Review

The biology of Australian weeds 52. *Malva parviflora* L.

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Name

Malva (mallow) is derived from the Greek *malache* or *malakos* (soft), possibly referring to either the downy leaves or its medicinal properties (Mitich 1990). The genus *Malva* is a member of the tribe Malveae of the family Malvaceae (Corner 1976). In 1753, Carolus Linnaeus was the first to distinguish *Malva* species within the Malvaceae family based on their characteristic epicalyx (Ray 1998). He originally identified 15 different *Malva* species. Currently, there are thought to be 25–40 species of *Malva* throughout the world. However, numerous species initially placed in *Malva* have been transferred to other genera and there is much doubt about the correct nomenclature of many *Malva* and other Malvaceae species (Ray 1995). It was previously thought to be extremely unlikely that any species in the genus *Malva* naturally occurred in Australia (Ray 1995); however three native *Lavatera* L. species have recently been changed to *Malva* (Ray 1998).

Malva parviflora Linnaeus is one of several introduced *Malva* species that have naturalized in Australia. Linnaeus named *parviflora* from the Latin *parvus* (little), and *Flora*, goddess of flowers (Mitich, 1990). Common names in Australia for *M. parviflora* are small-flowered mallow, marshmallow, whorled mallow, whorlflower mallow and ringleaf marshmallow, whilst overseas names include cheeseweed, little mallow and least mallow.

Description

Malva parviflora is a glabrous or pubescent annual (Dalby 1968) with a single long taproot. Stems are either prostrate-ascending or erect (Figure 1) and can grow up to 1.2 m high (Lamp and Collet 1984) and 2.1 m wide (Michael *et al.* 2006b). Leaves are alternate, dull dark green and generally variable in size (2–12 cm wide, 1–7 cm long) (Michael *et al.* 2006b), but fairly consistent in shape (Everist 1974) (Figure 2). Leaves have 5–7 deltate, crenate lobes (Dalby 1968) with leaf petioles (1.5–22 cm) longer than the blade (Michael 2006). Stipules are lanceolate to ovate, 2–5 mm long (Dalby 1968).

Flowers emerge in axillary clusters (2–4 flowers per axil) on distinct peduncles 3–5 mm long. Epicalyx segments are linear and 5–15 times as long as broad. The outer surface of the calyx has spreading stellate hairs with 5–6 arms, each arm 0.05–0.3 mm long (Barker 1977). Petals are white with pinkish tips, oblong and slightly narrowed at the base, and have glabrous claws. They are 3–8 mm long, scarcely longer than the

Figure 1. *Malva parviflora* showing its erect growth habit.

