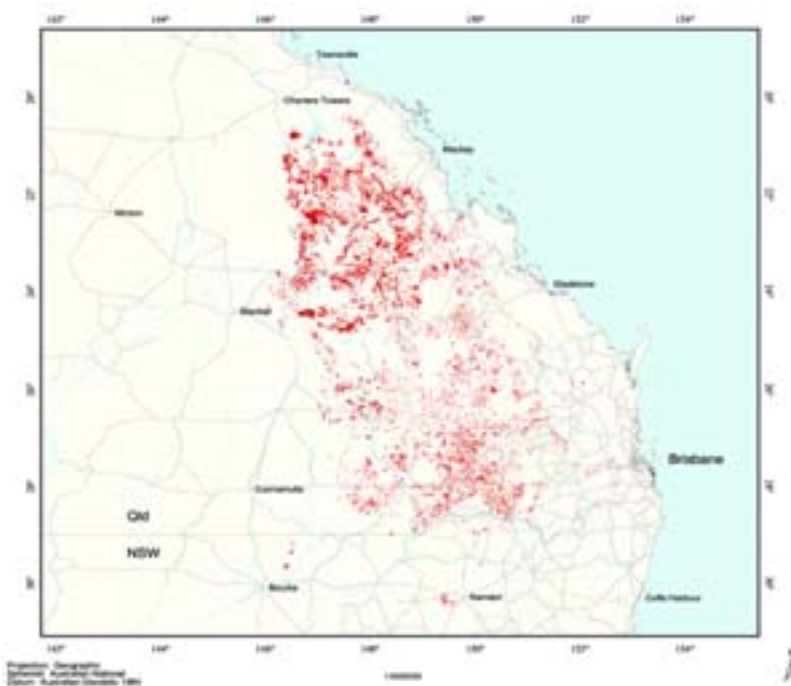


Figure 11. Distribution of the Brigalow (*Acacia harpophylla* dominant and co-dominant) of Queensland and northern NSW threatened ecological community.



Figure 12. Distribution of the Buloke Woodlands of the Riverina and Murray-Darling Depression Bioregions threatened ecological community.



Figure 13. Distribution of the Grassy White Box Woodlands of NSW threatened ecological community.

Grasslands

Native grasses have the ability to compete with *Lippia* when not exposed to frequent defoliation. Taylor (2003) found *Sporobolus mitchelli* was able to maintain cover relative to *Lippia* when initial cover was greater than 25%. In addition, the root growth rate and maximum rooting depth of *S. mitchelli* exceeded that of *Lippia*. *Paspalum distichum* and *Eleocharis plana* can effectively outcompete *Lippia* in wetter sites (Roberts 2002), and Hobson (1999) established that under specific, suitable flooding regimes the growth of *Paspalum distichum* was favoured over that of *Lippia*.

Within most grazed floodplain pastures, individual paddocks are commonly stocked at low density and plants are exposed to livestock for extended periods of time. Graze periods are usually greater than one month and often up to six months at a time. Under such conditions the most desirable (palatable) species experience frequent defoliation and only partial rest. Continual frequent defoliation of native grasses results in a significant reduction in root biomass and density and significantly restricts the plants ability to access soil moisture and nutrients. In addition, the native grass species of the floodplains would have been well adapted to regular cycles and periods of inundation. These wet and dry cycles were significantly altered with the changed water regimes associated with river regulation. Weakened by environmental changes, in combination with continual exposure to livestock and frequent defoliation, the competitive ability of these species has been progressively diminished and ultimately has led to their decline in floodplain pastures. During periods of severe soil moisture stress, such conditions result in plant death.

