

BELLYACHE BUSH

Bellyache bush

(Jatropha gossypifolia)

in Queensland

PEST STATUS REVIEW SERIES - LAND PROTECTION BRANCH

by
S.M. Csurhes



**Queensland
Government**
Natural Resources
and Mines

Acknowledgements

The authors wish to thank the many people who provided information for this assessment. In particular, Grant Telford, Marie Vitelli, Shane Campbell, Andrea Wilson, Wendy Forno, Rod Randell and Local Government weed control officers from around the State. Special thanks to Peter Jeffrey and Joe Vitelli for technical information and unpublished data. Peter Mackey provided valuable editorial advice.

Cover and contents design:
Grant Flockhart and Sonia Jordan

Photographic credits:
Natural Resources and Mines staff

ISBN 0 7242 7298 4
Published by the Department of Natural Resources and Mines,
Qld.

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Land Protection
Department of Natural Resources and Mines
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1.0 Summary

Bellyache bush (*Jatropha gossypifolia* L.) is a deciduous shrub native to tropical America. It was imported into Australia in the late 1800's, probably as a garden ornamental, and had naturalised in Queensland by 1912.

The plant has been cultivated as a garden ornamental for at least the last 90 years and naturalised specimens can be found near most towns in northern and central Queensland. It is clear that garden specimens have acted as foci of naturalisation, primarily due to the dumping of unwanted plants and cuttings. The majority of infestations are associated with old townships, dumps, roadsides, over-grazed paddocks and the banks of watercourses.

Bellyache bush can tolerate a broad range of soil types but thrives on sandy loam (alluvial) soils associated with creeks and rivers. Although no formal ecological studies have been conducted, recruitment of seedlings and survival of mature plants is probably enhanced by regular soil disturbance, an absence of fire and lack of competition from other plants. Typically, these conditions prevail along the banks of watercourses where the ground is regularly disturbed by flooding, trampled by stock and where plant competition and fire regimes have been modified by sustained grazing pressure.

The worst infestations in Queensland exist along the banks of the Burdekin River and its tributaries, where some 40,000 hectares are infested. At some locations along the Burdekin, bellyache bush has formed pure stands. Despite being naturalised in Queensland for at least 85 years, there are few substantial infestations outside the Local Government areas of Dalrymple, Bowen and Burdekin.

Since bellyache bush is unpalatable to stock it tends to proliferate at the expense of palatable pasture species. The development of dense infestations can prevent the growth of pasture grasses and reduce the profitability of cattle enterprises, although no formal impact data currently exist in Australia. Most parts of the plant, including the seeds, are toxic. The recent death of 312 animals, including 290 cattle, 7 horses and 15 goats, in the Dalrymple Shire has been attributed to the consumption of bellyache bush during drought.

As a preventative measure, 15 Local Governments have spent an estimated \$58,500 on the control of small scattered populations of bellyache bush. At least 10 Local Governments have destroyed all mature plants known to exist within their Shires and are now removing seedlings. Considering the plant's impact in the Burdekin catchment, where two landholders alone have spent c. \$56,240 on control, preventative control in other catchments will produce substantial long-term savings to the State economy.

Without continued intervention, bellyache bush will become more abundant. Productive river frontages and flats throughout much of northern and central Queensland appear to be the areas at most risk of invasion, primarily on loamy (alluvial) sands that are grazed by cattle. Although the plant exists over much of

its predicted climatic range, existing infestations have the potential to increase in size and density, mainly along watercourses but also onto non-alluvial soils.

Bellyache bush reproduces from seeds and vegetatively from broken stems and roots. Most seeds fall close to the parent plants. However, if the plant is growing close to waterways, flowing water can disperse the plant's pods. Seeds can also be transported as a contaminant of garden soil and within mud adhering to stock and machinery. Dispersal of seeds by birds has been reported. Prolific seedling emergence can occur for at least four years following destruction of mature plants. There is anecdotal evidence that a small proportion of seeds remain viable for 15 years.

Fire can kill young plants, provided sufficient fuel exists. Regular slashing can reduce the plant's rate of spread and can kill mature plants, although seedlings survive. Chemical control is effective and two herbicides, metsulfuron methyl and fluroxypyr, are registered for use in Queensland. Research into biological control is currently being undertaken by the CSIRO under contract to the Northern Territory Department of Primary Industries and Fisheries, with funding support from Queensland's Department of Natural Resources and Mines.

There is a lack of information on bellyache bush in the literature, especially on its biology, ecology and natural distribution. Most of our existing knowledge is anecdotal and in many cases has been inferred from field observations.

2.0 Taxonomic Status

Synonyms of *Jatropha gossypifolia* Linn. (1753) include *Adenoropium gossypifolium* (L.) Pohl. (1827), *A. elegans* Pohl., *J. elegans* Klotsch (1852) and *J. staphysagrifolia* Miller. Within the literature, the Latin name is frequently spelled *J. gossypifolia*. In Australia, the plant is referred to as 'bellyache bush'. Overseas, common names include 'cotton-leaf physic nut', 'cotton-leaved jatropha', 'purging nut', 'American purging nut', 'wild cassava', 'red fig-nut flower' (Africa), 'damar merah' (Indonesia) and 'castor oil plant' (erroneous).

Jatropha is a morphologically diverse genus of c.175 species of trees, shrubs, rhizomatous sub-shrubs and geophytes, each having a narrow geographical range in seasonally-dry, tropical regions (Olowokudejo 1993, Dehgan 1984). The genus was reviewed by Dehgan and Webster (1979) and is divided into two sub genera; *Jatropha* and *Curcas*, which are, in turn, divided into a number of sections and subsections. A diagram that illustrates the phylogenetic relationship between the various sections is provided by Dehgan (1984). *J. gossypifolia* belongs to the genus *Jatropha*, section *Jatropha*, subsection *Adenphorae* (Family: EUPHORBIACEAE).

Within the literature, occasional mention is made of different varieties of bellyache bush. For example, Backer and Bakhuizen van der Brink (1963) listed *J. gossypifolia* L. var. *elegans* within the naturalised flora of Java. The Missouri Botanical Garden's 'TROPICOS' database (Anon. 1998a) lists two varieties, *J. gossypifolia* var. *elegans* (Klotzsch) Müll. Arg. and *J. gossypifolia* var. *gossypifolia*. The United States Germplasm Resources Information Network (GRIN) database (Anon. 1998b) lists a third variety, *J. gossypifolia* var. *staphysagrifolia* (Mill.) Müll. Australian records do not differentiate varieties.

2.1 Description

Bellyache bush is a perennial, erect shrub or small tree usually about 2.5 m tall but which can exceed 4 m in some areas (P. Jeffrey, *pers. comm.* 1998). Some specimens have a single stem, whereas others can have two or more stems. The stems are thick, rather soft, coarsely hairy, 1-2 m long and exude a watery sap when damaged (Parsons and Cuthberston 1992). Stems rise from a herbaceous crown. The general morphology of bellyache bush is shown in Figure 1.

The plant's leaves are arranged alternately along the stem. Leaf petioles are 2-7 cm long and the leaf blades are palmately 3-5-lobed, 45-90 x 50-130 mm; the lobes are more or less elliptic (Wheeler 1992). Immature leaves are deep purple and sticky. Older leaves are generally glossy green although some may have a purple colouration (Pitt and Miller 1991). Petioles and leaf margins are covered with coarse, gland-tipped, sticky brown hairs. Because of its deep purple immature leaves, this weed tends to be readily noticed by landholders. Bellyache bush is deciduous in winter (an adaptation to dry seasons and "drought"). New leaves are produced with the onset of the wet season. The roots are rather fleshy and tuberous, another adaptation that enables the plant to persist in seasonally-dry, sandy soils in hot, tropical environments.

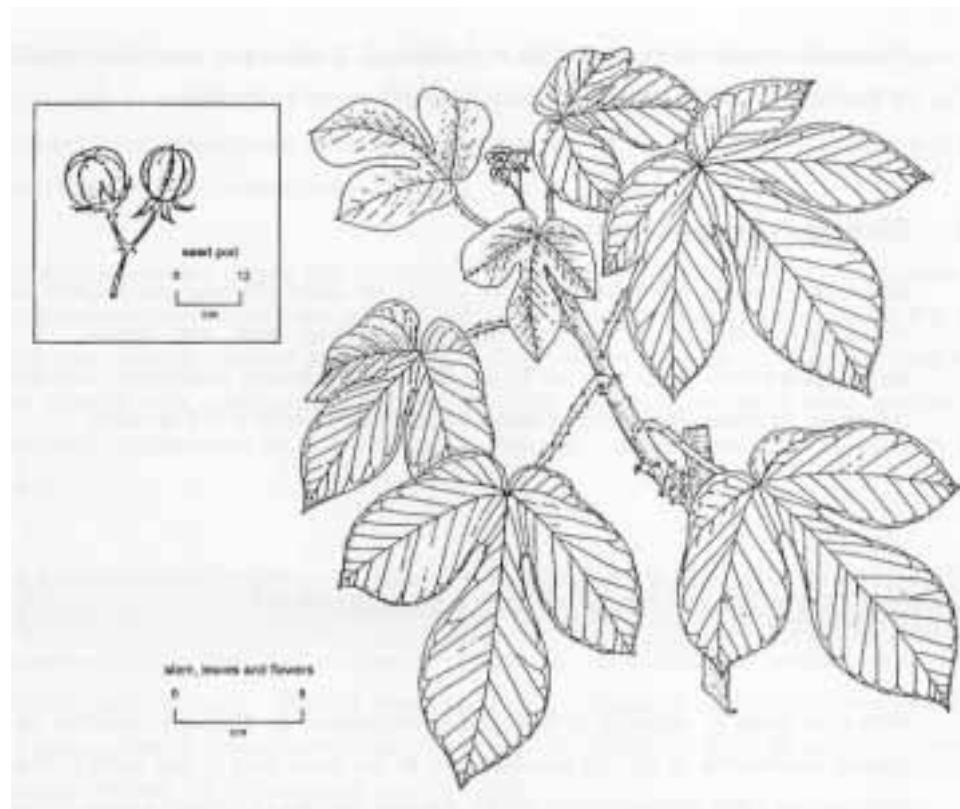


Fig. 1. Leaves, flowers and seed pods (inset) of *Jatropha gossypifolia* L.

