Review

The biology of Australian weeds
45. *Calotropis procera* (Aiton) W.T.Aiton

Blair S. Grace, Northern Territory Department of Natural Resources, Environment and the Arts, PO Box 30, Palmerston, NT 0831, Australia.
Email: blair.grace@nt.gov.au

Name

The genus name *Calotropis* is derived from Greek *calos* (beautiful) and *tropis* (keel of a boat), referring to scales in the flowers (Rahman and Wilcock 1991). The specific name *procera* is derived from *cera*, Latin for wax, referring to the leaves (Parsons and Cuthbertson 2001).

Commonly used synonyms for *Calotropis procera* (Aiton) W.T.Aiton (Asclepiadaceae) include *C. procera* (L.) Dryand., *C. procera* (Aiton) R.Br., *C. heterophylla* Wall., *C. busseana* K.Schum, *C. syriaca* Woodson, *C inflexa* Chiov., *Asclepias procera* Aiton and incorrectly, *C. procera* (Willd.) R.Br. ex Aiton (Forster 1992).

The common names rubber bush, rubber tree and Indian milkweed refer to the milky sap or latex produced in the stems and roots. Kapok refers to the fluffy fibre attached to the seeds. Other common names used in Australia include king's crown kapok, auricula tree, cabbage tree, King Edward's crown, Prince of Wales' crown and calotrope.

Description

Calotropis procera is a distinctive medium sized shrub or small tree up to 4 m high. Its stems are grey-green, smooth, rather crooked and older stems are covered with a soft, thick corky bark. The plant commonly branches at the base. Stems exude copious quantities of sticky latex when damaged. Latex is produced by lactifer cells in the stems and roots (Ogundipe 1993).

Leaves are large (5–20 cm long, 4–10 cm wide) and elliptic, rounded or ovate, grey-green in colour, with six prominent veins underneath. Leaves are thick in cross section, with a short pointed tip and a heart-shaped base that partly clasps the stem. Petioles are 3–4 mm long and 4–5 mm wide. A brush of hairs occurs at the base of the midvein. Each pair of opposite leaves is at right angles to adjacent pairs. The plant is not deciduous.

Flowers are more or less tubular, five lobed, 2–3 cm across (Figure 1) without milky sap. They are white with a deep purple blotch at the base of each lobe and deep purple scales between the petals and the stamens. Flowers are grouped in umbels on which the outer flowers open first and the inner ones do not develop fully.

Fruits are grey-green pods 8–12 cm long. They are rounded at the base, but shortly pointed at the tip, similar to a mango. Each fruit contains hundreds of seeds, which are brown, flattened and have a tuft of long white hairs 2–3 cm long at one end. Seeds weigh 5.9–7 mg (Amritphale *et al*. 1984).

The taproot grows up to 4 m long, with spreading lateral roots. Roots form large tubers with a starchy cortex that contains canals full of milky latex, giving roots a spongy texture.

Taxonomy

The genus *Calotropis* contains three species, *C. procera*, *C. gigantea* (L.) W.T.Aiton and *C. acia* Buch.-Ham. (Rahman and Wilcock 1991). *C. acia* is not known to be present in Australia. *C. gigantea* is distinguished from *C. procera* mainly by having wider corollas and shorter sepals. Strains of *C. gigantea* in Australia are sterile, and it is a garden plant that is capable of some limited spread by suckering from roots.

Figure 1. Floral anatomy of *Calotropis procera*. Habit of flowering branch (A), apical view of flower (B), side view of flower with part of corolla removed showing staminal column (C) and side view of staminal corona and staminal column (D). From Forster (1992) (reproduced with permission).

There are no known hybrids of *C. procera* in Australia. Two subspecies of *C. procera* are recognized, but only one, *C. procera* ssp. *procera* is naturalized in Australia (Forster 1992). There is considerable polymorphism within *C. procera* in its native range, but it is morphologically uniform in Australia, suggesting that Australian populations have resulted from one or very few introductions (Forster 1992).

History

Calotropis procera was possibly introduced into Australia through seeds in the padding in camel saddles, or as an ornamental plant during a gold rush in North Queensland (Parsons and Cuthbertson 2001). It was first recorded as naturalized around Chillagoe and Georgetown, North Queensland in 1935, but was present much earlier (Parsons and Cuthbertson 2001). It was first observed in the Northern Territory in the Mataranka area, near Katherine in 1946–7. It spread along the Roper River from there in the 1950s and the Victoria River, in north-western Northern Territory in the 1960s.

In Western Australia, a small patch near Kununurra was recorded in 1965, which had expanded rapidly to 5000 ha by 1969, and the plant now encompasses very large areas of the Kimberley (Figure 2). Earlier records of *C. procera* may exist in Western Australia, but it was confused with *C. gigantea*. *C. procera* was first recorded in northern South Australia in 1989. There is currently concern that it is spreading in central Australia (Chris Brown personal communication).

Calotropis procera was introduced to north-eastern Brazil in the early 1900s (Ellison and Barreto 2004).

Distribution

Calotropis procera is native to tropical and subtropical Africa and Asia but is more common in the Middle East. It occurs in West Africa as far south as Angola, North and East Africa, Madagascar, the Arabian Peninsula, southern and south-eastern Asia, to Malaysia (Rahman and Wilcock 1991). The species is now naturalized in Australia, Indonesia, many Pacific islands, Mexico, Central and South America, the Caribbean islands (USDA NRCS 2004, Rahman and Wilcock 1991) and north-eastern Brazil (Radunz 1983, Ellison and Barreto 2004).

In Australia, *C. procera* is widespread in the northern regions and is a problem in native pastures in drier monsoon areas of tropical Australia (Martin 1996). It is found mostly in northern Queensland, northern parts of the Northern Territory and Western Australia (Figure 2). Infestations further south appear to be spreading; these include patches in northern parts of South Australia and southern Northern Territory, as well as the Barkly Tablelands of Queensland and the Northern Territory. The fact that *C. procera* is widespread in tropical areas with over 1000 mm annual rainfall through to arid areas with rainfall less that 200 mm suggests that it can tolerate a wide range of environmental conditions, hence it has a wide potential distribution (Figure 3).

