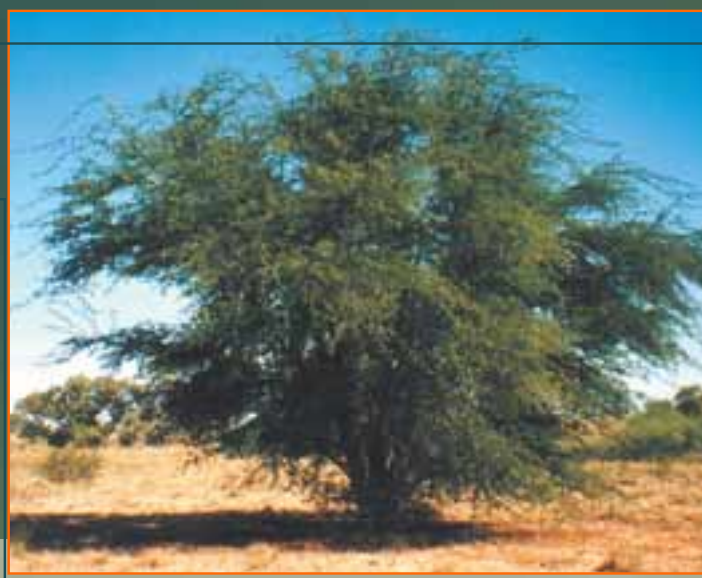
Best Practice Manual

Mesquite



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National Prickle Bush Management Group

Northern Territory Government

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Mesquite

Control and management options for mesquite (*Prosopis* spp.) in Australia

October 2003

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Foreword

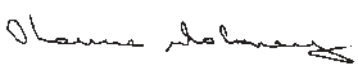
Mesquite is one of Australia's worst weeds. While it already infests nearly a million hectares, its capacity to thrive in a range of climates, soils and landscapes means that over 70% of the Australian mainland is threatened.

However, as the vast majority of current mesquite infestations are relatively small and sparse, it is critical that all possible efforts be directed to confining, controlling and, where possible, eradicating this weed. If mesquite is not controlled, it is likely that future generations will inherit an unproductive thorny shrubland.

The National Prickle Bush Management Group recognises that only through the combined efforts, diligence and commitment of all affected landholders, community and catchment groups, agencies and others will we effectively gain ground on this weed.

This manual brings together, for the first time, a comprehensive range of control and management tools for combating this weed. I recommend the manual to all landholders affected by mesquite and suggest its reading to others at risk of invasion.

Further, I commend all those who have been responsible, both directly and indirectly, for its production.



Louise Moloney
Chairperson
National Prickle Bush
Management Group

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Introduction

Mesquite

A Weed of National Significance

Mesquite (*Prosopis* species) is an exotic plant that has been recognised as a Weed of National Significance due to its invasiveness and subsequent ecological, economic and social impacts.

The impacts on landholders include reduced pasture production and mustering and watering difficulties. As its thorns are dangerous, mesquite may also harm people and damage stock and infrastructure. Its impact on the environment includes loss of biodiversity, change to natural landscapes and an increase in land degradation. It also provides refuge for feral animal populations.

Mesquite is by no means a new problem to Australia. It was introduced in the late 1800s, but appeared to be no threat until favourable conditions in the mid-1900s provided it with the opportunity to spread vigorously. It now covers almost one million hectares of Australian land—only a portion of the total area at risk of invasion. Mesquite has the ability to become more of a problem than prickly acacia (*Acacia nilotica*) if control programs are not carried out (ARMCANZ & ANZECCFM 2001).

A national approach

To tackle the current and potential threat of mesquite, a national strategy was launched in 2001. The vision of this strategy is that 'Mesquite species and hybrids are confined and eventually eradicated from Australia'. Further, the aim of the strategy is to deliver the following four desired outcomes:

1 Mesquite management is coordinated and maintained at a national level.
2 All core infestations are confined and subject to long-term management, leading to ultimate eradication.
3 All isolated and scattered infestations are eradicated.
4 Mesquite species are prevented from spreading.

The strategy is being led by the National Prickle Bush Management Group (NPBMG). Comprising agency and community representatives from across Australia, the NPBMG is responsible for overseeing and monitoring the implementation of the national strategies for the three Weeds of National Significance, mesquite, prickly acacia and parkinsonia.

Use of this manual

The control and management options presented in this manual are the combined results of years of trials carried out by many dedicated researchers, landholders, herbicide companies, government officers, landcare groups and others. The variations between mesquite plants and infestations, and their subsequent differences in response to control methods, have provided many challenges for those involved in the trials. It is a credit to these people that a range of control and management options for the different forms of mesquite are now available.

It is hoped that this manual, which aims to provide the most current information on mesquite in Australia, will be an invaluable reference tool equipping all land managers with the necessary skills and knowledge to achieve their individual goals.

Section 1

Mesquite–ecology and threat

Section 1

Mesquite–ecology and threat

Description

All mesquites are very similar in appearance and can be easily confused. For the specific identification of mesquite, a specialist should be consulted.

Mesquite can be either a multi-stemmed shrub with branches drooping to ground level, or a single-stemmed tree with a spreading canopy that can grow to 15 m in height. *Prosopis pallida* is often a single-stemmed tree with a wide girth, while the remaining species and hybrids are generally multi-stemmed shrubs that can grow to 10 m, but are more commonly 3–5 m high.

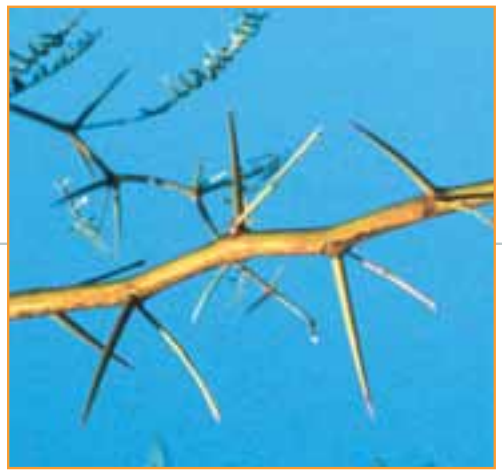
Throughout this manual, the different types of mesquite will be referred to as either tree form, which are mostly single-stemmed (*P. pallida*), or shrub form, which are mostly multi-stemmed (*P. velutina*, *P. glandulosa*, *P. juliflora* and all hybrids).

The foliage is usually dark green but can vary to bluish green. Twigs are smooth, with dark red or green bark. Older bark is rough and grey or brown in colour. The trees often look untidy, with individual zigzagged twigs sticking out beyond the main canopy.

▸ Shrub-form mesquite.

▲ Tree–form mesquite can grow to 15 m.

▲ Shrub-form mesquite.



▲ Thorns originate just above the leaf axis.

Mesquites are mostly thorny, although some thornless variations can occur. Thorns usually occur in pairs above each leaf stalk or along the main stem. They can range in length from 4 mm to more than 75 mm.

Flowers

Flowers are greenish yellow in colour. They are grouped in spike-like clusters on short stalks giving the overall appearance of a cylinder-shaped 'lamb's tail'. They are 5–12 cm long.

Flowers of all mesquite varieties have similar characteristics. The lamb's tail appearance of the flowers is a distinguishing characteristic of the *Prosopis* species.

◀ Lamb's tail appearance of the mesquite flowers.

Pods

Seed pods are 5–20 cm long, straight to slightly curved, smooth, and with slight constrictions between the seeds. Ripe pods are straw-coloured or sometimes purplish. Each pod contains from 5 to 20 hard seeds, which are round or oval in shape.

▲ Variation in pod colour.

Leaves

Leaves of mesquite are fernlike in appearance. Each leaf has 1–4 pairs of leaf branches (pinnae), with each branch having 6–18 pairs of individual leaflets (leaves). Leaf characteristics of the different mesquite species vary (refer to illustrations over page for more detail).

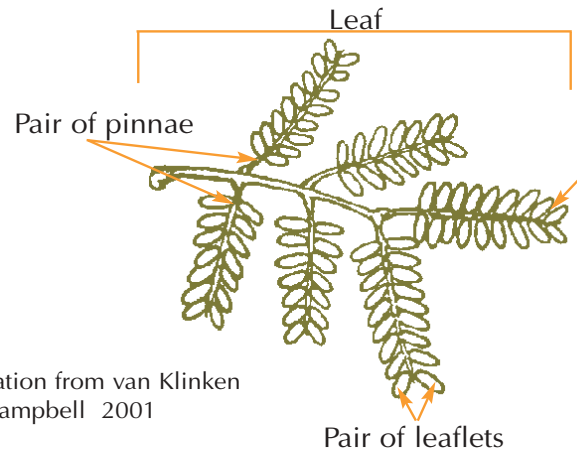


Illustration from van Klinken and Campbell 2001

Figure 1
Mesquite leaf with three pairs of pinnae. The pinna is the smallest individual branch that holds the leaves; they always occur in pairs. The leaflet is the smallest individual leaf.

Identifying mesquite species

Telling the different species of mesquite apart can be quite difficult. The main differences occur with the leaflets. More detail is given in figure 2, below.

Figure 2
(a) *P. pallida* branch with flower; usually 2–4 pairs of pinnae; leaflets are spaced closely together.
(b) *P. velutina* branch; two pairs of pinnae; leaflets close together.
(c) *P. glandulosa* branch; one (sometimes two) pairs of pinnae; leaflets widely spaced.
(d) On hybrids, leaves can vary greatly from plant to plant. This hybrid has long, widely spaced leaflets.

Note: Hybridisation can occur between two or more species and can result in a range of intermediate characteristics.

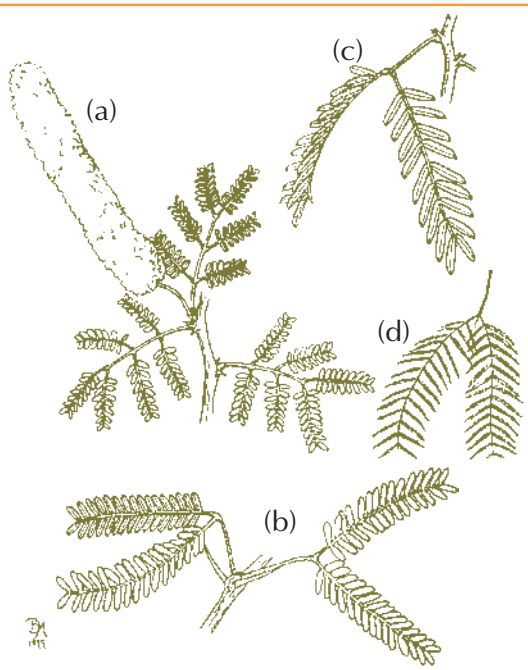


Illustration from van Klinken and Campbell 2001

Important note
As mesquite species vary in their weediness and their response to control methods, it is important to identify them correctly before starting any control work. Inspect plants closely; if in doubt about their identification, consult your local weeds officer, or send a sample to your state or territory herbarium. When doing so, aim to include the different plant features that are present.

Distinguishing between the 'prickle bushes'

Mesquite is often confused with other prickle bushes such as prickly acacia, parkinsonia, mimosa (*Mimosa pigra*) and mimosa bush (*Acacia farnesiana*). These prickle bushes, with the exception of mimosa bush, are also Weeds of National Significance.

It is possible to tell the difference between prickle bushes by the appearance of the flowers and pods. However, if neither of these is available, they can be distinguished by their bark colour and, in some cases, their leaves. As this can be difficult, a local weeds officer should be consulted.

The major differences between the prickle bushes are listed in table 1 (overleaf).

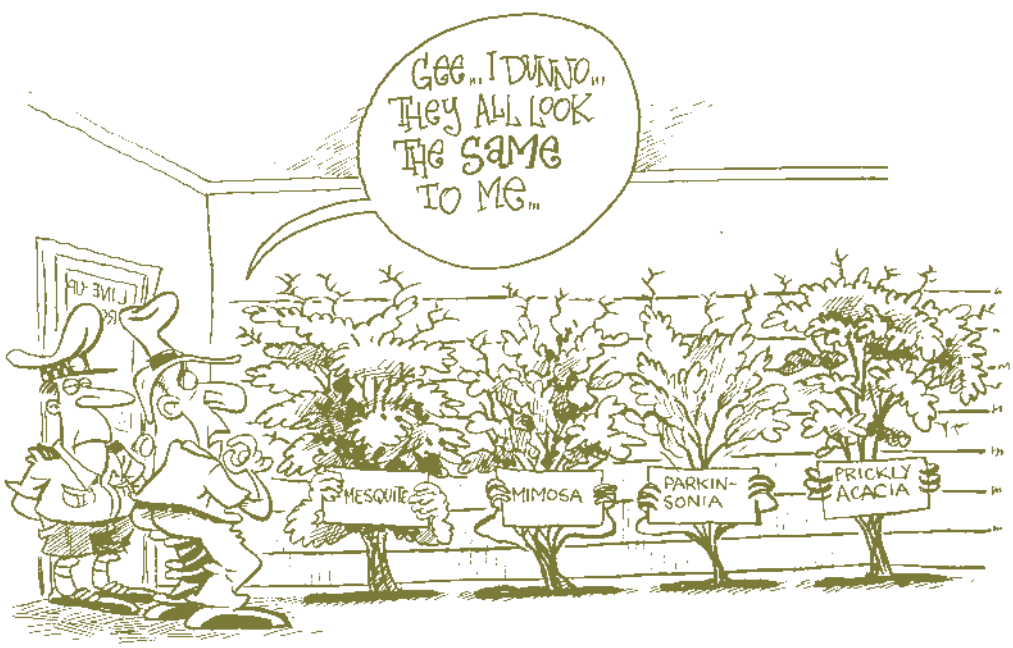


Table 1: Differences between prickle bushes

	Mesquite *Prosopis* spp.	Prickly acacia *Acacia nilotica*	Parkinsonia *Parkinsonia aculeata*	Mimosa *Mimosa pigra*	Mimosa bush *Acacia farnesiana*
Pod shape	Up to 20 cm long; slight constrictions between seeds; straight or slightly curved	Up to 23 cm long; constrictions between seeds	Up to 10 cm long; thin constrictions between seeds; straight	3–8 cm long; one-seeded, bristled segments, which fall away from the pod leaving a skeletal outline	Cigar-shaped; up to 6 cm long; slightly curved
Pod colour, hairiness	Straw-coloured, sometimes purple; no hairs	Blue-grey; fine hairs	Straw-coloured; no hairs	Brown when mature; covered with dense bristles	Brown to black; no hairs
Flowers	Cylindrical, greenish-yellow spike, 5–8 cm long	Ball-shaped, golden yellow, about 1 cm across	Five petals, mainly yellow, one with an orange spot	Round, fluffy, pink or mauve balls, 1–2 cm across	Ball-shaped, golden yellow, about 1 cm across
Leaves	Fernlike; 1–4 pairs; often with a gap between leaves	Fernlike; 4–10 pairs; often overlapping	Long, flattened leaf stalk with tiny oblong leaflets along each side	Central leaf stalk prickly; 20–25 cm long. Each leaf contains about 15 opposite segments, 5 cm long and divided into pairs of leaflets that fold up when touched or injured	Fernlike; 2–4 pairs; with a gap between leaves
Leaflets	6–18 pairs	10–25 pairs	——		8–18 pairs

Table 1: (continued)

	Mesquite *Prosopis* spp.	Prickly acacia *Acacia nilotica*	Parkinsonia *Parkinsonia aculeata*	Mimosa *Mimosa pigra*	Mimosa bush *Acacia farnesiana*
Tree shape	Variable—either a multi-stemmed shrub to 5 m, or a spreading tree to 15 m	Spreading tree to 10 m	Small tree or shrub usually to 5 m	Multi-branched shrub to 5 m	Usually rounded shrub to 3 m
Bark	Rough, grey; smooth dark red or green on small branches	Tinge of orange and/or green on saplings; dark and rough on mature trees	Smooth and green; straw-coloured and lightly textured at base of older trees	Stems green at first; becoming woody; initially covered with thick hairs	Grey, with prominent white spots
Branch shape	Zigzagged	More or less straight	Slightly zigzagged	More or less straight	Zigzagged

For further information on the identification of prickle bushes refer to section 5, p.86.