The flowers are purple/red with yellow centres and are produced in clusters on branched stalks in the upper leaf axils. Both male and female flowers are in the same inflorescence, with 2-8 females and 27-54 males per inflorescence. The average male-to-female ratio is 11:1. Each inflorescence may bloom for 18 days (Reddi and Reddi 1983). Male flowers have 8-12 stamens with filaments that are connate towards the base. Anthers are 2-celled, opening by longitudinal slits. Female flowers, which are larger than the male flowers, have 3 styles and a 2-5-celled ovary with one ovule per cell. The fruit capsule (seed pod) is sub-globular (round to oblong), about 12 mm long and 10 mm wide, separated into mericarps (i.e. a 3-lobed capsule). Each pod contains 3-4 orange-brown, ovoid seeds (c. 7-8 mm long and 4 mm wide) with caruncles (Wheeler 1992, Anon. 1996b).

There appears to be geographical variation in morphology with plants in central Queensland being more sparsely foliated when compared to those in north Queensland (C. Glen, *pers. comm.* 1998). This is probably a response to different climatic and edaphic conditions, however, there is a chance that one or more varieties of the species exist in Queensland (as mentioned in section 2.0, there are at least three varieties noted in the literature and it is not known which varieties exist in Australia).

2.2 Distinguishing characters

Bellyache bush is often mistaken for castor oil plant (*Ricinus communis*) which also colonises riverbanks and freshly deposited alluvial soils and gravel. It is easily distinguished from castor oil plant by the shape of the leaves (bellyache bush leaves have 3-5 lobes, whereas the leaves of castor oil plant are divided into 7-9 lobes).

3.0 History of Introduction and Spread

Bellyache bush is reported to have been introduced to northern Australia either as a garden ornamental or as a medicinal plant in the latter part of the 1800's (Parsons and Cuthbertson 1992, Pitt and Miller 1991). Several species of *Jatropha* were introduced into the Darwin Botanic Gardens approximately 100 years ago and it is likely that bellyache bush was one of these (Anon. 1888).

F. M. Bailey, colonial botanist, listed bellyache bush as a naturalised component of Queensland's flora in 1912 (Bailey 1912). However, there was no information provided on the plant's distribution. The first specimen recorded by the Queensland herbarium came from Townsville in 1913 (Queensland herbarium HERBRECS database). It is not known if this was a cultivated specimen or a naturalised plant. Subsequent specimens were recorded from Townsville in 1916 and 1918 (Queensland herbarium HERBRECS database).

P. Jeffrey (*pers. comm.* 1998) suggests that infestations in Queensland originate from the Charters Towers area, probably from garden specimens planted prior to 1900. At that time, reticulated water was unavailable in the town and local residents tended to plant very hardy plants such as rubber vine, chinee apple and bellyache bush, three species that have become invasive weeds.

In 1979, bellyache bush had "naturalised in a few places in northern Queensland, particularly around Charters Towers and Townsville." (Kleinschmidt and Johnson 1979). Today, scattered populations exist throughout the tropical zone of northern Australia, generally in areas where the soil is bare or has been moved around, such as around mining sites, abandoned homesteads, refuse tips, along the banks of creeks and river beds and on over grazed pastures.

Over the past 4-5 years, the abundance of bellyache bush appears to have increased substantially, particularly along the Burdekin River in north Queensland. During this time, the most heavily infested area has experienced severe drought and the combined effect of drought and grazing by cattle has probably removed palatable plant species and created opportunities for unpalatable species such as bellyache bush to colonise bare soil.

In Australia and elsewhere, bellyache bush continues to be grown as a garden plant for its shining, purple-tinged foliage and deep red flowers. Some gardening enthusiasts have commented that "the plant is among the most elegant of *jatrophas* and well worth trying" (Rodriguez undated). Recent weed awareness programs undertaken by some Local Governments in Queensland have resulted in surprising numbers of garden specimens being detected (G. Twiner, *pers. comm.* 1998).

4.0 Current and Predicted Distribution

4.1 Distribution - overseas

Bellyache bush is native to tropical America, from the Caribbean region and Mexico to southern Brazil and Paraguay (Gardner and Bennetts 1956). Within this region, it is widespread (Palmer unpubl.). The Missouri botanical garden's 'TROPICOS' database holds 84 records of the plant from Central America (Costa Rica, Honduras and Nicaragua), South America (Bolivia, Colombia, Ecuador, Paraguay, Peru and Venezuela), the Caribbean (Dominican Republic, Puerto Rico and Leeward Islands) and Africa (Cameroon and Ghana).

There is very little published information on the plant's natural habitat in tropical America. However, field notes prepared by a CSIRO entomologist, who is currently collecting potential biocontrol agents in the Caribbean region (Dominican Republic and Puerto Rico), state that the plant grows on well-drained sand, sandy loams, loams and stony soils, in low elevation coastal areas, within a range of land uses (urban areas, crop lands and range lands). Herbarium records of plants collected from the Dominican Republic describe collection sites as "dry scrub", "semi-moist brushy roadside near stream" and "arid thorn scrub", generally at low elevation (0-60 m) but with one specimen collected from an elevation of 400-420 m (Herbarium, Carnegie Museum, Pittsburgh, USA). These collection points are generally along the island's southern coast. The plant inhabits the coast of Venezuela and Isla Margarita which lies some 40 km north of the Venezuelan coast (W. Forno, *pers. comm.* 1998). According to Campbell and Hammond (1989), most of Venezuela's coast is desertic, with 0-600 mm annual rainfall. Dry forest, composed mainly of deciduous, low to medium sized trees, and savanna vegetation occur in the drier parts of northern Venezuela. From this information, it can be assumed that bellyache bush originates from a seasonally-dry, tropical environment, probably on well-drained sandy and rocky soils, where the natural vegetation is relatively open and may include savanna and deciduous thorn scrub.

For many decades, bellyache bush has been transported across the world as a garden ornamental and as a medicinal plant. Today, bellyache bush is pan-tropical and can be found in at least 36 countries, including Brazil, Peru, Puerto Rico, the Dominican Republic, Jamaica, Trinidad, Indonesia, Malay Peninsula (Singapore, Jurong), Florida, New Guinea, New Caledonia, Guam, Palau, Northern Mariana Islands, Hawaii, India and coastal areas of western Africa (Holm *et al.* 1979, Irvine 1961, Chadhokar 1978, Dehgan 1982, Swarbrick 1997, Wagner *et al.* 1990, Dalziel 1948, Ridley 1924). Within these countries, the plant has tended to naturalise in dry, disturbed habitats. For example, in Andhra Pradesh, India, it has become very common "along roadsides, railway tracks and eroded places" (Rao and Raju 1994). In Indonesia, it tends to grow wild in the drier parts of islands such as West Timor, Sumba, Lombok and Sumbawa (Wilson 1997). In Java, it has naturalised along roadsides and in waste places "in dry areas at low altitudes" (Backer and Bakhuizen van den Brink 1963). Similarly, in New Guinea, naturalised populations exist in areas that experience a seasonally-dry climate (central district; Sialum, Morobe district) (Henty 1980).

4.2 Distribution - Australia

Bellyache bush exists as scattered populations over a large area of northern Australia (Figure 2). Infestations vary considerably in size, from small clumps of 10-20 individuals to infestations covering many hectares. Hnatiuk (1990) recorded specimens from the Northern Territory, Western Australia and Queensland, primarily in tropical zones of each State. Most infestations lie between the 400 and 1200 mm average annual rainfall isohyets.



Fig. 2. Distribution of bellyache bush (*Jatropha gossypifolia*) in Australia.

Queensland: Small, isolated infestations and garden specimens are scattered throughout much of northern and central Queensland (Figure 3). The plant exists in most pastoral districts of the State, including Burke, Cook, Leichhardt, Mitchell, North Kennedy, South Kennedy and Wide Bay (Queensland Herbarium 1994). The most extensive infestations exist within the Burdekin River catchment, where its distribution extends from Fletcher Creek, 50 km north of Charters Towers, to the Burdekin river mouth and back along many of its tributaries (P. Jeffrey, *pers. comm.* 1998). This includes the Local Government areas of Bowen, Burdekin and Dalrymple (which includes Charters Towers) and the catchments of the Bowen, Suttor, Bogie and Belyando Rivers. P. Jeffrey (*pers. comm.* 1998) estimates that some 40,000 hectares of grazing land bordering the Burdekin River are infested with bellyache bush

As part of the current study, weed inspectors from 19 Local Governments, covering the plant's "core" distribution, were asked to provide information on the plant's distribution. This information is presented below. The information was supplemented with information provided by Regional Land Protection officers and research staff employed by the Queensland Department of Natural Resources and Mines.