Habitat

Several authors claim that *C. procera* is most common in overgrazed areas (Cheam 1984a,b,c, Barkhadle *et al.* 1994, Parsons and Cuthbertson 2001, Smith 2002), although it can also persist in other areas with high levels of disturbance, such as coastal sand dunes (Anon. 2001), watercourses and roadsides (Parsons and Cuthbertson 2001). It can also form dense thickets on alluvial flats (Parsons and Cuthbertson 2001). Although dense stands are common in disturbed or heavily grazed areas, *C. procera* is capable of establishing and persisting in areas with good pasture cover (Table 1).

Most dense infestations occur on well drained soil such as sandy levee soils along waterways rather than heavier clays (Table 1). Plants growing in clay have stunted growth (Hall 1967). *C. procera* frequently occurs around oases in arid parts of the Middle East (Willmer 1988) and is common in boundaries between cultivated fields in northern Pakistan (Hussain *et al*. 2003). Its occurrence on coastal sand dunes is probably related to its ability to tolerate high soil salinity (Parsons and Cuthbertson 2001). Its growth increases with increasing nitrogen, but it is capable of surviving and reproducing in soils with low nitrogen (Chadwick and Obeid 1963) and it is clearly able to persist in very poor soils in northern Australia.

There were no gross morphological differences observed between *C. procera* plants growing at low (0–300 m) and high (1700–2000 m) altitudes (Alwadi and Abulfatih 1996). This suggests the plant is tolerant of temperatures ranging from frosts to extreme desert heat. Young stems are surrounded by whitish fluffy indumentum (Ogundipe 1993), which would provide protection from frost and desiccation.

Growth and development

Little is known about the growth, development or phenology of *C. procera* in Australian rangelands. In pot trials, seedlings grew quite slowly initially, but growth rates increased after eight weeks (Table 2). Much of the early growth went into developing a strong root system (Cheam 1984a,b). One mature plant from western Northern Territory (2.4 m high, with stem diameters of 65, 120 and 190 mm) had above-ground portions that weighed 6.6 kg and below ground portions that weighed 2.2 kg (wet weights) (Stuart Wilson unpublished data).

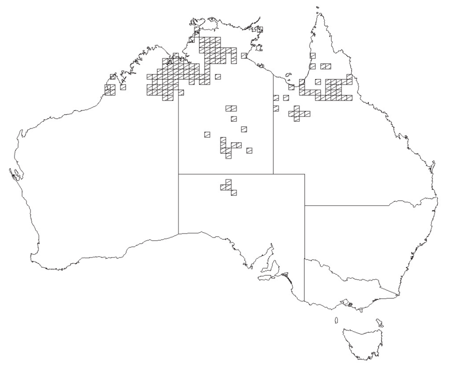

Figure 2. The distribution of *Calotropis procera* in Australia. Data were taken from Forster (1992), Parsons and Cuthbertson (2001), Navie (2004), Australia's Virtual Herbarium (2005), Mark Gardener (personal communication) and Northern Territory Government records.

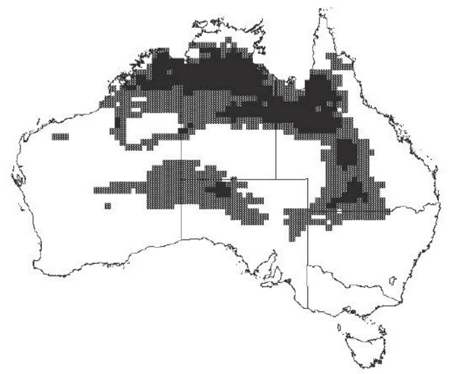

Figure 3. The potential distribution of *Calotropis procera* in Australia. From Thorp and Lynch (2000) (reproduced with permission).

Seedling growth is strongly affected by allelochemicals from buffel grass (*Cenchrus ciliaris* L.), but seed germination and seedling survival is unaffected (Cheam 1984a,b). Young stems contain chlorophyll and become porous as they mature (Ogundipe 1993).

Reproduction

Calotropis procera is capable of producing large quantities of seeds. However, suckering from roots and crowns may be important in the thickening of local patches (Parsons and Cuthbertson 2001, Smith 2001).

Flowers

It is unknown at what age *C. procera* begins to flower and seed, but Parsons and Cuthbertson (2001) tentatively suggest that this occurs once plants are two years old. Flowers appear all year round in the Northern

Table 1. Results of a survey of 10 experienced landholders and weed specialists in the Northern Territory. Numbers refer to the per cent of respondents that answered each particular question.

Question	Responses
Is rubber bush an important weed?	Yes 62%
Why?	Shades out pasture 36%; Invasive 27%; Hard to control 18%; Hinders mustering 18%; Toxic 19%
Should governments invest in control of existing infestations?	Yes 72%
Should governments invest in research?	Yes 78%
Should governments invest in limiting spread?	Yes 67%
Does it invade areas with good pasture cover?	Yes 57%
What sort of country does it seem to do best on?	Well drained soils 100%
Do you think it is spreading in your area?	Yes 62%
Do infestations normally die off or persist?	Persist 72%
Have you noticed stock or other animals eating it?	Yes 100%
What animals browse on rubber bush?	Cattle 100%, goats 10%
What animals never browse on rubber bush?	Horses 100%
Do you suspect it made animals sick?	Yes 14%
Do you suspect it killed any animals?	No 100%
Have you tried to control rubber bush with chemicals?	Yes 80%
Have you tried to control rubber bush with grazing or pasture management	Yes 14%
Have you tried to control rubber bush with fire?	Yes 17%
What effect does fire have?	Comes back, possibly with fewer seeds. It is not always possible to have sufficient grass to support a fire.
What would you recommend as the best way to control or manage this weed?	Picloram + triclopyr + diesel, basal bark 80% Triclopyr + diesel, basal bark 20%
What control techniques have not been successful?	Fluroxypyr foliar spray; Tebuthiuron pellets; Hexazinone granules; Glyphosate foliar spray; 2,4-D foliar spray; Mechanical control; Crash grazing
How much do you spend controlling rubber bush on your property per year (including labour)?	mean $7625

Territory, although there are fewer flowers in the early dry season (April–May) (Hall 1967).

Calotropis procera is pollinated by carpenter bees in Israel, where it appears to be intimately co-evolved with one species (*Xylocopa sulcapites* Maa) (Willmer 1988). In Australia it is pollinated by a range of insects, noticeably bees (Table 3). In the Northern Territory, fruits mature in the wet season (November to February) (Smith 2001).

Seeds

Seeds are produced in November in north-western Northern Territory (Stuart Wilson personal communication). Seeds are dispersed short distances by pods bursting (Smith 2001) and the tufts of hair on the seeds may assist dispersal over short distances by wind (Hall 1967). Human activity, water and possibly animals (Kumar *et al*. 1997) would be important in long distance dispersal. The lipid content of the seeds, combined with surface tension from hairs would provide buoyancy.