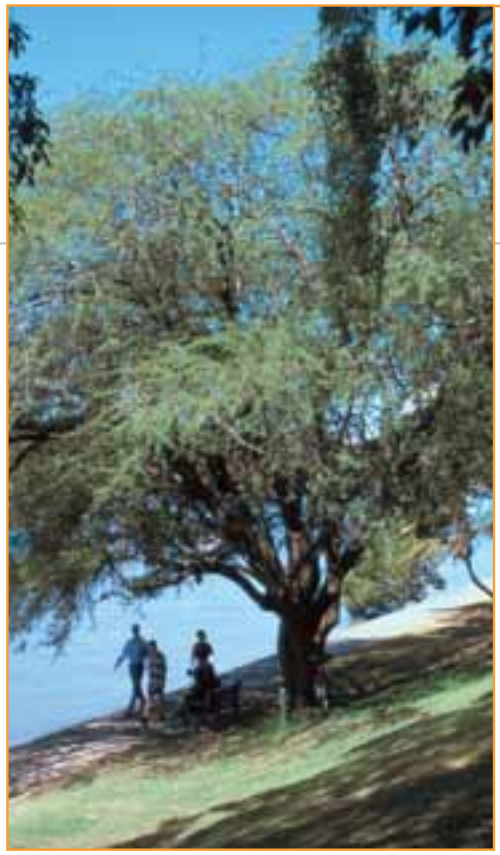
Different features of the prickle bushes

Ecology and biology of mesquite

Little information has been gathered to date on the growth, development and invasiveness under local conditions of the mesquite species present in Australia. However, available information from the countries of origin can be used to predict how the plants may behave in this country.

Mesquite is long-lived

One thing that is clearly evident about mesquite is that, once established, it can be very long-lived, even in the harshest of environments. In the United States, one of the countries of origin, plants at one location were believed to have an average age of 33–44 years, with the oldest trees estimated to be over 170 years old. In Australia, a single mesquite plant growing in the Botanic Gardens in Brisbane is known to be more than 115 years old, and large trees growing around the township of Hughenden in north-western Queensland have been there for more than 40 years, according to long-term residents.



▲ 115-year-old tree growing in the Botanic Gardens, Brisbane.

This longevity may help explain why very few dead plants are ever observed in mesquite infestations. This has serious implications for management, as it means that once established, a plant will continue reproducing indefinitely if not controlled.

Preferred habitats

In Australia, mesquite infestations can be found in climatically diverse regions—from areas with annual mean daily temperatures of 10˚C to 15˚C in the south, to over 25˚C in the north, and with median annual rainfall from as low as 150 mm to as high as 1200 mm.

Populations often begin along riparian zones, where dispersal is relatively easy, and favourable conditions for recruitment occur most frequently. This represents an early phase of invasion. However, mesquite is also superbly adapted to upland habitats where it can rapidly form dense populations in a range of conditions and soil types (from sandy, to loam, to cracking clay). This transition has been observed repeatedly around the world.

In its native range, mesquite grows naturally in exceedingly harsh conditions, (e.g. in Death Valley in California where the annual average rainfall is as low as 50 mm, and daily average maximum temperatures in summer are close to 45˚C). Some of the many adaptive abilities that allow mesquite to thrive under such conditions are:

- *The ability of roots to adapt to a wide variety of soil conditions.* Roots can grow upwards towards the soil surface to capitalise on little rainfall, but can also grow to depths of 80 m and extend laterally more than 30 m. This is the most extensive root system of any plant in the world.

- *Large carbohydrate reserves stored in the roots.* These reserves act as a buffer against environmental stress and serve as a carbohydrate source for new growth following defoliation, allowing mesquite trees (and even seedlings) to survive repeated top-kills and many years of constant defoliation.

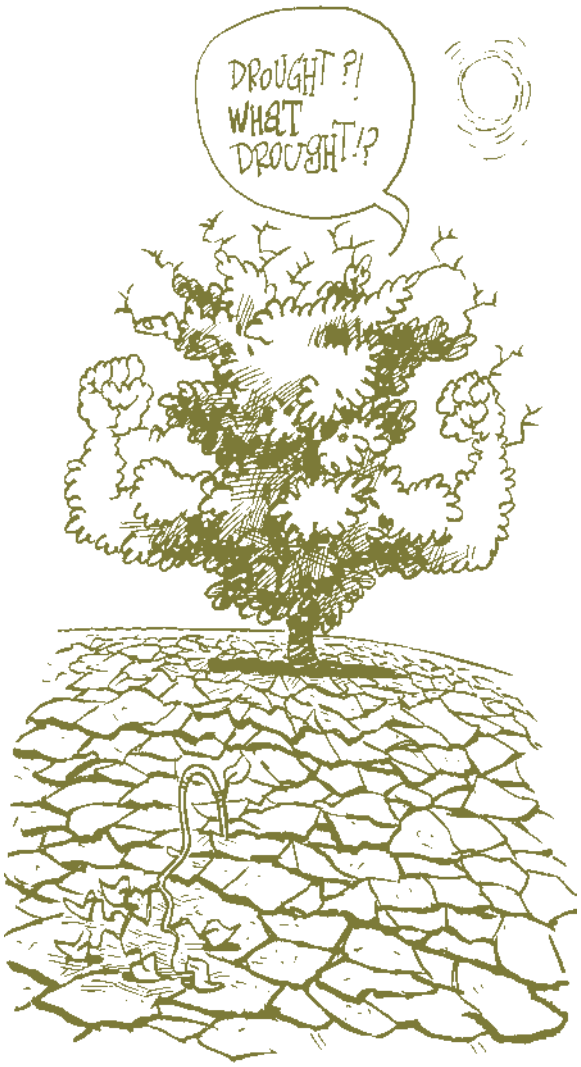
▲ Extensive root system.

- *The ability to alter leaf properties to minimise water loss.* Under arid conditions, the plant can modify to reduce stomatal conductance, change leaf orientation, increase wax accumulation and pubescence, increase leaf thickness and decrease leaf size. This minimises wastage of scarce water.

- *The ability to extract soil water and actively photosynthesise when soil moisture is so low that most other desert plants shut down or die.* Mesquite can actively grow even during prolonged drought.

- *The ability to defoliate under stressful conditions.* This allows the plant to essentially shut down during cold, dry, winter conditions or prolonged drought, conserving root reserves for refoliation once conditions improve.

  Nevertheless, if abundant moisture is available, mesquite can be a greedy water user and will take the opportunity to grow rapidly while favourable conditions prevail.



Rate of spread

The ability of mesquite to increase in density from low levels can be related to a number of factors—most importantly, substantial seed production, an effective dispersal mechanism, and favourable environmental conditions for seed germination and subsequent seedling survival.

Reproductive ability

Field observations in Australia suggest that plants generally produce their first flowers and seeds when they are between two and five years old, although pod production within one year has been observed under ideal conditions. Mesquite flowers predominantly in spring and early summer, with pods taking two to three months to mature.

Mesquite plants can produce large quantities of seed, although the number of pods produced by trees can vary greatly from year to year, and from plant to plant. While there are no figures available for pod production in Australia, estimates for large trees growing overseas range from 16 kg of pods annually, to as much as 367 kg. In terms of seed production, this equates to about 140 000 seeds at the lower range, and millions of seeds for very large trees growing under favourable environmental conditions.

▲ Horses will readily spread mesquite.

Several mesquite species are known to be self-incompatible, which means they require cross-fertilisation between plants before pods can be produced. This may help explain field observations at certain locations in Queensland where mature, isolated trees do not appear to have produced any seedlings.

Dispersal

Mature pods have high sugar and protein content and are highly sought after by many native animals (e.g. emus, kangaroos and wallabies); domestic animals (e.g. cattle, horses and sheep); and feral animals (e.g. pigs).

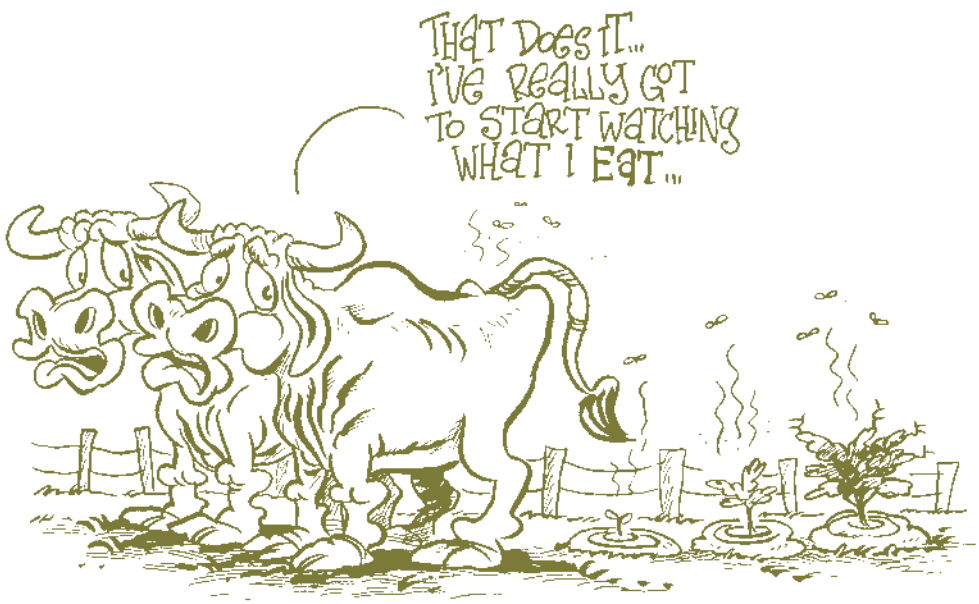
Seed survival rate through the gut can differ greatly between animals—being high (>70%) in cattle, and relatively low (<25%) in sheep and other herbivores that masticate their food. Animals also differ in the way they disperse—that is, how far they can travel from water, or how successfully they can get through fencing. This, in turn, can have an important effect on the way consumed seeds are dispersed, especially as some can take more than a week to pass through the gut.

▲ Seedling growing in kangarooo manure.

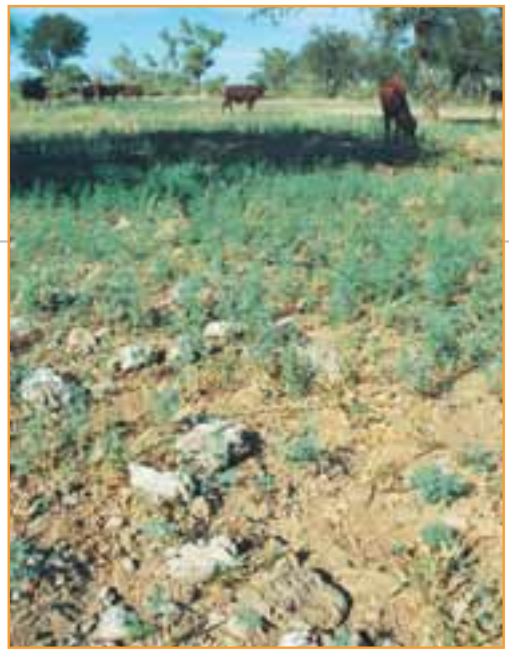
Seeds are finally deposited in the dung. In some animals, such as cattle, this is moist and nutrient-rich—providing an ideal microclimate for seedling emergence. Overall though, all animals that consume mesquite pods and pass viable seeds in their dung are capable of dispersing mesquite. In fact, the largest infestation in Australia, at Mardie Station in the Pilbara, spread when the property was running sheep, a relatively poor vector of mesquite seed.

Mesquite pods also float and can therefore be effectively spread by floodwater. Fortunately, the presence of pods is generally rare because of predation by animals. However, spectacular spread has been observed after flood events that coincided with peak pod fall.

Long-distance dispersal that results in new outbreaks is generally the result of human activity—for example, from intentional planting, attachment of seeds to machinery, or stock movement.



Seedlings sprouting from cattle manure.



Seed dormancy and seed-bank longevity

Mesquite seeds have hard-seeded dormancy, which means that the hard seed coat needs to be damaged (physically, mechanically or chemically) before the seed can absorb water and germinate. Seeds can remain dormant indefinitely if kept free of predators and stored in a dry environment at moderate temperatures. However, under natural conditions, they are intermittently exposed to hot and wet conditions. After favourable rainfall, seed burial trials have found that the majority of seeds will lose dormancy within two to three years, although dormant seeds can still be present after 10 years. As seed densities in the soil can be very high, the potential for a small portion to remain viable for more than 10 years means that sites where plants have been controlled will need to be revisited regularly if reinfestation is to be prevented.

Once seeds lose dormancy, all they require is enough water for germination. This generally occurs after significant rainfall in late spring and summer, although it can happen all year round. Dormancy, therefore, ensures that not all seeds germinate after just one rainfall event, thereby increasing the likelihood of seedling survival.

When will population explosions occur?

Mesquite is so well adapted to arid conditions that populations in Australia can continue to expand even under drought conditions. However, major population explosions occur after significant rain events. Optimal conditions are high summer rainfall to germinate the seeds, and good follow-up rain within several weeks of germination to ensure high seedling survival to the robust juvenile stage; however, massive recruitment can occur even after a single significant (e.g. cyclonic) rainfall event.

Some of the most spectacular population explosions have occurred as a result of record rainfall years that may occur only several times a century in any one place. High rainfall can result in seed spread across flood plains, high seedling survival and rapid growth.

Once established, seedlings are very resilient, and studies on some species have found that even after two weeks they can survive top-removal. Long-lived adult plants ensure that populations bridge the gaps between major recruitment periods.

Differences between mesquite species

The mesquite species in Australia have different distributions, growth habits and responses to management. To properly appreciate the potential threat each poses to the Australian environment, and to optimise their management, it will be necessary to develop a better understanding of their differing biology.

In summary, the key features of mesquite that contribute to its weediness are that:

- adults are exceedingly long-lived
- plants can adapt to survive drought conditions
- seed banks are relatively long-lived
- seeds are adapted to dispersal by a wide range of herbivores
- seedlings are tough.

History of spread

Throughout the early 1900s, mesquite was widely planted on properties throughout northern Australia—around homesteads as a shade tree, and in paddocks for shelter and as a possible food source for stock. It was also grown as an ornamental tree in town gardens.

Mesquite was planted around mining sites in the Cloncurry area of Queensland as it was thought to be a good soil stabiliser (Jeffrey & March 1995). Around the mining areas of Broken Hill in New South Wales it was used to reduce dust and erosion (Cunningham et al. 1992).

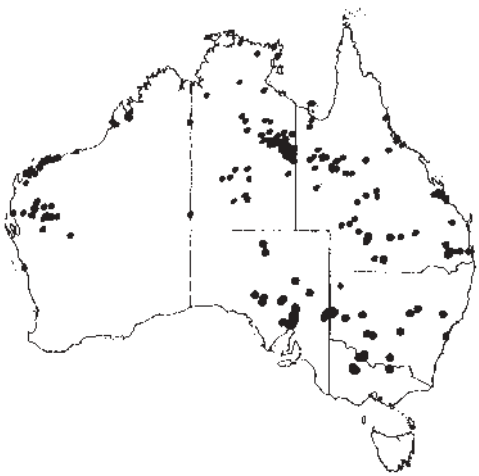
By the 1920s and 1930s, it was widely distributed throughout Queensland, the Northern Territory and Western Australia. Its introduction into other states was scattered and varied (van Klinken & Campbell 2001).

Initially, plants showed little tendency to spread, and it was not until after the 1945 floods in Western Australia that the weediness potential of mesquite became evident. A couple of trees planted in the 1930s around the homestead and shearing shed at Mardie Station (WA) rapidly multiplied, resulting in the largest and worst mesquite infestation in the

country. The infestation currently stands at 30 000 ha of dense mesquite, and 120 000 ha of scattered plants.

Similarly, the infestation in Quilpie, Queensland started from a couple of shrubs planted around a homestead. After significant rainfall events in the 1950s, mesquite spread to a nearby lake, and plants are now scattered over approximately 300 000 ha of land in south-west Queensland, with a core infestation of 4000 ha.