Banana Shire: Three small infestations near Woolton and one near Bell creek are being sprayed with herbicide. The plant is declared under local law.

Bauhinia Shire: One infestation comprising several thousand plants exists on a grazing property north of Springsure. Some 7-8 km of creek bank are infested. The infestation originated from garden specimens (I. Schuk, *pers. comm.* 1998).

Belyando Shire: The Shire's main infestation is at a dump in Moranbah and covers c. 10-15 hectares. This area has been sprayed once with herbicide and seedlings are being controlled. Another infestation is at "Grosvenor Downs" near Moranbah. Other smaller infestations exist south of Clermont (near an old caravan site associated with an old mine) and along Copperfield Road (C. McAdam, *pers. comm.* 1998).

Bowen Shire: The plant is common throughout the Shire with heavy infestations along the banks of the Burdekin River, where it extends up to 1 km away from the river and almost 30 km along the river (R. Anderson, *pers. comm.* 1999). It also exists at Gumlu (north of Bowen), the mouth of the Elliot River and along the banks of Euri Creek (including some 50 hectares on the lower floodplain of Euri Creek) (G. Dalton, *pers. comm.* 1998). Bowen Shire Council undertakes control on Council and Crown land.

Broadsound Shire: Small clumps (c. 10-20 plants each) have been sprayed with herbicide near the McKenzie River school and at the Dysart dump. Seedlings are being treated. Several garden specimens have also been removed (G. Wehmeier, *pers. comm.* 1998).

Bourke Shire: The plant is not yet a significant problem in north-west Queensland. However, it has been in the area for many years and isolated infestations have been found along the Gregory River. The largest infestation along the Gregory river is c. 50-60 m in diameter. The plant has been observed growing as far as 500 m from the banks of the Gregory River (G. Telford, *pers. comm.* 1998).

Burdekin Shire: Dense populations with some pure stands exist along the banks of the Burdekin River. Most populations are less than one hectare in size, but some are 2-3 km long and 200 m wide (M. Pyott, *pers. comm.* 1998). Scattered infestations exist elsewhere in the Shire.

Cook Shire: Scattered plants exist between Lakeland and Mt. Carbine on disturbed sites associated with mining activity and an old telegraph station (B. Toms, *pers. comm.* 1998).

Dalrymple Shire: Scattered populations of varying size exist along the Burdekin River and its tributaries. The plant has been spreading at a slow but steady rate over at least the past 40 years (B. Neilson, *pers. comm.* 1998).

Duarina Shire: A single infestation covering some eight hectares exists at the Duaringa dump site. The infestation is thought to have originated from dumped garden specimens and is being sprayed regularly by Local Government staff.(G. Lang, *pers. comm.* 1998).

Emerald/Peak Downs Shires: A small infestation was detected near the "gem fields" about three years ago (C. Smith, *pers. comm.* 1998). The plant has spread some 300 m along a tributary of Policeman creek. Since discovery, the infestation has been sprayed three or four times every year and is now being monitored for seedlings. Isolated plants have also been found near Rubyvale and Sapphire. The plant is declared under local law.

Fitzroy Shire: The largest infestation in the Shire is approximately 2000 m² in size and is located at a dump site near Gracemere. This area has been sprayed with herbicide and is being monitored for seedlings. Scattered, wild plants exist at four or five other locations. There are a considerable number of garden specimens within the Shire. All naturalised plants are associated with old camp sites and dumping areas. To date, there have not been any naturalised specimens found in any of the creeks within the Shire (R. Black, *pers. comm.* 1998).

Flinders Shire: A dense infestation exists along Jardine Creek, approximately 20- 30 km from Hughenden. It extends for some 3 km along the banks of the creek and is a threat to the Flinders River downstream. It is the largest infestation in the Flinders River catchment (R. Lowe *pers. comm.*, 1999). A smaller infestation exists near Bullack Creek.

Jericho Shire: A few plants exist near an old main roads department camp site. All mature plants have been treated with herbicide and the site is being monitored for seedlings (T. Cosgrove, *pers. comm.* 1998).

Livingstone Shire: A single infestation at Nerimbera (D. Ballantine, *pers. comm.* 1998).

Rockhampton City: The plant exists as scattered, small stands (c. 10-20 m² in size), usually associated with land fill and dump sites. Naturalised plants have been treated with herbicide. It is a common ornamental within the city (C. Jones, *pers. comm.* 1998).

Thuringowa Shire: Scattered, isolated plants have been found, however, no major infestations have been detected (G. Lyons, *pers. comm.* 1998).

Whitsunday Shire: Some 500-600 plants (100 x 10 m in area) have been found at Peter Faust Dam. All plants have been sprayed with herbicide and seedlings are being removed. This infestation originated from a garden (J. Arnold, *pers. comm.* 1998).

Garden specimens are known to exist in Cloncurry, Clermont, Springsure, Dysart, Mornington Island, Mt Isa, Prairie, the Richmond racetrack, Banana Shire, Burketown, Hughenden, Gregory Downs and Emerald (P. Jeffrey, N. March, T. Mitchell, G. Telford, C. Smith, *pers. comm.* 1998) and probably many other locations. Nurseries on Mornington Island are selling the plant as a garden ornamental (G. Telford, *pers. comm.* 1998).

Several Queensland Local Governments have declared the plant under their local laws and many small infestations are being treated regularly with herbicides.

Provided follow-up control continues (including removal of garden specimens), the plant could be eradicated from a significant proportion of its current range.

Northern Territory: Bellyache bush has been recorded from at least 30 localities, including infestations around Darwin, Middle Point, Batchelor, Katherine, Willeroo, Mataranka and the Barry's caves on the Barkly Highway (Pitt and Miller 1991, Parsons and Cuthbertson 1992). It is abundant at a few locations, including the largest infestation of over 700 hectares of the Aroona Creek system on Willeroo Station, 125 km south west of Katherine. At this site, plant numbers are increasing at 145% per year (Pitt *et al.* 1990, Pitt and Miller 1991). There are other large infestations near Daly Waters, Tipperary Station (near Daly River) and Channel Island (near Darwin) (Smith 1995). It is also reported from Mary River Station in Kakadu (P. Jeffrey, *pers. comm.* 1998).

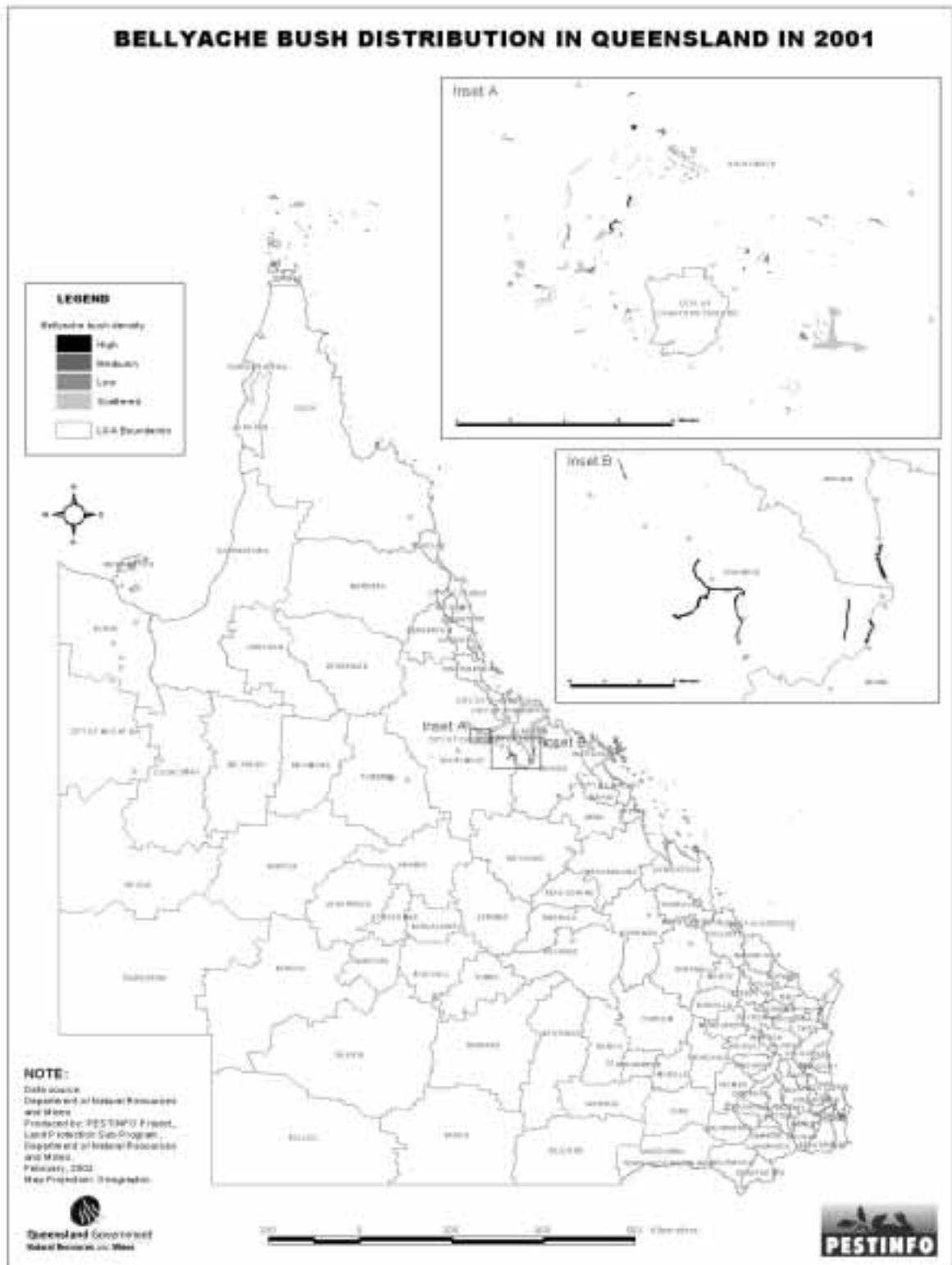


Fig. 3. Distribution of bellyache bush (*Jatropha gossypifolia*) in Queensland.