Table 2. Heights of seedlings of *Calotropis procera* grown in pots over time since germination. Data from Cheam (1984a,b).

	3 weeks	6 weeks	8 weeks	9 weeks
Seedling height (mm)	45	49.6	50–53	172

In northern Australia, seeds germinate with the onset of the wet season, and growth is rapid until the dry season. *C. procera* seeds are commonly observed germinating in cattle dung heaps in India (Kumar *et al.* 1997).

Most seeds collected in India germinated at temperatures between 28 and 36°C, and germination decreased at temperatures above 36°C (Amritphale *et al*. 1984). Seeds collected from Brazil germinated best between 23 and 33°C, with little germination at 34°C or above (Labouriau and Valadares 1976). Seeds may require exposure to red light in order to germinate (Parsons and Cuthbertson 2001), suggesting that germination is likely to be limited under dense vegetation. However, Amritphale *et al*. (1984) found that germination was not affected by light. Seed weight and effects of scarification have been found to vary between varieties of *C. procera* (Amritphale *et al*. 1984). Between 2 and 35% of seeds collected from India were dormant, and this proportion varied with variety. More seeds became dormant after being stored at room temperature in the dark (Amritphale *et al*. 1984). Very few seeds (0–6%) collected from Brazil were dormant and most seeds germinated within one or two days, depending on temperature (Labouriau and Valadares 1976). Mature seeds contain 10–15% water, which they can retain for up to 45 days in dry conditions (Labouriau and Valadares 1976). The numbers and longevity of *C. procera* seeds in the soil is unknown.

Table 3. Insects found on *Calotropis procera* in northern Australia (Grace unpublished data). Taxonomy follows CSIRO (1991).

Order, Family	Species (common name)	Region[A]	Comment
Hemiptera, Diaspididae	*Pinnaspis* sp. (Scale insect)	Bark	Linked to defoliated, unhealthy plants
Hymenoptera, Apidae	*Apis mellifera* L. (European honey bee)	Kath	Observed visiting flowers, probable pollinator
	Austroplebia sp. (native bee)	VRD	Observed visiting flowers, probable pollinator
Hymenoptera, Syrphidae	unidentified (native bee)	VRD	Observed visiting flowers, probable pollinator
Hymenoptera, Vespidae	*Polistes shach* Fabricius (paper wasp)	VRD	Observed visiting flowers, possible pollinator
Hymenoptera, Formicidae	*Iridomyrmex sanguineus* Forel (meat ant)	VRD	Observed visiting flowers, unlikely to pollinate. Ants are nectar robbers in Israel (Willmer 1988).
	Iridomyrmex sp., *anceps* group	VRD	Observed visiting flowers, unlikely to pollinate
Diptera, Tachinidae	unknown sp.	VRD	Adults observed visiting flowers, possible pollinator. Possible parasitoid of *Danaus petilia*
Lepidoptera, Nymphalidae	*Danaus petilia* Stoll = *D. chrysippus petilia* Miskin (lesser wanderer)	VRD, Kath, Kim	Feeds on leaves, common on Asclepiadaceae throughout Australia (Common and Waterhouse 1981, Lushai *et al.* 2005). Capable of sequestering some plant toxins (Rothschild *et al.* 1975)
Lepidoptera, Psychidae	unknown sp. (case moth)	Kath	*C. procera* leaves had obvious feeding damage

[A] Bark = Barkly region of Northern Territory, Kath = Katherine region of Northern Territory, VRD = Victoria River District of Northern Territory, Kim = Kimberly region of Western Australia.

Population dynamics

Very little is known about the population dynamics of this plant (Parsons and Cuthbertson 2001), a situation that should be redressed (Meadley 1971, Bebawi *et al*. 2002) if sound weed management techniques are to be developed. Dense infestations in riparian zones in the Victoria River District of the Northern Territory contained seven plants per square metre (Hall 1967).

Investigations into this plant's longevity and competitive ability, in particular, have been called for (Bastin *et al.* 2003). Anecdotal observations suggest that certain populations of *C. procera* may persist for several years, and then disappear (Hall 1967, Steve Wingrave personal communication), but there are few data to back up such claims and some landholders suggest that populations persist (Table 1). A large single stemmed plant about 4 m tall had a stem diameter of 20 cm, and counts of growth rings were inconclusive (Blair Grace unpublished data).

If seeds do have a requirement for red light to germinate, as mentioned by Parsons and Cuthbertson (2001), then recruitment is likely to be inhibited under a canopy of vegetation. Bastin *et al*. (2003), however, found plant densities were similar in grazed and ungrazed plots. Most landholders surveyed considered that *C. procera* can invade land with good pasture cover (Table 1). How pasture, grazing and environmental conditions affect seedling germination and recruitment needs to be quantified.

Table 4. Toxic substances found in *Calotropis procera*.

Substance	Effect	Comment	Reference
Latex	Heart poisons	Little latex in leaves	Seiber *et al.* 1982, Watt and Breyer-Brandwijik 1962
Latex	Nausea and vomiting	Little latex in leaves	Parsons and Cuthbertson 2001
Latex	Proteolytic activity		Watt and Breyer-Brandwijik 1962, Atal and Sethi 1962
Latex	Causes keratoconjunctivitis	Eye irritation in humans clears up without intervention	Mahmoud *et al.* 1979
Latex	Killed goats	Administered orally, injected by intravenous and intraperitoneal routes	el Badwi *et al*. 1998
Roots	Inhibits oestrus cycle, prevents pregnancy	Ethanolic extracts used in in-vivo trials with rats	Circosta *et al.* 2001, Kamath and Rana 2002
Various extracts	Anti-sperm		Qureshi and Qureshi 1991

Importance

There is conflicting information about the importance of *C. procera* as a weed in Australia. Landholder perceptions of pasture plants can be shaped by social factors rather than biological or agronomic factors (Allan and Whalley 2004). Some landholders state that *C. procera* may be perceived to be a larger problem than it really is, because it is tall and distinctive (Rod McColm personal communication) and sparse populations of tall weeds may prompt the use of control measures for cosmetic reasons rather than because of effects on pasture productivity (Popay and Field 1996).