Most, if not all, of the main mesquite infestations have derived from plantings of a small number of trees (van Klinken & Campbell 2001).



▲ Map showing location of all recorded mesquite in Australia. [Information based on maps in van Klinken and Campbell 2001]

Current distribution

Mesquite has naturalised in every state and territory of Australia, with the exception of Tasmania and the Australian Capital Territory.

Prosopis pallida

Prosopis pallida occurs in scattered infestations throughout Queensland, Western Australia and the Northern Territory, with most infestations occurring in north-west Queensland. Major infestations occur in the Cloncurry and Hughenden areas; however, control work has reduced the size of these infestations.

Scattered *P. pallida* occurs in Western Australia, mostly in patches in the Pilbara and western Kimberley regions.

In the Northern Territory, scattered infestations occur mainly throughout the Barkly Tableland. Control programs by both government and landowners have dramatically reduced the size of these infestations.

P. velutina and *P. velutina* x *P. glandulosa torreyana* hybrids

Major infestations of *P. velutina*, and *P. velutina* x *P. glandulosa torreyana* hybrids occur along the Bulloo River in south-west Queensland, with the largest infestation occurring north of Quilpie. There are scattered plants along the flood plains of the Warrego River near Cunnamulla, and an isolated infestation on the Bulloo Lakes. Control efforts by landowners, and local and state governments have reduced the spread of this infestation.

Infestations in New South Wales are mostly scattered throughout the Milparinka and Broken Hill areas and cover approximately 27 000 ha. Control work in the 1980s killed all mature trees in these areas; however, owing to a lack of follow-up, mesquite has regenerated. Isolated plants have also been found in the south-western Riverina district and in the north-western areas of Gilgandra, Coonable and Bourke.

In South Australia, infestations have been recorded in the Woomera and Port Augusta regions. As a result of control work, these infestations have been reduced to isolated trees.

Victoria has had two small infestations, thought to be *P. velutina*, in Swan Hill and Wangaratta in the north of the state. These infestations have been treated; however, the current condition is unknown.

P. glandulosa var. *glandulosa*

The largest infestation of approximately 1000 plants of *P. glandulosa* var. *glandulosa* occurs in the eastern Kimberley region. Smaller isolated infestations occur in New South Wales and in the Rockhampton area of Queensland. Treatment of these infestations has reduced them dramatically.

P. juliflora

P. juliflora is the least common species of mesquite found in Australia. There has been confusion as to its identification and, to date, there have been only two confirmed recordings—one at Geraldton in Western Australia and one at Townsville in Queensland. The latter has been controlled.

Hybrids

The range of species compositions means that plant form and features may vary within and between plants and infestations—technically these features are referred to as different morphotypes.

Hybrid infestations occur in north-west Queensland around the McKinlay area, but are most widely distributed in Western Australia. The largest is on Mardie Station in the Pilbara region. Other scattered light infestations occur on stations south of Derby, Broome and Kununurra. There are also patches of mesquite in the Gascoyne region of the state.

The problem

Mesquite has the potential to become a serious and widespread pastoral and environmental weed in Australia (Csurhes 1996). Although sparse stands may provide shade and shelter for stock, impenetrable thickets can form over time—the threat posed by mesquite far outweighs any benefits that the plant may have.

Infestations commonly begin along watercourses (natural and constructed), but plants will do just as well away from water. Mesquite is an aggressive competitor in rangeland situations and will rapidly invade upland country. Some infestations, such as those in McKinlay and Cloncurry, Queensland, have had no relationship with water (S Campbell 2003, pers. comm., 1 March). However, any limited distribution along watercourses is typical of the early phases of invasion and should be considered a warning (Csurhes 1996).

Mesquite can have a dramatic impact on primary production and the environment. If uncontrolled, the plant will continue to spread at an increasingly rapid rate.

Direct effects of mesquite on landholders include:

- reduced pasture and loss of production
- increased financial costs—prickly acacia currently costs landholders more than $5 million per year in lost production, control costs and increased management costs. Mesquite has the potential to be as bad a pest, if not worse, than prickly acacia, (E Miller 2003, pers. comm., 3 March)
- increased difficulty and expense in mustering stock
- damage to infrastructure if weeds are growing along fence lines and watering points—thorns can also damage vehicles by puncturing tyres and damaging paint work

- increased medical expenses—currently about $20 000 per year is spent on medical treatment for problems caused by the thorns of the prickle bushes (E Miller 2003, pers. comm., 3 March).

The environmental effects of mesquite include:

- increased land degradation and loss of soil moisture due to their extensive and deep root system
- loss of biodiversity—mesquite competes with and takes over native vegetation, causing a change in habitat
- provision of refuges for feral animal populations
- damage to environmentally sensitive areas such as watercourses.

As weed populations tend to increase more rapidly over time, control becomes more difficult and costly. The Department of Natural Resources and Mines has already spent millions of dollars in attempting to eradicate mesquite and prevent it from becoming a major pest in Queensland (E Miller 2003, pers. comm., 3 March). Though this work has reduced the rate of spread, mesquite continues to be a problem.

Although control costs can initially be high for landholders, the benefits gained in the long term far outweigh this. The Australian Agricultural Company demonstrated that the weed control program for their Gulf stations would provide a reasonable rate of return of 12–13% on the funds invested into weed control over a 20-year period (J White 2003, pers. comm., 20 February).

Potential threat

All Australian mainland states and territories have favourable climatic conditions for the growth of all species and hybrids of mesquite, which is generally adapted to hot and dry conditions, and grows well in a diverse range of soil types (van Klinken & Campbell 2001).

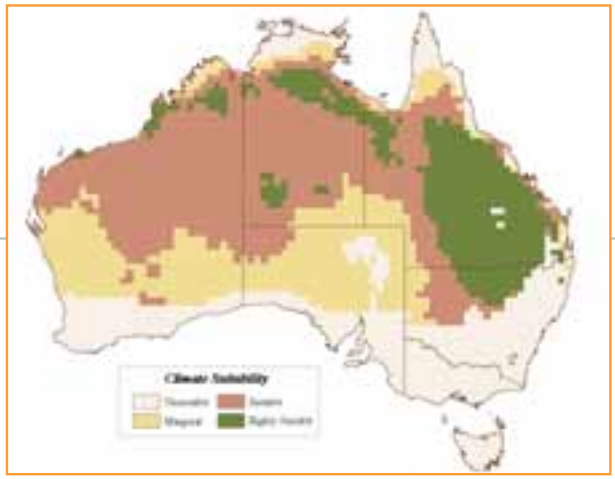
Exceptions are areas of very high rainfall such as Darwin, and areas of extreme frost and cold such as southern Victoria.

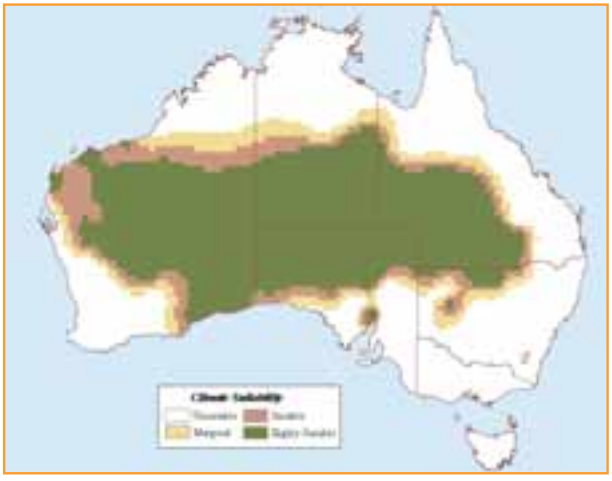
The semi-arid and arid regions of the country are most at risk of invasion by mesquite. *P. pallida* is mostly suited to northern areas of the country, with distribution likely to be limited in the south by cold stress and severe frosts.

The species *P. glandulosa* and *P. velutina* are more tolerant of colder climates and will also do well in cooler areas, such as western New South Wales.

Potential distribution of mesquite in Australia

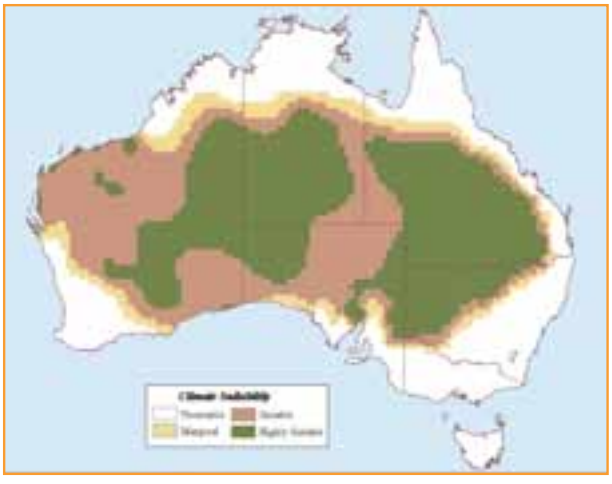
a) *Prosopis pallida*





b) *Prosopis velutina*

c) *Prosopis glandulosa* var. *torreyana*



Potential distribution data is based on CLIMEX information
[Note] As there are many varieties of mesquite hybrids, they have not been mapped. All major hybrid varieties are a combination of the three major species mapped and potential distribution is likely to be in similar areas to those already indicated.

Managing mesquite

section 2

Section 2

Managing mesquite

Most infestations of mesquite in Australia have originated from dispersal of seeds by humans; however, floodwaters, run-off and animals have also played a major role in its spread.

Weed control can be expensive, and prevention is by far the cheapest option. Reducing the risk of spread by good management practices and strategies may dramatically reduce control costs in the future.

Mesquite seeds can be spread unknowingly during day-to-day activities. This can be minimised by understanding that they can be spread by:

- stock/grazing animals
  - cattle*
  - sheep
  - goats (domestic)
  - horses*
- feral animals
  - pigs*
  - goats
- native animals
  - emus*
  - kangaroos and wallabies
  - birds (e.g. parrots)
- water
  - watercourses
  - flood plains

*These animals are major vectors of mesquite in areas where they occur.

Management strategies

The aim of management strategies is to prevent or reduce the spread of mesquite—an important part of any control program. They are based on the plant's seed dispersal mechanisms (see p.12)

The success of any management strategy depends on:

- correctly identifying mesquite, particularly at the seedling stage
- monitoring susceptible areas such as roadsides, watering points and stockyards
- identifying the most likely means of spread into, and within, the property, and minimising these risks
- treating mesquite plants before they set seed.

Strategies for managing stock, infrastructure, machinery and vehicles, feral and native animals, and water should all be considered when developing the control program.

Stock

Stock purchased at sales may have viable seeds in their gut. To prevent mesquite from entering the property in this way, quarantine stock in holding facilities before putting them out into 'clean' pasture. If they have viable seeds, plants will come up in the yards and will be much easier and cheaper to control.

Mesquite seed can take up to eight days to pass through the gut of pigs (see 'Mesquite seed spread by feral pigs', (p.76). No information is currently available for the time it takes mesquite seed to pass through the gut of cattle or sheep, but it is recommended that stock that have been in mesquite-infested areas should be quarantined for at least eight days prior to moving them into 'clean' areas.

▲ Seedlings in horse manure.

Remove stock from infestations while pods are available and do not allow them to graze on mature pods. Alternatively, maintain stock in an area of dense mesquite only, and do not let them out. However, the latter option will thicken growth in already infested paddocks.

▼ Travelling stock can move seed large distances.

Mesquite, once planted as a shade tree in stockyards, should be removed.

Infrastructure

- Strategically fence off infestations or major seed source areas from susceptible country. In combination with managing stock movement, fencing is the cheapest form of containing mesquite, as it will prevent stock from moving from infested areas to non-infested ones.
- Replace mesquite with other shade-producing trees or artificial shade structures. Although removing mesquite that is providing shade for stock may be a difficult decision for some landholders, it should not be a deterrent in any decision made to control the plant. Speak to local authorities for further information on which trees would be the most appropriate to plant for shade in different areas.
- Cap bores and remove bore drains as they provide an ideal environment in which mesquite and other weeds can establish.

Machinery and vehicles

As mesquite seed can be spread by machinery and vehicles:

- wash down vehicles and machinery after they have been in infested areas
- work from clean areas to infested ones to prevent seed spread
- consider where trucks transporting stock have come from—check that manure in the trucks does not contain seed that could fall out into the paddock.

Public washdown facility.

Feral animals

Feral animals may play a role in increasing both the size and density of mesquite infestations; however, controlling the movement of these animals can be difficult. Monitoring clean areas for seedlings and controlling them before they reach maturity and produce pods is important if feral animals are identified as agents of spread. This is particularly important if mesquite is growing on neighbouring properties. If feral animal control is the best option, conventional control methods to reduce numbers include trapping, shooting and baiting.

The reduction of feral animal numbers is best when an integrated approach is taken. No method used alone will be the most effective.

▼ Feral pig manure containing mesquite seed.

▲ Seed in emu manure.

Native animals

Native animals probably play only a small role in spreading mesquite. If native animals such as emus and kangaroos have been identified as contributing to the spread, then:

- monitor clean areas for seedlings, and control them as soon as they emerge. This is of particular importance in areas where neighbouring properties have mesquite infestations.
- identify areas on the property where native animals are likely to feed on mesquite pods and control these areas as a priority.

Water

Though the dispersal of seed by water is difficult to control, the likelihood of this becoming a problem can be minimised by:

- controlling infestations that occur in upper catchment situations
- monitoring susceptible areas regularly for seedling growth, particularly after periods of high rainfall.

▲ Water can transport pods and seeds throughout a catchment.

Developing a weed control plan

Any control program should be planned to ensure that the best possible results are achieved with minimal cost and effort.

Even though the control or eradication of mesquite is the focus of this manual, the same principles can be used for other weeds on the property, and ideally should be included in the same plan. A successful plan cannot be developed in isolation and must be integrated into the overall property management plan (March 2000).

Although 'controlling' mesquite is referred to throughout this manual, steps should always be taken to eradicate infestations wherever this is possible.

It is recommended that a weed control plan have at least a five-year to ten-year timeframe and be reviewed annually.

The control or eradication plan should include the following steps.

Step 1. Identify and prioritise problem areas

The easiest way to identify these areas is by using a map of the property.

- On the map, outline all natural features, improvements and property boundaries. Then identify areas where mesquite is located, including a description of the species, the size of the infestation and the density.
- Prioritise the areas for control or eradication, at the property level and at a paddock-by-paddock level.
- Consider what legal or ethical responsibilities you may have (e.g. threat of mesquite to neighbouring properties).
- The property map can be an aerial map, a satellite image or a hand-drawn map. Remember that the better and more current the map, the greater will be the accuracy when determining control costs and tracking the long-term effectiveness of control efforts.
- Separate transparent overlays are useful when developing the map. One suggestion is to use one overlay outlining property improvements, one for vegetation types and natural features and another devoted solely to weed infestations. The use of different overlays can make each section of the map easier to interpret and will also be helpful in determining management options, such as optimal placement of fences and removal of bore drains.
- To help prevent infestations from spreading further, control efforts should initially be focused on high seed source areas or isolated outbreaks. A good rule of thumb is to start with the easiest section to control, and then gradually work towards the thicker patches

Step 2. Determine the control options

- Identify the resources that are already available or affordable, such as spray equipment, machinery and labour. This will indicate the most economic and beneficial control options.
- Decide on the most effective and relevant management options to reduce spread into other areas.
- Determine the control methods required to address all phases of the control program—initial, follow-up and ongoing monitoring.
- Identify the most appropriate management strategies to control the mesquite species present on the property, noting that different types of mesquite will respond differently to the same control methods. Therefore, work out

which options (or combinations of options) are appropriate for each situation (see pp.38–41).

Implementing the correct management strategies from the start may reduce future control costs. High cost control options are not necessarily the best for all situations. If in doubt, contact a local weeds officer to assist with any decisions.

Step 3. Develop a financial plan

- Estimate the cost of the management strategies and control options for each priority.
- Compare the costs of control with other operations occurring on the property to make sure that the chosen methods are economically viable.
- Integrate control costs into short-term and long-term budgets.
- Check to see if there are any financial incentives available to assist with control programs.
- Consider all costs when developing a financial plan, including the hourly running costs of machinery and labour. If necessary, seek advice from local government or departmental weeds officers before committing a large amount of funds.

