Examining the impact of control over time on the seed bank of *Mimosa pigra* on Top End, Australia floodplains

Jane Barratt,[1] Michael Douglas,[2] Quentin Paynter[3] and Mark Ashley[4]

Abstract

Mimosa, *Mimosa pigra* L., is renowned for producing an abundance of seeds, many of which remain in the population as a persistent seed bank. Integrated control programs have been effective in reducing the above-ground cover of mimosa but little is known about its effect on the soil seed-bank. The viability of mimosa soil seed banks following integrated control was investigated in two floodplains in the Top End of northern Australia in relation to time since control and vegetation type. Mimosa seed banks under all vegetation types were considerably lower (by at least 50%) than under stands of mimosa. Most of this reduction occurred within the first year of control, although seed stores still remained in the soil three years after initial control. There were few consistent differences in the density of mimosa seed banks between vegetation types. The results also indicated considerably lower seed counts under mimosa compared to previous studies. The lower seed count under mimosa may be attributed to the effectiveness of current biological-control programs. Integrated control therefore appears to be reducing viable mimosa seed. Nevertheless, significant numbers of seeds remain in the seed bank, highlighting the importance of follow-up control and sound land-management practices (avoiding overgrazing and maintaining suitable vegetation cover) in order for competitive species to suppress mimosa re-establishment.

Keywords: mimosa, seed bank, integrated control, floodplain, seed viability.

Introduction

Mimosa, *Mimosa pigra* L., is a tall (~5 m) leguminous shrub of moist, open sites in the wet–dry tropics (Lonsdale *et al*. 1995) and is considered one of the greatest threats to the wetlands of the Top End and potentially throughout northern Australia (Lonsdale 1994). Mimosa grows rapidly, flowers quickly, and produces large quantities of seed that are spread readily by floodwaters, animals, and people (Lonsdale 1994). Over 800 km^2 of seasonally inundated floodplains in the Northern Territory (NT) are now covered with nearly monospecific thickets of mimosa (Lonsdale 1992).

In the large stands of mimosa, the growing plants are outnumbered approximately 10,000 to 1 by seeds in the soil (Lonsdale and Segura 1987). The seeds can remain viable for long periods (up to 23 years) (Lonsdale *et al*. 1995) so a large propor-

[1] School of Biological, Environmental and Chemical Sciences, Charles Darwin University, Darwin, NT 0909, Australia <Jane_barratt@hotmail.com>.
[2] School of Biological, Environmental and Chemical Sciences, Charles Darwin University, Darwin, NT 0909, Australia <Michael.Douglas@cdu.edu.au>.
[3] CSIRO Division of Entomology, PMB 44, Winnellie, NT 0821, Australia <Quentin.Paynter@csiro.au>.
[4] Caring for Country Unit, Northern Land Council, PO Box 42921, Casuarina, NT 0811, Australia <Mark.Ashley@nlc.org.au>.

tion of the mimosa population therefore lies dormant in the soil as a persistent seed bank.

In some areas, integrated control programs have successfully reduced the cover of mimosa (Searle 2004), but the impact of integrated control on the soil seed bank is not known. Indeed, the mimosa seed bank has not been quantified since the mid-1980s (see Lonsdale *et al*. 1988). Preventing mimosa reinvasion requires information on both the number of mimosa seeds that persist in the years following control (as these represent a major source of potential re-colonists) and on the availability of native vegetation (as this can inhibit mimosa establishment, thereby reducing the reliance on follow-up herbicide treatments). This project aims to measure the mimosa seed bank and characterise the native seed bank under current mimosa infestations and in areas where mimosa had been controlled up to three years previously.

Methods

Seed bank samples were collected from two river systems in the Top End of the NT: from the Finniss River catchment within Wagait Aboriginal Reserve in November 2001, and from the lower- and upper-Adelaide River (LAR and UAR) in July 2002.

Samples collected on the Finniss River catchment were taken from a range of sites within, or up to 5 km from, an experimental integrated control site (12°56'S, 130°33'E (Paynter *et al*. 2000). Mimosa was first recorded in this area in 1979, and a continuous stand developed in the study site, which had been heavily grazed by feral water buffalo, *Bubalis bubalis* Lydekker, during the mid 1980s (C. Deveraux, pers. comm. 2002). The field sites once contained several large (~250 ha) mimosa patches, on 'black soil' (black cracking clay) floodplain.