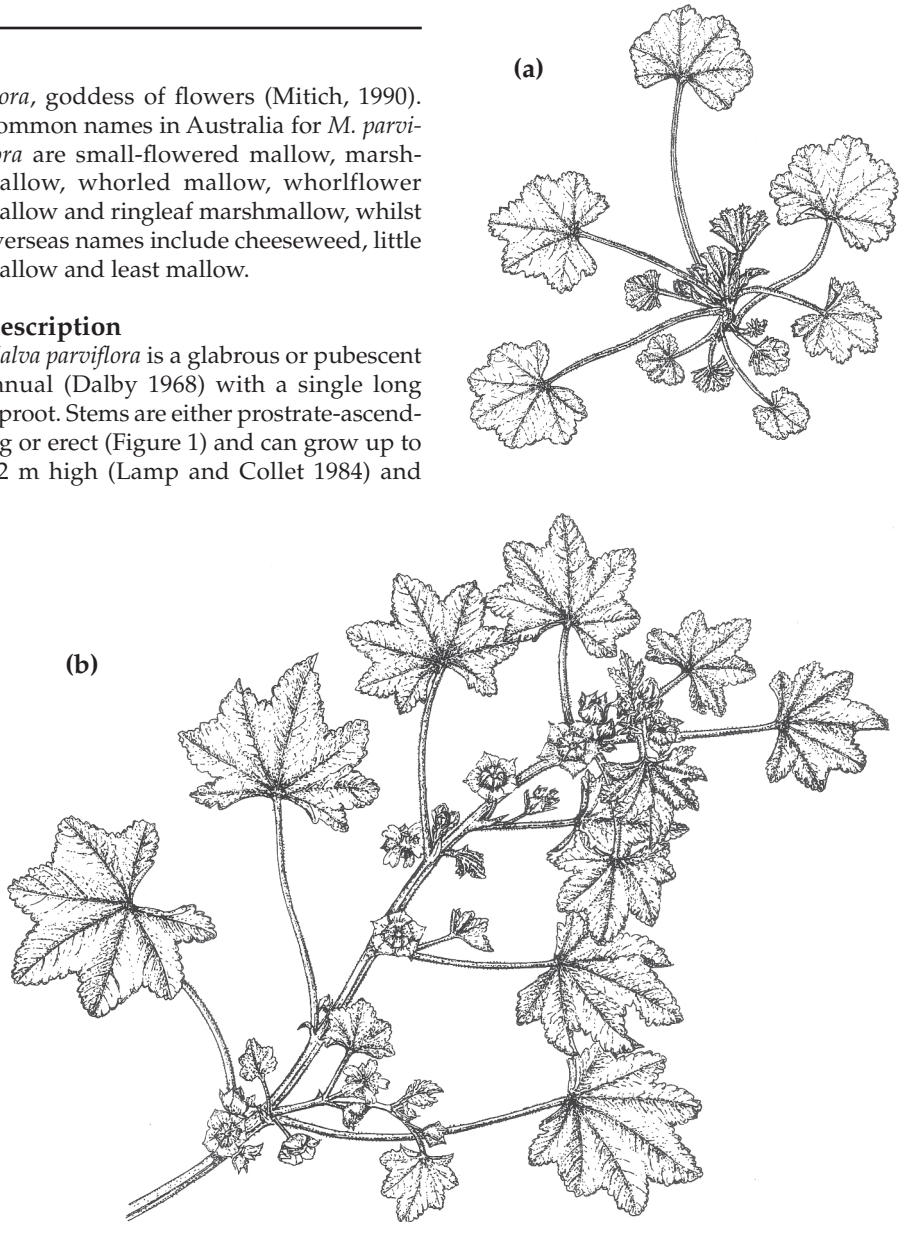

Figure 2. Anatomy of *Malva parviflora* plant showing seedling (a) and flowering stem (b) (Moerkerk and Barnett 1998).

epicalyx (Michael 2006). Flowers are bisexual and unperfumed (Michael 2006). Pollen sacs contain approximately 31 pollen grains, which are large (85 µm diameter) and sticky (Michael *et al.* 2006b).

The fruit (schizocarp) is a round capsule approximately 1 cm in diameter containing between 8–12 mericarps. When ripe, mericarps change colour from green to dark brown (Michael *et al.* 2007). They are narrowly and partially separated from each other in the mature fruit, with angles on dorsal surface and toothed wing-like margins. Seeds are dark-brown when ripe and variable in weight (0.008–0.17 g per 50 seeds). Seeds are reniform and non-hairy with an exotegmic seed coat comprised of six zones (Kumar and Singh 1991). *Malva parviflora* has a campylotropous ovule with integuments covering the embryo except for a small part of the chalazal end (Corner 1976). The seed oil of *M. parviflora* is known to contain glycerides of cyclopropene fatty acids (malvalic and sterculic), cyclopropane (dihydromalvalic and dihydrosterculic), epoxy and conjugated dienol acids (Ahmad *et al.* 1984). The diploid chromosome number for *M. parviflora* is $2n = 42$ (Bidack and Brandham 1995).

Table 1. Distinguishing characteristics of the small-flowered mallow group (information sourced from Hanf 1983).