Western Australia: One of the earliest reports of bellyache bush as a weed in Western Australia was by Gardner and Bennetts (1956) who stated that the plant “has recently made its appearance in the Wyndham district.” Today, the plant exists as a scattered weed of grazed woodlands, creek lines, townships and waste land in the Kimberley (Hussey *et al.* 1997, Keighery 1994, APB Infonote 1994). Scattered plants have been found along the Great Northern Highway between Wyndham, Halls Creek, Fitzroy Crossing and Derby, continuing south along the coast from Cape Leveque to Cape Bossut in northern Western Australia (Parsons and Cuthbertson 1992). It is reported to be spreading slowly. According to the Western Australian Agriculture Protection Board, bellyache bush “seems to be associated with pressures from over-stocking, less frequent use of fire as a pasture management tool and the availability of disturbed sites around towns” (APB Infonote 1994).

According to Parsons and Cuthbertson (1992), the plant does not occur in the southern half of Australia.

4.3 Potential distribution in Australia

The potential range of bellyache bush includes most of the tropical savanna of northern Australia, where major features of the climate are hot, wet summers and pronounced dry seasons in winter. A preliminary ecoclimatic model, developed using the “CLIMEX” modelling package (Skarratt *et al.* 1995), suggests that the climate experienced across northern Australia’s ‘dry tropics’ is similar to that experienced in the plant’s native range (Figure 4). The existing distribution of scattered, naturalised populations of bellyache bush in Australia corresponds with this prediction. As such, it appears that embryonic populations have already become established over most of the plant’s potential range. Within its existing distribution, additional populations will continue to establish and existing infestations are predicted to increase in density.

Bellyache bush has the potential to grow on a range of soil types but is expected to become most abundant and problematic on regularly disturbed sandy loams associated with creeks, rivers and flood-plains within the ‘dry tropics’. Additional populations will continue to develop on a range of other soil types including friable clay soils, shallow, rocky ridges and red duplex soils.

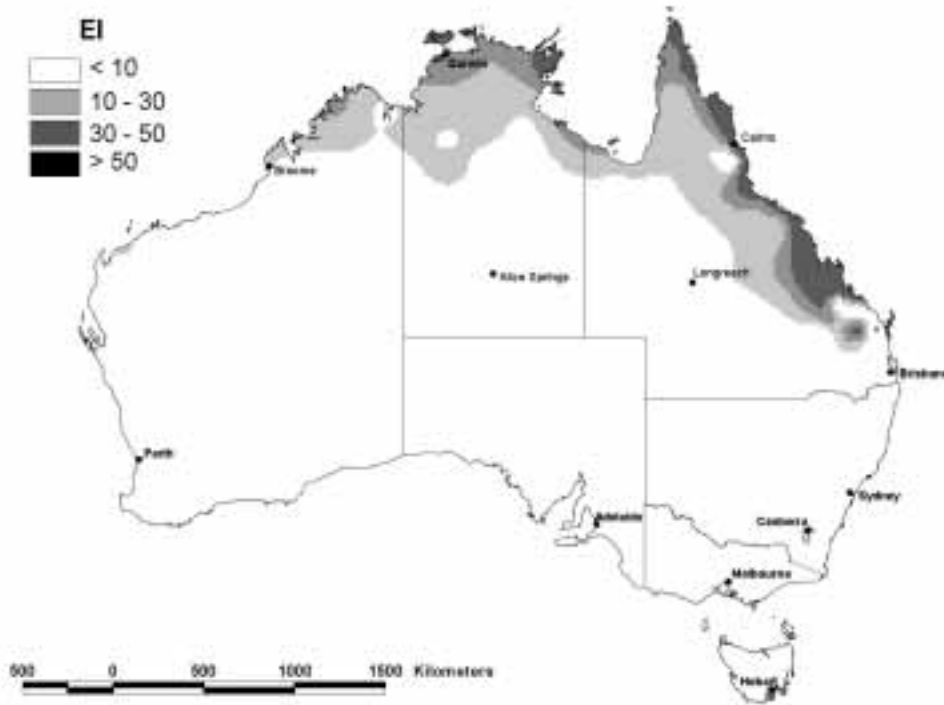


Fig. 4. Potential distribution of *Jatropha gossypifolia* generated by "CLIMEX".

5.0 Estimates of Current and Potential Impact

5.1 History as a weed overseas

Bellyache bush has been listed as a weed in India, Brazil, Jamaica, Trinidad, Indonesia, Peru, Puerto Rico, the Dominican Republic, south-eastern parts of the United States, New Guinea, New Caledonia, Guam, Palau, Northern Mariana Islands, French Polynesia, New Caledonia and Africa (Holm *et al.* 1979, Irvine 1961, Chadhokar 1978, Swarbrick 1997, Waterhouse 1997). In Java, it is a weed of sugar cane but no data are available on its impact. It is a major weed in West Timor where it has formed extensive, dense, almost pure stands in degraded pastures (B. Waterhouse, *pers. comm.* 1998). Wilson (1995) commented that it was possibly West Timor's worst weed after *Chromolaena odorata*. Bellyache bush has become a prominent weed on the drier parts of several islands in eastern Indonesia (R. McFadyen, *pers. comm.* 1998). Within its native range (the Caribbean), bellyache bush is predominantly a weed of dry, waste places.

Despite being listed as a weed in many countries, there is virtually no published information on its impact. In many areas where it has been listed as a weed, it is a ruderal plant, generally restricted to waste land and other highly disturbed habitats. In some countries it is considered benign because of its extensive use in traditional medicine systems. Considering the plant's pan-tropical distribution, it is not surprising that it has naturalised in the tropical region of Australia.

5.2 Impact elsewhere in Australia

Bellyache bush was declared in the Northern Territory because of its toxic seeds. Since declaration, however, its capacity to form dense thickets, interfere with pasture growth, obscure fence lines, interfere with mustering and displace native vegetation has become apparent (Miller 1982, Pitt *et al.* 1990). In Western Australia, bellyache bush has displaced pasture species and native vegetation. It also obscures fence lines and hinders mustering (APB Infonote 1994).

5.3 Current impact in Queensland

5.3.1 Economic and social impact

To date, there have not been any formal studies on the plant's impact in Queensland.

The plant is unpalatable to stock (Ashley 1995), harbours feral pigs and can impede mustering (Anon. 1994). In addition, most parts of the plant contain toxins in varying concentrations. Quisumbing (1951) extracted toxic alkaloid from the roots of var. *elegans*. Similarly, Chopra *et al.* (1965) found that the bark of variety *elegans* contains an alkaloid jatrophine (0.4% of dried bark). The toxic dose for guinea pigs is about 0.2g/kg body weight injected subcutaneously. Webb (1948) and Kingsbury (1964) reported that the seeds of bellyache bush are toxic in the same way as *J. curcas* (physic nut). The toxic substance is toxalbumin which, when eaten, can cause gastro-enteritis and death. Everist

(1974) noted that no records of animal poisoning had been recorded in Australia. In 1995, however, stock losses in the order of some 312 animals were attributed to bellyache bush in the Dalrymple shire of north Queensland. This figure involved 35 separate reports of stock losses; 11 reports received by P. Jeffrey from the Queensland Department of Natural Resources and Mines and 24 reports by J. Fry, Stock Inspector, Queensland Department of Primary Industries. In total, 15 goats, 7 horses and some 290 cattle were reported to have died after consuming bellyache bush. The largest single case of poisoning was a herd of 20 cattle grazing on river flats during drought (P. Jeffrey, *pers. comm.* 1998). In a year when stock losses were so high, many landholders did not fully investigate causes of death and tended to attribute stock losses to starvation and plant poisoning in general (P. Jeffrey, *pers. comm.* 1998). As such, actual stock losses caused by bellyache bush in 1995 probably exceeded 315. This figure is considered to be unusually high due to drought, since grazing animals tend to eat less palatable, or even poisonous, plant species at the onset of starvation. Most of the goat deaths (which involved four herds) were recorded from "hobby farms" near Charters Towers, at a time when the soil had been grazed bare (P. Jeffrey, *pers. comm.* 1998). Losses of cattle and horses occurred on properties along the Burdekin River and appeared to involve accidental ingestion of the seeds of bellyache bush when animals were browsing on sparse, dry grass and fallen leaf litter (P. Jeffrey, *pers. comm.* 1998). All cases of poisoning occurred between June and November (dry season). There have not been any reports of human fatalities attributed to bellyache bush in Australia.