To determine the viability of the soil seed bank of mimosa on the Finniss River site, soil cores were taken from areas currently covered with dense stands of mimosa (termed 0 years since control) and from areas where mimosa had been controlled one, two or three years previously. Control in these sites has been integrated, involving the use of fire, chaining, and herbicide (Paynter *et al.* 2000). A typical first-year control cycle comprises of mimosa being aerial sprayed around November. The treated vegetation is then flattened (by dragging a chain between two bulldozers) in the following June and fire may then be used to remove the flattened plants. In subsequent years, follow-up control takes place using herbicides. Where mimosa had been controlled, samples were taken from areas dominated by six other vegetation types: *Pseudoraphis spinescens* (R.Br.) Vick., *Hymenachne acutigluma* (Steudel) Gilliland, *Leersia hexandra* Sw., *Cyperus* spp., *Echinochloa colona* (L.) Link, and *Urochloa mutica* (Forssk.) representing the most widespread wetland plant communities. Where possible, each vegetation type was sampled within each year class, but not all combinations were available (Table 1). Samples were collected from 35 sites located within four regions on the floodplain separated by approximately 2–11 km.

At each site, six replicate seed bank samples were taken to a depth of 5 cm using a 7 cm diameter auger. The soil cores were removed from the auger and placed in labelled plastic bags before returning to the laboratory. Mimosa seeds were extracted from four of the six replicate samples from each site (140 in total) by soaking the samples overnight in tap water and then washing through a 1 mm mesh sieve. Seeds were then tested for viability and germinability, following the method of Lonsdale *et al*. (1988). Seeds were placed on moist filter paper

Table 1. Distribution of study sites from within four regions (R1–R4) on the Finniss River in relation to vegetation type and years since control. Numbers in parentheses indicate the number of sites from which samples were collected within that region. No entry indicates a combination of vegetation type and time since control that was not present within any region.

Vegetation type	Year since control			
	0	1	2	3
Pseudoraphis spinescens	–	R4(1)	R1(1), R4(1)	R3(2), R4(1)
Mimosa pigra	R1(2), R3(2), R4(1)	–	–	–
Hymenachne acutigluma	–	R3(2)	–	R3(3)
Leersia hexandra	–	R1(1)	R3(2)	R3(3)
Cyperus spp.	–	–	R3(1)	R3(2)
Echinochloa colona	–	–	R3(1)	R3(2)
Urochloa mutica	–	R1(1), R3(1)	R1(1), R3(1)	R2(1), R3(2)

and incubated for seven days at 30°C on a 12–hour day/night cycle. The seeds germinating during this period were the germinable fraction. The remaining seeds were scarified by abrasion with fine sandpaper at the embryo end to ensure imbibition, and incubated for a further seven days. Seeds germinating after scarification were classed as viable but not germinable. The total in these two categories comprised the viable fraction. The remaining seeds were assumed to be dead.

The remaining two replicate soil samples for each site (70 in total) were used to determine the persistence of species other than mimosa in the soil cores. The samples were placed in plastic containers, 12 cm diameter and 7 cm deep, with holes in the bottom to allow drainage. The samples were then placed in trays outdoors, where they were subject to ambient temperatures and sprayed with a fine mist of water three times a day. Emerging seedlings were identified after six months using Cowie *et al*. (2000).

On the Adelaide River, the mimosa seed bank was assessed under dense stands of mimosa at six of the sites previously studied by Lonsdale in the mid 1980s (Lonsdale *et al*. 1988). In our study, six replicate soil cores from each site (36 in total) were collected and processed following the methods described above to determine the number of viable mimosa seeds. Samples were collected from three sites in the LAR and three sites in the UAR.

For the Finniss River data, the density of viable mimosa seed and the total richness and abundance of other vegetation germinating from the soil cores were analysed using general linear modelling (GLM). Vegetation type and time were considered fixed factors, and region a random factor. Sites were the replicates in this design and individual soil cores were considered subsamples from within a site. The mimosa seed bank was compared between the Finniss River and Adelaide River using a one-way ANOVA. Where appropriate the data were log-transformed to meet the assumptions of ANOVA. All statistical analyses were done using Statistica Version 6 (StatSoft Inc., Tulsa, USA).

Results

Eighty-eight viable mimosa seeds were found in the 140 soil core samples for the Finniss River. Mimosa seed density ranged from 260 seeds m^{-2} to 1,559 seeds m^{-2}. There were no significant differences in the density of mimosa seed banks among any factors when all vegetation types were considered across time. There were few consistent trends in mimosa seed bank among vegetation types (Figure 1). *Leersia hexandra* showed some reduction in mimosa seed bank with each year after control, while *P. spinescens* and *Cyperus* sp. showed some reduction in mimosa seed bank between two and three years after control. *Echinochloa colona*, *H. acutigluma* and *U. mutica* showed no clear change in mimosa seed bank over time. Because of the lack of consistent differences between vegetation types, this factor was not considered in subsequent analyses.