The bare ground created following the decline in perennial grass populations is then highly susceptible to occupation by exotic species. Over the duration of this study it was observed that *Lippia* was not present at locations which supported dense stands of perennial grasses. In dense stands of perennial grass the boundary of the stand presents a barrier to invasion by *Lippia* (Taylor, 2003). When carried on flood waters there are a limited number of outcomes at the site of deposition of a viable *Lippia* fragment. The most probable outcomes are either;

- i) it may come to rest on bare soil, which, with a high moisture content following the recession of flood water is likely a very favourable site for establishment or
- ii) it may be deposited above the soil surface suspended by the canopy of an intact stand of perennial vegetation. In such a position the *Lippia* fragment is exposed to sunlight and possible dessication within a short period of time, depending on seasonal conditions.

Intact grass canopies with a greater projected cover are far more resilient to *Lippia* invasion than a short canopy or where large gaps occur within a stand (Taylor, 2003).

The vast areas of bare ground that are currently present throughout the entire length of the Murray Darling Basin provide the perfect environment for the establishment of thousands of hectares of *Lippia* following the next flood event. All floodplain grasslands and pastures, which have a high percentage of bare ground present, are at risk and indeed have a very high probability of being invaded by *Lippia* carried on floodwaters.

Perennial plant regeneration

Specific soil moisture, soil temperature and light conditions are required for germination and successful establishment of all plant species. The presence of these conditions and the duration required are more critical for perennial plants. The specific combination of these conditions for recruitment of native perennial groundcover and trees are likely to occur infrequently on the slopes and plains. Habitat alteration, flood and environmental flow control and species invasion are closely linked and important causes of floodplain degradation (Tockner and Stanford, 2002). The altered conditions create a relatively more favourable environment for the establishment and growth of exotic species such as Lippia.

Declining levels of *Eucalyptus* species regeneration has been linked to the occurrence of high densities of Lippia in the Condamine (Lucy *et al.* 1995). In many areas of mature Eucalypt woodland there was an absence of regeneration of *Eucalyptus* spp. where Lippia was the predominant ground cover species.

Ecosystem health

In many situations where Lippia formed a dense ground cover there were indications of very poor plant health. This was evident particularly in the perennial grasses and tree species. Present at high density, Lippia grows thickly to the base of trees. Whether the presence of Lippia is a cause of declining tree health or the poor condition of trees in combination with the presence of Lippia are both symptoms of an unhealthy and suffering ecosystem is a matter for further investigation.



Plate 11

Poor tree health as indicated by low foliage density of the crowns and weak, senescent perennial grasses in a Lippia dominated area west of Narrabri, NSW.

Erosion

Soil loss

Lippia's tendency to dominate in floodplain and areas adjacent to rivers and streams has led to many farmers cultivating areas previously managed for grazing as a means of suppressing Lippia and also enabling income to be generated from the land. This practice has a very high risk associated. In periods of high rainfall and flood, the potential risk for huge losses of soil from these areas is very high. In grazed pastures, including floodplain areas, Lippia is often present in low density in association with high levels of bare ground. In the absence of plant or litter cover there is a high risk of movement of soil particles via wind or water. Overland flow of water creates channels and in severe cases tunnelling may form.

Soil profile stability

The decline in perennial grass cover and replacement with Lippia has affected soil profile stability over vast areas. Native perennial grasses produce a very extensive network of fine fibrous roots which enhance soil profile stability. In the absence of native grasses the solid deep taproot of Lippia is well adapted to poorly structured soils. The growth of Lippia in high density may also promote further soil structural decline. Many farmers reported the ability of Lippia to effectively extract soil moisture, further opening up naturally occurring cracks in the clay and causing soils to subside, creating a very uneven surface.

Bank erosion

The effect of Lippia on soil structure is most apparent on stream banks. The root system of Lippia is ineffective at binding the cracking clay soils and on bank edges this exacerbates the instability of the soil on steep banks. The low growth of Lippia, the increase in bare ground and the absence of tall grasses that previously dominated the floodplain results in increased speed of water movement across the land surface. This rapid movement of water results in the edges of creek and river banks becoming increasingly eroded and steep.



Plate 12

Bank slumping on the edge of the Namoi River near Boggabri, NSW.