It is generally acknowledged that the plant's shallow root system precludes growth of other plants under its canopy. Pure stands of bellyache bush prevent the growth of pasture species and can render "river flats" and "river frontages" totally unproductive, thereby reducing the overall productivity of land used to graze cattle. Anecdotal reports suggest that the plant initially invades disturbed areas, dominates these areas and then slowly spreads onto less disturbed land. At present, the plant appears to have a locally significant impact on grazing land along the banks of the Burdekin River and some of its tributaries. However, elsewhere in the State, its impact is insignificant. Like most weeds, the plant's impact on primary production varies considerably, depending on its abundance. According to weed control staff from several Local Governments where bellyache bush exists as small populations, the plant's impact on primary production is negligible due to the fact that it has been declared and treated with herbicide, thereby preventing it from becoming more widely naturalised. If preventative action had not been taken by Local Governments, the plant's impact outside the heavily infested Burdekin catchment would have become much greater.

As part of the current study, weed inspectors from 15 Local Governments, covering the plant's "core" distribution, were asked to estimate total Local Government expenditure (to date) on control of bellyache bush (Table 1).

Table 1. Estimated Local Government expenditure on control of bellyache bush in Queensland (total expenditure to date)

Local Government	Estimated Expenditure (total to date) (\$)	Source
Banana	3 000	G. Twiner (<i>pers. comm.</i> 1998)
Bauhinia	500	I. Schuk (<i>pers. comm.</i> 1998)
Belyando	6 000	C. McAdam (<i>pers. comm.</i> 1998)
Bowen	3 000	G. Dalton (<i>pers. comm.</i> 1998)
Broadsound	1 000	G. Wehmeier (<i>pers. comm.</i> 1998)
Burdekin	8 000	M. Pyott (<i>pers. comm.</i> 1998)
Dalrymple	10 000	B. Neilson (<i>pers. comm.</i> 1998)
Duaringa	20 000	G. Lang (<i>pers. comm.</i> 1998)
Emerald/Peak Downs	3 000	C. Smith (<i>pers. comm.</i> 1998)
Fitzroy	500	R. Black (<i>pers. comm.</i> 1998)
Jericho	200	T. Cosgrove (<i>pers. comm.</i> 1998)
Peak Downs	2 000	Anon. 1997
Rockhampton	600	C. Jones (<i>pers. comm.</i> 1998)
Thuringowa	500	G. Lyons (<i>pers. comm.</i> 1998)
Whitsunday	200	J. Arnold (<i>pers. comm.</i> 1998)
Total	58 500	

In addition to Local Government expenditure on control, an unknown number of landholders have been undertaking control work for several years. Figures on private expenditure are scarce but include two anecdotal reports, as follows:

Property A: Approximately 18 kilometres of river country on 'Kings Creek Station', located within the Burdekin catchment, have been fenced off after being dominated by bellyache bush. The owner of the property is reported to have spent some \$50,000 over 10 years in an attempt to prevent the plant's spread (Anon. 1996a).

Property B: A landholder in Belyando Shire is reported to have spent \$6 240 during 1994-97 on control of bellyache bush (Anon. 1997).

Landholders who have fenced off heavy infestations along creek lines refer to these areas as "sacrifice paddocks". The objective of fencing off areas is to try and keep areas outside these paddocks free of the plant. Total expenditure by landholders on control of bellyache bush in Queensland has not been assessed.

However, total expenditure (to date) by 15 Local Governments combined with the two landholders mentioned above totals \$114,740.

5.3.2 Environmental impact

As far as the author is aware, there has not been any research on the plant's environmental impact. However, Smith (1995) and Csurhes and Edwards (1998) have listed the plant as an environmental weed. Smith (1995) commented that native bees (*Trigona* spp.) are attracted to the plant's sticky leaves and stems but did not say whether they are harmed. Of particular concern is the plant's impact within riparian habitats where it appears to be in direct competition with native plants in the early stages of successional development, perhaps replacing native colonisers and delaying or preventing subsequent invasion by secondary species of native shrubs and trees. In addition, bellyache bush is barely utilised by native phytophagous insects despite ample opportunity for their recruitment (Wilson 1997) and, unlike native plants, is not expected to contribute in any substantial way to the survival of native insectivorous fauna such as birds or lizards. Other native wildlife, such as parrots, possums, bats and macropods appear incapable of utilising the plant in any way. Hence, it can be speculated that extensive thickets of the plant could degrade wildlife habitat and perhaps reduce biodiversity at a local level.

5.4 Potential impact in Queensland

Miller and Pitt (1992) suggest that bellyache bush is one of many "sleeper" species, whose population may still be in a "lag phase" of exponential development. The population might remain fairly static until favourable environmental conditions allow a population explosion to occur. This phenomenon has been observed for other woody weeds such as *Acacia nilotica* (prickly acacia) in Queensland and *Mimosa pigra* in the Northern Territory.

Bellyache bush has the potential to degrade grazing land on alluvial soils (sand and clay) and possibly other soil types over large areas of tropical savanna and to threaten the future productivity of some grazing enterprises. Soil types most likely to be invaded are sandy loams and friable clay soils associated with the banks of watercourses and their associated floodplains. Bellyache bush can persist on a range of soil types, and has been observed to grow on rocky ridge lines (P. Jeffrey, *pers. comm.* 1998), clay soils of the Gulf savanna (G. Telford, *pers. comm.* 1998) and brigalow soils (G. Twiner, *pers. comm.* 1998). In Western Australia, bellyache bush grows on a range of soil types, including pindan, black soils and on the edges of salt marshes (APB Infonote 1994). One of the worst infestations in the Northern Territory exists on friable clay soil (J. Pitt, *pers. comm.* 1998). The plant is not considered to pose a major threat to areas that are cultivated regularly to grow crops. However, crops planted opportunistically in alluvial soils on fertile flood-plains can be invaded by bellyache bush in situations where large quantities of seeds are being washed into the crop from upstream sources. For example, a plantation of juvenile leucaena (*Leucaena leucocephala*) planted in sandy soil near Ravenswood, close to the Burdekin River, was abandoned following invasion by bellyache bush from upstream seed sources. Control of established bellyache bush within the stand of leucaena was

extremely difficult, since herbicide application would have killed the juvenile leucaena (J. Vitelli, *pers. comm.* 1998).

P. Jeffrey (*pers. comm.* 1998) suggests that bellyache bush could rival rubber vine as a weed of the Burdekin river system. Of concern is the plant's potential to colonise areas that might be cleared of rubber vine in the future.

Without intervention, the future economic impact of bellyache bush is expected to be two-fold. Firstly, the plant will continue to form dense thickets that exclude pasture plants and hinder mustering operations. Secondly, the plant's toxic leaves and seeds are expected to cause an increasing number of stock deaths, although it is impossible to predict how many will occur. The number of deaths is likely to vary depending on drought and the availability of feed. Like many poisonous plants, stock will probably consume bellyache bush's fallen leaves and seeds only when they are starving and normal feed is non-existent.

If bellyache bush becomes more abundant, human health risk associated with the plant's highly toxic seeds might increase, particularly if it becomes prevalent along watercourses flowing through towns and adjacent to school yards.

Extensive, pure stands of bellyache bush have the potential to cause significant damage to native ecosystems, especially the riparian communities of Australia's semi-arid tropical zone. Humphries *et al.* (1991) commented that riparian habitats (drainage lines, watercourses and associated habitats) currently have the densest infestations of locally prevailing weeds and consequently are the habitats at greatest risk across Australia. Within riparian communities, pure stands of bellyache bush are expected to smother and replace certain native plant species and interfere with normal successional processes which follow sporadic disturbance events such as flooding. If the composition of native plant communities is altered, then the abundance and diversity of certain invertebrate and vertebrate fauna will also be affected. The impact of bellyache bush on native fauna is expected to reach maximum intensity during drought when riparian habitats act as refuges for residual wildlife populations.

5.5 Potential impact of related species

Two other species of *Jatropha* have histories as weeds overseas. *Jatropha curcas* is listed as a weed in Peru, Brazil, Fiji, Honduras, India, Jamaica, Panama, South Africa and Indonesia whereas *J. glandulifera* is a weed in India (Holm *et al.* 1979). In Queensland, the species of greatest concern is *J. curcas* (physic nut), which has pest potential in the northern half of the State, although it does not appear to be as invasive as bellyache bush. *J. curcas* was introduced as a garden ornamental and was naturalised around Charters Towers by 1912 (Bailey 1912). A native of the Caribbean, it prefers humid and sub-humid tropical zones and is morphologically and biologically similar to bellyache bush. Seeds of *J. curcas* are toxic to humans and stock. Cattle deaths have been reported in Europe (Parsons and Cuthbertson 1992). The plant reproduces from seeds although seed production is not as prolific as bellyache bush. *J. curcas* has a limited distribution in the Northern Territory and along the Queensland coast. It has been used in several countries as a source of medicine, to provide shelter, as a source of oils and for combating desertification (Henning 1996).