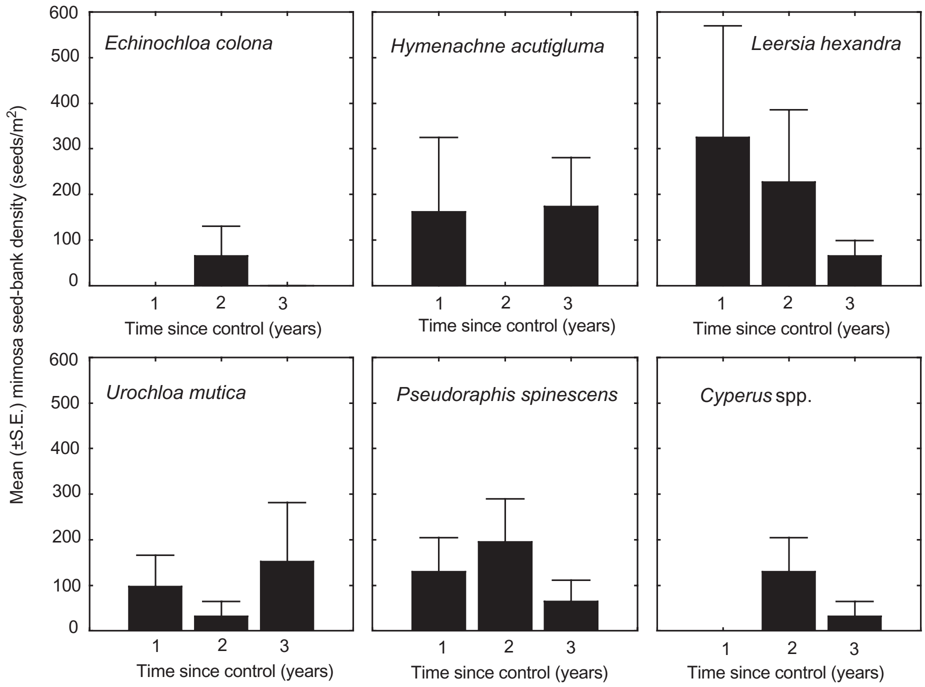

Figure 1. Mean mimosa seed bank density on Finniss River in six different vegetation types one to three years after mimosa control.

When all four years were considered, there was a significant difference in mimosa seed bank over time ($F_{1,135} = 16.6$, $P < 0.001$). When year 0 was excluded, however, time was not significant. Under dense mimosa (year 0) mean seed density was around 500 seeds m^{-2} and this dropped by at least 50% following control (Figure 2).

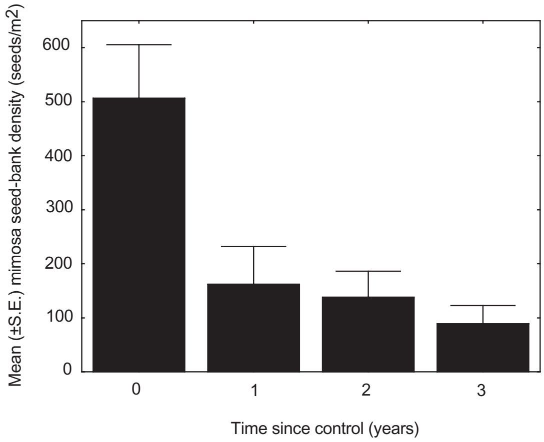

Figure 2. Mean mimosa seed bank at Finniss River amongst samples collected from sites infested by mimosa (Year 0) and sites where mimosa was controlled one, two and three years previously.

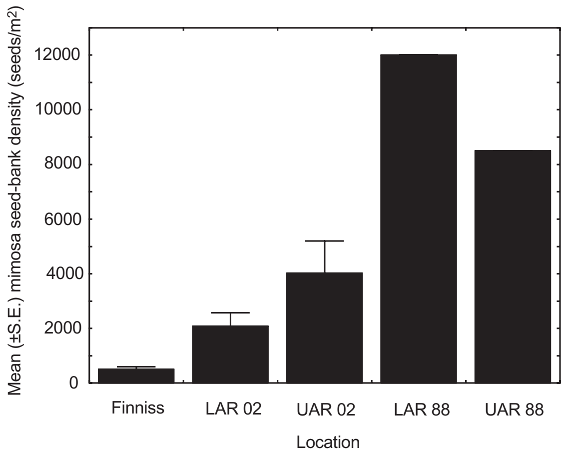

Figure 3. Mimosa seed bank density for the Finniss River in 2001, the Lower- and Upper Adelaide River (LAR and UAR) in 2002, and the LAR and UAR based on Lonsdale *et al.* (1988).