Environmental costs

The value of ecological services provided by floodplains have been calculated by Tockner and Stanford (2002) as \$19,580 US/ha/yr (equivalent to \$29,666 AUD, where \$1USD = \$0.66AUD¹). The major benefits from these services were categorised as:

Disturbance regulation	37%	
Water supply	39%	
Waste treatment	9%	(Costanza <i>et al.</i> , 1997)

By way of comparison, forests were valued at \$969 US/ha/yr (\$1,468 AUD) and cropland \$92 US/ha/yr (\$140 AUD). The estimated agricultural benefits of planned irrigation projects range between \$20-31 US/ha/yr (\$30-47 AUD/ha/yr) (Tockner and Stanford, 2002).

In Illinois (USA) Schaeffer *et al* (2002) valued the services provided by floodplain land at \$7,500 US/ha/yr = (\$11,363AUD/ha/yr). The value of regional floodwater storage contributed 86% of this figure.

The recreational and nutrient removal value of the Danube floodplains was calculated at 384 Euro/ha/yr, (\$668 AUD/ha/yr where 1 Euro = \$0.59 AUD²) and the capacity of Estonian floodplain wetlands to reduce nitrogen was worth 510 Euro/ha/yr (\$864 AUD/ha/yr) (Andreasson-Gren and Groth, 1995).

Such valuation of environmental services provided by floodplains, on a per hectare basis, to my knowledge has not been calculated in Australia. These figures serve only to provide an indication of the significance of healthy floodplains and riverine environments to sustaining the health of our natural resources and agricultural industries.

There are in excess of 3 million ha of wetlands and floodplains in the Murray Darling Basin excluding wetlands less than 5,000 ha in area and the unregulated river systems of Queensland (MDBC, 2003). Assuming a relatively conservative estimation of the value of the ecosystem services provided by the wetlands and floodplains of the Murray Darling Basin to be \$1,000/ha/yr the total value of these services is \$3,000,000,000 annually.

There has been an average 60% reduction in area of the major floodplain wetlands of the Murray Darling Basin, assuming an equivalent level of reduction in function the cost in terms of lost ecosystem services equates to \$1,800,000,000 each year. The costs may be measured in terms of :-

- loss of floodplain area
- loss of perennial vegetation biomass
- loss of biodiversity (terrestrial and aquatic)
- increased rate of erosion (soil loss, runoff)
- reduction in water quality
- increased invasion by exotic species

¹ Conversion rates from USD and Euros were calculated from the average comparative value of AUD during June 2003.

Review of current control methods

Herbicides

The most commonly used chemicals for the control of Lippia are Lantana DP600 and 2,4-D Amine. A wide range of chemicals and chemical combinations have been trialled over many years and there appears to be no chemical currently available that will effectively suppress the growth of Lippia long-term. Of the farmers surveyed who had attempted any form of chemical control, only 15% acknowledged any level of suppression and the average period for which suppression was achieved was only 5 months.

It would appear that the current suite of chemicals available for control is generally ineffective in the current manner in which they are applied. This apparent lack of efficacy may be due to inappropriate timing of application or climatic effects post spraying. Multiple applications are required within a growing season to achieve any level of suppression of Lippia. There are also difficulties associated with spraying in areas adjacent to susceptible crops and the hazards associated with the use of chemicals adjacent to waterways and streams.

A number of farmers indicated a need for investment into further research by chemical companies into an effective herbicide to control Lippia. However, at the recent symposium on Biological Control of Weeds in Canberra it was concluded that chemical herbicide development had peaked during the last 50 years (Conroy 2003). It is unlikely that any further chemical herbicide development will be undertaken in the near future (Storrie pers.comm.).

Cultivation

Cultivation is commonly perceived as the cheapest and most effective method of suppression in areas badly infested with Lippia. While annual cropping in the short term provides the potential to generate income from otherwise non-productive land, the long-term sustainability of the practice is questionable. The problem with cultivation of areas adjacent to rivers and creeks is the huge risk of soil loss during floods. In addition, the soil surface remains exposed for extended periods of time increasing the risk of reinvasion by Lippia in the event of flooding through the deposition of Lippia fragments in receding floodwaters.