Some authors (e.g. Smith 2001) suggest *C. procera* is a high priority weed, which successfully competes with desirable pasture species (Crothers and Newbound 1998) and grazing this plant can lead to stock death. Other authors consider it is only a problem in overgrazed and disturbed areas (Cheam 1984a,b,c) where little useful fodder exists, while other authors suggest it can be a useful fodder.

Some reports suggest that *C. procera* is a useful source of green forage during the dry season and in droughts, particularly in northern Australia. Important weeds can also have value as pasture (e.g. Gardener *et al.* 2005). *C. procera* has been classified as a problem in pastures and roadsides and unique natural ecosystems (scrubland and savannah) in Brazil (Ellison and Barreto 2004).

Detrimental

Calotropis procera can form dense thickets that interfere with stock management, particularly mustering (Crothers and Newbound 1998, Parsons and Cuthbertson 2001, Smith 2001, Table 1). Many landholders consider it a problem, mainly because it shades out pasture, is capable of rapid invasion and is hard to manage (Table 1). There are no data on impacts of *C. procera* on biodiversity.

Calotropis procera contains a range of toxic compounds (Table 4), many of which are concentrated in the latex. Leaves can take up heavy metals (Pb, Co, Ni, Mn, Cr, Cd and Cu) present in the environment (Díaz and Massol-Deya 2003).

Pastoralists and weed specialists surveyed found little evidence that stock die or become sick as a result of browsing on *C. procera* in Australia (Table 1), and pathology tests found no evidence of toxicity to stock (Radunz *et al.* 1984). Although ingesting large quantities of latex has killed goats and rats, it is important to note that there is little latex in the leaves (Parsons and Cuthbertson 2001), the part most likely to be eaten by stock. However, one weed specialist commented that cattle can become sick after eating large quantities of leaves, although this rarely happens (Murray Fuller personal communication).

Goats that ate larger quantities of latex, or had it injected died, but ingesting small doses (0.005 mL per kg body weight per day) of latex resulted in no deaths, but gave rise to symptoms such as nervous signs, frequent urination, frothing at the mouth, dyspnoea and diarrhoea (el Badwi *et al.* 1998). Ingesting latex caused rats to lose weight, but produced no changes in measured blood parameters (Dada *et al.* 2002). Feeding high doses (5–10% w/v of diet) to rats resulted in severe liver damage and death (Pahwa and Chatterjee 1988). The rate of latex production in India is lowest in the dry season (Atal and Sethi 1962), which is when *C. procera* is most likely to be grazed.

Compounds produced for plant defence commonly vary with season, stage of plant development, and environmental conditions and may even be induced as a result of herbivory. Lev-Yadun and Ne'eman (2004) hypothesize that toxic compounds and volatile secondary compounds with repellent odours in *C. procera* are likely to increase over the dry season.

Everist (1981) concluded that *C. procera* was very unpalatable but sometimes eaten by stock. Powdered stems are slightly bitter to humans (Ogundipe 1993). The palatability of *C. procera* to stock may vary between sites. Cattle and sheep may avoid eating the plant in India and parts of Africa, but commonly eat it in Indonesia (Radunz 1983). *C. procera* contributed a small (<3%) proportion of the diet of sheep, cattle and goats on the southern boundary of the Sahara Desert (Nolan 1999). In West Africa, sheep and goats eat flowers and withered leaves, but generally avoid fresh leaves (Watt and Breyer-Brandwijik 1962). In feeding trials in the Northern Territory, sheep initially avoided fresh leaves and flowers, but ate them readily after six weeks, and cattle readily ate hammer milled leaves and flowers (Radunz 1983). Goats readily ate dried *C. procera* leaves as up to 50% of dietary dry matter in Sudan (Abbas *et al.* 1992).

Calotropis procera is browsed by stock in northern tropical parts of Australia, but it has been suggested that populations in arid Australia are not palatable (Crothers and Newbound 1998), possibly because environmental conditions trigger production of defensive compounds (Lev-Yadun and Ne'eman 2004). It is also possible that northern regions have more grass available, so *C. procera* can be used as a high nitrogen supplement to fibre with low digestibility, compared to more arid regions, where less grass is generally available. A recent survey of landholders across the Northern Territory, however, suggests that the plant is commonly browsed by cattle across its range (Table 1).

Beneficial

Calotropis procera may be more useful as a browse than commonly thought. Much of the research on *C. procera* may have been biased towards looking at its toxic components rather than the potential to use it as stock feed (Abbas *et al.* 1992). Leaves do have useful nutrients; they contain 16–20% protein, low tannin (3.1%) (Abbas *et al.* 1992, Touré *et al.* 1998) and high levels of minerals, although much of the calcium is bound up in oxalate crystals (Atal and Sethi 1962, Ogundipe 1993). Adding up to 75% of dietary dry matter from *C. procera* leaves improved digestibility of rice straw and peanut cake-based diets fed to sheep, and *C. procera* was more digestible than several other tree forages tested (Touré *et al.* 1998). Anecdotal evidence suggests that camels suffering from night blindness caused by Vitamin A deficiency can be cured by forcing them to eat *C. procera* leaves (Abbas *et al.* 1992). Steers fed *C. procera* milled leaves (up to 10 g per kg body weight per day) in the Northern Territory actually gained more weight than the control group that was fed rice and hay (Radunz *et al.* 1984).

It has been suggested that stock may tolerate *C. procera* as part of the diet under good conditions, but may die from eating *C. procera* when stressed (e.g. during mustering) (Anon. 2001, Smith 2001). *C. procera* retains green leaves all year round, even during poor seasons, so sometimes it may be the only green feed available.

Some of the biologically active compounds in *C. procera* have potential for use in the pharmacological industry and the plant has been used extensively for medicinal purposes in many countries. Traditional uses and pharmacologically active compounds in *C. procera* have been comprehensively studied (summarized in Table 5).

Calotropis procera also has a range of traditional non-medicinal uses. Arab tribesmen once burned its wood to obtain a fine-texture charcoal used in gunpowder. The fibres attached to the seeds have been used in padding and weaving, and intoxicating liquor has been produced from this plant (Rahman and Wilcock 1991). The latex has been used to coat arrow heads in India and Africa. In addition, its anti-nematode properties (Khurma and Chaudhary 1999) have led to it being used as green mulch that can reduce crop losses from nematodes. Cloth has been produced from fibres in *C. procera* stems (Varshney and Bhoi 1988), and the latex has been used to curdle milk and help ferment beer (Watt and Breyer-Brandwijik 1962). Proteolytic enzymes in the latex have potential commercial uses in food preparation (Atal and Sethi 1962). *C. procera* has also been well studied as a potential fuel source.