6.0 Biology and Ecology of Spread and Control

6.1 Habitat

Bellyache bush is an opportunistic coloniser of disturbed sites. It can form pure stands in open areas where the natural vegetation has been damaged or removed by cattle, man (e.g. following road construction or dwelling construction) or floodwaters. At hundreds of sites in northern Australia, it has become abundant along roadsides, around abandoned homesteads and near old mine sites. Like many weeds, colonisation by bellyache bush is probably an indicator of significant exogenous or endogenous disturbance.

Bellyache bush is a tropical species that is particularly well adapted to areas that experience a pronounced dry season. Most naturalised populations in Australia lie between the 400 and 1200 mm average annual rainfall isohyets, with some of the heaviest infestations found between the 600 and 1000 mm average annual rainfall isohyets. In Queensland, most naturalised populations exist within the 'dry tropics' climate zone. This region includes vast inland areas and extends to sub-coastal and coastal areas between Townsville and Rockhampton. Features of the 'dry tropics' include high rainfall variability (including droughts) and a pronounced summer wet season during which most of the annual rainfall occurs. The annual dry season is a very important stress to which the biota of the region has had to adapt (Ridpath and Corbett 1983). In the Northern Territory, bellyache bush persists in coastal, monsoonal areas, where average annual rainfall exceeds 1000 mm per annum, but is most prevalent in drier areas further inland, extending into the semi-arid and arid zone. One of the worst infestations in the Northern Territory occurs at Willeroo Station (15° 17'S, 131°17'E), which has a tropical climate and an average annual rainfall of 733 mm, of which about 94% falls in the "wet season" between November and March.

Most of the plant's existing distribution falls within tropical savanna, an area where the natural vegetation is predominantly open woodland and grassland, traversed by meandering creeks and rivers. It is along the banks of watercourses and their associated flood plains where bellyache bush thrives. The larger watercourses, such as the Burdekin River, feature extensive areas of freshly deposited sands and sandy loams. Floodwaters associated with summer storms and occasional low-pressure systems regularly disturb these sandy alluvial deposits, often causing significant damage or removal of other plant species. Disturbance by floodwaters, which generally occurs in combination with persistent grazing and trampling by cattle, probably creates ideal conditions for opportunistic invasion by bellyache bush. On fresh alluvial deposits, seedlings of bellyache bush experience freedom from competition with other plant species and an absence of fire. Within this habitat, pure stands of bellyache bush have developed.

Land use in the seasonally dry savannas of northern Australia is predominantly extensive pastoralism (Tothill and Mott 1983). During periods of drought, grass cover is often significantly reduced by cattle and other domestic herbivores, especially in areas close to water.

Jatropha species generally tolerate infertile soils (Dehgan 1982) and most species are well adapted to eroded land, land that has been subject to mining and coarse alluvial deposits. In Queensland, bellyache bush seems to prefer sandy loams but will tolerate a wide range of soil types including clay soils of the Gulf savanna (G. Telford, *pers. comm.* 1998), clay soils associated with the brigalow belt (G. Twiner, *pers. comm.* 1998) and even dry, shallow, rocky soils associated with highly weathered ridges (P. Jeffrey, *pers. comm.* 1998).

Bellyache bush is generally absent from grasslands, forests and woodlands that are burnt regularly. Fire often fails to penetrate riparian vegetation and this probably favours survival of bellyache bush. In the Dalrymple Shire and elsewhere in the 'dry tropics' of north Queensland, below average rainfall experienced over the past few years has meant that fire has been absent (B. Neilson, *pers. comm.* 1998). This might be one reason why some landholders have commented that the plant's spread has been more noticeable over this time.

6.2 Dispersal

The plant's most significant and effective mode of spread, not only within Australia but elsewhere in the world, has been its dispersal by humans for use as a garden ornamental. In virtually every Local Government area of Queensland where the plant has been recorded, the majority of infestations occur in close proximity to dumping sites near towns, camp sites, mining sites, old telegraph stations and railway camps. Dumped cuttings and unwanted potted specimens have regenerated and have subsequently produced seeds. Vegetative regeneration can occur from broken stems, tuberous roots and the plant crown following injury to the plant. It is clear that garden specimens have acted as foci of naturalisation throughout tropical Australia.

The pods of bellyache bush can float, thereby facilitating long-distance dispersal of seeds along watercourses and onto flood plains. Ashley (1995) and Smith (1995) stated that seeds are also dispersed in mud on the hooves of cattle and on vehicles and machinery. However, several weed control officers in Queensland have questioned the likelihood of this form of dispersal. Since seeds are relatively heavy and lack hooks or sticky secretions, dispersal as a component of small amounts of mud is unlikely to represent a significant mode of spread. Having said this, the plant is certainly spread when seeds contaminate topsoil used for lawns and gardens.

Ridley (1930) reported that the seeds of the closely related plant, *Jatropha curcas*, are consumed by two bird species, *Turtus leucopterus* (Jamaican turtle dove) and *Chamaepelia passerina*, in Jamaica. Ridley commented that it was not known whether the seeds passed through the bird's digestive tract in good enough condition to germinate. Birds are reported to feed on the seeds of bellyache bush in Western Australia (APB Infonote 1994) but it is not known to what extent this occurs in Queensland or whether seeds pass undamaged through the digestive tracts of seed-feeding birds. McAdam (*pers. comm.* 1998) reports that seedlings have been observed to establish upstream of parent plants growing along a watercourse. This may suggest dispersal by animals such as birds.

The plant's pods dehisce explosively to release the seeds and most seeds fall within a few metres of parent plants (J. Vitelli, *pers. comm.* 1998). In locations where the plant is growing outside the influence of floodwater, spread of infestations is often radial with each new generation of seedlings forming an additional ring of plants around the parent plants.

6.3 Phenology

Hussey *et al.* (1997) stated that flowering occurs from February to May. However, field observations in north Queensland suggest that flowering tends to be opportunistic in response to adequate soil moisture. Depending on rainfall, flowering of specimens in north Queensland is usually initiated soon after the onset of the wet season in October or November and can extend into winter, provided soil moisture remains high. Flowering has been observed to occur in plants that are only 4-6 weeks old and 15-30 cm tall (J. Vitelli, *pers. comm.* 1998), however, most plants start to flower at about two years of age (APB Infonote 1994).

Bellyache bush is monoecious and its breeding system incorporates self and cross-pollination. In India, 18 species of insects, including bees, wasps, flies and butterflies promote both self and cross pollination (Reddi and Reddi 1983). The flowers offer nectar as the only reward to insect visitors. Reddi and Reddi (1983) have described the pollination ecology of bellyache bush in detail.

In north Queensland, sterile bellyache bush plants have been reported to occur sporadically among dense stands of fertile individuals (at an estimated ratio of 1:5000 fertile plants). Sterile plants have lighter green foliage, are stunted (0.5 - 1.5 m tall) and do not produce flowers (J. Vitelli, *pers. comm.* 1998). The origin of these sterile individuals is not known. Of possible relevance is a report of partially fertile hybrids of various species of *Jatropha* being produced under artificial conditions (Dehgan 1984).

6.4 Seed production and seedling recruitment

Seed production is prolific. In Western Australia, a 1.5 m tall plant produced over fifty seed pods a month, each pod containing 3-4 seeds (APB Infonote 1994). Similar data has been collected in north Queensland (Figure 5). Pod production varies considerably throughout the year and has been recorded to reach a maximum in autumn (May) following good rains.

Like most plants, successful recruitment of bellyache bush is probably intermittent and may be influenced by a combination of factors such as rainfall (quantity and timing), soil type and disturbance (including floods, grazing and fire). Field observations in northern Australia suggest that soil moisture is an important prerequisite for germination and seedling growth. Although episodes of mass germination can occur whenever soil moisture is high, most germination occurs at the onset of the wet season, generally between October and December in northern Australia. Seedlings develop at a moderate rate during the remainder of the wet season, slowing in the following dry winter unless there is sufficient ground water close to the soil surface (Parsons and Cuthbertson 1992).

There is anecdotal evidence that bellyache bush takes advantage of the lack of competition from pasture grasses during drought and spreads away from watercourses onto flood plains and nearby woodland. Research is needed to investigate the rate of seedling recruitment and survival in years when rainfall is below average compared to years when rainfall is average or above average.