The large majority of graziers recognise this risk and prior to Lippia invasion would have never considered cultivating such areas and have done so with the dual objectives of suppressing Lippia and generating income.

Survey respondents indicated that Lippia was evident in cultivated paddocks within 2.5 years of cessation of regular soil disturbance. In areas severely affected by Lippia perennial pastures may potentially be sown following one or two years of cereal cropping to 'clean' the paddock. Following the establishment of a perennial pasture appropriate grazing management must be applied to ensure the density of grass cover is maximised and the persistence of the sown species. Maintenance of a vigorous dense pasture base will limit the ability of Lippia to re-establish.

The current use of technologically based control methods being applied to *Lippia* are neither effective nor sustainable in the long term. The primary reason for the failure of conventional methods of treatment is that neither adequately address the cause of the problem and reinvasion of *Lippia* into treated areas is generally a matter of time between treatment application and the subsequent rainfall or flood event. There is a desperate need to re-evaluate current methods of management across the entire Murray Darling Basin area to, in the initial stages, prevent further degradation of the landscape and then work to enhance the quality and health of the range of ecosystems present.

Grazing management

In extensive livestock grazing systems animals are traditionally grazed at low density and allowed access to large areas of land for extended periods of time. An inherent characteristic of grazing animals is their ability to selectively graze, seeking out the most palatable and usually most nutritious species in the pasture. Even under low stocking rates animals will concentrate their grazing efforts on the most desirable pasture plants. Defoliation of grasses causes a reduction in root biomass and with frequent defoliation the root system is constantly being contracted. In conditions where soil moisture is not limiting this has relatively little effect on the ability of a grass plant to access sufficient moisture and nutrient to regenerate new leaf material. However, when moisture becomes limiting the ability of these continually defoliated plants to regenerate is significantly diminished.

Under natural conditions, floodplain vegetation communities are well adapted to annual flooding regimes and have the ability for rapid growth in response to high soil moisture levels present following floods. Grass plants would experience an annual opportunity to regenerate large amounts of root biomass. The changed water regime imposed throughout the MDB has significantly reduced flood frequency and consequently the regular opportunity for grassland plants to regenerate root reserves. With the constant pressure of frequent defoliation reducing root biomass, in combination with longer and more extreme periods of moisture stress, the desirable pasture species of the inland floodplain have declined significantly and in many areas are non-existent. The gaps created in these areas provide the perfect opportunity for establishment of annual species and invasive exotics such as *Lippia*.

Individual pasture plants need to be provided adequate periods of time to recover from each grazing event to allow regeneration of root reserves to enhance their ability to persist during periods of moisture stress. The most effective method of achieving the required period for pasture recovery is by combining stock and concentrating the grazing in small areas of the property for relatively short periods of time, allowing relatively larger areas to be rested from grazing at any one time. Respondents employing this method of grazing management indicated they have effectively restricted the spread of *Lippia* for periods of between 7 and 17 years.

The use of planned grazing management with application of higher stock density for short periods of time and ensuring suitable recovery periods to encourage the persistence of desirable pasture components should be investigated further. The value of this form of grazing management in regenerating grasslands and restoring ecosystem function has been demonstrated in a wide range of environments and is worthy of further investigation within the MDB.

The strategic application of chemicals in conjunction with the implementation of a grazing management regime which enhances the competitive ability of grasses growing in association with Lippia may be an effective control measure.

Under normal circumstances, when evaluating the carrying capacity of the land and determining appropriate stocking rates, other grazing animals such as kangaroos need to be considered. The problem associated with large numbers of kangaroos has been exacerbated during the drought and many landholders indicated a need for the culling quota to be increased to adequately address the problem. The presence of large mobs of kangaroos in many areas already affected by overgrazing and Lippia invasion places additional pressure on stressed grasses. Some farmers noted the presence of hundreds of kangaroos grazing pastures, many of which had been destocked due to a lack of dry matter.