As oil prices increased in the late 1970s, many plants, including *C. procera*, were investigated as potential sources of liquid fuel (Cribb 1980). Stems, leaves and pods all contained extracts with energy levels comparable to coal and fossil fuels (Erdman and Erdman 1981). Further research found that although it is feasible to produce diesel and petrol from resin in *C. procera* stems, this is vastly more expensive than doing so from oilseed crops such as sunflower, which are in turn more expensive than crude oil (Bell 1982). More recently Behera *et al*. (2000) found that allowing microbes to break down the *C. procera* latex could make the process much cheaper. *C. procera* seeds are 26% oil (Osman and Ahmad 1981), but they are small, and produced in low numbers compared to many existing crop plants, so *C. procera* has little potential for use as an oil seed crop. Much of the oil is saturated, and unlikely to have pharmacological or industrial uses (Osman and Ahmad 1981).

It has even been suggested that *C. procera* is useful as an obvious indicator of poor rangeland condition in northern Australia. Under such conditions, its deep root system may also be useful in reducing erosion and it could be planted to stabilize sand dunes in its native range (Khan 1997).

Legislation

Calotropis procera is a Class B weed (growth and spread is to be controlled) in the Northern Territory, south of 16°30' (Miller 2003). In Western Australia it is a P1 weed (movement of plants and seeds, including contaminated stock, fodder and machinery is prohibited) north of 26°S, excluding

Table 5. Selected substances found in *Calotropis procera* with potential or traditional medical or veterinary uses.

Substance	Effect	Comment	Reference
Flowers, buds, roots	Anti-malaria	Various fractions tested in vitro	Sharma and Sharma 1999
Flowers	Steroid with unspecified effects		Khan and Malik 1989
Leaves	Cures night blindness	May help overcome Vitamin A deficiencies in stock	Abbas *et al.* 1992
Latex	Topical fungicide	Applied topically to stock. Kills ringworm and promotes hair regrowth	Ahmad *et al.* 2004
Latex	Anti-coccidia	Latex given orally to treat *Eimeria ovinoidalis* Tarım in sheep	Mahmoud *et al.* 2001
Latex	Treatment of haemorrhoids	Administered anally	Giday 2001
Latex	Topical disinfectant	Applied topically latex has bacteriolytic activities	Rahman and Wilcock 1991, Shukla and Murti 1961
Latex	Anti-diarrhoea	Dried	Kumar *et al.* 2001, Burkill 1985
Latex	Anti-viral properties	Inhibits Tobacco Mosaic Virus infection, when applied to leaves	Khurana and Singh 1972
Latex or powdered seeds	Treatment of blackleg (*Clostridium* spp.) in stock	Administered topically	Giday 2001
Latex	Analgesic	Various extracts from latex	Majumder and Kumar 1998
Root	Toothache cure	Root used as toothbrush	Watt 1889 (in Rahman and Wilcock 1991)
Root	Anti-inflammatory, analgesic	Extract from roots	Basu and Nag Chaudhuri 1991, Rahman and Wilcock 1991
Roots	Anti-ulcer	Chloroform extract from roots	Basu *et al.* 1998
Root bark	Used in treating dysentery, and as expectorant		Atal and Sethi 1962
Twigs	Anti-diarrhoea	Twigs dried and powdered	Burkill 1985
Bark	Cure for elephantiasis, leprosy, eczema	Applied topically	Wren 1975
Whole plant	Anthelmintic		Atal and Sethi 1962

certain municipal districts, and a P2 (targeted for eradication) weed in certain municipal districts (Department of Agriculture 2004). It is not currently a declared noxious weed in any other Australian state or territory. *C. procera* is specifically excluded from the list of plant seeds permitted to be imported into Australia (Schedule 5 of the *Federal Quarantine Proclamation* 1998). However, this list is presently under revision.

Weed management

The vast areas of the Northern Territory, western Queensland and northern Western Australia infested by *C. procera* make control difficult, expensive and often impractical (Parsons and Cuthbertson 2001), especially when much of this land has little production value. 'There is no economical method of controlling extensive infestations of calotrope [*C. procera*] under pastoral situations' (Cheam 1984c). Research into cheaper control options for larger areas, such as biological control and fire, should be a high priority (Bebawi *et al*. 2002).

Herbicides

There are currently no herbicides specifically registered for control of *C. procera* in Australia, although trials have been completed with the aim of registration (Joe Vitelli personal communication). Herbicides that have previously been registered for *C. procera* include picloram, 2,4-D, imazethapyr and triclopyr (Parsons and Cuthbertson 2001, Smith 2001). These herbicides were applied using cut-stump and basal bark methods for larger plants, which would be time consuming, and hence impractical for scattered plants in rangelands. Smaller plants could be treated with foliar spray. Herbicide treatments often had to be repeated (Parsons and Cuthbertson 2001). Basal bark applications of picloram plus triclopyr mixed in diesel appears to be the most commonly used means of controlling *C. procera* (Table 1), giving a kill rate of around 90% (Murray Fuller personal communication).

Grazing and pasture management

'Grazing management that promotes a large body of perennial grass growth is the most positive form of calotrope [*C. procera*] control' (Milson 2000). Parsons and Cuthbertson (2001) suggest that managing *C. procera* requires drastic changes in grazing management, especially reducing stocking rates. Interestingly, only one landholder surveyed had attempted to manage *C. procera* by crash grazing a small infestation. This resulted in a higher density infestation the following wet season. Hard grazing by cattle had some success in controlling the weed in the Victoria River District of the Northern Territory (Hall 1967). Long term weed containment in pastures and rangelands requires knowledge of the plant's biology (Popay and Field 1996), but such information is not available for *C. procera* and there are very few data about managing weeds using grazing in the tropics.

A long-term grazing exclusion trial suggested possible effects of grazing and pasture competition on *C. procera* populations. Five years after cattle were excluded from parts of run-down pastures in the north west of the Northern Territory, less *C. procera* occurred in grazed plots than in ungrazed plots. After 16 years, the density of *C. procera* was similar between grazed and ungrazed plots, and there was no

C. procera recorded after this (Bastin *et al.* 2003). The authors note that grazing pressure outside the exclosures had been low during this trial, and that it took more than six years for the biomass of perennial grasses to recover both inside and outside the enclosures. These results suggest that cattle may reduce recruitment of *C. procera*, possibly by feeding on young plants. If seeds do require exposure to red light to germinate, then a good sward of perennial grass is likely to prevent establishment and spread.