Bellyache Bush Pod Production over Time

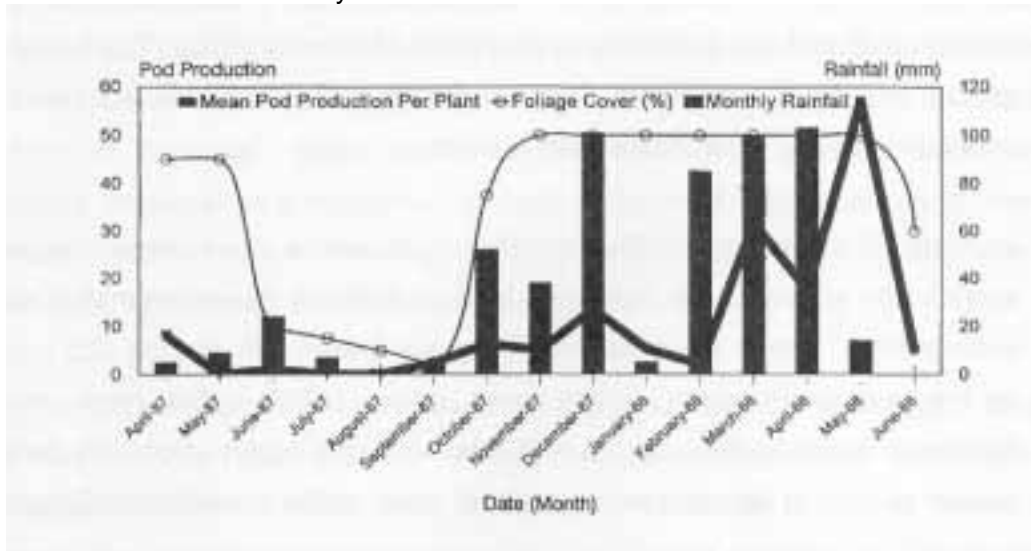


Fig. 5. Mean monthly pod production by *Jatropha gossypifolia* recorded over 15 months from 20 mature plants growing on a sandy, alluvial creek flat 10 km east of Charters Towers, north Queensland (unpublished data; J.S. Vitelli).

Seedlings have been observed to emerge en masse every year for four years after the death of parent plants. In 1994, Mr Colin McAdam (Belyando Shire Council) killed 8-10 mature plants using herbicide. Since January 1997, Mr McAdam has counted and removed 706 seedlings from the site. Additional seedlings continue to emerge following rain and Mr McAdam is still monitoring the site. There is anecdotal evidence that seedlings have emerged 15 years after an area of bellyache bush was cleared (P. Jeffrey, *pers. comm.* 1998) but it is difficult to confirm whether seedlings emerged from soil-stored seeds or were transported into the area from elsewhere. There have not been any formal studies on seed longevity in Queensland. However, a study in the Northern Territory found that most buried seeds germinated after two years with some seeds persisting when buried at a depth of 10cm (J. Pitt, *pers. comm.* 1998).

In north Queensland, dense infestations of bellyache bush have been recorded to comprise $20,000 \pm 17,000$ mature plants per hectare together with $140,000 \pm 16,000$ seedlings per hectare (J. S. Vitelli, unpublished data).

7.0 Efficacy of Current Control Methods

Options for the control of bellyache bush include herbicide application, mechanical destruction, burning and repeated cultivation (cropping) of the soil. To date, control efforts by landholders have tended to be ad hoc and many people still ignore the plant (J. Vitelli, *pers. comm.* 1998). At least 10 Local Governments are very active in pursuing control, usually after weed control staff have attended field days and have been alarmed by first-hand inspection of heavy infestations along the Burdekin River. Most control work undertaken by Local Governments has targeted small, geographically isolated infestations ranging in size from a few plants up to 5-10 hectares. Weed control staff generally use the foliar applied herbicide "Brushoff®" for control of small populations of bellyache bush and have found this method to be very effective, provided follow-up control of seedlings is maintained.

7.1 Chemical control

Chemical control, using hand-held application equipment, is feasible when dealing with scattered plants growing in situations where the operator can move through the infestation. Extensive, dense infestations are more difficult and expensive to treat but can be controlled by slashing (to reduce the biomass), or where possible burning, followed by herbicide application. On suitable soil types, dense infestations can be ploughed and replaced with a crop or pasture, followed by spot treatment with herbicide (P. Jeffrey, *pers. comm.* 1998).

Repeated herbicide application is essential to deal with regrowth, seedlings and re-invasion from other areas. Follow-up control of seedlings is often overlooked by landholders (J. Vitelli, *pers. comm.* 1998). Following initial treatment of mature plants, a site needs to be inspected and re-treated every three months to kill seedlings and prevent flowering and seed production. If a heavy infestation is sprayed and then ignored, the resultant population in six months time can be three times as dense as the original (mature) infestation, due to the mass germination of seedlings (J. Vitelli, *pers. comm.* 1998). Seedlings will continue to emerge for at least four years after death of the parent plants.

7.1.1 Foliar sprays

Screening trials completed by the Tropical Weeds Research Centre (TWRC) at Charters Towers found that a range of foliar-applied herbicides, including metsulfuron methyl ("Brushoff®"), imazapyr ("Arsenal®"), glyphosate, 2,4-D (ethyl ester, amine, acid and DP acid), fluroxypyr ("Starane®") and picloram/triclopyr ("Grazon®") are effective (90-100% mortality) when applied to bellyache bush (Biological Branch Annual Report 1988). Trial work found that the addition of poly dimethyl siloxane ("Pulse®"), a wetting agent, increased the activity of metsulfuron methyl, glyphosate, 2,4-D/atrazine and 2,4-D amine when applied as foliar sprays.

Only two chemicals, metsulfuron-methyl (sold as "Brushoff®") and fluroxypyr (sold as "Starane®"), applied as foliar sprays, are registered for use in Queensland (Table 2).

Table 2. Herbicides registered for control of bellyache bush in Queensland (Anon. 1996b).

Herbicide	Rate	Application method	Approx. cost
Brushoff® (600g/kg metsulfuron methyl)	1g/10Lwater + 20ml Pulse(wetting agent)	foliar application	\$15.20/100L
Starane200® (200g/kg fluroxypyr)	525mls/100L water (1:200)(add wetting agent at rate of 1:400)	Foliar application	\$14/100L

Foliar-applied herbicides can achieve 95-100% mortality of mature plants, provided plants are wetted to the point of run-off. The efficacy of foliar-applied herbicides that are not root-absorbed, such as glyphosate, declines considerably when the plant has shed its leaves in winter. By comparison, the efficacy of metsulfuron-methyl, which is root-absorbed, remains high even if foliage cover is low (Figure 6). Metsulfuron-methyl (Brushoff®) is the preferred foliar-applied herbicide in Queensland, due to its cost and residual property (i.e. ability to kill plants irrespective of foliage cover and ability to suppress growth of seedlings following destruction of parent plants) (P. Jeffrey, *pers. comm.* 1998).

Aerial application of foliar herbicides to dense infestations along watercourses has not been investigated in Queensland. This technique might be impractical in some locations due to excessive interception of herbicide mixture by native trees that tend to hang over the banks and beds of infested watercourses (J. Vitelli, *pers. comm.* 1998). In trials undertaken by the Northern Territory Department of Primary Industries and Fisheries, three rates of metsulfuron methyl (50, 75 and 100g active ingredient per hectare) and three rates of glyphosate mixed with simazine (1.5 + 2.0, 1.5 + 4.0 and 3.0 + 4.0kg active ingredient per hectare) were aerially applied by helicopter to a dense infestation of mature bellyache bush. Twelve months after treatment, there were no visible effects from herbicide application (Pitt and Smith 1990).

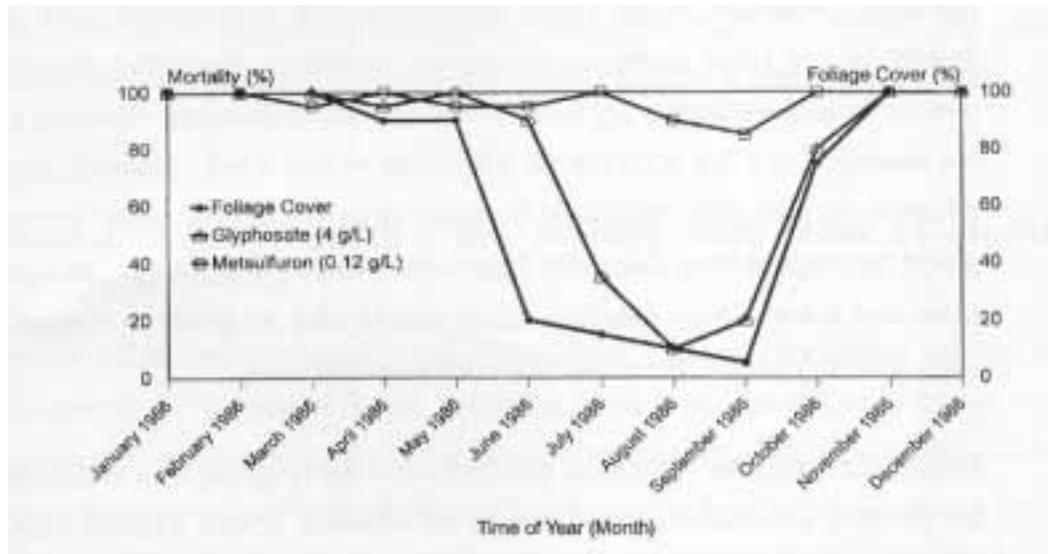


Fig. 6. Seasonal effects on efficacy of two herbicides, glyphosate (4g/L) and metsulfuron methyl (0.12g/L), applied as foliar sprays to bellyache bush (*Jatropha gossypifolia*) growing near Charters Towers, north Queensland (unpublished data from J.S. Vitelli).

7.1.2 Basal-bark and cut-stump application

In trials undertaken by TWRC, “Access®”, “Garlon®”, “AF Rubber vine (2,4-D) spray®”, “Starane®” and neat diesel were effective when applied as either basal-bark or cut-stump applications. Similarly, research in Western Australia found that “Garlon 600®” applied to cut stumps at a rate of 1:50 in diesel is effective (Peirce 1998). If herbicide and diesel are not applied immediately after cutting, the plant will regenerate in the following wet season (Pitt and Miller 1991).