Step 4. Schedule activities

- Consider the effectiveness of control methods at different times throughout the year and balance this with the time available for control.
- Timetable any weed control activities for the year.

Mesquite control should become an annual part of property management. When developing a plan, take into consideration that monitoring and follow-up control will also be necessary after initial treatment, and ensure that any treated areas are followed up within a year.

Step 5. Monitor progress

Monitoring is an integral part of any control program. It will visually show what has happened after treatment and will identify areas of regrowth where follow-up is required.

- Use the map of the property as a starting-point record of the problem before any control work has commenced.
- On the map, show any new and previously treated areas.
- Set up photo points at different points of control (see p.31).
- Document control costs and resource requirements.
- Incorporate monitoring activities into the yearly timetable.

Information on setting up monitoring sites is given in more detail on (pp.30–32).

▲ Helicopter surveillance can be useful on large properties.

Step 6. Follow up what was started

Follow-up control is crucial. No control method for mesquite gives a 100 % kill rate and some level of seedling regrowth is almost guaranteed.

- Identify areas from the monitoring sites where follow-up is needed as a result of regrowth or from seedling germination.

Further information is given on p.34.

Conclusion

Any control plan is useless without implementation. If, because of the size of the problem or the lack of experience, it is difficult to start the planning process, it is advisable to gain professional advice and/or to start on a smaller scale.

The development of a weed control plan and commitment to its implementation are essential for the long-term effectiveness of control efforts. While the plan should be structured, it should be flexible enough to allow for changes brought about by uncontrollable external influences such as drought and fluctuating commodity prices. It is also critical to review the plan annually to assess the effectiveness and efficiency of the control options and strategies implemented.

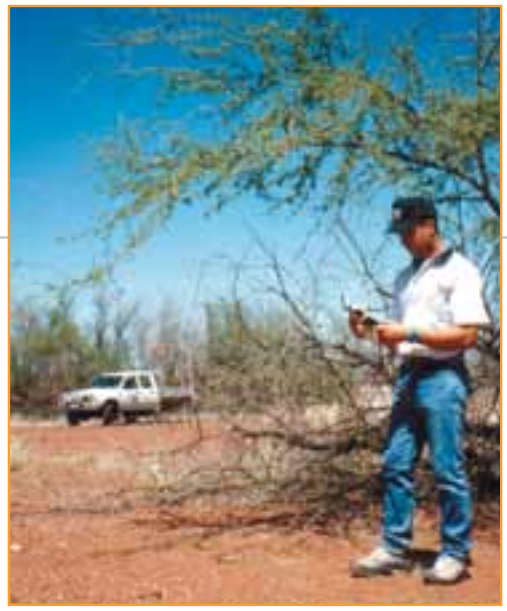
Monitoring mesquite control

The control of mesquite is a long-term commitment. Control programs need to be well planned and include monitoring and follow-up systems, which are just as important as the control plan itself.

Regular monitoring will show the changes that have resulted from control work over time, and is more efficient than relying on memory alone. It will show how effective initial treatments have been and will assist in identifying what more is required to ensure that regrowth is minimised and seedlings controlled before they reach reproductive maturity.

Monitoring not only assists landowners in making decisions about future control work, it also shows the differences in pasture condition and hence their carrying capacity. Results from monitoring will assist in the annual review of the control plan. They will identify areas that have responded well to treatment and others that have not.

For the development and implementation of a monitoring program to be successful, two types of data are necessary:



Recording mesquite locations using a GPS.

- **Starting point data** provides information on the vegetation as it *currently* stands and is the basis for comparison in future years. This information should be used in conjunction with the weed control plan. Starting-point data can be obtained from photo points and vegetation sites.

- **Progressive data** is a cumulative record of the information collected from different monitoring sites over a number of years. It will show if control strategies are working, if any regrowth has occurred and if there has been any change in pasture production and composition.

As major changes in vegetation occur gradually, monitoring will give an early indication of them. Timely adjustments to management practices can then be made, making success more likely.

The monitoring system can be as simple or as complex as desired. The recommended minimum requirement for monitoring is for photographs to be taken annually, at the same time of the year, from each of a number of established photo points.

Photo points

The benefit of having photographs as records is that they will show changes in the landscape over time, indicating if an infestation is increasing or decreasing, and if native vegetation has returned after control. Photographic records will assist landholders in determining what measures are required to control regrowth and prevent seedling re-establishment.

To record what the vegetation looks like, and the density of mesquite on a property at a given time:

- Establish photo points for each different land type and infestation area, at least 100 m from fence lines, tracks and waterways.
- At each photo point, put in a 1.8 m star picket with a painted top (for safety and ease of location in the future).
- Identify each point with a GPS reading (if possible), and a name (e.g. long paddock 01). This information can be recorded on a metal tag attached to the post.
- Standing at the star picket with a standard 35 mm camera, focus the camera towards the horizon and take the picture.
- Record the date.
- Record the direction (compass bearing) from which the photo has been taken, so that in the future, photos taken from the same point can be taken from the same angle.
- Note what photo on the film has been taken at each point.

Vegetation transects

Collecting specific vegetation information within a given area will give an accurate representation of what is currently growing in the paddock and its condition.

Record all vegetation, including grasses, herbage, woody weeds and native trees. The purpose of this is to see, over time, how control work has decreased weed density, and to show the effect that this is having on pasture regeneration.

A vegetation monitoring site can be marked out as shown in figure 3. A record of all the vegetation within each quadrat (50 cm x 50 cm square) should be taken. An example of a recording sheet is given in table 2.

Record each site separately. Note factors that may influence the results such as:

- treatment of mesquite already conducted
- grazing pressure at different times of the year
- climatic conditions (e.g. extremely wet/dry year).

Vegetation information should be collected at least once a year at the same time.

Results obtained can be used in determining follow-up control, and how it could best be achieved for a particular area of infestation. They will also show any improvements in pasture composition that control measures may have brought about.

To estimate mesquite density, select an area that is representative of the infestation and mark out three different areas of 10 m x 10 m (10 m^2). Count the number of mesquite plants greater than 1.5 m in height within each of the three areas. (As plants less than 1.5 m are seedlings or juvenile plants, some of which will die naturally, counting only mature plants over 1.5 m will give a more accurate figure for density level). Using the following example, calculate the approximate density per hectare (ha). This will indicate if there has been a change in the density over time and will assist in working out control costs.

Example

No. of trees area 1:		9
No. of trees area 2:		7
No. of trees area 3:		2
Total:		18
Average per 10 m^2:		18/3
	=	6
Trees per ha:		6 x 100
	=	600

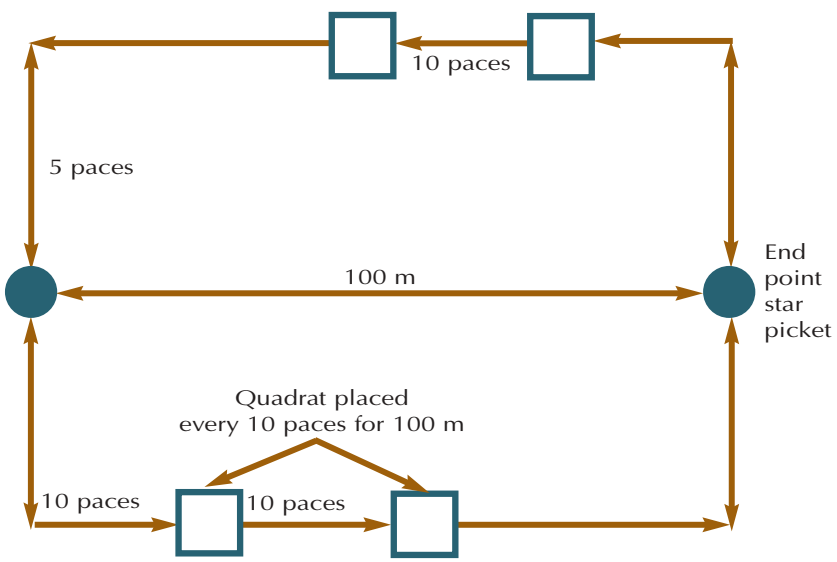


Figure 3 Vegtation transects

Table 2: Example recording sheet

Site name:		Date:	
Quadrat	Major plants present	% ground cover	Comments
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
18			
19			
20			
General comments (control, climate, etc.)			

For further information on monitoring, refer to section 5.

Follow-up control

Follow-up control with mesquite is critical and any good program will include follow-up measures. Rarely will any control method be 100% effective—partly because of the limitations of the initial control methods, and partly because new seedlings will almost certainly emerge from the long-lived seed bank.

Poor kill rates and the consequent need to re-treat trees can be due to:

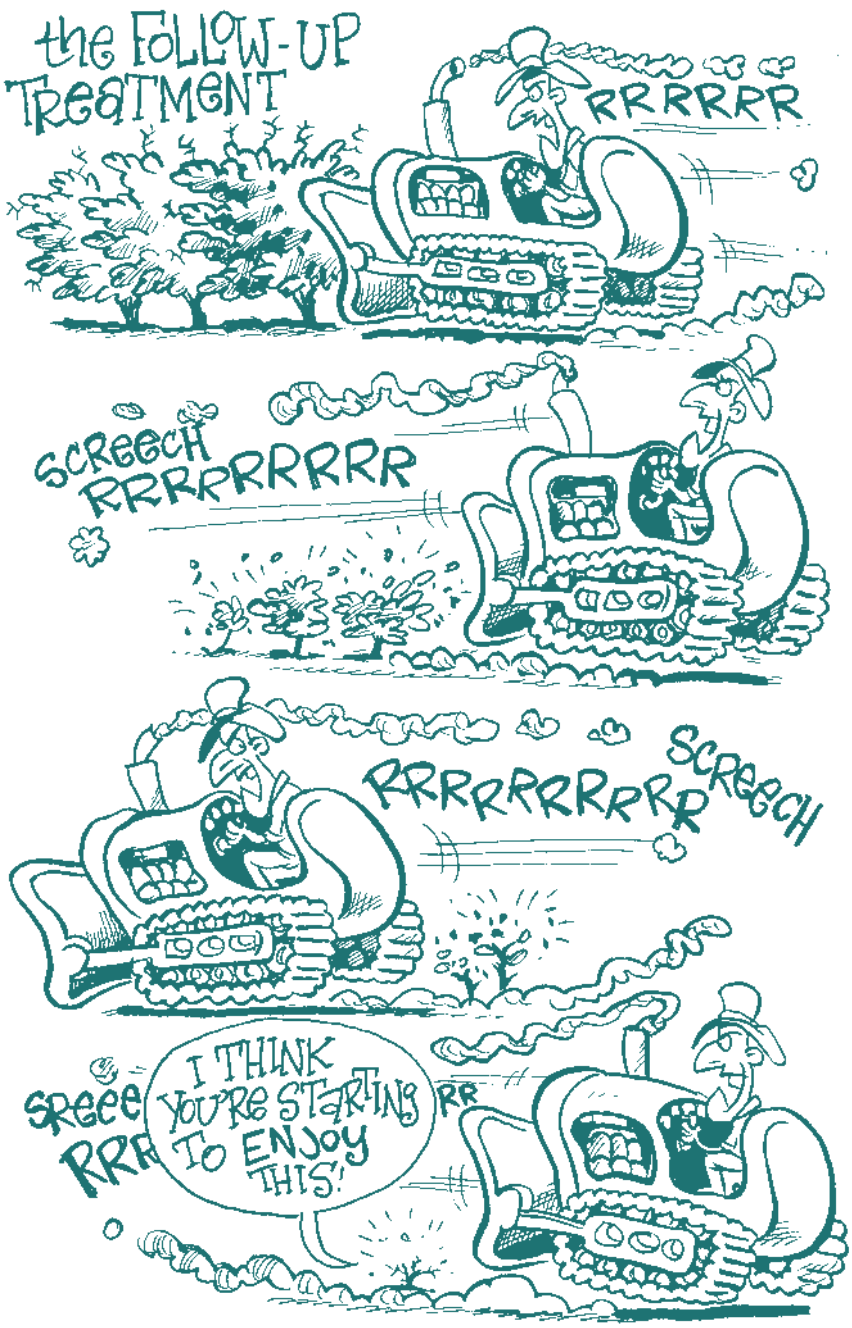
- use of inappropriate control method for the species of mesquite
- use of incorrect herbicide
- incorrect mixing rates
- unfavourable weather conditions
- poor equipment
- incorrect application of herbicide
- missed trees
- time of the year.

Seed banks can be large and long-lived. If not controlled at an early stage, plants can quickly grow to maturity and seed, setting the control program back to the beginning. However, as the rapid recruitment of new seedlings can deplete the seed bank, seedling emergence can be a good thing, provided there is follow-up control.

Seedling emergence after initial control will occur in most situations; however, it can be accelerated by the following:

- *Initial control method*. Some control options can actually encourage seedling emergence e.g. mechanical disturbance of soil. In these instances, it is important to monitor for new growth regularly and, if possible, to re-sow at the time of treatment with suitable pasture species to provide competition for the emerging mesquite seedlings.

▲ Incorrect application of herbicide treatment can result in regrowth.


the FOLLOW-UP TREATMENT
RRRRRR
SCREECH RRRRRRRRR
RRRRRRRRRR
SCREECH
SREEE RRR
I THINK YOU'RE STARTING TO ENJOY THIS!
RR

- *Rainfall.* High rainfall following initial treatment will provide optimal conditions for the germination of mesquite seeds and will usually result in a high level of seedling regrowth. Low rainfall will generally have the opposite effect and fewer seedlings will germinate. Most seeds will typically germinate within three years; however, it is important to continue monitoring, as seedlings may still emerge after more than 10 years.
- *Soil moisture.* Areas that naturally have more soil moisture for longer periods throughout the year, such as along riverbanks, bore drains, dams and creeks, can also show high levels of seedling germination after initial treatment.
- *Soil seed load.* In areas where thick infestations have been treated, large numbers of mature trees will have been dropping seeds in the soil for a number of years. In these situations, there will be a high level of seed in the soil ready to germinate once the older trees have been killed.

Follow-up control can take many years and must be complemented by ongoing monitoring and preventative action. It is important to plan, budget for and implement follow-up control, or the future problem of mesquite will be just as bad, if not worse, than the initial one.

Mass seedling germination following mechanical control.

The mesquite control toolbox

Section 3

Section 3

The mesquite control toolbox

Integrating control options

As mesquite species respond differently to control methods, the most effective method or combination of methods will vary depending on the size, density and species of mesquite present. For this reason, correct species identification should be made before any control work is started.

Rarely will one control option fix the problem. Usually a combination of methods (e.g. mechanical, chemical, biological and management) will be most effective. Assessment of the best option should be carried out on a paddock-by-paddock basis, and a plan made for each individual situation.

In general, the shrub form of mesquite is more difficult to control than the tree form. This should be taken into account when deciding on control methods.

The following should be considered:

- size, density and species of the infestation
- short-term and long-term objectives of the project
- accessibility of the infestation and the type of land infested—for example, flat open plains, along major watercourses and flood plains
- availability of resources—for example, spray equipment, tractor, dozer, labour
- management options
- easiest and most cost-effective methods
- complementary control options—for example, chain pulling, followed by burning, followed by application of herbicide
- type and amount of native woody vegetation present. This will have implications on what options can be used without the need for a tree-clearing permit.

When working out the control program, keep in mind that:

- widespread use of chemical and mechanical control can be expensive in rangeland situations
- seed banks can be large and long term, so follow-up control is extremely important
- mechanical control can provide the opportunity to re-sow with suitable pasture species, which will provide competition for new mesquite seedlings as they emerge.

As mesquite has different survival characteristics (see section 1), control, therefore, requires a long-term program.

Control options

In this manual, control methods have been separated into two categories—those suitable for:

- tree-form mesquite —mostly single-stemmed (*P. pallida*).
- shrub-form mesquite —mostly multi-stemmed and includes all hybrid varieties, *P. velutina*, *P. juliflora* and *P. glandulosa* complexes.