Growth of *C. procera* seedlings, but not seed germination, was inhibited by allelochemicals from buffel grass (*Cenchrus ciliaris* L.) (Cheam 1984a), concentrated in the upper soil surface (Cheam 1984b). Careful consideration should be made before planting buffel grass, as it can be a nuisance itself (see Puckey and Albrecht 2004), and likely to be more of a concern to land managers of conservation areas than *C. procera* (John Woinarski personal communication). In addition *C. procera* commonly grows alongside buffel grass in northern Western Australia (Blair Grace personal observation). As for most weeds of grazing land, grazing management should focus on promoting perennial grasses.

Physical

Physical removal of *C. procera* can be effective if most of the roots are removed (Hall 1967), or at least the top 25–30 cm (Parsons and Cuthbertson 2001, Department of Agriculture 2004). This can be very hard to achieve (Smith 2001) and would rarely be economically feasible in rangelands. Single shallow ploughing is useless as plants rapidly grow back (Hall 1967, Stuart Wilson personal communication), often as stands of multi stemmed plants that occupy more space than before ploughing (Steve Wingrave personal communication). Commonly used weed control techniques such as chaining and stick-raking generally are therefore unlikely to be effective.

Fire

The large energy stores in the roots allow plants to regrow after fire (Anon. 2001). Landholders sometimes burn infestations in November in the Victoria River District of the Northern Territory to prevent seeding and flowering (Stuart Wilson personal communication), and plants that grow back the following year may produce fewer seeds (Table 1). As for grazing, the use of fire to manage *C. procera* should also consider the likely effects on perennial grasses present. There is commonly little fuel available under dense *C. procera* stands to support hot fires in pastoral areas of the Northern Territory.

Natural enemies

Given the range of toxic compounds contained in *C. procera*, it is not surprising that the plant is attacked by few phytophagic insects in its native range (Abbassi *et al.* 2003, Lev-Yadun and Ne'eman 2004). Few insects cause more than minor damage to *C. procera* in Australia, and Table 3 lists some of these. An unidentified stem borer destroyed most above-ground growth of *C. procera* in several square kilometres in the Kimberly region of Western Australia, but several months later the insect could not be found and the plant had regrown from rootstock (Blair Grace unpublished data).

Ellison and Barreto (2004) suggest that *C. procera* in Latin America is a suitable target for classical biological control. In a survey of fungi on *C. procera* in Brazil, Barreto *et al*. (1999) found three species with potential for use as biological control agents. *Phaeoramularia calotropidis* Ell. & Everh. forms lesions on leaves. It is widespread in tropical America, Egypt, India, Pakistan, Myanmar, Africa and Brazil. Although damaging in Sudan, it appears to have little impact in Brazil. *Mycosphaerella* sp. (possibly a reproductive phase of *P. calotropidis*) covers leaves with black sooty growth and causes leaf distortion. The third potential fungus, *Uredo calotropidis* Cummins, requires investigations into its taxonomy and host range. A fruit fly *Dacus longistylus* Wiedemann was observed destroying fruit in Sudan (Parsons and Cuthbertson 2001), but has no potential for use in classical biological control because it is also a pest of crops.

Acknowledgments

Thanks to the many people who contributed to this paper, in particular Mark Gardener and Andrew Mitchell who gave valuable comments and suggestions about early drafts. Cameron Yates helped produce maps. Ben Hoffmann, Glenn Bellis and Graham Brown helped identify insects and provided information on their ecology. The input of everyone who replied to the surveys is greatly appreciated, especially Larry Johns and Murray Fuller. Paul Forster allowed me to use his diagrams, and Stuart Wilson kindly dug up an entire bush and weighed it.

References

Abbas, B., El Tayeb, A.E. and Sulleiman, Y.R. (1992). *Calotropis procera* – feed potential for arid zones. *Veterinary Record* 131, 132.

Abbassi, K., Atay-Kadiri, Z. and Ghaout, S. (2003). Biological effects of alkaloids extracted from three plants of Moroccan arid areas on the desert locust. *Physiological Entomology* 28, 232-6.

Ahmad, H., Khan, S., Khan, A. and Hamayun, M. (2004). Ethnobotanical resources of Manikhel Forests, Orakzai Tirah, Pakistan. *Ethnobotanical Leaflets.* http://www.siu.edu/~ebl/. Accessed January 2005.

Allan, C. and Whalley, R.D.B. (2004). Some factors influencing landholder opinion of the native grass *Microlaena stipoides*. *Rangeland Journal* 26, 178-89.

Alwadi, H.M. and Abulfatih, H.A. (1996). Uniformity of morphological characteristics of *Calotropis procera* found at two altitudinal ranges, in Saudi Arabia. *Arab Gulf Journal of Scientific Research* 14, 169-76.

Amritphale, D., Gupta, J.C. and Iyengar, S. (1984). Germination polymorphism in sympatric populations of *Calotropis procera*. *Oikos* 42, 220-4.

Anon. (2001). Calotrope. Facts Pest Series, PP41, Queensland Government.

Atal, C.K. and Sethi, P.D. (1962). Proteolytic activity of some Indian plants. II. Isolation, properties, and kinetic studies of calotropain. *Planta Medica* 10, 77-90.

Australia's Virtual Herbarium (2005). Centre for Plant Biodiversity Research, Council of Heads of Australian Herbaria (http://www.cpbr.gov.au/cgi-bin/avh.cgi). Accessed January 2005.

Barkhadle, A.M.I., Ongaro, L. and Pignatti, S. (1994). Pastoralism and plant cover in the lower Shabelle region, Southern Somalia. *Landscape Ecology* 9, 79-88.

Barreto, R.W., Evans, H.C. and Pomella, A.W.V. (1999). Fungal pathogens of *Calotropis procera* (rubber bush), with two new records from Brazil. *Australasian Plant Pathology* 28, 126-30.

Bastin, G.N., Ludwig, J.A., Eager, R.W., Liedloff, A.C., Andison, R.T. and Cobiac, M.D. (2003). Vegetation changes in a semiarid tropical savanna, northern Australia. *Rangeland Journal* 25, 3-19.

Basu, A. and Nag Chaudhuri, A.K. (1991). Preliminary studies on the antiinflammatory and analgesic activities of *Calotropis procera* root extract. *Journal of Ethnopharmacology* 31, 319-24.

