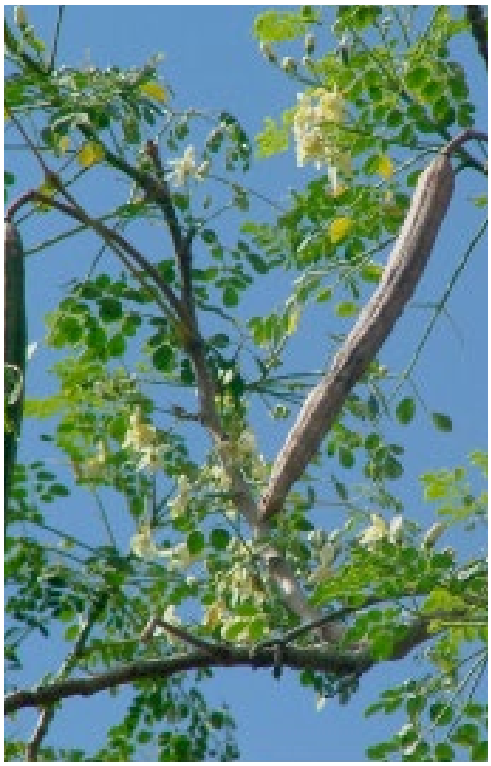
Department of **Agriculture and Fisheries**
Biosecurity Queensland

Invasive plant risk assessment

Horseradish tree

Moringa oleifera



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Front cover: *Moringa oleifera*
Photo: Sheldon Navie

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Summary

Moringa oleifera is a small to medium-sized deciduous tree that develops a swollen underground rootstock. It produces large elongated capsules, each containing numerous seeds.

Moringa oleifera has been grown since ancient times and is now widely cultivated and naturalised throughout the tropical and subtropical world. It is drought resistant, preferring regions with a wet/dry climate, but can grow in a wide range of habitats on a variety of soils.

Almost all parts of the plant are potentially useful, including for food, fodder, medicine, fuel wood and fertiliser. The seeds are probably the most useful part of the plant, containing a significant percentage of high quality oil. Recently, the large-scale cultivation of *Moringa oleifera* has been suggested as a potential source of biofuel.

This species is regarded as potentially invasive or moderately invasive in tropical regions of the world. It has escaped from gardens in northern Australia, and is currently naturalised in north Queensland and northern Western Australia. Currently, it is considered a minor weed in northern Australia, but its status may change over time.

Moringa oleifera appears to spread relatively slowly, eventually forming dense thickets around parent trees. Like other tree species with similar ecological characteristics, it may pose a long-term threat to certain natural ecosystems in the wet/dry tropics of northern Australia. The large-scale commercial cultivation of this species might accelerate the rate of naturalisation and population development in northern Australia.

Introduction

Identity and taxonomy

Species identity: *Moringa oleifera* Lam.

Common names: annual drumstick, annual moringa, behen tree, behn tree, ben oil tree, ben tree, benzolive tree, cabbage tree, clarifier tree, drum stick, drum stick plant, drum stick tree, drumstick, drumstick tree, drumsticktree, horse radish tree, horseradish, horse-radish tree, horseradish tree, kelor, kelor tree, miracle tree, moringa, moringa tree, mother's best friend, never die, River Nile tree, West Indian ben, sprokiesboom [Afrikaans], sajna [Bengali], ben ailée [French], mouroungue [French], moringa ailée [French], néverdié [French], pois quénique [French], meerrettichbaum [German], munuga [Hindi], saijan [Hindi], seijan [Hindi], muringueiro [Portuguese], quiabo-da-quina [Portuguese], morunga [Sinhalese], murunga [Sinhalese], maranga [Spanish], paraíso [Spanish] and paraíso blanco [Spanish], mzunze [Swahili], mronge [Swahili], mrongo [Swahili], mlonge [Swahili], kamunggay [Tagalog], malunggay [Tagalog], chum ngây [Vietnamese]

Synonyms: *Anoma moringa* (L.) Lour., *Guilandina moringa* L., *Hyperanthera decandra* Willd., *Hyperanthera moringa* (L.) Vahl, *Hyperanthera pterygosperma* Oken, *Moringa edulis* Medic., *Moringa erecta* Salisb., *Moringa moringa* (L.) Small, *Moringa myrepsica* Thell., *Moringa nux-eben* Desf., *Moringa octogona* Stokes, *Moringa oleifera* Lour., *Moringa parviflora* Noronha, *Moringa polygona* DC., *Moringa pterygosperma* Gaertn., *Moringa zeylanica* Pers., *Copaiba langsdorfii* (Desf.) Kuntze, *Copaifera langsdorffii* Desf., orth. var., *Copaifera nitida* Hayne, *Copaifera sellowii* Hayne

Family: Moringaceae

The *Moringa* genus comprises some 13 species from Africa, Madagascar, western Asia and the Indian subcontinent (Verdcourt 1985). *Moringa* is the only genus in the family Moringaceae. The species in the genus *Moringa* have generally been divided into three groups or sections in the past (i.e. Moringa, Donaldsonia and Dysmoringa in Verdcourt 1985), but have also recently been categorised by habit, wood anatomy and phylogenetic trees (Olson 2002). Section Donaldsonia or the 'bottle tree' group consists of four species of trees, mostly from southern Africa and Madagascar, with swollen trunks and radially symmetrical flowers (Olson 2002). A second group known as the 'tuberous clade', comprising section Dysmoringa and part of section Moringa, consists of six species of tuberous shrubs and sarcorhizal trees from north-eastern Africa with thick and fleshy tuberous roots (Olson 2002). The third group, to which *Moringa oleifera* belongs, is known as the 'slender tree clade'. It consists of three species of slender-trunked trees, from the Indian subcontinent and the Arabian Peninsula, with tough roots and bilaterally symmetrical flowers (Olson 2002). The other two species in this group are *M. concanensis* and *M. peregrina*.