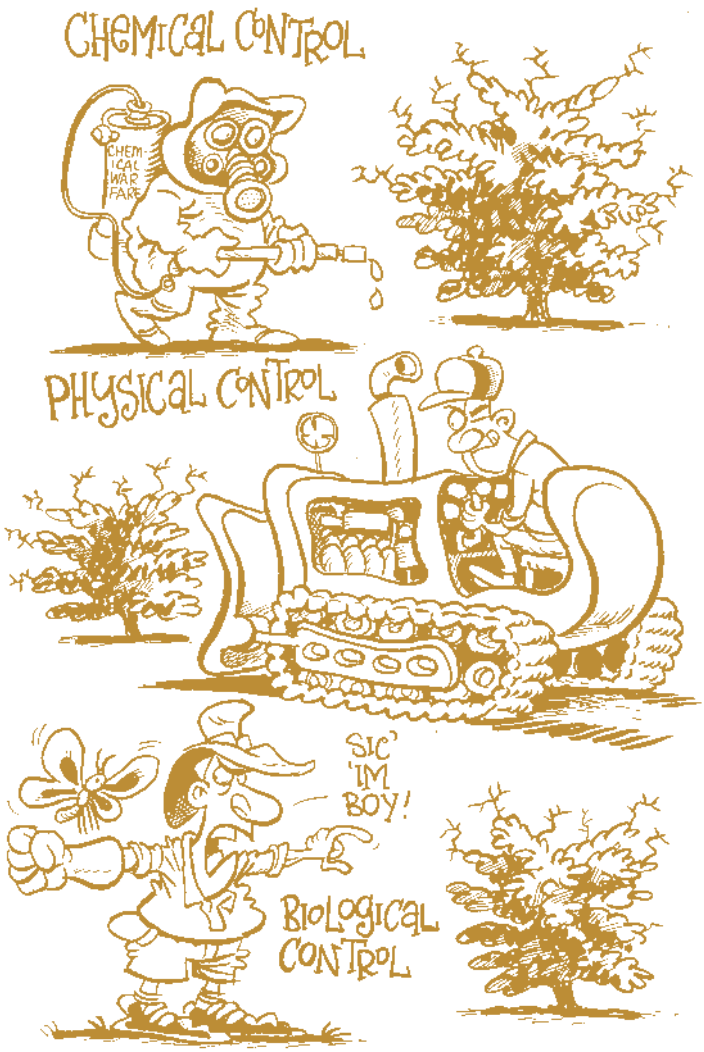


Table 3: Tree form—mostly single-stemmed (*P. pallida*)

Control option	Situation				
	Scattered	Low density	Medium density	High density	Regrowth/ seedlings<1.5 m
Physical control					
Blade ploughing [1]		✔	✔		
Chain pulling [2]			✔	✔✔✔	
Dozer pushing	✔	✔	✔✔	✔✔	
Stick raking		✔	✔✔	✔✔	
Fire		✔✔	✔✔✔	✔	✔✔
Chemical control					
Basal bark spraying	✔✔✔	✔✔✔	✔✔	✔	✔✔
Cut stump technique	✔✔	✔✔	✔		
Foliar spraying					✔✔✔

Key
Suitability of control option: ✔= low ✔✔ = moderate ✔✔✔ = very good
[1] Front-mounted blade ploughs are the recommended option for use on tree-form mesquite. Blade ploughing is effective for the removal of small trees; however, it is not recommended for large mature trees and may damage machinery.
[2] Chain pulling is effective only if followed by burning.

Density levels
scattered: one or two isolated plants or clumps of plants
low: 1–50 plants per ha
medium: 50–500 plants per ha
high: >500 plants per ha

Table 4: Shrub form—mostly multi-stemmed (*P. velutina, P. glandulosa, P. juliflora* and hybrids)

Control option	Situation				
	Scattered	Low density	Medium density	High density	Regrowth/ seedlings<1.5 m
Physical control					
Blade ploughing		✔	✔✔	✔✔	✔
Chain pulling					
Dozer pushing					
Stick raking [3]		✔	✔✔	✔✔	✔✔✔
Fire			✸	✸	✔
Chemical control					
Basal bark spraying	✔✔✔	✔✔✔	✔✔	✔	✔✔
Cut stump technique	✔✔	✔✔			
Foliar spraying					✔✔✔

Key
Suitability of control option: ✔= low ✔✔= moderate ✔✔✔ = very good
[3] Stick raking with a cutter bar is the recommended method to use on shrub-form mesquite.
✸Only extremely hot fires that spread throughout the canopy are effective in these situations.
Refer to (p.50) for further information.

Density levels
scattered: one or two isolated plants or clumps of plants
low: 1–500 plants per ha
medium: 500–5000 plants per ha
high: >5000 plants per ha

Physical control options

Blade ploughing

Recommendations

Tree form

- The use of a front-mounted blade-plough attachment is recommended for the treatment of low-density to medium-density infestations. Ideally, plants should be young so that the blade can push through the stems easily. Older, more mature plants are difficult to treat in this way and can damage machinery. Rear-mounted blade ploughs are not recommended.

Shrub form

- The front-mounted Ellrott blade plough is considered a suitable option for control of medium-density to high-density infestations. The rear-mounted Homan plough is also suitable but is not as effective as the front-mounted model. Both of these options can be very expensive.

Description

Grubber attachments are mounted on either the front or rear of dozers or tractors. Front-mounted attachments can be easier to manoeuvre and can penetrate an infestation more quickly, bringing the costs down (depending on whether the dozer is hired or owned).

▲ Front-mounted blade plough (Ellrott design).

A 4 x 4 tractor of at least 80 hp for smaller infestations, and dozer of minimum size D6 are recommended for blade ploughing medium to high density mesquite. Blades are pushed or pulled under the trees and stems are cut off below ground level. Success depends on cutting the root system below the bud zone (20–30 cm) to reduce the likelihood of re-shooting. Multi-stemmed plants may grow back if they snap off at ground level.

▲ Rear-mounted blade plough (Homan design).

Front-mounted blade plough

Care should be taken to avoid native trees and shrubs when blade ploughing, unless a permit has been granted. Check state or territory native tree-clearing guidelines.

Timing

In southern states, the recommended time for blade ploughing is during spring, before seed set. In northern Australia, this method is likely to be most effective in late autumn and winter when root reserves are low and are not being replenished (Parsons & Cuthbertson 2001).

Advantages

- Provides the opportunity to re-sow with suitable pasture species.
- Results in immediate kill of up to 95% of treated plants
- Is less labour intensive than chemical treatment.
- Loosens soil surface and allows for increased water retention.

Disadvantages

- Can place large strain on equipment, especially if used on large trees and in areas with hard-setting soil.
- May result in re-shooting if trunks snap off at ground level (i.e. are not cut below the bud zone).
- Is not as effective on shrub forms.
- Though disturbed soil will promote seedling emergence, this will help reduce the soil seed load.

Cost

Cost will vary depending on the size of the dozer used, owned versus hired dozers, density of trees, operator experience, transport requirements and the type of implement used.

Chain pulling

Recommendations

Tree form

- Best for the control of high-density infestations. Chain pulling is effective only if used in combination with fire, and followed up with herbicide treatment.

Shrub form

- Not recommended—considered ineffective because of the robust nature of these species and the potential for regrowth at the root system.

Description

Two dozers are used to pull the chain through dense infestations, first in one direction and then in the other to remove the trees from the ground. At a minimum, the dozer should be a D8. The chain should be heavy enough so that it is not pulled up over the plants. A triple chain with swivels has been effective in killing a higher proportion of smaller plants.

When used alone, chain pulling, will give moderate kill rates. The main objective of this method is to push woody trees to the ground to provide fuel for burning. After chain pulling, grazing should also be kept to a minimum to allow grass fuel to accumulate. This will ensure that the fire will travel between clumps of woody material. With sufficient fuel, any plants that survive the chain pulling will be burnt.

Care should be taken to avoid native trees and shrubs when chain pulling, unless a permit has been granted. Check state or territory native tree-clearing guidelines.

Timing

Optimum time to pull is from July to October during the dry season, and before the first rains in areas with summer rainfall. Tree-form mesquite is uncommon in areas that do not have a summer rainfall.

▲ Three-twine chain.

Advantages

- Usually used as part of an integrated program incorporating fire. Pulling alone will give only a 20–30% kill rate; while pulling followed by burning may result in up to 95% kill rates.
- Provides the opportunity to re-sow with suitable pasture species.
- Results in improved access and easier mustering.

Disadvantages

- Results in a low kill rate if not combined with other options.
- Requires a high level of follow-up control.
- Disturbed soil promotes seedling emergence; however, this will help to reduce the soil seed load.
- Can be expensive on a large scale.

▲ Chain pulling in action.

Cost

Cost will vary depending on the size of the dozer used, owned versus hired dozers, density of trees, operator experience and transport requirements.

▲ Two dozers are required to pull the chain.

Dozer pushing

Recommendations

Tree form

- Most suited to medium and high densities of mesquite; however, is still effective for low and scattered densities. Cost is the most limiting factor for this type of control.

Shrub form

- Not recommended for this type of mesquite because of its robust nature and potential for regrowth at the root system.

Description

A blade is used to push individual trees at, or slightly below, ground level. This can be achieved by using at least an 80 hp 4 x 4 tractor with attached implement (in low-density situations) or with a dozer with blade attachment. The size of the machinery will depend on the size and density of the infestation.

Care should be taken to avoid native trees and shrubs when bulldozing, unless a permit has been granted. Check state or territory native tree-clearing guidelines.

Timing

Optimum time for pushing is from July to October during the dry season, and before the first rains in areas with summer rainfall. Tree-form mesquite is uncommon in areas that do not have a summer rainfall.

▲ Dozer pushing.

Results of dozer pushing.

Advantages

- Results in immediate kill.
- Achieves a moderate to high kill rate.
- Improves access and ease of mustering.
- Is less labour intensive than chemical control.
- Provides the opportunity to re-sow with suitable pasture species.
- Tree form does not tend to germinate as well as shrub form after soil disturbance.

Disadvantages

- May result in re-shooting if trunks snap off at ground level.
- Requires a high level of follow-up control.
- Though disturbed soil will promote seedling emergence, this will help to reduce the soil seed load.

Cost

Cost will vary depending on the size of the dozer used, owned versus hired dozers, density of trees, operator experience and transport requirements.

Stick raking

Recommendations

Tree form

- Most effective for medium-density to high-density infestations.

Shrub form

- Suitable for the removal of dead mesquite and dense regrowth of hybrids.

Description

A stick rake, with cutter bars to cut the stems below ground level, is attached to the bottom of the dozer tines. The minimum size of dozer required is D7. After cutting, the mesquite is pushed into windrows for burning.

Stick raking *P. velutina* regrowth using a D6 dozer without a cutter bar has been effective, achieving up to 50% kill rate.

Care should be taken to avoid native trees and shrubs when stick raking, unless a permit has been granted. Check state or territory native tree-clearing guidelines.

Timing

Optimum time is from July to October during the dry season and before the first rains, in areas with summer rainfall. In areas of winter rainfall, the ideal time is during spring before seed set.

▲ Stick rake with cutter bar.

Advantages

- Results in excellent kill rates if properly applied.
- Provides the opportunity to re-sow with suitable pasture species when the fallen material is pushed into windrows.
- Is effective in strategic areas such as mustering lines, fence lines and watercourses.
- Results in improved access to previously impenetrable, thorny thickets.

Disadvantages

- May result in re-shooting if trunks (of trees and particularly multi-stemmed shrubs) snap off at ground level.
- Results in very high disturbance of soil, causing initial loss of perennial grasses and potential for erosion.
- Though disturbed soil promotes seedling emergence, this helps to reduce the soil seed load.

▲ Stick raked mesquite pushed into windrows.

- Requires a high level of follow-up control.
- Can be expensive if used on a large scale.

Cost

Cost will vary depending on the size of the dozer used, owned versus hired dozers, density of trees, operator experience, transport requirements and if implements are used.

▼ Mesquite being stick raked.

Fire

Recommendations

Tree form

- Best for low and medium density infestations and for seedlings. Can be used for high-density populations if there is sufficient fuel load.
- A very effective tool when used after chain pulling.

Shrub form

- Burning can be used to clean up windrows that have been stick raked.
- Beneficial only if the fire is very hot and can carry through the canopy.

Description

Fire is most beneficial for the control of tree-form mesquite. It is an under-utilised 'cheap' option that can result in good kill rates, and is currently the only method that will reduce the seed bank. Only very hot fires are effective on all other species of mesquite as they are relatively fire-tolerant. Fire is also used to burn mesquite stacked into windrows after stick raking.

Controlling mesquite successfully with fire requires effective planning. As fuel can be built up if grazing is minimised, the use of fire as a method of control should be integrated into stock management.

▲ Sufficient fuel is required for an effective fire.

Firebreaks need to be installed and appropriate permits and notification are required.

Timing

Burning is best done late in the dry season when trees are stressed, there is plenty of fuel, and the weather is hot. Intense fires can be produced under these conditions. Burn conditions are critical for obtaining a successful fire, even more so for more fire-tolerant species. Refer to 'Using fire as a management tool for the control of mesquite' on p.70.

Advantages

- Good kill rates of up to 95% for the tree form.
- Results in emergence of fewer seedlings.
- Depletes the seed bank of seeds up to 2 cm deep in the soil.
- Is relatively cheap compared with other control options.

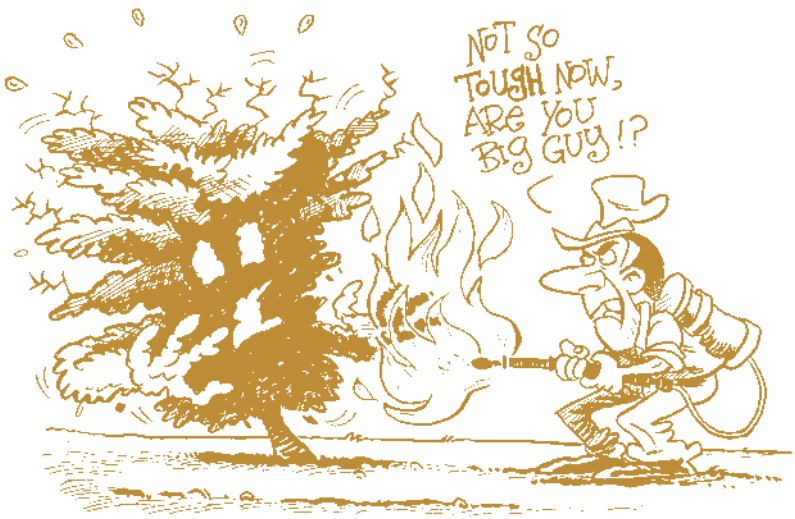
Disadvantages

- It is difficult to generate fires that are sufficiently hot to kill shrub forms.
- A high fuel load is required for the most favourable fire conditions.
- Pasture is sacrificed for fuel load.
- Fire can be a danger to other pastures.
- Method may promote the germination of undamaged seeds in the following wet season.
- There is a risk to neighbouring property and infrastructure if the fire becomes uncontrollable.
- Ensuring safe burning practices can involve a large number of people.

▲ Effects of fire on tree-form mesquite.

Cost

Using fire is generally a much cheaper option than mechanical or chemical control. However, it is necessary to consider the labour requirements and the feed value of the pasture that will be used as fuel.



Chemical control options

Basal bark spraying

Recommendation

Both tree and shrub form

- Best for use in scattered, low-density and medium-density infestations, and also for regrowth. At high infestation levels, can become very costly and time consuming.

Application

- Ensure any debris is removed from the base of the plant to allow maximum coverage.
- Carefully spray completely around the base of the plant to about 30 cm above ground level.
- Thoroughly spray all crevices and each stem of multi-stemmed *Prosopis* species—any area missed on the stem of either form of mesquite will regrow.
- Spray up to 1 m above ground level for the control of larger trees.
- Spray plant to the point of run-off.

Timing

Best time to spray is when plants are actively growing and soil moisture is good. In southern areas where there is a dominant winter rainfall, this is during spring and summer. In tropical parts of Australia, it is from March to July.

▲ Basal bark spraying of shrub-form mesquite—all stems must be treated.