Character	*M. parviflora*	*M. neglecta*	*M. pusilla*	*M. nicaeensis*
Corolla to calyx ratio	1:1	2:1	1:1	2.5:1
Corolla colour	pale pink	pale pink/ white	pale pink/ white	pale violet
Mericarp on dorsal face	distinctly reticulate ribbed	faintly ribbed	distinctly reticulate ribbed	distinctly reticulate ribbed
Adjacent margins of the mericarp	toothed	smooth	smooth	smooth

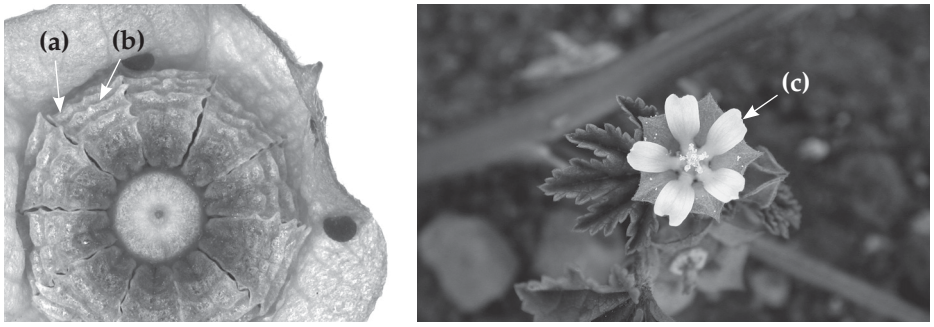

Figure 3. Distinguishing characteristics of *Malva parviflora* (a) toothed margins of the mericarp, (b) ribbed mericarp, (c) pale pink corolla with ratio of 1:1 with calyx.

Taxonomy

Malva is traditionally distinguished from other genera within the Malveae tribe of Malvaceae by its characteristic triphyllum or three non-fused epicalyx bracts (Ray 1998). In particular, this character has been used to distinguish *Malva* from *Lavatera*, a closely resembling genus with connate epicalyx bracts. However, it has been suggested that the use of epicalyx characters to separate *Malva* and *Lavatera* is untenable based on morphological and molecular analysis of the nuclear ribosomal-DNA Internal Transcribed Spacer region (Ray 1998). Recently, as a result of this genetic analysis, several native Australian *Lavatera* species have been reassigned to *Malva*.

Within the *Malva* genus, species which have petals less than 12 mm long are regularly misidentified and have proven difficult to distinguish. These include *M. parviflora*, *M. pusilla* Sm., *M. nicaeensis* All. and *M. neglecta* Wallr. Taxonomists frequently mistake *M. parviflora* for *M. neglecta* or *M. pusilla* in Canada (Makowski and Morrison 1989) and all *M. parviflora* samples in the Herbarium at the University of Kashmir, India have turned out to be *M. neglecta* (Naqshi *et al.* 1988). However, several characteristics distinguish the small-flowered mallows (Table 1, Figure 3).

History

The first known reference of *Malva* in Australia was in 1845 (Miquel 1845) with a description of a species called *M. preissiana* Miq. However, there is no further mention of *M. preissiana* in any literary source examined, suggesting that the species name no longer exists and has been replaced. Bentham (1863) noted that four European *Malva* species, *M. rotundifolia* L. (also known as *M. pusilla* Sm.), *M. parviflora*, *M. verticillata* L. and *M. sylvestris* L., were naturalized as weeds in some parts of Australia and he described their diagnostic characteristics (Barker 1977). In 1889, Schomburgk observed that the four species had escaped from gardens in South Australia and 'established themselves as in the old country, about hedges, roadsides, and in cultivated, as well as in waste grounds and pastures lands' (Schomburgk 1889). It is highly likely that *M. parviflora* was introduced intentionally as a garden plant as it was cultivated in Europe as a salad vegetable and a 'green manure' (Dalby 1968, Barker 1977). In 1922, it was recorded as being present at high 'luxurious' densities in agricultural areas of New South Wales, where it was thought to have caused the potentially fatal 'staggers' syndrome in livestock (Dodd and Henry 1922). *M. parviflora* is now naturalized in all states of Australia (Barker 1977, Hnatiuk 1990, Low 1991, Auld and Medd 1992, Lazarides *et al.* 1997, Ray 1998, Council of Heads of Australian Herbaria 2008).