Description

The following description was generated from Qaiser (1973), Stanley (1982), Verdcourt (1985), ICRAF (2001) and Lu and Olson (2001).

Moringa oleifera is a deciduous tree occasionally growing up to 15 m in height, but is usually less than 10 m tall (Figure 1).

Figure 1. Habit of *Moringa oleifera* (photo: Chris Gardiner)

It has a large underground rootstock and normally a single main trunk with a wide, open and typically umbrella-shaped crown. The trunk is generally 10–45 cm wide and covered in a pale-grey bark, but may occasionally reach up to 60 cm in diameter (figures 2 and 3).

Figure 2. Base of the trunk of *Moringa oleifera* (photo: Sheldon Navie)

Figure 3. Rough, pale-grey bark on the trunk of *Moringa oleifera* (photo: Sheldon Navie)

The wood is relatively soft and the tough bark varies from smooth to rough in texture, but is usually not fissured. It exudes a whitish to reddish gum when damaged. The younger stems are finely pubescent and the younger shoots are greenish or purplish in colour.

The large alternately arranged leaves are borne on petioles 4–15 cm long. These leaves are tri-pinnate and usually 25–60 cm long, but they may occasionally be as small as 6.5 cm long and as large as 90 cm long. They bear tiny stalked glands at the base of the petiole and leaflets, which exude a clear or amber-coloured liquid. The leaves have 5–11 main branches (i.e. pinnae) that are pulvinate. Each of these branches is borne on a stalk 1–3 cm long and has 5–11 smaller branches (i.e. pinnules). The smaller branches have stalks (i.e. petiolules) 4–8 mm long and bear 3–13 leaflets (Figure 4).

Figure 4. Leaves and flowers of *Moringa oleifera* (photo: Sheldon Navie)

Individual leaflets are ovate, elliptic or oblong in shape (10–24 mm long and 5–18 mm wide). However, the terminal leaflet on each petiolule is usually obovate and slightly larger. These leaflets are sparsely tomentose to puberulous when young, but become glabrous at maturity. They have rounded to cuneate bases, entire margins, rounded to emarginate apices and are borne on stalks 1–4 mm long.

The inflorescence is a widely spreading axillary panicle 8–30 cm long. Flowers are white to cream, fragrant and about 2.5 cm across. They are borne on pedicels 12–21 mm long and the flower buds are ovoid in shape (figures 5 and 6).

Figure 5. Flower clusters of *Moringa oleifera* (photo: Sheldon Navie)

Figure 6. Close-up of *Moringa oleifera* flowers (photo: Sheldon Navie)

Each flower has 5 petal-like sepals (3 of which are reflexed at anthesis) and 5 petals (4 of which are reflexed at anthesis). The 2 dorsal sepals and 1 dorsal petal that usually remain un-reflexed form a projecting keel, while the rest of the perianth reflexes downwards to form a 'banner' at right angles to the keel. Sepals are elongated in shape (i.e. lanceolate to linear–lanceolate), 7–15 mm long by 5–6 mm wide, and have obtuse apices. They are white or

cream, sometimes with yellow streaks in the centre, and are usually puberulent. The white or cream petals are slightly spoon-shaped (i.e. spathulate), 1–2 cm long by 5–6 mm wide, with prominent veins. They have acute apices and are glabrous or puberulent at the base.

The 5 fully formed stamens (about 10 mm long) have waxy yellow or orange anthers and alternate with a row of 5 staminodes (about 7 mm long). These stamens and staminodes have filaments that are hairy at the base. The hairy ovary is oblong (about 5 mm long) with a single locule containing numerous ovules. It is topped with a single slightly hairy style and a minute stigma. Flowering can occur throughout the year.

The large elongated capsules (usually 18–50 cm long and 1–3 cm wide, or occasionally 10–90 cm long) have 9 indistinct lengthwise ribs (Figure 7). These fruit are green and somewhat tomentose when young, but turn pale brown as they mature. They are dehiscent and split open via three valves when fully mature.

Figure 7. Immature fruit of *Moringa oleifera* (photo: Chris Gardiner)

The numerous seeds, about 20 in each fruit, are sub-globose or slightly three-angled (7–15 mm across) with three papery wings (5–25 mm long and 4–7 wide). They are dark brown or blackish in colour and embedded in the pits of the valves of the fruit.