7.1.3 Root-absorbed herbicides

Root-absorbed herbicides such as “Velpar®”, “Graslan®”, “Simazine®”, “Oust®” and “Atrazine®” were effective in research trials undertaken by TWRC.

7.2 Mechanical/Physical control

A slasher fitted with blunt blades can shatter large, mature plants and cause some mortality. However, some plants regenerate from undamaged roots and root crowns. Seedlings and small plants usually survive slashing. Repeated slashing can be useful method to achieve temporary suppression of seed production. Slashing can also increase the likelihood of a fire once the slashed material has dried. Slashing appears to be more effective on clay soils compared to sandy soils (P. Jeffrey, *pers. comm.* 1998). Since plants can regrow from discarded fragments, slashed or pulled plants should be gathered, dried and burnt, where feasible. Care should also be taken to ensure that the slasher does not carry seeds into areas that are free of the plant.

Mechanical methods that cause significant soil disturbance tend to create ideal conditions for seedling establishment and should be avoided, unless suitable follow-up techniques are applied (J. Vitelli, P. Jeffrey, *pers. comm.* 1998).

Since the plant is shallow-rooted, it can be removed by hand, especially if the soil is moist. This technique is being used in Kakadu National Park (P. Barrow, *pers. comm.* 1998) and is best suited to small infestations.

7.3 Biological Control

In Central America, bellyache bush is kept in check by a *Jatropha* mosaic virus (a white fly-vectored geminivirus) (Kim *et al.* 1986), as well as a range of insects and probably a number of other invertebrates and pathogens. Elsewhere in the world bellyache bush is generally free from its natural range of pests and diseases. In Australia, the plant rarely suffers any significant damage from indigenous insects or pathogens. One of the few native insects capable of utilising the plant is a tiny (c. 3-4 mm adult wingspan) leaf-mining moth, *Epicephala* sp. (Gracillariidae). The moth's larva produces a silvery mine on the upper leaf surfaces. This moth was first collected in north Queensland in 1989 and has since been observed annually on bellyache bush in late summer (M. Vitelli, *pers. comm.* 1998). Colin Wilson has also observed the moth utilising bellyache bush in the Northern Territory. Damage caused by the moth is not sufficient to control the plant.

A biological control research program has been commenced by the Northern Territory Department of Primary Industries and Fisheries with work being contracted to CSIRO (the Queensland Department of Natural Resources and Mines has recently announced a contribution of \$35,000 per year towards the project). A CSIRO field entomologist has completed an initial survey of potential biocontrol organisms in Venezuela. The first insects are expected in Australian quarantine facilities by the end of 1998 (W. Forno, *pers. comm.* 1998). A number of natural enemies show promise, including a stem-boring beetle.

7.4 Land management practices – fire, fencing, cultivation, de-stocking and integrated control

In September 1994, the Northern Territory Department of Primary Industries and Fisheries initiated research on the use of fire for bellyache bush control at Willeroo Station. Initial results suggested that fire was effective in controlling isolated or scattered bellyache bush plants within established pastures where fuel loads were high. However, in dense thickets of bellyache bush, where pasture growth/fuel load was suppressed, fire failed to kill mature plants. It was suggested that within dense thickets, fuel loads are insufficient to generate fire temperatures and flame height sufficient to destroy mature plants. Subsequent trial work found that bellyache bush regenerated after fire (J. Pitt, *pers. comm.* 1998). Fire might provide control of germinating seedlings following chemical control or physical removal of mature plants (Ashley 1995). Further research is required.

Bellyache bush is rarely a problem on land that is regularly cultivated. However, cultivation is not always feasible on grazing land and will depend on factors such as soil type and topography (i.e. the practicality of regular ploughing and crop maintenance).

Fencing might help reduce the plant's rate of spread since some seed is spread within mud adhering to the hooves of cattle (Ashley 1995). At Willeroo Station in the Northern Territory, fencing appears to have been successful in reducing dispersal of bellyache bush out onto clean pastures (Ashley 1995).

Ashley (1995) suggested that improved pasture management might be the key to improved bellyache bush management. Good quality pastures, with a low disturbance regime, do not seem susceptible to invasion. By avoiding over grazing and other soil disturbances, landholders may be able to prevent or delay invasion of bellyache bush. Pasture management research is required to investigate this aspect of control.

Integrated control, involving the application of suitable stocking rates, fire regimes, chemical, mechanical and biological control need to be developed.

7.5 Commercial exploitation

Commercial exploitation is often suggested as a form of control for introduced pests, both plant and animal. Some people argue that if a market can be developed for a pest, or its products, then that pest will be harvested (removed) from the wild to such an extent that the pest will no longer be a problem. Unfortunately, most bellyache bush infestations are located in remote and inaccessible areas and will probably regenerate from seeds soon after it has been removed for commercial purposes. In addition, commercial production of any product derived from bellyache bush is likely to be much more efficient and profitable if the plant is cultivated as a managed crop, rather than removed from the wild.

Bellyache bush has a long history of use as a medicinal plant in tropical countries. In fact, the name, 'bellyache bush', refers to the medicinal and purgative properties of the seeds (Parsons and Cuthbertson 1992). Extracts from the various components of the plant, including the leaves, stems, bark, seeds and roots, have been used to treat a number of human ailments ranging from anaemia, vertigo, worms, leprosy, dysphonia, urinary complaints, ulcers, itches, snake bite and venereal disease (Das and Das 1994). The plant has also been used as an antibiotic, an anti-fertility agent and a blood purifier. In parts of Africa, the plant is the object of superstition and is believed to ward off lightning (Dalziel 1948, Ogbobe and Akano 1993). Since the 1970s, various parts of the plant have been studied as a source of novel medicinal drugs, including potential anti-cancer drugs. For example, anti-leukemic compounds have been isolated from the plant's roots (Taylor *et al.* 1983). Other potential uses that have been investigated include a source of oil for energy (Forni-Martins and Cruz 1985), a source of plant food for human and animal consumption, an additive for plastic formulations (Ogbobe and Akano 1993) and a source of insecticides (Prasad *et al.* 1993, Chatterjee *et al.* 1980). In Asia, the plant is used for lamp oils and dye (Smith 1995). Since the plant has excited considerable interest because of its medicinal activity and novel metabolites (Das and Das 1994), biochemical companies, or other private interests, in Australia may eventually seek to cultivate the plant.

8.0 Management and Control Practices

8.1 Legislative status in Queensland

Bellyache bush is not a declared plant under the Queensland *Rural Lands Protection Act* 1985. However, at least four Local Governments have listed the plant under their local laws (Burdekin, Belyando, Emerald and Peak Downs Shires). Several additional local governments are considering declaration.

8.2 Legislative status in other States

Bellyache bush is declared as a Class B noxious weed (spread to be controlled) in the Northern Territory (under the *Noxious Weeds Act* 1978).

It is a declared plant in the Derby/West Kimberley and Broome shires (categories P1 and P3) in Western Australia. It cannot be introduced and any plants in the shires must be destroyed (APB Infonote 1994).

8.3 Demand for declaration and control in Queensland

The apparent recent range expansion of bellyache bush has led to a growing number of requests for the plant's declaration under the *Rural Lands Protection Act*. Community-based groups such as the 'Mt Coolon Woody Weeds Action Group' and the 'Bowen Rural Land Care Group' are currently raising awareness of the plant's impact. As public awareness increases, demand for declaration will probably increase.

A bellyache bush focus group, comprising Federal, State and Local Government representatives as well as graziers and Land care members, has been established. The focus group held a workshop at the Tropical Weeds Research Centre in Charters Towers on 4th June 1997. Priorities for research on control and ecology were set and a project plan developed (project entitled: "Ecology and control of bellyache bush"). The workshop recommended that bellyache bush be declared under the *Rural Lands Protection Act* (category P3 in the Local Government areas of Bowen, Burdekin and Dalrymple and category P2 for the remainder of the State) (Anon. 1997).

Several local government weed control officers have commented that declaration is essential in order to remove garden specimens. Without declaration, many landholders refuse to remove garden specimens after being asked to do so. Considering the fact that virtually all naturalised populations of bellyache bush originate from dumped garden specimens, removal of all cultivated specimens is essential to avoid naturalisation of the plant in additional regions.

8.4 Containment and eradication strategies in Queensland

Bellyache bush is too widespread to be eradicated from Australia (Csurhes and Edwards 1998) or from Queensland. However, removal of small, isolated infestations and garden specimens outside the Burdekin catchment appears

feasible (i.e. outside the Local Government areas of Dalrymple/Charters Towers, Bowen and Burdekin). Within these Shires containment strategies should focus on removal of any small, “outlier” populations (where feasible), improvement in landholders awareness of the plant’s potential impact and the provision of information on how landholders can avoid the establishment and proliferation of bellyache bush on their properties. The general aim of control operations should be to remove small “outlier” populations of the plant and restrict its distribution to existing heavily infested areas.

Pre-requisites for improved management of the problem include an improved understanding of the plant’s ecology/biology and the influence of fire and grazing pressure on invasion processes and abundance.

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