Distribution

The natural origin of species within the genus *Malva* is uncertain because many species have become widespread weeds (Ray 1995). The centres of diversity are most likely to be in the Mediterranean region and south-western Asia, extending as far as Turkmenistan and Afghanistan, (Hanf 1983, Jessop and Toelken 1986, Makowski and Morrison 1989, Mitich 1990). *Malva* has naturalized in many countries including Australia, Finland, Denmark, Korea, Japan, Argentina, Chile, India, Lesotho, Namibia, Zimbabwe, South Africa and the United States (Naqshi *et al.* 1988, Randall 2002, Hinsley 2007, USDA 2008). It also occurs abundantly in New Zealand (Low 1991).

The number of *Malva* species currently present in Australia varies between different sources, with estimates of nine (Council of Heads of Australian Herbaria 2008), six (Walsh and Entwisle 1996) and five (Hnatiuk, 1990). *Malva parviflora* is thought to be the most common and widespread naturalized *Malva* species in Australia (Council of Heads of Australian Herbaria 2008) (Figure 4). It is more prevalent in the southern half of Australia where climatic conditions are temperate, which is consistent with its supposed Mediterranean origin. Its presence in humid tropical areas of Australia as well as its world wide distribution indicates *M. parviflora* is highly adaptable to an extensive range of climatic conditions.

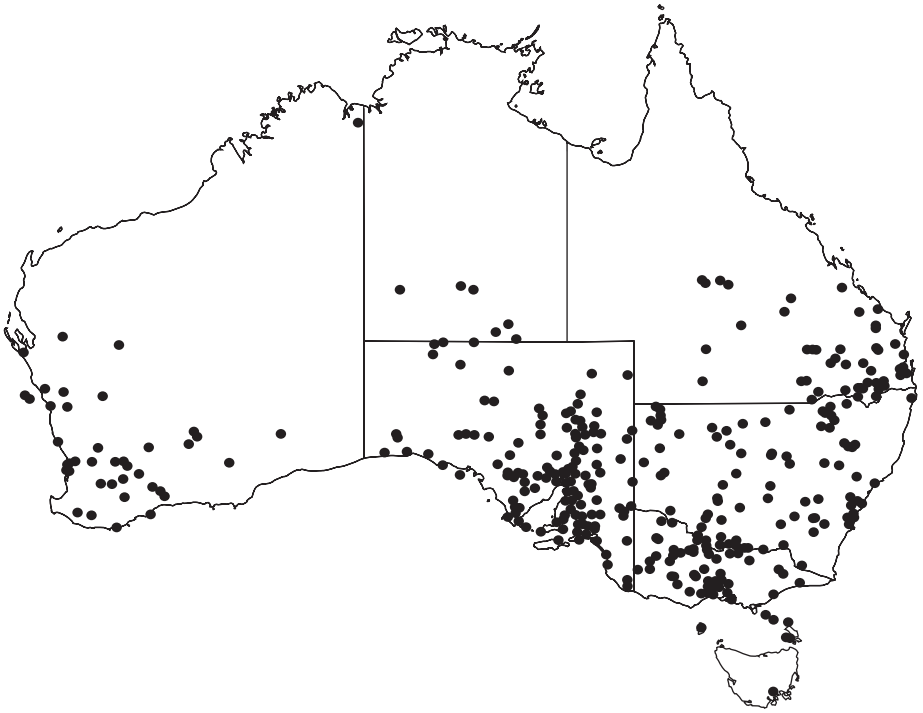

Figure 4. Distribution of *Malva parviflora* in Australia. Data sourced from the Australian Virtual Herbarium (Council of Heads of Australian Herbaria 2008).

Habitat

Malva parviflora is widespread throughout Australia, particularly the southern half, and occurs over an extensive range of climatic regions (Figure 4). Plants can grow in areas with average rainfall as low as 315 mm (Merredin, Western Australia) (Michael *et al.* 2006b) and as high as 950 mm (Rockhampton, Queensland) (Council of Heads of Australian Herbaria 2008). Plants can also grow in a broad range of soil conditions including rocky or stony soil, sand, loam and clay (Michael *et al.* 2006b, Western Australian Herbarium 2008). Although not usually considered a halophyte, *M. parviflora* inhabits saline soils in Bahrain (Kivilaan and Bandurski 1981) and parts of the Western Australian (WA) coastline (Western Australian Herbarium 2008). It is most commonly found in disturbed ground and pastures of farming land, although it can occur in other areas such as gardens, crops, roadsides and wastelands (Barker 1977, Lamp and Collet 1984, Auld and Medd 1992, Lazarides *et al.* 1997, Western Australian Herbarium 2008).