Biology and ecology

Moringa oleifera can grow at a remarkable rate when young, with 3–4 m of growth in the first year not being unusual in favourable conditions (Price 2000). In cultivation, trees raised from seed start flowering after 2 years of growth, while trees grown from large cuttings can begin to produce fruit 6–12 months after planting (Bosch 2004). Mature trees eventually reach a height of 6–15 m when growing in good conditions. However, plants growing in marginal conditions grow much slower and can have a stunted and shrubby habit, sometimes only reaching 3 m in height.

This species is deciduous during the dry season and has an enlarged underground rootstock. These two characters make *M. oleifera* very drought tolerant. In the Northern Hemisphere, *M. oleifera* loses its leaves from December to January, though during droughts it may also lose its leaves at other times of the year (HDRA 2002). New growth usually begins to appear in February to March, and flowering often precedes or coincides with the appearance of the new leaves (Bosch 2004). The flowering season typically continues through to March, while its fruit ripen from April to June (HDRA 2002). Its flowering is not influenced by day length (EcoPort 2007). This species also quickly sends out new growth from the trunk after being cut or damaged, or from the ground when frosted (ICRAF 2001).

The bisexual flowers of *M. oleifera* are highly cross-pollinated, and pollination is mainly facilitated by animals (i.e. the flowers are zoophilous). For example, bees (*Xylocopa* spp.) and sunbrids (*Nectaria* spp.) have been observed to be active and reliable pollinators in other parts of the world (ICRAF 2001). *M. oleifera* does dot seem to require any specific pollinators, as it readily produces viable seed in all parts of the world where it has been introduced (including Australia). During one study on the mating system of *M. oleifera*, it was found that 74% of seed were produced as a result of cross-pollination and the remaining 26% of seed were produced by self-fertilisation (Muluvi et al. 2004). While these rates may be influenced by environmental factors, this study confirms that *M. oleifera* has a mixed mating system and is capable of reproducing from a single individual.

A single tree can produce 300–400 fruit per year within 3 years of planting, while a mature tree can produce up to 1000 fruit per year (HDRA 2002). As each fruit contains approximately 20 seeds, a mature tree can therefore produce about 20 000 seeds per year.

Reproduction and dispersal

There is little information in the literature as to the dispersal mechanisms of *M. oleifera*; however, much can be determined from its seed morphology and the locations in which it tends to become naturalised. While the seeds are relatively large, they are strongly winged. This may allow them to be spread short distances from the parent tree by wind. It may also aid their dispersal downstream in water during floods (the mature pods may also float in water), as populations are sometimes found growing along waterways. Many naturalised populations occur around old dump sites. This suggests that these plants have grown from seed, or even pieces of stem, that have been dumped in garden waste. DuPuy (1993) notes that discarded branches remain viable for a relatively long period, and often form roots. Larger scale spread of *M. oleifera* is usually as a result of its deliberate introduction for cultivation.

HDRA (2002) states that 'seeds can be planted as soon as they are mature but should only be kept for up to 3 months in natural conditions'. Hence, they probably do not have any significant innate dormancy and begin to lose their viability after a relatively short period of time. Germination rates for fresh seeds are around 80%, going down to about 50% after 12 months storage, with no seeds usually being viable after 2 years of storage (Bosch 2004).

Origin and distribution

The exact origin of this species is somewhat obscure due to its widespread cultivation since early times. It was utilised by the ancient Romans, Greeks and Egyptians, and is now widely cultivated throughout the tropical and subtropical regions of the world (Fahey 2005).

However, *M. oleifera* is thought to be indigenous to the sub-Himalayan tracts of northern India (Qaiser 1973; GRIN 2007). It is also commonly found throughout other parts of India as well as in the Punjab plains, Sind, Baluchistan and North West Frontier Province areas in Pakistan, though these populations have probably resulted from early cultivation (Qaiser 1973). Some authors have also considered it to be native to parts of western Asia (i.e. Oman, Qatar, Saudi Arabia, the United Arab Emirates and Yemen) and even northern Africa (ICRAF 2001), but it is now generally regarded as being a very early introduction to these areas.

Moringa oleifera is also widely naturalised in other tropical regions of the world (figures 8 and 9). It has been reported from large parts of southern and eastern Asia including Afghanistan, Israel, Iran, Nepal, Bangladesh, China, Taiwan, Sri Lanka, Myanmar, Malaysia, the Philippines, Thailand, Vietnam, Indonesia and Papua New Guinea (Verdcourt 1985; ICRAF 2001; Lu & Olson 2001; Papillo 2007). It is also widely naturalised in sub-Saharan Africa, including in Zimbabwe, Madagascar, Zanzibar, South Africa, Tanzania, Malawi, Benin, Burkina Faso, Cameroon, Chad, Gambia, Ghana, Guinea, Kenya, Liberia, Mali, Mauritania, Nigeria, Niger, Sierra Leone, Sudan, Ethiopia, Somalia, Zaire, Togo, Uganda and Senegal (Verdcourt 1985; ICRAF 2001; GBIF 2007; Hyde & Wursten 2007; MBG 2007; Papillo 2007; RBG Kew 2007).