Plate 13

Vigorous native pastures may effectively compete with Lippia. This pasture west of Wee Waa comprised about 15% Lippia cover.



Plate 14

Lippia comprises about 15% cover in this overgrazed pasture west of Moree, NSW.

Research & extension priorities

Biological Control

Biological control may be the only effective option to control *Lippia* where it occurs as a dominant groundcover component in reserve areas, woodlands and forests, along stream banks where access is difficult and cultivation is not an option.

Locating a biological control agent specific to *Phyla canescens* may be difficult, given how closely related the species is to *Phyla nodiflora*. The confusion surrounding the taxonomy of *Phyla canescens* and *Phyla nodiflora* and the issue of *P. nodiflora* being native to Australia needs to be addressed. Such identification issues are important for all forms of control and may be important for setting host specificity limitations on potential biological control agents. If necessary the Biological Control Act may be used to test the relative importance of possible damage by biological control agents to *P. nodiflora* versus the cost of *Lippia* to the nation, to determine if progressing biological control is deemed desirable.

There are a number of species of butterfly larvae that utilise *Phyla* spp. as a food host. Examples include the Phaon crescent *Phyciodes phaon* which deposits eggs in clusters on the undersides of the host plant leaves, *Phyla* (*Lippia nodiflora*) (Hanife-Genc, and Nation, 2002) and more locally the Meadow Argus butterfly, *Junonia villida* which utilises *Phyla canescens*, and a wide range of other native and introduced forbs, as a larval food host (Grund, 1999).



Photos: Jerry F. Butler, University of Florida

Plate 15 Larva of the phaon crescent, *Phyciodes phaon* grazing on leaves of *Phyla canescens* (left) and the adult phaon crescent (right).

The length of time required for the successful approval and implementation of a biological control program is of the order of many years. The next extensive flood event, or cycle of wetter than average annual rainfall, will result in an enormous increase in the density and/or distribution of *Lippia* throughout the MDB. Hence, the need for immediate initiation of a biological control program is of paramount importance.

Phytochemistry

Many authors refer to the close relationship between *Phyla canescens* and *Phyla nodiflora*. It is apparent also in the similarity in the chemical composition of both species. Elakovich (1987) (cited in Lucy *et al.* 1995) notes *Lippia nodiflora* contains sesquiterpenes and monoterpenes. Tomas-Barberan *et al.* (1987) refer to *Lippia nodiflora* and *Lippia canescens* as containing the same flavenoid pattern and both possessing flavenoid sulphates, a characteristic absent in other species of the genus.

There is a suggestion by a number of authors, scientists and graziers of the allelopathic effects of *Lippia* on plants growing in association. It has been stated and observed that areas of bare ground exist around *Lippia* plants. Certainly, this was also observed in this study, although, the question needs to be asked whether the presence of *Lippia* caused the bare ground or *Lippia* was able to readily establish at these sites because of the presence of bare ground. In equally as many situations other plant species were growing in close association with *Lippia* and exhibiting no immediate detrimental effects. The evidence for the allelopathic effect of *Lippia* appears to be largely anecdotal with the exception of the reporting by Elakovich (1987) of the presence of sesquiterpenes and monoterpenes which are known to be allelopathic in *Lippia nodiflora* (Lucy *et al.* 1995).

Lippia species have been widely used in traditional medicine in eastern countries. The oils of the plant used for gastro-intestinal and respiratory disorders as well as for seasoning (IMP, 1995). The essential oils (phenolics or flavenoids) were assumed the active component (Pascual *et al.* 2001). Flavonoids are common in all higher plants and at least 4000 are known. Some functions of bioflavonoids in plants include antifungal and antibactericidal activity. Often, in plants the flavenoids have the effect of acting as 'antifeedants' because they are unpalatable to ruminants animals and they can also affect pollination by either inhibiting or stimulating insect activity (Anon, 2003). The comparative phytochemical composition of local ecotypes of *Phyla canescens* and *Phyla nodiflora* is worth investigation.