Advantages

- Results in greater than 97% kill rate if carried out correctly.
- Kills quickly.
- Is target-specific.

▶ Basal bark spraying of tree-form mesquite.

Disadvantages

- Is labour intensive.
- Requires that all stems of multi-stemmed shrubs are sprayed or regrowth will occur.
- Is costly if large areas and dense patches are treated.

Registered herbicides

Triclopyr 240 g/L plus picloram (ester) 120 g/L at a rate of 1 L/60 L diesel mix. For example, Access®.

As all herbicides must be applied strictly in accordance with the directions on the label, always read them carefully before use.

Cost

Cost depends on the size of the plant being treated, and the thickness of the stem.

An Access® 100 L mix will cost approximately $182 (excl. GST) based on the following assumptions:

- chemicals—$53 per litre
- diesel—$0.94 per litre.

▲ Result of basal bark spraying near a watering point.

Cut stump technique

Recommendations

Tree form

- Good for low densities. Because of its growth habit, the tree form is easier to treat using the cut stump technique than the shrub form.

Shrub form

- The cut stump technique is suitable for shrub-form mesquite in scattered and low-density situations. This method of application is best when stems are less than 50 mm in diameter.
- The drooping canopy and multiple stems of this form of mesquite make it much more difficult to treat in this way.

▲ Stump should be cut as close to the ground as possible.

▲ For thinner stems, garden shears can be used.

Application

If properly used, the cut stump technique may result in higher kill rates than basal bark spraying. For the best results, this method usually requires the efforts of a two-person team—one for cutting and the other for applying the chemical. Thinner stems (< 50 mm in diameter) can be cut by a person working alone using a branch cutter. Stems of trees should be cut horizontally as close to the ground as possible and the cut surface swabbed or sprayed with herbicide mixture immediately (within 15 seconds), otherwise the tree will seal itself and the chemical will be unable to penetrate the stump.

Timing

This treatment can be used at any time of the year.

Advantages

- Results in limited regrowth.
- Requires less chemical than basal bark spraying.
- Results in good kill rates.
- Is target-specific.

Disadvantages

- Is time-consuming and extremely labour intensive.
- Will not result in good kill rates if chemical is not applied immediately after cutting.

Registered herbicides

Triclopyr 240 g/L plus picloram (ester) 120 g/L at a rate of 1 L/60 L diesel mix. For example, Access®.

As all herbicides must be applied strictly in accordance with the directions on the label, read this carefully before use.

Cost

The thicker the stem, the more chemical mix will need to be applied.

An Access® 100 L mix will cost approximately $182 (excl. GST) based on the following assumptions:

- chemicals—$53 per litre
- diesel—$0.94 per litre.

▲ Apply herbicide mix immediately after stem is cut.

Foliar spraying

Recommendations

Both tree and shrub form

- Best for seedlings and regrowth of previously treated areas on plants under 1.5 m in height.

Application

Best applied with a spray unit. A wetting agent must be used and plants sprayed to the point of run-off. For best results, apply to actively growing plants with a large area of foliage.

Timing

Best time to spray is when plants are actively growing and soil moisture is good. In southern areas where there is a dominant winter rainfall, this is during spring and summer. In tropical parts of Australia, this is from March to July.

Advantages

- Is less labour intensive than other chemical treatments.
- Good for follow-up control when plants are young and actively growing.

Disadvantages

- Spray equipment can be expensive to purchase.
- Regrowth can occur if spray is not applied correctly.

▲ Foliar spraying.

Registered herbicide

Triclopyr 300 g/L plus picloram (salt) 100 g/L. For example, Grazon DS® and Grass-Up®:

- rate of 350 mL/100 L water mix
- rate of 670 mL/100 L water mix for *P. velutina* in Queensland only.

A 100% concentrate non-ionic surfactant (e.g. BS 1000) must be added at a rate of 100 mL/100 L.

As all herbicides must be applied strictly in accordance with the directions on the label, read this carefully before use.

Cost

More herbicide is required per plant for foliar spraying than for basal bark spraying or cut stumping.

Approximately 1.5 L of herbicide mix is required per plant to spray regrowth and seedlings under 1.5 m in height.

Biological control

Biological control is another option for use on mesquite. It involves the introduction of insects or pathogens that will feed on the plant. Such programs are long term and include:

- selecting potential biological control agents
- ensuring that they are safe for release in Australia
- mass-rearing and releasing them
- monitoring them to determine whether they are established and causing damage.

Once established, only a proportion of biological control agents typically reach sufficient numbers to have a significant impact on the target species—and it may be many years until this point is reached.

Mesquite is a particularly challenging target for biological control, in part because it is a tough plant with large root reserves. It also grows in a range of climates within Australia and biological control agents will not necessarily perform equally well everywhere.

To date, four introduced biological control agents have been released in Australia for the control of mesquite. All have been distributed throughout most parts of Queensland, Northern Territory, Western Australia and New South Wales, with varied success. Although the impact in the Pilbara region has been dramatic, this is unlikely to be the case elsewhere in Australia, as the control agents do not reach sufficiently high densities.

Biological control should be regarded as only part of a control program. Even at their best, the available agents are unlikely to kill mesquite; however, they may improve the effectiveness of other control techniques by reducing its growth and spread rates. Therefore, consider integrating this method with other control techniques and management options.

▲ *Algarobius bottimeri.*

Bruchid seed-feeders

Two seed-feeding beetles, *Algarobius prosopis* and *Algarobius bottimeri*, have been introduced to Australia with the intention of reducing viable seed numbers and thereby the invasiveness of mesquite.

The newly hatched larvae of the beetles will destroy mesquite seeds in mature pods both in the tree and on the ground by drilling through the pod and into the seed where they feed and develop. Adults emerge after about 6–10 weeks, leaving a characteristic emergence hole.

Both species of beetle were released at many sites in Queensland and also in the Pilbara during 1996 and 1997. Both have established in Queensland and Western Australia; however, their impact is likely to be limited, as it is believed that vertebrate herbivores consume most of the pods before the beetles can damage the seeds.

▲ *Algarobius prosopis.*

New agents

Since the release of the seed-feeding beetles, two other agents, *Prosopidosylla flava*, a sap-sucking psyllid that causes dieback, and *Evippe* spp., a leaf-tying moth that defoliates plants, have been released throughout Western Australia, Queensland, the Northern Territory and New South Wales since 1998. The psyllid, which appears to prefer cooler climates, has only established in small populations in south-west Queensland and north-west New South Wales, where its numbers are too low for it to have any impact on mesquite. It is probable that ant predation is preventing this agent from being effective.

◀ Emergence hole caused by bruchid seed-feeders.

In contrast, the leaf-tying moth has become established at all release sites, but is most abundant in the hotter parts of Australia. It is causing most damage in the Pilbara region (WA) where it is causing death of 50–100% of leaves, and prolonged defoliation throughout the 150 000 ha infestation. This is already resulting in greatly reduced seed set and decreased plant growth rates. The leaf-tying moth also causes relatively heavy defoliation in the Barkly region (NT) and in northern Queensland. However, this effect is probably not yet sufficiently prolonged to have a major impact in these areas.

Where the moth is abundant and damaging, it will rapidly recolonise cleared areas of mesquite to attack regrowth. It can therefore be an excellent complement to other control techniques.

▲ *Evippe* spp.

▲ *Prosopidosylla flava* nymph.

▼ Early stages of *Evippe* leaf-tie.

Results of *Evippe* leaf damage.

Redistribution of agents

Redistributing biological control agents can be a valuable way of maximising their impact. The Department of Natural Resources and Mines has already widely released all the seed feeding agents in large numbers, and CSIRO has released the psyllid and the leaf-tying moth.

Redistribution of the psyllid and the seed-feeders is probably not worthwhile. Despite massive releases, the psyllid has not been effective anywhere in Australia, and redistribution requires considerable expertise. The seed-feeders cause only limited damage and are probably already very well distributed as they are excellent dispersers.

Most benefits are likely to result by redistributing the leaf-tying moth in northern Queensland, where it may reach sufficient densities to improve results when used with other control methods. Even redistribution into relatively small mesquite populations that are being targeted for eradication can be valuable, as the moth can potentially reduce the seed set of remaining trees.

The *Evippe* spp. has the capacity to spread over 100 km within a few years; however, it may not yet have reached all mesquite infestations. Assisted redistribution could, therefore, speed up the impact by several years.

Contact local weed officers or CSIRO Entomology for further information.

Case studies

Section 4

Section 4

Case studies

The following case studies demonstrate the range of approaches that have been adopted for mesquite management throughout Australia.

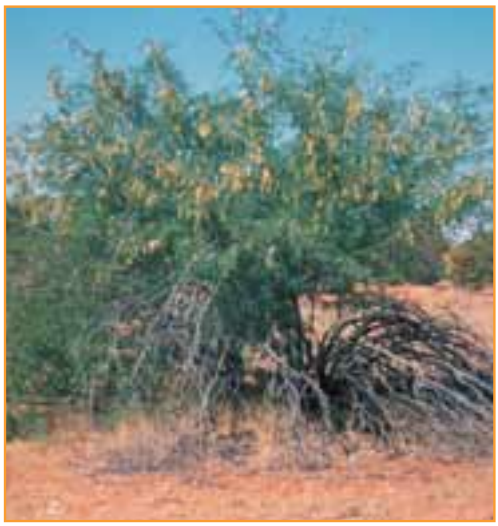
New South Wales

Mesquite in the Broken Hill area

Eric McCormick, Department of Infrastructure, Planning and Natural Resources, Broken Hill

One of the largest mesquite infestations in New South Wales occurs south of Broken Hill on White Leeds Station. *Prosopis* taxonomy remains unresolved. In the past, it was identified as *P. juliflora* by the herbarium in Sydney; however, it has since been reported that at least two species occur in the region —*P. glandulosa* and *P. velutina*.

Mesquite was introduced to the Broken Hill area about 70 years ago for dust abatement, for shade around homesteads and watering places, and for forage. A core infestation along Kellys Creek is currently 8 km long by 200 m wide. Plants range in size and are scattered on both sides of the creek where impenetrable thickets have formed. These have established on previously disturbed areas and range in size up to 4000 square metres.



▲ Previously treated mature and juvenile mesquite, showing the need for long-term follow-up.

The initial infestation was first treated by basal bark spraying in 1970, with all mature plants treated by 1974. Above average rainfall between 1974 and 1978 favoured the germination of new seedlings, which were treated by ongoing basal bark spraying. Summer rainfall events of the 1980s favoured germination. Control through a government-funded program continued until 1992, when all known mature plants were treated. At this time, responsibility for control was passed to the owner/occupier/lessee.

During 1993, the lessee of the property mechanically cleared boxthorn and pepper trees on either side of Kellys Creek in an effort to assist with future mesquite control. In 1995, the lessee died and all control work ceased. By 1996, the once-emergent seedlings now stood as mature mesquite up to 2 m high, with an understorey of plants up to 1 m high. Soil disturbance (as a result of the removal of the boxthorn and pepper trees) and favourable rainfall events since 1992 favoured their germination.

In 1998 the current lessee employed a contractor to remove mesquite thickets by pushing (using a Komatsu WA400 front-end loader). After clearing, limited chemical follow-up control was undertaken. The cleared areas then developed into impenetrable thickets.

▼ Dense thicket treated November 2002 with Grazon® 350ml / water 100L plus wetting agent.

▲ Mature mesquite on drainage line.

In December 2002, $40 000 was expended on chemical control (part government and part lessee contributions). Scattered mature plants were treated with diesel/Access® basal bark application and dense thickets were treated with an overall spray application of Grazon DS® mix with a Quik Spray unit mounted on a Toyota Landcruiser.

All scattered plants and thickets either side of Kellys Creek were treated. At the time of treatment, plants were actively growing and an estimated 90% kill was achieved. Any plants that were missed in the initial spraying, or that had survived, were treated in follow-up procedures in March 2003. The long-term follow-up program is now extremely important. On more than one occasion the same infestation has been treated and the lack of follow-up has seen the infestation return to the same levels prior to any control taking place. Chemical control of emerging plants will be conducted on an annual basis. Continued surveillance and control of areas outside the core area are in place to prevent spread and reinfestation.

Northern Territory

Mesquite on the Barkly Tableland

Jon Peart, Department of Infrastructure, Planning and Environment, Tennant Creek

The predominant species of mesquite found on the Barkly Tableland, Northern Territory, is *P. pallida*. The first recorded presence of mesquite on the Barkly was in 1961. In 2003, of the 12 original infestations, only six remain. Two major infestations occur at Alroy Downs and Lake Nash; the remainder are either single plants or small clumps.

Mesquite was originally introduced for shade and fodder around bores and waterholes, and has remained reasonably confined to these areas. The infestation on Alroy Downs occurs on the Playford River at the homestead. Chemical and mechanical control practices, carried out over the past 10 years, have significantly reduced the size of the infestations. I remember travelling along the Tableland Highway, past the Alroy homestead in the late 1980s and only being able to see the house water-tank up on its tank-stand.

During 2001–02, a station dozer pushed over large, mature mesquite trees along the river. In December 2002, a larger bulldozer was contracted to complete the removal of any remaining trees. In 2003, as a result of the control measures, only four or five juvenile plants can be seen.

Control of any plants germinating following the wet season is yet to be carried out. The control methods used on Alroy can be said to have been successful. The most effective control measures to date have been mechanical and chemical (basal bark spraying). In some areas, access to the trunks for basal bark spraying has been difficult. When mature trees are pushed over, it is easy to gain access to the newly germinated or remaining plants.

The Northern Territory Government, in conjunction with CSIRO (Brisbane), has been involved with the distribution of biological control agents for mesquite in the Territory. The agents released were a leaf-tying moth (*Evippe* spp.) and leaf tip-eating

psyllids (*Prosopidosylla flava*). The first release of the biological agents into the Territory occurred at Alroy Downs, Austral Downs and Lake Nash in May 1998.

There were several releases of the agents over two years, especially of the psyllids. The *Evippe* established at Alroy Downs, but there was no real evidence of psyllid establishment. Forty kilometres from the original release site, at an isolated mesquite infestation, the *Evippe* is still much in evidence. Here, all the mature trees had approximately 70% of their leaves tied and all seedlings to 1.5 m had over 90% of their leaves tied.

Continued on-ground control using the basal bark method is being carried out at the infestation on Alroy. An investigation is pending on the site at Lake Nash to determine the value of pushing over the existing mature trees and spraying the plants that subsequently emerge. For major infestations, CSIRO has advised that mechanical and basal bark spraying control options be used in conjunction with biological agents.

▲ Result of basal bark spraying near waterhole.

In 2002, funding was made available through the Commonwealth Government in the form of WONS (Weeds of National Significance) monies. An amount of $40 000 was allocated to the Barkly region for the eradication of mesquite. Control programs in the region were accelerated as a result. One can see the advantages gained through eradication of mesquite, particularly at the Alroy and Rockhampton Downs infestations and throughout the entire Northern Territory.

▶ Results of mechanical treatment of mature mesquite.

Queensland

Bulloo River flood plain mesquite control project

Robert Cobon, Department of Natural Resources and Mines, Charleville

Background

The infestation of Quilpie mesquite (*P. velutina*) originated from a couple of shade trees planted around the homestead of Comongin Station, north of Quilpie, Queensland, in the 1930s. Following significant rainfall events in the 1950s, mesquite spread to an adjacent lake and has since spread throughout the Bulloo catchment.

The core infestation now consists of 4000 ha of dense mesquite located north of Quilpie, on Como, Comongin and Wanko stations. The remaining scattered infestation covers an area of 300 000 ha, extending from 30 km north of Quilpie to Toompine in the south.

Quilpie is located on the banks of the Bulloo River in south-west Queensland. The Bulloo catchment ends at the Bulloo Lakes on the New South Wales border. The Bulloo River flood plain country is at immediate threat of mesquite invasion, as soil moisture has a major influence on distribution. The Bulloo Lakes, a permanent water source, support a diverse range of flora and fauna including extensive bird populations.

As a result of spread by livestock and machinery, small isolated infestations have been located and subsequently treated on the adjoining catchments of Murray–Darling and Lake Eyre.