Basu, A., Sen, T., Pal, S., Mascolo, N., Capasso, F. and Nag Chaudhuri, A.K. (1998). Studies on the antiulcer activity of the chloroform fraction of *Calotropis procera* root extract. *Phytotherapy Research* 11, 163-5.

Bebawi, F.F., Campbell, S.D. and Stanley, T.D. (2002). Priority lists for weed research in the wet- and dry-tropics of north Queensland. *Plant Protection Quarterly* 17, 67-73.

Behera, B.K., Arora, M. and Sharma, D.K. (2000). Studies on biotransformation of *Calotropis procera* latex – a renewable source of petroleum, value-added chemicals and products. *Energy Sources* 22, 781-807.

Bell, A. (1982). High cost of fuel from sappy plants. *Ecos* 32 (Winter, 1982), 13-14.

Burkill, H.M. (1985). 'The useful plants of West Tropical Africa', 2nd edition. (Royal Botany Gardens, London).

Chadwick, M.J. and Obeid, M. (1963). The response to variations in nitrogen level of some weed species of the Sudan. *Weed Research* 3, 230-41.

Cheam, A.H. (1984a). Allelopathy in buffel grass (*Cenchrus ciliaris*) Part 1. Influence of buffel grass association on calotrope (*Calotropis procera* (Ait.) W.T.Ait.). *Australian Weeds* 3, 133-6.

Cheam, A.H. (1984b). Allelopathy in buffel grass (*Cenchrus ciliaris*) Part 2. Site of release and distribution of allelochemical in the soil profile. *Australian Weeds* 3, 137-9.

Cheam, A.H. (1984c). A 'natural herbicide' against calotrope. *Journal of Agriculture, Western Australia* 25, 42-3.

Circosta, C., Sanogo, R. and Occhiuto, F. (2001). Effects of *Calotropis procera* on oestrous cycle and on oestrogenic functionality in rats. *Farmaco* 56, 373-8.

Common, I.F.B. and Waterhouse, D.F. (1981). 'Butterflies of Australia'. (Angus and Robertson, Hong Kong).

Cribb, J. (1980). Oil strike on the farm. *National Farmer* 13 November 1980, pp. 8-9.

Crothers, M. and Newbound, S. (1998). Rubber bush. Agnote F64, Northern Territory Department of Primary Industries and Fisheries, Darwin.

CSIRO (1991). 'The insects of Australia'. (Melbourne University Press, Melbourne).

Dada, Y.O., Lamidi, M.T., Eghianruwa, K.I. and Adepoju, F. (2002). Effects of oral administration of the latex of *Calotropis procera* on weights, hematology and plasma biochemistry in rats. *Tropical Veterinarian* 20, 218-25.

Department of Agriculture (Western Australia) (2004). Declared plant list. (http://agspsrv34.agric.wa.gov.au/programs/app/Weeds/calotropis_d.htm). Accessed December 2004.

Díaz, E. and Massol-Deya, A. (2003). Trace element composition in forage samples from a military target range, three agricultural areas, and one natural area in Puerto Rico. *Caribbean Journal of Science* 39, 215-20.

el Badwi, S.M.A., Adam, S.E.I., Shigidi, M.T. and Hapke, H.J. (1998). Studies on laticiferous plants: Toxic effects in goats of *Calotropis procera* latex given by different routes of administration. *Deutsche Tierarztliche Wochenschrift* 105, 425-7.

Ellison, C.A. and Barreto, R.W. (2004). Prospects for the management of invasive alien weeds using co-evolved fungal pathogens: a Latin American perspective. *Biological Invasions* 6, 23-45.

Erdman, M.D. and Erdman, B.A. (1981). *Calotropis procera* as a source of plant hydrocarbons. *Economic Botany* 35, 467-72.

Everist, S.L. (1981). 'Poisonous plants of Australia'. (Angus and Robertson, Sydney).

Forster, P.I. (1992). A taxonomic account of the genus *Calotropis* R.Br. (Asclepiadaceae) in Australia. *Nuytsia* 8, 201-8.

Gardener, M.R., Sindel., B.M., Whalley, R.D.B. and Earl, J.M. (2005). Can *Nassella neesiana*, Chilean needle grass, be incorporated into a grazing management system in Australia? *Plant Protection Quarterly* 20, 36-40.

Giday, M. (2001). An ethnobotanical study of medicinal plants used by the Zay people in Ethiopia. *CBM Skriftserie* 3, 81-99.

Hall, N.H. (1967). Noxious weeds: rubber bush. Pamphlet 13, Northern Territory Administration, Primary Industries Branch, Darwin.

Hussain, I., Cheema, A.M. and Khan, A.A. (2003). Small rodents in the crop ecosystem of Pothwar Plateau, Pakistan. *Wildlife Research* 30, 269-74.

Kamath, J.V. and Rana, A.C. (2002). Preliminary study on antifertility activity of *Calotropis procera* roots in female rats. *Fitoterapia* 73, 111-5.

Khan, A.Q. and Malik, A. (1989). A steroid from *Calotropis procera*. *Phytochemistry* 28, 2859-61.

Khan, M.H. (1997). Sand dune vegetation of Cholistan (Pakistan) and some control measures against wind erosion. Wind Erosion: An International Symposium/Workshop, Manhattan, Kansas, USA. http://www.weru.ksu.edu/symposium/.

Khurana, S.M.P. and Singh, S. (1972). Studies on *Calotropis procera* latex an inhibitor of tobacco mosaic virus. *Phytopathology Z* 73, 341-6.

Khurma, U.R. and Chaudhary, P. (1999). Comparative effects of extracts of different parts of *Calotropis procera*, *Cassia fistula*, *Ricinus communis* and *Sesbania sesban* on *Meloidogyne javanica* juveniles. *Journal of Environmental Biology* 20, 287-8.

Kumar, S., Bagchi, G.D. and Darokar, M.P. (1997). Antibacterial activity observed in the seeds of some coprophilous plants. *Pharmaceutical Biology* 35, 179-84.

Kumar, S., Dewan, S., Sangraula, H. and Kumar, V.L. (2001). Anti-diarrhoeal activity of the latex of *Calotropis procera*. *Journal of Enthopharmacology* 76, 115-8.

Labouriau, L.G. and Valadares, M.E.B. (1976). On the germination of seeds of *Calotropis procera* (Ait.) Ait.f. *Anais da Academia Brasileira de Ciências, Caracas* 48(2), 236-84.