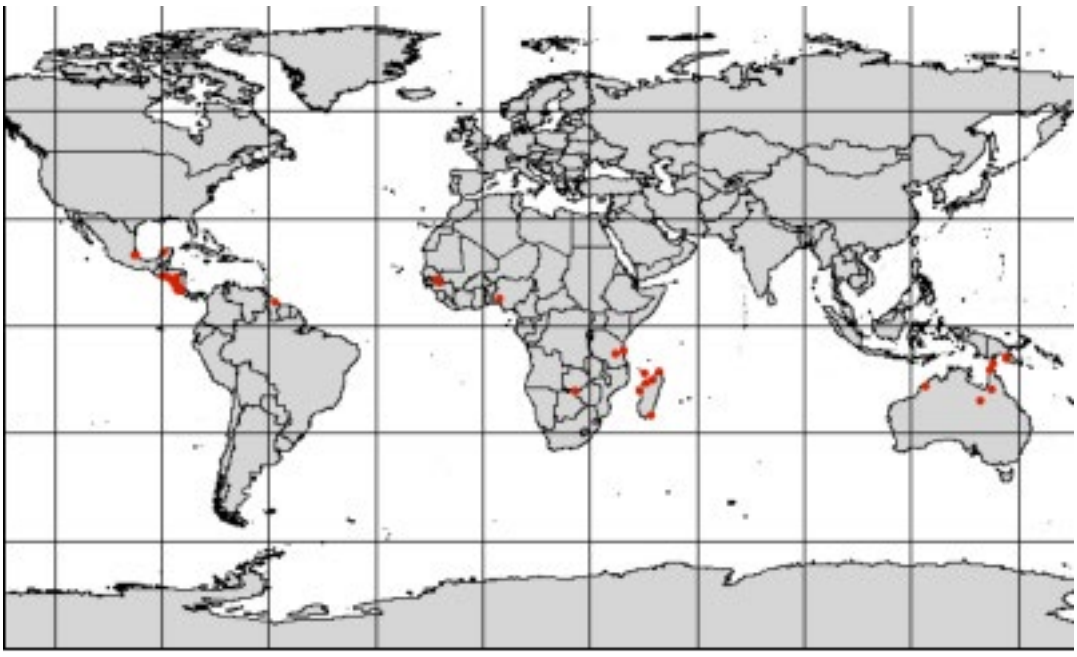

Figure 8. Worldwide distribution of *Moringa oleifera* based on herbarium records in the GBIF network (GBIF 2007)

Figure 9. Countries where *Moringa oleifera* has been recorded as either native or naturalised (derived from published references)

In tropical America, *M. oleifera* is naturalised in south-eastern United States (i.e. Florida), the Caribbean (i.e. Cuba, Haiti, the Dominican Republic, the Bahamas, Jamaica, Puerto Rico and the Virgin Islands), Mexico, Central America (i.e. Belize, Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua and Panama) and South America (i.e. Colombia, Guyana, Venezuela, Brazil and Paraguay) (ICRAF 2001; Liogier & Martorell 2000; MBG 2007; Papillo 2007; RBG Kew 2007; USDA 2007). *Moringa oleifera* is also naturalised on several Pacific islands, including Kiribati, Guam, the Marshall Islands, the Northern Mariana Islands, the Solomon Islands and the Federated States of Micronesia (Hancock & Henderson 1988; ICRAF 2001; PIER 2007).

Status in Australia and Queensland

Moringa oleifera has been planted as an ornamental tree in many parts of northern and eastern Australia. Stanley (1982) stated that it was occasionally found as a relic of cultivation in abandoned places in tropical Australia and that it was probably not fully naturalised. However, it has continued to spread from cultivation in recent years and is now regarded as being fully naturalised in Queensland and Western Australia (CHAH 2007). It is also naturalised on Christmas Island (DuPuy 1993; Swarbrick 1997). *Moringa oleifera* has also been recorded in the northern parts of the Northern Territory, but these records may only refer to cultivated specimens (AVH 2007).