SWEEP team carrying out foliar spraying of regrowth.

Control

Since the 1970s, ongoing chemical and mechanical trials have been conducted to identify suitable herbicides and methods of control. The highly adaptive features of *P. velutina* have created challenges in finding best practice control.

Mechanical control was found to be effective for the initial control of medium to dense infestations. It consisted of either blade ploughing light, sandy soils, or stick raking to remove treated plants and regrowth.

Large areas of dense mesquite were initially treated by chemical means during the Strategic Weeds Eradication and Education Program (SWEEP), which was very successful with a greater than 90% kill. However, when it was necessary to treat the regrowth, access through the areas of dead mesquite was a problem. To overcome this, a boom on a dozer blade or stick rake, followed by fire, was used to open these areas up.

Fire has been an important tool in gaining access to treated areas. Fire will rarely kill *P. velutina* (because of limited fuel loads and subsequent low heat), but is valuable as it can delay regrowth. Sufficient fuel loads, however, are often a problem because of mesquite competitiveness, dry conditions and total grazing pressure (domestic, feral and native animals).

▲ Result of blade ploughing.

The following sequence was found to be very effective. Initially, mesquite was treated mechanically (by blade ploughing then stick raking). This was followed by fire to clean up dead matter. Chemical control was then used on regrowth less than 1.5 m in height (foliar spray using Quik Spray units and Grazon DS® at 1:285 plus wetter 1–2 mL/L).

On Quilpie mesquite, basal bark spraying as a chemical method of control has stood the test of time. Although labour-intensive at high densities, it is a cost-effective method for scattered to medium infestations, with kill rates of greater than 95%.

Another method that was used was the excavator slash breaker. While being very expensive, it did achieve a mortality rate of greater than 40%. In 1996–97, suitable rain was received after control using this method, with approximately 50%

stump regrowth and mass seedling germination. Therefore, a low level of control can be achieved by cutting mesquite above the lateral node and this must be assessed against the efficiencies of time saving and cheaper mechanical requirements (e.g. stick rake with cutter bar attachment).

Of the four biological control agents released, the leaf-tying moth, *Evippe* spp., is the most visible. Populations of this moth have increased and readily spread following its release in October 1998. Monitoring has identified groups of mesquite trees with up to 100% of the leaves tied—mainly during autumn and early summer. Although difficult to quantify, such plant stress must reduce plant growth, seed production, and increase mesquite susceptibility to fire.

Conclusion

From 1980 to 2002, the Queensland Government has allocated $3 million to mesquite control in south-west Queensland. The current WONS project (June 2002–December 2003) will invest a further $350 000 from all stakeholders including $150 000 from National Weeds Program (NWP) funding.

Stakeholder partnerships between Quilpie Shire Council, landholders, community and Natural Resources and Mines have developed to foster local management of the project. This will increase control efficiencies while providing additional resources for Quilpie Shire.

The horse paddock on Comongin was solid mesquite prior to blade ploughing in 1990. In 13 years this paddock has been treated nine times, with germination still occurring. It is estimated this work has cost $1500/ha. Of the 4000 ha core infestation, 500 ha remains as original infestation.

Unfortunately, throughout the community, there is still a lack of understanding about mesquite, and hence poor implementation of preventative control measures and its

▸ Biological control release of *Evippe* spp. and *Prosopidosylla flava*—agents received from CSIRO.

▸ Before treatment. Photo October 1998.

importance in long-term sustainable land management. Principles such as property quarantine, control of seed vectors, containment by fencing, livestock management, and weed control incorporated into daily management will dramatically reduce the burden placed on future generations.

With little extra commitment, scattered or isolated mesquite control can be incorporated into daily/weekly management duties. Water runs, aerial and ground mustering, and fence checks (including weed monitoring and control) allow for cost-effective control that is highly strategic in reducing workloads in the future.

The landowner of Greenmulla Station south-east of Quilpie has adopted this approach and fitted farm motorbikes with large garden shears and herbicide. Whenever isolated mesquite is seen in the course of daily or weekly activities, it is immediately cut stumped. This type of commitment demonstrates the level required by all landholders if scattered infestations are to be eradicated in the shire.

▸ After integrated control combination of chemical, mechanical and biological methods. Photo May 2003.

Using fire as a management tool for the control of mesquite

Shane Campbell, Department of Natural Resources and Mines, Charters Towers

Fire can be an effective management tool in the control of some mesquite species, as trials in north-west Queensland have shown. *P. pallida* is very susceptible to fire and burning has dramatically decreased the overall density of the infestation within the research site. Three months after burning, only 8% of the original plants remained alive, compared to 100% tree survival in unburnt areas.

Burning has also reduced the seedling regrowth in subsequent years by destroying a portion of the seeds in the seed bank and by killing most of the large reproductive trees that would have been replenishing the seed bank. However, it was noted that *P. pallida* seedlings that did emerge in burnt areas often grew more quickly as they had less competition once the mature trees were killed.

Hybrid infestations (shrub forms) on Mardie Station in the Pilbara region (WA) have also been shown to be moderately susceptible to fire, at least when fuel loads were high and the fire exceptionally intense. Mortality from a hot fire averaged 88% and no seedlings emerged in burnt areas following favourable rainfall, despite being common in nearby unburnt areas.

All other species of mesquite in Australia appear to be quite tolerant of fire, although no research has been undertaken to determine if an intense fire would have any effect. The general consensus is that some mortality of young plants may occur and the seed bank could be reduced,

Control of *P. pallida* using fire.

but mature plants will generally survive. Nevertheless, even if trees are not completely killed by fire, if the tops are killed, the seed production is reduced for a number of years and woody cover is temporarily reduced. This could assist with other control techniques and increase grass production. When compared with chemical and mechanical treatment, fire is relatively inexpensive. It can also be more easily applied over larger areas provided sufficient resources are available to ensure burning is undertaken safely.

A major constraint in the use of fire is having sufficient fuel loads to carry the fire across an infested paddock. Locking up a paddock and keeping stock away can build up fuel loads. If sufficient fuel is not available to carry a fire across most of the area to be burnt, patchy fires will occur and the number of plants killed will be greatly reduced. For a susceptible species such as *P. pallida*, all attempts should be made to ensure that the initial burn is highly effective. Although closing off a paddock can be an economic loss to landholders, burning of mesquite is a cheaper option than the chemical or mechanical alternatives.

▸ Regrowth of grass 12 months after fire treatment.

▲ Dead *P. pallida* after fire treatment.

One way to increase the fuel load and enhance the effects of fire may be to integrate mechanical control methods. For example, excellent results have been achieved where dense *P. pallida* infestations have been initially chain pulled, left for a period to allow material to dry out and then burnt. Similarly, pushing plants over into windrows and then burning them can be extremely effective, though quite expensive.

It can be concluded that fire does have a role to play in controlling some of the mesquite species present in Australia. How effective it will be will depend on a number of factors, including the species present, timing and intensity of the burn, and size and density of the trees.

Tackling mesquite with barter days

Jim Edwards, Hughenden Landcare Group

The mesquite infestation of *P. pallida* in the Flinders Shire covers approximately 20 000 ha. It is located about 20 km east of Hughenden and stretches roughly 25 km west along the Flinders River and Porcupine Creek. In 1998, the Hughenden Landcare group was formed to address the problem.

▼ Results of basal bark spraying.

The mesquite plant grows in a prickly formation and can grow to 10 m high with a girth of 1 m; it can have 20–30 mm long thorns. The plant prefers loamy or clayey soils in which it can spread very quickly. It can grow in black soil but does not spread as quickly.

Mesquite creates a management problem for the grazier. Because the plant is so prickly, it restricts cattle mustering and can lame horses and cattle with its thorns. In some areas, the trees form impenetrable barriers.

In August 1998, the eight members of the Hughenden Landcare group purchased 60 000 L of dirty diesel from the Hughenden Power Station. Chemical was then mixed with the diesel for basal bark treatment.

The Landcare coordinator at the time suggested that we have barter days. This type of support had been tried by another Landcare group and seemed a good idea to us. A barter day is where the whole group meets on a designated property to spray trees and then rotates until all members' properties have been treated. The group starts early, works till 12 noon, and finishes with a barbeque lunch. The attendance on these days was good and included the eight members plus some town helpers (totalling 12 at times).

▲ Basal bark treatment of mesquite during a barter day.

On good days, over 1000 L diesel/chemical mix was used. Each member chose where they wanted to spray—usually around watering points or laneways. The group has had 30 barter days in total.

The total area the group covered on these days was good, but it became evident later that the basal bark treatment was not 100% effective. This was because some sprayers were not aware of how much spray was required to kill a tree, and were not applying the treatment correctly. However, looking back at the areas treated, about 90–95% of the trees were killed—a good kill rate.

There has been some follow-up in areas where seedlings have come up, but it is thought that foliar spraying would be more efficient than basal bark spraying. The group has not used foliar spraying; however, the Flinders Shire stock routes supervisor has tried this method and found it to be quite effective.

A severe flood affected the Hughenden area in February 2001 and damaged fences and other infrastructure on all the group members' properties. Since then there have not been any barter days but there are plans to meet again in the future.

Mesquite is still a problem in the Flinders Shire. But the barter days have been very successful: we treated mesquite, were encouraged by each other's success and enjoyed the social atmosphere—weed control can often be a very boring and unrewarding type of job.

▶ Hughenden Landcare barter day.

Mesquite on Corfield Downs

Melissa Brien and Peter Klem, Winton Shire Council, in conjunction with Ben and Teena Titley, property managers

Corfield Downs is located 90 km north of Winton and 20 km west of Corfield in central-west Queensland. The property was purchased in mid-2002 to use as a cattle fattening block and is run in conjunction with breeding properties in the Gulf and Middleton. Corfield Downs merged with a neighbouring property, Venture Downs, in 1994. It now covers 45 000 ha of open Mitchell Grass Downs with coolibah-lined creeks and channels, vine tree ridges, some heavy stands of prickly acacia, a few parkinsonia and a number of mesquite trees.

It is believed that mesquite was brought on to Venture Downs in the 1980s by sheep—the main business on the property at the time. The trees had been left as shade trees and are now scattered throughout a 540 ha paddock and around the shearing shed. It is estimated that there are 2.5 mature mesquite trees per hectare with up to 50 small seedlings under each mature tree. Mesquite is now found growing down Waiora Creek, which runs through the main infested paddock, and individual trees have been spotted throughout the surrounding area covering approximately 13 000 ha.

Mesquite on Corfield Downs.

▲ Mesquite can hinder mustering.

Before living on Corfield Downs, we were not aware of the problems mesquite caused, and thought it was merely a shade tree. Since being told by a local rural lands officer of the negative impacts that mesquite can have, we now see it as a pest and are looking at eradicating it from the property. The added assistance of some WONS funding has acted as a catalyst to our taking action in eradicating mesquite.

While we acknowledge it creates dense shade for large numbers of native and domestic animals, the negatives far outweigh the positives. The management difficulties we have experienced from mesquite include reduced pasture production (as no grass grows under mature trees), mustering is difficult, seedlings and thorns spread far from the mature trees, and thorns cause many flat tyres.

Our plan is to control the scattered trees away from the main infestation first. We plan to visit neighbours and observe their eradication programs as we have heard that mesquite can be difficult to kill. We want to do some trials on different methods of control. We are not going to rush into control as we feel that we have some time to eradicate it.

Future plans include using a combination of management strategies, monitoring and more traditional control measures. We will be keeping a photo record of areas before and after treatment. We will map the infestation using GPS for future reference when the trees are gone but the seed bank remains, and we will quarantine stock to prevent further spread. Our goals are not just centred on Corfield Downs; we are located on the top of a watershed and what we do here affects people below. If we eradicate it we will be helping ourselves for the future.

Mesquite seed spread by feral pigs

Ben Lynes, Department of Natural Resources and Mines, Charters Towers

In recent times, concerns have been raised that feral pigs may be dispersing mesquite seed into previously clean areas because, unlike domestic livestock, they cannot be contained by conventional fencing. Through National Weeds Program (Natural Heritage Trust) funding, a research program was started to increase our understanding of the role that feral pigs play in the dispersal of mesquite.

How well and *how far* could feral pigs spread mesquite? In a captive feeding trial, feral pigs were housed in individual pens and fed a known quantity of mesquite (seed or pod) on three separate occasions with their regular diet. The number and condition of mesquite seeds that passed through the gut of feral pigs were recorded, and intact seeds tested for viability in the laboratory. Some interesting things came out…

Seed viability testing showed no difference between boars and sows, or between bare seed and whole pods. Of all the mesquite seed consumed, an average of 14% passed as viable; one dung sample contained 45% of the eaten mesquite seed. Of the passed intact seed, 50% remained viable. The second surprise was how long it took the mesquite seed to pass through the gut of the feral pigs.

Pig housed in individual pen.

The largest proportion of viable mesquite seeds was excreted on day tree (highest rate was 43%). The average time for all viable seed to pass was five days, and the maximum observed time was eight days. Feral pigs could disperse mesquite seed considerable distances following seed ingestion, but how far?

Prior to the peak mesquite podding season, a number of feral pigs were trapped within mesquite infestations in the Hughenden region of north-west Queensland. These individuals had radio tracking devices attached to them and were then released for regular monitoring of their movement patterns during the 2002 dry season.

◂ Feral pig tagged with radio-tracking device.

At the same time, transects or observation points were established among both dense and sparse mesquite to identify how often feral pigs visited infestations to feed. All dung collected along these transects was kept for analysis, as were samples of dung from adjacent clear grazing land during peak pod fall. During the wet or rainy season, observations were made of the number of seedlings emerging from feral pig dung in the field and how many seedlings later survived.

Feral pig activity within mesquite rose as seed pod availability increased, and declined as pod production ceased. Early indications of the radio tracking are that feral pigs spend a great deal of time within mesquite infestations when pods are available, venturing only short distances (several kilometres in radius). Mesquite offers feral pigs shade, security and a source of nutritious food when other foods are scarce. Feral pigs may disperse mesquite large distances; however, their primary role seems to be that of thickening sparse infestations, linking patches, and assisting encroachment or broadening mesquite infestations.

Mesquite seedlings emerging from feral pig manure.

At particular risk of mesquite spread are properties adjoining mesquite infestations, especially if they have water sources that feral pigs may use. In such situations, we have observed in excess of 50 mesquite seedlings emerging from the dung of one feral pig.

Cattle and emu dung has also been collected from the mesquite field site. This dung is in the process of being sieved to determine the presence of intact mesquite seed. The information generated from this research program will help land managers to identify more precisely where mesquite plants could occur, and better understand the relationship between mesquite and dispersal agents such as feral pigs.

Control of mesquite on Yeeda Station

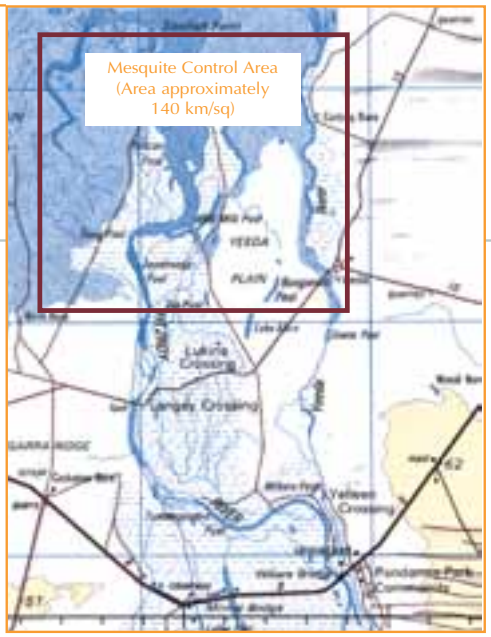
Noel Wilson, Department of Agriculture, Western Australia, Kununurra

It is not known for certain how mesquite was introduced to Yeeda. One possibility is that a station or stations upstream from Yeeda planted mesquite trees for cattle fodder, shade or ornamental purposes and that seed pods from these trees were washed down by the flooding of the Fitzroy River and deposited over the Yeeda flood plains. There is no recorded evidence of old mesquite trees being found around old station homesteads to support this theory, although isolated trees have been found along the Fitzroy River on two other stations.