Significant germination of vegetation other than mimosa occurred in all samples, including those collected under dense mimosa. A total of 612 plants from 29 species germinated from the 70 cores, with 81 plants from 18 species germinating from the 10 samples collected beneath dense mimosa. There was no significant difference between years for either the mean richness or abundance of non-mimosa vegetation. Richness ranged from zero to six species per sample and abundance ranged from zero to 51 plants per sample. Of the plants that germinated from the soil samples, relative abundance was similar for mimosa and non-mimosa vegetation. *Glinus oppositifolius* (L.) DC., *Cyperus* sp. and *Fimbristylis depauperata* R.Br., were the most abundant species in both mimosa and non-mimosa vegetation and together they accounted for approximately half (56% and 43%, respectively) of total abundance.

There was no significant difference ($P = 0.06$) in the seed bank density under mimosa between the Finniss River in 2001 and the Adelaide River (upper or lower) in 2002 (Figure 3). All seed bank densities recorded during this study were dramatically lower than those reported from the Adelaide River during the mid 1980s. (Lonsdale *et al*. 1988) (Figure 3). Since the mid 1980s, the seed banks in the upper and lower Adelaide River have declined by approximately 50% and 80%, respectively.

Discussion

Mimosa seed banks appear to have greatly declined in Top End floodplains since the mid 1980s. In the Lower Adelaide River, densities in 1984–85 were approximately 12,000 seeds m^{-2} (Lonsdale *et al*. 1988) but were 80% lower in 2002. Similarly, low seed bank densities found at the Finniss River indicate that this trend may be widespread. This decline in seed bank density is likely to be partly the result of the mimosa biological control program, as equivalent reductions in seed production have been attributed to the biological control agent *Carmenta mimosa* Eichlin and Passoa (Q. Paynter, pers. comm. 2002).

Although integrated control of mimosa at the Finniss River drastically reduced the mimosa seed bank, enough viable seeds were still present after at least three years for large stands of mimosa to potentially re-establish. This highlights the need for sound land-management practices following the initial removal of mimosa. For example, activities that reduce competing vegetation, enhancing mimosa regeneration from the seed bank (Lonsdale and Farell 1998), such as burning or overgrazing, should be minimised. Follow-up control of those seeds that germinate should be a high priority (Lonsdale *et al*. 1988, Cook *et al*. 1996) and other wetland vegetation should be maintained to suppress mimosa establishment.

At the Finniss River, the establishment of other vegetation following integrated control was facilitated by the presence of a surprisingly diverse seed bank, even in areas that had been dominated by mimosa for many years. The germination of non-mimosa species clearly indicates either the persistence of a non-mimosa seed bank, or consistent seed importation during the annual flooding. Lane *et al*. (1997) had also previously noted that mimosa invasion had little or no impact on the nature of seed banks, attributing this to the young (two to three years) age of mimosa stands and the closeness of native vegetation. Our study extends this finding to stands of mimosa that are approximately 10 years old.

There was no evidence that the type of wetland vegetation that recolonised a site following mimosa control affected the density of the mimosa seed bank over time. However, it is difficult to draw conclusions on this as not all vegetation types were represented in each year class. Furthermore, there were large errors associated with the replicate samples, due to the relatively small size of the soil corer and insufficient replication. Our corer was chosen to be comparable with previous studies, but the currently low mimosa seed densities would be better sampled with a larger corer, or by taking more samples.

Three years of integrated control reduced the dominance of mimosa, creating the opportunity for the successful establishment of non-mimosa vegetation. Therefore, irrespective of mimosa soil seed bank persistence and mimosa seed importation rates, maintenance of non-mimosa vegetation cover will prevent the growth of mimosa seedlings and reduce the requirement for subsequent management. For pastoral land this will create the potential for increased economic gain by increasing the amount of productive land available for grazing. In terms of conservation, native pasture cover provides important resources for many animals, such as vital breeding and nesting grounds for the magpie goose (Braithwaite *et al*. 1989, Whitehead *et al*. 1992, Lonsdale *et al*. 1995). This also has implications for mimosa control in non-strategic locations, such as mimosa infestations downstream of larger infestations that will be constantly exposed to seed importation with annual inundation. It indicates that mimosa control in areas of larger infestations such as the Adelaide, Finniss, Daly and Mary River catchments may be sustainable, provided post-control vegetation management is adopted. This finding represents a significant step forward in strategic weed management and provides a management option beyond biological control for mimosa stands positioned amongst extensive infestations.

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