Ecophysiology

A number of recent studies have focused on the ability of *Lippia* to tolerate varying degrees, length of time and depth, of inundation (Hobson, 1999; Taylor, 2003). Studies should be initiated to determine other levels of environmental tolerance limits of *Lippia*. Clearly, *Lippia* can persist and regenerate rapidly after extended periods of inundation. Irrigation canals in the Murrumbidgee catchment may be inundated for 2 to 3 months each year up to depths in excess of 1 metre, during the dry season *Lippia* provides a solid mat of cover through these canals.

The increasing tendency for *Lippia* to establish in areas away from flood affected areas indicates its ability to quickly adapt to changed environmental conditions. *Lippia* can persist, and in some situations continue to grow, in situations of very low soil moisture and is reportedly also tolerant of fire. Investigations to quantify the environmental tolerance levels and mechanisms of survival or regeneration under a range of temperature and soil moisture regimes would be a useful aid to evaluating the ability of other species to potentially displace *Lippia*.

Dispersal mechanisms

Vegetative

Under inundation *Lippia* has the ability to switch from sexual to asexual reproduction. Morphological changes which occur under inundation include internodes thickening, becoming shorter and more fragile, these readily fragmented pieces are carried on floodwater (Lucy *et al.* 1995; Taylor 2003).

Lippia spreads radially over the soil surface allowing rapid growth of individual plants over a wide area. The nodes along each stem put down roots and with the morphological changes which occur under flood conditions, each fragment effectively becomes a viable unit once in contact with the soil surface, being transported in floodwater and redeposited as water subsides.

Livestock may transport pieces of *Lippia*. The predominantly clay soils on which *Lippia* occurs become very sticky in wet conditions, fragments of *Lippia* may be carried on stock hooves to ground above the normal flood level.

The reported occurrence of *Lippia* on and around the high water level of upland dams and streams would suggest dispersal by waterbirds. This dispersal may come from pieces of *Lippia* being transported by attachment or deposition of viable seed ingested while foraging on *Lippia*. The viability of the seed following passage through the digestive system of waterbirds and livestock requires further investigation.

Seed production

While *Lippia* has the potential to flower prolifically, many landowners reported carpets of white flowers during the spring-summer period, McCosker's (1994b) seed bank study indicates a relatively small soil seed reserve. From 4 sites in the Gwydir catchment, 18 replicate specimens from each site produced an average of 243, 1148, 263 and 43 *Phyla canescens* seedlings/m² respectively over an 11 month period following 3 cycles of wetting and drying (McCosker 1994b). This number is low in comparison to the seed bank of other potentially invasive species, however, this number of seeds/m² is certainly sufficient to enable successful germination and establishment of *Lippia*. Investigations into the dormancy characteristics and the longevity of viable *Lippia* seed in the soil seed bank may provide information on the ability of *Lippia* to regenerate from soil seed reserves.

Other potential dispersal mechanisms

Although livestock reportedly do not favour *Lippia* in their diet, ingestion of seed from pastures where it is present may be possible under some circumstances. The viability of seed after being passed in faeces requires investigation.

As *Lippia* is still a common garden species in many areas throughout the Murray Darling Basin a possible mechanism of spread is via disposal of garden waste or cuttings which are often deposited along roadsides and waterways.

Site Characterisation

Lippia tends to dominate areas with apparently poor soil structure. Observation at many sites where Lippia was the dominant groundcover species would suggest that conditions of poor soil structure and low levels of organic matter favour its growth over other more desirable plant species. Such soil conditions are widespread on riparian areas and flood plains throughout the Murray Darling Basin. The thick woody tap-root of Lippia enables it to successfully establish and persist in poorly structured soils. At many of these sites soil biological activity also appeared to be minimal, however, this observation needs to be quantified.