A more probable explanation is that cattle were imported from a mesquite-infested property in the early 1960s and that these cattle passed out ingested seeds on arrival. New plants were commonly found along stock routes, stock watering points and old marshalling yards—further evidence that cattle were responsible for the spread of mesquite on Yeeda.

Control of mesquite on Yeeda Station first commenced in 1980. Mesquite (*P. pallida*) at this time was confined to the lower reaches of the Fitzroy River; mature trees up to 5 m in height were not uncommon. Reports from the manager of Yeeda Station in 1985 stated that the mesquite was spreading in an easterly direction quite rapidly and had spread along the Yeeda Creek, a tributary of the Fitzroy River.

Inspecting mesquite on Yeeda Station.



▲ Mesquite control area on Yeeda.

Control work from 1980 until 1996 consisted of two to four operators, for about one month, each year, searching the infested area and chemically treating all trees found. The chemical control method employed throughout this time was basal bark spraying using Garlon 600®[1], and then later, Access® mixed with distillate at a ratio of 1:60. This treatment was very successful and is still being used today on trees close to desirable non-target species and along watercourses.

By 1996, the mesquite infestation at Yeeda was well under control, with only 50 to 100 new plants being found annually. The Yeeda infestation mainly consisted of scattered individual trees spread over approximately 140 square kilometres. (This is still the case today). There were isolated thickets of less than one hectare in parts of this infestation.

Helicopter surveillance of the control area is now undertaken annually. This allows the whole area to be searched, and any trees found are treated in less than a day. Some ground surveillance is also carried out, where any trees found are controlled. This is also used as an education session for TAFE students. The number of trees found annually now is under 50. The focus of the control is to find and treat the trees before they start to seed.

Regular monitoring and follow-up control has been beneficial. If regrowth is not treated immediately, seeding trees would cause the infestation to spread and increase in density. As the area is remote, targeted monitoring is necessary to prevent trees seeding and replenishing the seed bank. If this monitoring is not carried out, the infestation could be back to the original infestation size over a period of time.

It is also very important for station staff to be familiar with the plants and control methods so they can treat plants when found.

[1] Garlon 600® is no longer registered for use on mesquite

Pilbara Mesquite Management Committee unites efforts to manage mesquite

Jodi Graham (Pilbara Mesquite Management Committee Project Officer), Karratha
Dr Rieks van Klinken (Research Scientist) CSIRO, Darwin

In the Pilbara region of Western Australia, the planting of 'thornless' varieties of mesquite (*Prosopis* spp.) 70 years ago around the homestead and mills of Mardie Station has resulted in what is now the single largest infestation of mesquite in Australia (about 150 000 ha). At least four species were introduced onto Mardie Station and have since reverted to the thorny wild type and hybridised. So far, hybrid forms have been identified from the species *P. glandulosa*, *P. velutina*, *P. juliflora* and *P. pallida*. The hybrids can grow in tree form but mostly grow in the multi-stemmed shrub form. At Mardie Station, mesquite spread rapidly after cyclonic rain events, with the densest growth occurring along the flood plain tributaries of the Fortescue River. The mesquites grow in the saline mud flats near the coast, in heavy alluvial clay and on bare patches of earth where little else can, or will, grow.

▲ Mardie Station has the largest infestation of mesquite in Australia.

Since 1952, the huge scale of the problem has led to extensive efforts to control the mesquite by costly chemical and mechanical means. However, these control efforts have not succeeded in preventing its spread or recovering any land previously lost to it. In 1998, a biological control agent (a leaf-tying moth called Evippe) was introduced. It rapidly established itself, has resulted in the reduction of foliage

cover by more than 50% and has significantly decreased pod production. Ironically, the success of the defoliating moth could make the application of foliar sprays less effective because of the lack of leaf surface area for the chemical to hit—although this can be overcome by timing applications to coincide with the flushing of mesquite after rains.

In response to previous efforts to control mesquite on Mardie Station, the Pilbara Mesquite Management Committee (PMMC) was formed in April 2000 to identify knowledge gaps in mesquite ecology and control, and to develop a long-term strategy to manage mesquite effectively. The PMMC believes that although eradication is unachievable, it is possible to stop mesquite spreading to neighbouring stations and native reserves in the Pilbara.

Since its inception, the PMMC has been an active and focused group, with participation from a wide range of stakeholders from government, industry and the community. In 2001, the group successfully acquired $250 000 from Natural Heritage Trust funding to employ a project officer to implement the research that will help to produce and implement a strategy for the best practice management of mesquite in the Pilbara. This work is expected to take four years.

In Australia, fire is commonly used for managing woody weeds, as it is cheap and easy to use when treating large areas. Together with biological control, it is the only cost-effective way of managing large infestation such as those in the Pilbara.

However, the hybrid mesquite in the Pilbara is relatively fire resistant and only exceptionally hot fires will cause sufficient mortality. Also, typically low and patchy fuel loads make it difficult to carry hot fires. A trial is therefore currently under way to integrate mechanical control with the strategic use of fire and, in particular, to find the best strategy to optimise fuel loads and conditions to generate fires of sufficient intensity to kill fire-tolerant mesquite. This trial will determine whether pushing and pulling the mesquite over with dozers and chains can increase and spread the fuel sufficiently to carry an intense fire. If the fire is hot enough and able to burn mesquite at a broadscale level, resprouting from the rootstock and seed germination should be minimal.

Containment of the core infestation is a key aim. Containment lines for mesquite on Mardie Station were initially those that fell within 2 km of the neighbouring boundaries. The PMMC aims to improve the identification of these containment

After a hot fire

lines by using the natural boundaries on Mardie Station, such as high, rocky country away from the creek lines, which impedes mesquite growth and spread. By using geographic information systems (GIS), the development of a 'habitat template' will help predict the spread of mesquite in the Pilbara by identifying the preferred habitats. These techniques will also be useful for designing containment zones elsewhere in Australia.

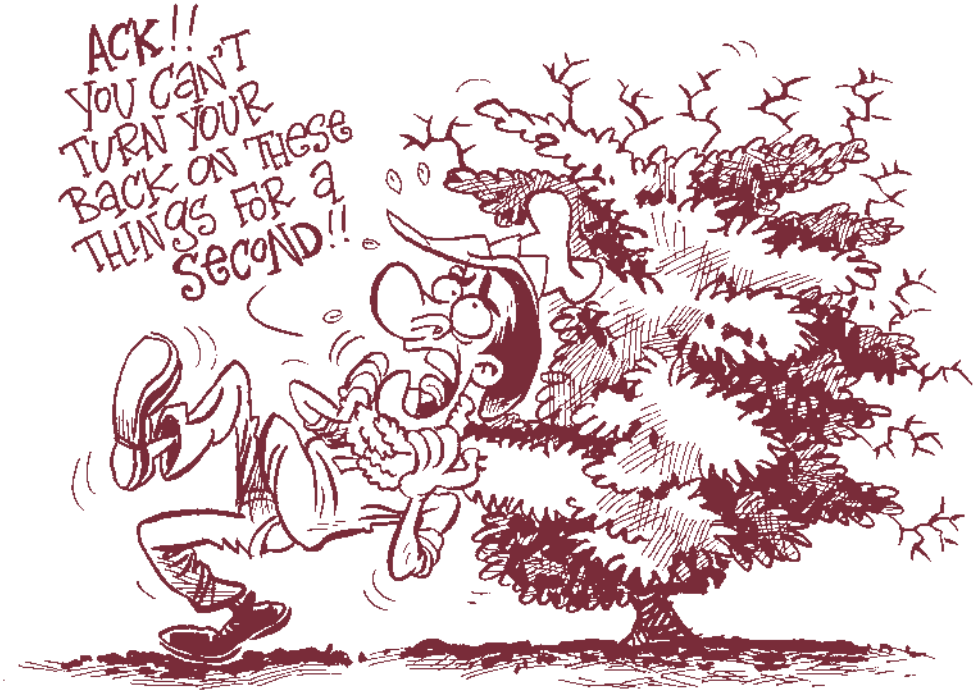
To prevent mesquite from crossing containment lines, staff at Mardie Station quarantine stock in a holding paddock that is free of mesquite for around one week until any mesquite seed in the gut has passed through.

All heavy machinery that enters the property is thoroughly washed before leaving the station. The cleaning is so thorough that a mesquite seed was once found in the duct of the air conditioning of a D6 dozer. Staff at

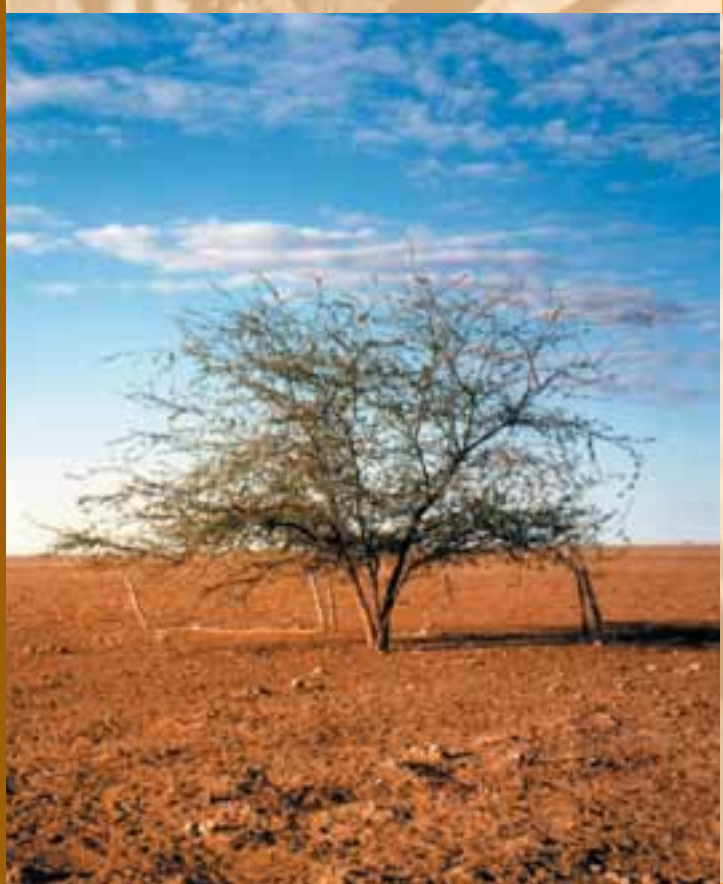
Results of leaf defoliation after biological control using *Evippe* spp.

the station also work with groups such as Conservation Volunteers Australia (CVA) to strategically spray mesquite that threatens to break beyond containment lines along the boundary of the station.

The formation of the PMMC has provided a basis for the integration of resources and knowledge, from those involved with mesquite management on a daily basis, to the innovative scientific research that has made possible the attempts to stop the spread of mesquite throughout the Pilbara and northern Australia.



Further information



Section 5
Further information

Contacts

Enquiries on declared weeds should first be referred to your relevant local government or shire council.

Obtain weed information sheets from state and territory government agencies and from their web sites.

Table 5: State, territory and general contacts

Organisation/department	Contact details
New South Wales	
Department of Agriculture	Tel: 1800 680 244 to report 'Notifiable weeds' class W1 Web site: www.agric.nsw.gov.au
Department of Infrastructure, Planning and Natural Resources	Web site: www.dipnr.nsw.gov.au
Northern Territory	
Department of Infrastructure, Planning and Environment	Tel: 08 8962 4491 or 08 8973 8107 Web site: www.ipe.nt.gov.au
Queensland	
Department of Natural Resources and Mines	Tel: 1800 803 788 Web site: www.nrm.qld.gov.au
South Australia	
Department of Primary Industries and Resources	Tel: 08 8226 0222 Web site: www.pir.sa.gov.au
Western Australia	
Department of Agriculture	Email: enquiries@agric.wa.gov.au Web site: www.agric.wa.gov.au

Organisation/department	Contact details
General	
CSIRO	Tel: 1300 363 400 Email: enquiries@csiro.au Web site: www.csiro.gov.au
CSIRO Entomology	Email: entomology-enquiries@csiro.au Web site: www.ento.csiro.au
Weeds Australia	Web site: www.weeds.org.au
Weeds CRC	Tel: 08 8303 6590 Email: crcweeds@adelaide.edu.au Web site: www.weeds.crc.org.au

Further information can be obtained from the following publications and web sites:

GRASS check: grazier rangeland assessment for self-sustainability 1997, 2nd edn, revised, manual, Department of Natural Resources and Mines, Brisbane.

Help stop the spread of prickle bushes 2003, poster, Department of Natural Resources and Mines, Brisbane.

Managing mesquite in Australia n.d., poster, CSIRO Entomology, viewed 29 July 2003, (www.ento.csiro.au/pdfs/posters/mesquite.pdf).

Mesquite national best practice workshop 2002, CD, Department of Natural Resources and Mines, Brisbane.

Mesquite WONS strategy 2001, booklet, National Weeds Strategy Executive Committee, Launceston.

Mesquite…is a threat 2002, leaflet, Department of Natural Resources and Mines, Brisbane.

Mesquite—Not wanted in NSW, leaflet, New South Wales Agriculture, Orange, New South Wales

Sustainable rangeland management, brochure, CSIRO Entomology, viewed 29 July 2003, (www.ento.csiro.au/research/weedmgmt/pdf/Rangelands.pdf).

What prickle bush is that? 2003, poster, Department of Natural Resources and Mines, Brisbane.

Declaration details in Australia

The following information on the declaration details of mesquite (*Prosopis* spp.) in Australian states and territories has been extracted from the respective state government web sites. For further information, please refer to the relevant web site. See p.86.

ACT

Not declared.

New South Wales

All *Prosopis* spp. W1 in 41 council areas. Any plant found must be notified to local council authority. Plants must be fully and continuously suppressed and destroyed. Cannot sell, move weed material or any animal or thing which has weed material in or on it.

Northern Territory

Class B: *P. pallida*. Growth and spread to be controlled.

Class C: All *Prosopis* spp. Not to be introduced to the territory.

Queensland

Class 1: All *Prosopis* spp. and hybrids except *P. glandulosa, P. pallida* and *P. velutina*. Generally not found in Qld. All plants must be eradicated. Ban on sale, introduction and use.

Class 2: *P. glandulosa, P. pallida* and *P. velutina*. Must be controlled. Ban on sale, introduction and use.

South Australia

All *Prosopis* spp. Proclaimed plant. Notifiable throughout the state. Plant must be destroyed.

Tasmania

Not declared.

Victoria

Prohibited weed. All *Prosopis* spp. to be eradicated.

Western Australia

P1 whole state—prohibits movement.

P2 whole state, except for defined area on Mardie Station. Eradication of existing and new infestations.

P4 defined area of Mardie Station. Prevent infestation from spreading beyond existing boundaries of infestation.

References

Agriculture and Resource Management Council of Australia and New Zealand & Australia and New Zealand Environment and Conservation Council and Forestry Ministers 2001, *Weeds of National Significance Mesquite (*Prosopis *species) strategic plan*, National Weeds Strategy Executive Committee, Launceston.

Campbell, SD & Setter, CL 2002, 'Mortality of *Prosopis pallida* (mesquite) following burning', *Australian Journal of Experimental Agriculture*, vol. 42, pp. 581–586.

Csurhes, SM (ed.) 1996, *Mesquite (Prosopis* spp.*) in Queensland*, Pest status review series, Department of Natural Resources, Brisbane.

Cunningham, GM, Mulham, WE, Milthorpe, PL & Leigh, JH 1992, *Plants of western New South Wales*, Inkata Press, Melbourne.

Jeffrey, PL & March, NA 1995, 'Mesquite', in N. March (ed.), *Exotic woody weeds and their control in north west Queensland*, pp. 30–35, Isa Printing Service, Mt Isa.

March, NA 2000, *Prickly acacia best practice manual*, Department of Natural Resources, Brisbane.

Parsons, WT & Cuthbertson, EG 2001, *Noxious weeds of Australia*, Inkata Press, Melbourne.

van Klinken, RD & Campbell, S 2001, 'The biology of Australian weeds. 37. *Prosopis* species', *Plant Protection Quarterly*, vol. 16 no.1.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