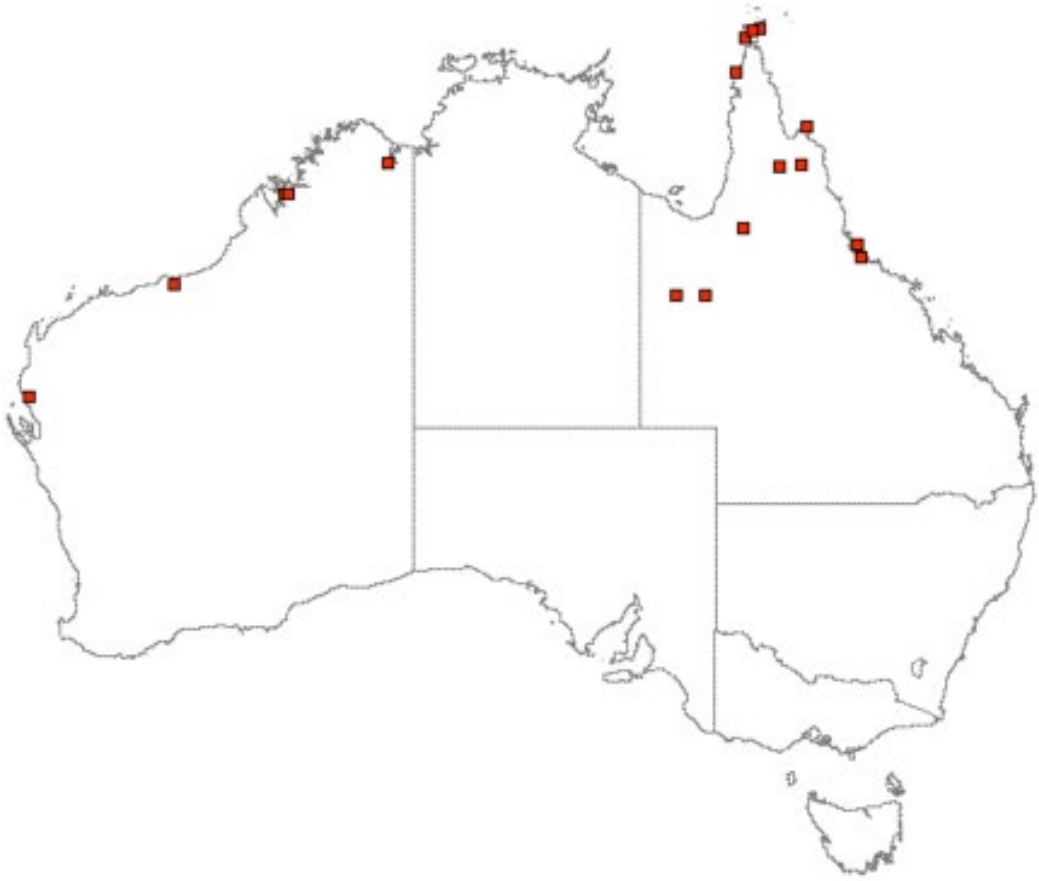

Figure 10. Locations where naturalised specimens of *Moringa oleifera* have been collected and lodged with Australian herbaria—map data from: EPA (2007), Florabase (CALM 2007) and Australia's Virtual Herbarium (AVH 2007). Note: Records of cultivated individuals have been removed.

In Western Australia, *M. oleifera* has been recorded from coastal districts in the northern and north-western parts of the state. Herbarium specimens of naturalised plants have been collected in the Northern Kimberley, Victoria Bonaparte, Carnarvon and Pilbara botanical regions in Western Australia (CALM 2007).

In addition to several cultivated specimens, 14 naturalised specimens have been collected in Queensland. These have all come from the northern and north-western parts of the state, from coastal sites as well as drier inland areas (see Figure 10). The majority (9) have been collected in the Cook Pastoral District on the Cape York Peninsula, with 3 records from the Burke Pastoral District and 2 from the North Kennedy Pastoral District (Bostock & Holland 2007). Many of these records are from sandy sites on offshore islands (i.e. Warraber Island, Nagir Island and Thursday Island in the Torres Strait, Pipon Island off Cape Melville and the Palm Islands near Townsville). The remainder are largely from old homesteads and disturbed sites, such as old dump sites and roadsides, but a couple of the collections were made from open forest areas (EPA 2007).

It is also occasionally cultivated as an ornamental in other parts of Queensland, including in suburban Brisbane. For example, single specimens are currently being cultivated in the Mount Coot-Tha Botanic Gardens, in Fig Tree Pocket and in Coopers Plains (pers. obs. 2007, EPA 2007).

Preferred habitats

Moringa oleifera grows best in the tropical regions of the world that have semi-arid or monsoonal climates. However, it has a wide climatic tolerance and can grow in conditions that range from humid to arid in tropical and subtropical regions (Duke 1983). The optimal annual rainfall for this species is thought to range from 700 to 2200 mm, but it is capable of growing in areas with an annual rainfall of between 250 and 3000 mm (Price 2000; HDRA 2002; EcoPort 2007). As mentioned earlier, it is very drought tolerant and can even survive in relatively arid areas (Papillo 2007). However, it is mainly found along watercourses and near seasonal wetlands when growing in drier regions (FAO 1988).

This species grows best where the average maximum daily temperate is in the range between 25 and 35 °C, although it can survive summer temperatures of up to 48 °C for a limited period of time and can tolerate frosts in winter (Price 2000). *Moringa oleifera* is usually found growing at altitudes below 600 m, but occasionally grows up to 1200 m in some tropical areas and has even been recorded on one occasion growing at 2000 m elevation in Zimbabwe (Price 2000; Bosch 2004).

This tree grows in a wide variety of soil types, but it prefers well-drained, sandy or loamy soils. *Moringa oleifera* will grow in clay soils but cannot tolerate water logging for any extended period of time (Price 2000). In Australia, it has been recorded growing on a very wide variety of soil types including sandy and coralline sandy soils, grey loam soils, red laterite soils, stony and rocky soils, quartzite clay soils and loamy clay soils (CALM 2007; EPA 2007).

It also tolerates a wide soil pH range (i.e. from 5 to 9), and grows quite well in alkaline conditions up to a pH of 9 (Price 2000). However, it prefers neutral to slightly acidic soils (Duke 1983; HDRA 2002). *Moringa oleifera* may also tolerate relatively saline soils, as it is one of three potential biofuel plants thought to be suitable for cultivation in saline land in Western Australia (Brockman 2007) and has been recorded naturalised around the edges of a salt pan in Townsville in northern Queensland (EPA 2007).