A study undertaken by Taylor (2003) showed sites that were dominated by *Sporobolus mitchelli* differed significantly to those dominated by Lippia with respect to the vegetation communities present, soil EC and soil texture. Further studies should be undertaken to quantify the soil chemical, physical and biological characteristics which occur at those sites dominated by Lippia. A total of 40 soil samples were collected from a range of sites in different environments in areas where Lippia dominated the vegetation. These samples may be useful in undertaking work related to site characterisation of Lippia populations.



Photo: Prof. John Duggin, UNE

Plate 16

The thick woody tap root and smaller fibrous roots associated with the nodes along the branches of Lippia.



Plate 17

Lippia dominating the vegetation in poorly structured soil near Maude, NSW.

Vegetation management

Where viable populations of perennial grasses remain, the most effective regeneration option is the resting of pastures to allow adequate recovery of individual plants following a defoliation event. A dense stand of perennial vegetation has the ability to resist invasion by Lippia. Native perennial grasses, under conditions where their competitive ability is not diminished by continual overgrazing, have a naturally greater degree of drought tolerance than Lippia (Taylor, 2003). Most that occur naturally on riparian zones and floodplains of the Murray Darling Basin will be also likely be well adapted to periods of inundation.

In areas where populations of perennial grasses are not longer extant, introduced pasture species may need to be sown. Recommendations for pasture establishment considerations and species options for management of Lippia are available (e.g. Illing, 2002). Most commonly used introductions are Bambatsi panic, Florens bluegrass and Purple pigeon grass. Over large areas it may be viable to establish introduced grasses in strips orientated along the line of flow of floodwaters to create an initial barrier or series of vegetation barriers to prevent reinvasion of Lippia at least in smaller flood events.



Plate 18

Queensland bluegrass growing through dense Lippia cover along King's Creek, Qld.



Plate 19

Bambatsi panic pastures may effectively resist Lippia invasion Toobeah, Qld.

Revegetation of stream, creek and river banks is necessary to prevent the continual erosion of these areas. Research into practical methods of revegetating these areas with perennial grasses should be a priority. Much of the land area badly affected by Lippia falls under Government control, an active management program needs to be established and implemented urgently.

Awareness and education

There are apparently still a large number of landholders who are unaware of the presence and potential impact of Lippia and associated problems. Land managers need to be aware of the plants appearance, potential areas of establishment and impact to be proactive in managing to prevent either the establishment or spread of Lippia. An extension program highlighting the agricultural and environmental issues should be developed to improve the awareness and educate the public in an effort to stem the continued deterioration of the resource base.

Threatened species conservation

Preparation of a nomination for listing of Lippia as a Key Threatening Process or as a Weed of National Significance will serve to highlight the need for national efforts to manage the problem. There is no doubt that Lippia meets the criteria for such listing in terms of invasiveness, impact, potential for spread and economic and environmental values. The success of such a listing would significantly raise the profile of the issue within the relevant government departments and compel action.

Concluding comments

To effectively identify the most appropriate method of management of a problem organism, the underlying cause must first be determined. Any control mechanism that does not address the cause of the problem will not be effective in preventing reinvasion within a relatively short period of time. While the change in water regime has resulted in significant changes to the ecology of the flood plains, a lack of understanding of the environmental effects of the changed conditions and the interaction between plants and grazing livestock and a failure to apply adaptive management has resulted in a widespread decline in the health of these ecosystems. One of the symptoms of declining ecosystem health is the increased incidence of large areas of bare ground, a highly favourable condition for the invasion of annual and exotic species. It is unlikely that simply restoring environmental flows will address the problem, in fact, this may potentially enhance the growth of Lippia (Taylor, 2003).

The most effective method of control is to target the weakest point in the life cycle of the organism, at what stage is it most vulnerable. In the case of Lippia that point appears to be at the establishment stage. One of the most commonly applied method of control is the use of chemicals, it is widely accepted that for maximum effect the chemical must be applied within the first week following flowering when the plants are actively growing (Motley *et al.* 2001). The depth, density and size of the taproot of Lippia provides an efficient store of reserves from which to regenerate growth, following suppression of foliage.