Lev-Yadun, S. and Ne'eman, G. (2004). When may green plants be aposematic? *Biological Journal of the Linnean Society* 81, 413-6.

Lushai, G., Zalucki, M.P., Smith, D.A., Goulson, D. and Daniels, G. (2005). The lesser wanderer butterfly, *Danaus petilia* (Stoll 1790) stat. rev. (Lepidoptera: Danainae), reinstated as a species. *Australian Journal of Entomology* 44, 6-14.

Mahmoud, O.M., Adam, S.E.I. and Tartour, G. (1979). The effects of *Calotropis procera* on small ruminants. *Journal of Comparative Pathology* 89, 251.

Mahmoud, O.M., Haroun, E.M., Sobaih, M.A., Omer, O.H. and Adam, S.E.I. (2001). Comparative efficacy of *Calotropis procera* latex and sulfadimidine against experimentally-induced *Eimeria ovinoidalis* infection in Najdi lambs. *Small Ruminant Research* 42, 135-40.

Majumder, P.K. and Kumar, V.L. (1998). Antiinflammatory activity of fractions of latex of *Calotropis procera* in carrageenan induced rat paw oedema. *Phytotherapy Research* 11, 166-7.

Martin, C.C. (1996). Weed control in tropical ley farming systems: a review. *Australian Journal of Experimental Agriculture* 36, 1013-23.

Meadley, G.R.W. (1971). Calotropis, or rubber tree (*Calotropis procera* (Linn.) Dryand.). *Journal of Agriculture, Western Australia* 12, 69-71.

Miller, I.L. (2003). Declared weeds of the Northern Territory. Information Sheet 7, Department of Business, Industry and Resource Development, Darwin.

Milson, J. (2000). 'Trees and shrubs of north-west Queensland'. (Department of Natural Resources, Brisbane).

Navie, S. (2004). 'Declared Plants of Australia: An Identification and Information System'. (CD ROM, University of Queensland, Brisbane).

Nolan, T. (1999). Natural resource development and utilisation in the Sahal. Report for European Commission STD-3 projects.

Ogundipe, O.T. (1993). Studies of *Calotropis procera* (Ait.) Ait.f.: The anatomy of stem. *Phytomorphology* 43, 147-52.

Osman, S.M. and Ahmad, F. (1981). Forest oilseeds. *In* 'New sources of fats and oils', eds E.H. Pryde, L.H. Princen and K.D. Mukherjee. pp. 109-27. (American Oil Chemist's Society, Indianapolis).

Pahwa, R. and Chatterjee, V.C. (1988). The toxicity of Indian *Calotropis procera* R.Br. latex in the black rat, *Rattus rattus* Linn. *Veterinary and Human Toxicology* 30, 305-8.

Parsons, W.T. and Cuthbertson, E.G. (2001). 'Noxious weeds of Australia', 2nd edition. (CSIRO Publishing, Melbourne).

Popay, I., and Field, R. (1996). Grazing animals as weed control agents. *Weed Technology* 10, 217-31.

Puckey, H. and Albrecht, D. (2004). Buffel grass (*Cenchrus ciliaris*): Presenting the arid NT experience to our South Australian neighbours. *Plant Protection Quarterly* 19, 69-72.

Qureshi, M.A. and Qureshi, N.M. (1991). A study on the anti-sperm activity in extracts from different parts of *Calotropis procera*. *Pakistan Journal of Zoology* 23, 161-6.

Radunz, B.L. (1983). Toxicity experiments of rubberbush (*Calotropis procera*) fed to cattle and sheep. Technote 30, Northern Territory Department of Primary Industries.

Radunz, B.L., Wilson, G. and Beere, G. (1984). Feeding rubberbush (*Calotropis procera*) to cattle and sheep. *Australian Veterinary Journal* 61, 243-4.

Rahman, M.A. and Wilcock, C.C. (1991). A taxonomic revision of Calotropis (Asclepiadaceae). *Nordic Journal of Botany* 11, 301-8.

Rothschild, M., von Euw, J., Reichstein, T., Smith, D.A.S. and Pierre, J. (1975). Cardenolide storage in *Danaus chrysippus* (L.) with additional notes on *D. plexippus* (L.). *Proceedings Royal Society London (B)* 190, 1-31.

Seiber, J.N., Nelson, C.J. and Lee, S.M. (1982). Cardenolides in the latex and leaves of seven *Asclepias* species and *Calotropis procera*. *Phytochemistry* 21, 2343-8.

Sharma, P. and Sharma, J.D. (1999). Evaluation of in vitro schizontocidal activity of plant parts of *Calotropis procera* – an ethnobotanical approach. *Journal of Ethnopharmacology* 68, 83-95.

Shukla, O.P. and Murti, C.R.K. (1961). Bacteriolytic activity of plant latices. *Journal of Scientific and Industrial Research* 20, 225-6.

Smith, N.M. (2001). 'Not from here: Plant invasions on Aboriginal lands of the Top End'. (Tropical Savanna CRC, Darwin).

Smith, N.M. (2002). 'Weeds of the wet/dry tropics of Australia – a field guide'. (Environment Centre NT, Darwin).

Thorp, J.R. and Lynch, R. (2000). The determination of Weeds of National Significance. (National Weeds Strategy Executive Committee, Launceston).

Touré, S.F., Michalet-Doreau, B., Traoré, E., Friot, D. and Richard, D. (1998). Occurrence of digestive interactions in tree forage-based diets for sheep. *Animal Feed Science and Technology* 74, 63-78.

USDA NRCS (2004). The PLANTS Database, Version 3.5 (http://plants.usda.gov). (National Plant Data Center, Baton Rouge, LA). Accessed December 2004.

Varshney, A.C. and Bhoi, K.L. (1988). Cloth from blast fibre of the *Calotropis procera* (Aak) plant. *Biological Wastes* 26, 229-32.

Watt, J.M. and Breyer-Brandwijik, M.G. (1962). 'The medicinal and poisonous plants of southern and eastern Africa', 2nd edition. (Livingstone, Edinburgh).

Watt, S.G. (1889). 'A dictionary of the commercial products of India. Volume I.' (Superintendent of Government Printing of India, Calcutta). (In Rahman and Wilcock 1991).

Willmer, P.G. (1988). The role of insect water balance in pollination ecology: *Xylocopa* and *Calotropis*. *Oecologia* 76, 430-8.

Wren, R.C. (1975). 'Potter's new cyclopaedia of botanical drugs and preparations'. (Health Science Press, Devon).