History as a weed elsewhere

M. oleifera has naturalised in at least 70 countries across the tropical and subtropical regions of the world. In some countries it is regarded as a resource, rather than a weed, due to its multiple uses. For example, in Africa it is highly prized as a fodder tree during droughts and famines. Nonetheless, there are numerous references in the literature to this species being invasive or potentially invasive. Bignelli et al. (1998), in an extensive and widely researched overview of invasive woody plants in the tropics, ranked *M. oleifera* as a 'moderately invasive' species. According to their system of classification, a 'moderately invasive' species is one that is spreading but still occurs at low densities and is not considered to be an immediate problem.

Moringa oleifera appears on several invasive species lists at an international level. For example, it is listed in the *Global compendium of weeds* (Randall 2002), where it is described as both an environmental weed and casual alien species, and in the *Global invasive species list* that was derived from it (Rice 2003). It also appears on the list of plant species that are thought to threaten Pacific islands' ecosystems (PIER 2007).

This species is reported to readily colonise stream banks and savannahs where the soils are well drained and the watertable remains fairly high all year round (ICRAF 2001; EcoPort 2007). Initial naturalisation and spread is usually associated with nearby cultivated individuals. For example, *M. oleifera* naturalised in northern Transvaal and parts of Natal after being cultivated for some time (Coates-Palgrave 1983). Similar escape from cultivation has been recorded in Puerto Rico (Liogier & Martorell 2000). Because of this, Papillo (2007) mentions that cultivation of *M. oleifera* can lead to it becoming an invasive species, therefore negating the positive aspects it presents.

Many references to this species being invasive or potentially invasive relate to tropical islands, including the Federated States of Micronesia (PIER 2007). Space et al. (2000a) listed *M. oleifera* as a potentially invasive tree species that is present on Kosrae and stated that this is one of several introduced trees that could gradually spread into forests. They also recommended that such species should be monitored since there is often a long time lag between a species' introduction and the development of a serious problem. *Moringa oleifera* is also regarded as a potential threat on Niue (Space & Flynn 2000), where it is being cultivated, and in the Chuuk Islands (Space et al. 2000b), where is has already become naturalised on Weno Island.

Elsewhere in the Pacific, it is invasive in the Solomon Islands (Hancock & Henderson 1988; PIER 2007). Other reports list it as a significant invasive alien species in the Marshall Islands and as a potentially invasive plant in the Republic of Palau (The National Biodiversity Team of the Republic of the Marshall Islands 2000; Shine et al. 2003; Space et al. 2003).

Moringa oleifera has been listed as a potentially invasive species in the Caribbean region (Kairo et al. 2003) and described as an alien forestry species associated with naturalisation events in Puerto Rico (Haysom & Murphy 2003). In Florida, in south-eastern United States, it is naturalised in disturbed upland habitats in Miami-Dade County (Gann et al. 2007) and is also present in Manatee County (Wunderlin & Hansen 2004).

Despite being listed as a weed in many countries, there is very little information on its impact. This species spreads relatively slowly and is generally described as a 'potentially invasive' or 'moderately invasive' species, and nowhere is it regarded as being highly invasive or very aggressive.

Groves et al. (2003), in their categorisation of weeds in natural and agricultural ecosystems in Australia, indicated that *M. oleifera* may be a minor problem in natural ecosystems. They regarded it as being 'naturalised but not important enough to warrant control at any location'. They did not consider it to be an agricultural weed, either because it was not considered a problem or because it was not known to occur in agricultural areas.

In Western Australia, *M. oleifera* has naturalised in a wide range of habitats, including riverine woodlands, creek lines, margins of northern woollybutt (*Eucalyptus miniata*) woodlands, coastal environs, levee banks, stony sites and disturbed natural vegetation along road verges (CALM 2007). However, it is not yet considered to be a significant problem. For example, *M. oleifera* is not mentioned in the recent and comprehensive second edition of *Western weeds* (Hussey et al. 2007).

Swarbrick (1997) also refers to *M. oleifera* as a 'garden escape' on Christmas Island, while DuPuy (1993) states that it is 'frequent in undergrowth surrounding settlements' and 'often persists as a relic of cultivation' on this offshore island.

Uses

Moringa oleifera has been used for such a wide variety of purposes that it has been described as a 'miracle tree'. It is grown in many parts of the world as a 'vegetable tree', with the roots, leaves, flowers and fruit all being used for food (Lu & Olson 2001). The leaves are probably the most widely used part, being compared to spinach in appearance and nutritional quality (Papillo 2007). Because *M. oleifera* produces leaves during the dry season and during drought, it is seen as a particularly useful green vegetable in developing countries when little other food is available (Folkard & Sutherland 1996). Its leaves and pods have considerable nutritional value, yielding many vitamins and minerals (Soto 2006), and the leaves can be eaten either cooked or dried (Papillo 2007). The fruit, or 'drumsticks', are cooked like green beans and have a similar flavour to asparagus (HDRA 2002). In India, they are grown commercially for this purpose and are canned and exported to other parts of the world (Papillo 2007). The green seeds, which are much like peas, and the surrounding white material in the fruit can be removed from mature pods and either boiled or fried (Price 2000).