Lippia has the ability to tolerate environmental extremes better than most other plant species with which it grows in association. Because of its low growth habit it is not subject to defoliation and it has the ability to regenerate vegetatively and from seed. The most effective method of control is to restrict its opportunity to establish by maintaining groundcover. The effect of both herbicide application and cultivation is to increase the level of bare ground present and at best both are only very short-term solutions to the problem. These areas will be particularly vulnerable to reinvasion.

There is an urgent need to review the management practices currently being implemented on all land types throughout the entire Murray Darling Basin if further degradation of resources and spread of Lippia is to be avoided. In the short term active management to increase the level of groundcover is an action that may be undertaken by landholders immediately to reduce the opportunity for Lippia establishment or spread. The immediate initiation of a biological control program may provide the most effective long-term option for the suppression Lippia where it occurs over a wide range of habitats, locations and climates.

Summary – Distribution and Impact of Lippia

- Lippia is a severe and increasing problem throughout the Murray Darling Basin.
- Lippia is estimated to be present over an area in excess of 5.3 million hectares.
- Lippia is present within each of the 19 catchments of the MDB to varying degrees.
- Lippia is creating the biggest problems in the Condamine, Border Rivers, Gwydir, Namoi and Lachlan catchments.
- Changes to the water regime in all catchments of the MDB have led to significant changes in the environment and constriction of wetland and floodplain area.
- Lippia invasion is one of the highly visible symptoms of the extent of the degradation and loss of ecosystem function throughout the MDB.
- Lippia occurs in every state of Australia.
- Lippia is readily dispersed throughout river systems in floodwaters.
- The distribution and density of Lippia in all MDB catchments has progressively increased with each flood recorded in the respective catchments over the past 15 years.
- Lippia has the ability to adapt to changing environmental conditions and is spreading through country not affected by floodwaters.
- Lippia establishes readily on bare ground.
- Given a suitable sequence of climatic events and suitable soil surface conditions Lippia has the potential to spread throughout the entire MDB floodplain area.
- Conservatively the estimated cost of Lippia to the livestock industry is \$38 million per year.
- Lippia has significantly impacted and continues to threaten biodiversity within the MDB.

- The loss and displacement of native grassland communities by Lippia has resulted in severe erosion problems.
- The cost of Lippia in terms of the reduction in environmental services provided by floodplains and wetlands is estimated to be \$1,800 million per year.
- There remains a degree of confusion regarding the taxonomy of *Phyla* spp.
- The comparative ecology of *Phyla canescens* and *Phyla nodiflora* requires investigation
- The claimed allelopathic effects of Lippia require further investigation.
- Dispersal mechanisms and soil seed bank characteristics of Lippia require further investigation.
- The environmental tolerances of Lippia should be investigated.
- Site characteristics within areas where Lippia dominates may provide insight into potential control mechanisms.
- Revegetation of river, creek and stream banks with perennial grasses is urgently required.
- Current chemical options are ineffective in suppressing Lippia and there appears little possibility of additional chemical options becoming available in future.
- Cultivation is perceived as the cheapest and most effective form of suppressing Lippia, although the practice of cultivating floodplains carries a high risk of soil loss and reinvasion of Lippia during floods and cannot be considered sustainable.
- Traditional low density grazing management has contributed to pasture decline and Lippia invasion.
- Applying planned grazing strategies utilising high stock density and allowing pastures adequate recovery from grazing offers an opportunity to re-establish groundcover and prevent Lippia invasion.
- Biological control should be developed as a matter of urgency as it appears to be the only management option that might provide control in much of the reserve, crown and council lands and riparian areas.
- Autecological studies are urgently required to improve our understanding of the reproduction and growth of Lippia in relation to its environment and to help identify appropriate management strategies.
- An education program needs to be undertaken to raise awareness of Lippia.
- Nomination for listing of Lippia as a Key Threatening Process will raise awareness of the issue.
- An urgent review of current management practices throughout the MDB is required to restore ecosystem health and productivity of agricultural land.