The roots have a pungent taste and are used as a substitute for horseradish, hence the common name 'horseradish tree'. However, the root bark has to be scraped off, as it contains two alkaloids and the toxin moringinine (Price 2000). The flowers and immature fruit are used to flavour curries (Qaiser 1973) and the gum in the bark is also used to season food (HDRA 2002).

Several parts of the plant are also used in native medicines and folk remedies for the treatment of ear, eye and bronchial complaints, skin infections, fevers, stomach ulcers, diarrhoea, syphilis and nervous disorders (Qaiser 1973; Price 2000; EcoPort 2007). For example, the juice from the leaves is believed to stabilise blood pressure, the flowers are used to cure inflammations, the pods are used for joint pain, the roots are used to treat rheumatism, and the bark can be chewed as a digestive (Papillo 2007). This is just a small selection of the wide range of ailments for which *M. oleifera* has been promoted as an effective medicine (HDRA 2002; Fahey 2005). It has also been widely described as having antibiotic properties and being a cancer preventative (Fahey 2005). Few rigorous scientific studies have been conducted to confirm these reports; however, a compound contained in the flowers and roots, pterygospermin, has been found to have powerful antibiotic and fungicidal properties (Price 2000).

It is also highly prized as a fodder tree in developing countries, where its leaves are fed to cattle, sheep, camels, goats, pigs, poultry and donkeys (RBG Kew 1999; HDRA 2002). The branches are often lopped for fodder, and animals are also known to browse the bark and young shoots of this species (Qaiser 1973; HDRA 2002). *Moringa oleifera* is used as a green manure in developing countries, where it is said to significantly enrich agricultural land (Price 2000).

The wood is a good fuel for cooking and other purposes (HDRA 2002), and yields a blue dye (Duke 1983). Woodchippings can also be used to make a good quality paper (HDRA 2002). The bark can be used as an agent for tanning hides (Duke 1983; Soto 2006) and can also be beaten into a coarse fibre that can be used to make rope or mats (HDRA 2002). The viscose resin that is exuded from the bark is used in the textile industry (HDRA 2002).

The crushed leaves are also used as a domestic cleaning agent in developing countries, being employed to clean cooking utensils and even walls (HDRA 2002). *Moringa oleifera* also provides nectar to honey bees for a long period of the year (ICRAF 2001; HDRA 2002).

Moringa oleifera has also been employed for erosion control in areas where strong winds and long, dry spells occur simultaneously (ICRAF 2001). Because it grows very quickly it is often planted as a living fence or windbreak in developing countries (HDRA 2002; Papillo 2007). In Australia and other parts of the world it is also cultivated as an ornamental or for shade and shelter (GRIN 2007).

However, the seeds are probably the most useful part of the plant. The oil that is extracted from them, which is sometimes known as 'ben oil', is used for a wide variety of purposes (Qaiser 1973; Stanley 1982). They also contain a powerful flocculant, which is used for clarifying turbid water in developing countries (Lu & Olson 2001).

The seeds contain about 35–40% oil. This oil is of excellent quality, similar to olive oil, and is slow to become rancid (Price 2000). It is used as a fuel for cooking purposes and burnt for light in developing countries (HDRA 2002). It is also used in perfumes, as a lubricant in watches and other fine machinery, and for making soap (Qaiser 1973; Stanley 1982; Price 2000).

The press-cake remaining after oil extraction has been shown to retain the active ingredients for coagulation, making it a marketable commodity as a flocculant. It can be used as a quick and simple method for cleaning dirty river water in developing countries (HDRA 2002). In fact, *Moringa oleifera* has been compared to alum in its effectiveness at removing suspended solids from turbid water (Papillo 2007). It can also be used to harvest algae from waste water, currently an expensive process using centrifuges (Price 2000). The press-cake also contains high levels of protein and makes and excellent stockfeed or a good fertiliser for use in agriculture (HDRA 2002; Brockman 2007).

In Australia, and other parts of the world, the greatest potential for this species is currently thought to be in its cultivation for the production of biofuel. Yields of about 10 metric tonnes of pods per hectare per year are thought to be achievable for this species (Duke 1983). It has been suggested that this would equate to between 1000 and 2000 litres of biodiesel per hectare per annum (Brockman 2007). Very high yields of oil have already been produced in overseas situations, but it has not yet been widely trialled in Australia (O'Connell et al. 2007). However, trials were recently initiated in south-western Western Australia and at Carnarvon, and are also planned for the Pilbarra region (Low a& Booth 2007; SWCC 2007).

It is particularly desirable because it is a very low water-use crop and may be cultivated on marginal land (i.e. in semi-arid areas, on poor soils and in saline areas) (Soto 2006; Brockman 2007; SWCC 2007). *Moringa oleifera* is being grown commercially on at least one farm at Bowen in northern Queensland. The vegetable products of this crop are being supplied to consumers in southern Australia, no doubt largely those from expatriate Asian communities (Soto 2006). Production of these vegetable products in this region is about 35 tonnes per hectare per year (Soto 2006).

In other parts of the world, *Moringa oleifera* is most commonly and quickly cultivated by cuttings. Ideally, these should be taken from healthy branches containing hard wood in the rainy season and be between 0.5 and 2 m in length (HDRA 2002). Frequent pruning of the growth tips of cultivated plants will maintain and increase leaf growth and control the height of the tree, making harvesting of the leaves and fruit easier (HDRA 2002).

Pest potential in Queensland

Currently, *M. oleifera* is only regarded as a minor weed in Queensland. It appears on the checklist of weeds in the Gulf Plains bioregion that are either considered to be minor weeds or not a problem (Tropical Savannas CRC 2007). It also appears on the James Cook University weed list (JCU 2007).

More information on the weediness of this species can be obtained from the data associated with the herbarium records of naturalised specimens. Many of these records refer to single trees or relatively few individuals making up these naturalised populations, and a significant proportion also refer to this species as being a remnant of cultivation or present near old settlement sites. However, a few of the records are more significant for one reason or another.

Possibly the largest recorded naturalised population in Queensland is located between Old Mapoon and Cullen Point along the western coast of the Cape York Peninsula. This population was found at an abandoned settlement in the year 2000, and the largest trees were probably planted at this site when the settlement was still occupied. These older trees were noted to be 'surrounded by a thicket of reproductive younger self-sown individuals' (EPA 2007).

An older population, located north-east of Strathmore Station in 1953, was said to consist of occasional trees growing amongst bloodwood (*Eucalyptus polycarpa*) near the base of a laterite jump-up. In 2005, a population of about 10 trees were spotted naturalised in open vegetation at Mt Louisa in Townsville. This population was growing on high ground around a salt pan near Louisa Creek, in an area that was an old tip site (EPA 2007).

Figure 11. Young *Moringa oleifera* trees naturalised in open vegetation near an old dump site at Mt Louisa in Townsville (photo: Chris Gardiner)

Another older record from Nychum homestead reports a population of this medium-sized tree to be growing in 'open forest on grey loam soil'. It was also noted that cattle will eat the foliage of this tree as high as they can reach, and in some cases the bark was even chewed off the trees.

One record from the Torres Strait notes that this species is a host for the spiralling whitefly (*Aleurodicus dispersus*) (EPA 2007), a relatively new and potentially serious pest of bananas and horticultural crops in northern Australia (Botha et al. 2000). Spiralling whitefly is currently regarded as an emerging pest in northern Queensland and the Northern Territory (Chin et al. 2007; Lambkin 2007), and as a potential pest in Western Australia (Botha et al. 2000).

These records indicate that *M. oleifera* can spread from cultivation and has weed potential in Queensland and other parts of northern Australia. While examples of naturalisation seem to be increasing, most records refer to small populations that are located close to cultivated individuals (EPA 2007). Like many other tree species that do not have very effective dispersal mechanisms (e.g. bird or animal-dispersed fruit), *M. oleifera* seems to spread at a relatively

slow rate. It seedlings generally do not appear far from parent plants, instead forming thickets around older individuals (EPA 2007; Low & Booth 2007). However, its rate of spread may be greater along watercourses (Low & Booth 2007).

It should be noted that *M. oleifera* is currently relatively rare in cultivation in northern Australia. Until very recently, cultivation of this species was mostly restricted to isolated individuals or small populations that were grown for ornamental purposes. Larger scale cultivation of *Moringa oleifera* is currently being trialled in other parts of Australia for its possible use as a biofuel (Low & Booth 2007; SWCC 2007). Should such larger scale cultivation occur in the future, it may become a source for more widespread naturalisation of this species, as has recently been the case with other tree species northern Australia (e.g. *Azadirachta indica*, *Mangifera indica* and *Acacia mangium*).

The literature would also indicate that *M. oleifera* is not an economic threat to agriculture in Queensland. Being a tree, it is not likely to cause problems in cropping areas. While it is reported to be a host of the spiralling whitefly, a potentially serious and not yet very widespread pest of horticultural crops in northern Queensland, numerous suitable alternative hosts for this species are already widespread in cropping or natural systems in northern Australia.

Moringa oleifera is also seen as a highly useful fodder for a wide range of livestock (HDRA 2002), even being cultivated for this purpose in some parts of the world, so it should not be of concern to the grazing industry.

Its main threat would seem to be as a weed of natural ecosystems in the wet/dry tropics of northern Australia. While it spreads slowly, over time it can form dense populations around parent trees. Like other tree species it may replace native vegetation and even transform areas such as grasslands and open woodlands (Grice & Martin 2005). Several tree species that spread in this manner have already become invasive in this part of northern Australia (e.g. *Bauhinia monandra*, *Delonix regia* and *Senna siamea*) (Smith 2002). Low and Booth (2007) suggested that *M. oleifera* should not be grown close to national parks or watercourses.

Moringa oleifera may also be of some concern on offshore islands in tropical and subtropical regions. It prefers the sandy soils that are common on such islands, has already become naturalised on islands off the north Queensland coast (e.g. on islands in the Torres Strait and the Great Barrier Reef Marine Park), and is regarded as being potentially invasive on islands in other tropical regions of the world (PIER 2007).

Control

As this species is not yet regarded to be a problem of any significance, control has not been required and there is a lack of information in this area. However, it should be noted that *M. oleifera* re-shoots vigorously after damage and older plants usually develop a swollen underground rootstock, which no doubt contains significant energy reserves. Any successful control measures will have to overcome these survival mechanisms.

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