Growth and development

There has been limited study of the growth, development or phenology of *M. parviflora* in Australia. However, under controlled field conditions, dry weight of *M. parviflora* plants reaches a maximum of 340 g (Michael *et al.* 2006b). Plants have a single, long taproot that allows them to survive long periods of drought. They can grow either prostrate or erect, with prostrate plants being generally associated with disturbed areas of frequent trampling or mowing (Barker 1977). Erect plants can grow up to 1.2 m high (Lamp and Collet 1984) and 2.1 m wide (Michael 2006) and predominantly occur when resources such as light and space are limited through plant competition (i.e. livestock yards or cropping situations) (P. Michael personal observation). In cropping situations, *M. pusilla*, a biologically similar species with the same chromosome number ($2n = 42$), exhibits a more erect growth habit and grows to the height of the crop, but when alone it spreads over the ground with branches over 1 m in length (Makowski and Morrison 1989). The presence of wild mustard, *Brassica kaber* (DC.) Wheeler, appears to inhibit the growth of *M. parviflora* under natural conditions, most likely caused by allelopathy (Vicol and Dobrota 1995).

Several sources state that seedlings emerge in autumn, indicating that the weed is a winter growing annual (Lazarides *et al.* 1997, Michael *et al.* 2006a); however, *M. parviflora* can emerge throughout the year in some climates (Chorbadjian and Kogan 2002). In cropping systems, most seedlings of *M. parviflora* emerge within two weeks of crop sowing (Chauhan *et al.* 2006a). Seeds buried at depths of 2 cm (Michael *et al.* 2006a) or 0.5–2 cm (Chauhan *et al.* 2006a) in the soil have higher emergence than seeds placed on the surface. Maximum seedling emergence from these depths is 60%, with buried seeds producing at least 13% more emergence than seeds on the surface. Seedling emergence decreases progressively as seeds are buried deeper than 2 cm, with no emergence occurring at 8 cm or deeper (Chauhan *et al.* 2006a). More seedlings emerge under no-tillage, when soil disturbance is limited to the sowing operation only, than minimum tillage systems, where there were two pre-sowing cultivations in addition to sowing (Chauhan *et al.* 2006b).

Reproduction

Floral biology

Malva parviflora plants can reproduce within two months of germinating. The first flowers open 51 days after germination (Michael *et al.* 2007), and reproduction occurs throughout the life of the plant (Cunningham and Mulham 1992). In Australia flowering occurs from March (early autumn) through to December (early summer) (Western Australian Herbarium 2008). Flowers are bisexual and contain 10 anther sacs, 10 ovules and a central feathery stigma. *M. parviflora* is predominately inbreeding. Each pollen sac contains 31 ±1.3 pollen grains, giving a pollen-ovule ratio of 31 and hence a very limited opportunity for outcrossing. Upon flower opening, anthers have already dehisced and pollen grains are attached to the stigma, indicating prior self-pollination. In addition flowers are small, unperfumed and open for only a few days, and thus unlikely to attract insect pollinators (Michael *et al.* 2006b).

Seed production and dispersal

Malva parviflora produces approximately 10 seeds per flower (Michael *et al.* 2007). Although there have been no studies of total seed production per plant, closely related species from the Malveae tribe of Malvaceae produce many seeds. Production of seeds from *Abutilon theophrasti* Medik. ranges from 7000 to 17 000 seeds (Winter 1960, Warwick and Black 1985). *Malva pusilla* propagates exclusively by seeds (Makowski 1987, Makowski and Morrison 1989) and can produce between 1000 to 5000 seeds per plant in a pure stand and an average of around 300 seeds per plant when in competition with wheat (Pyasyatskene 1978, Carlson and Eberlein 1983). Given the large number of flowers on plants at any given time, the long period of flowering and high seed number per flower, seed production per plant of *M. parviflora* is also likely to be in the thousands.

Malva parviflora seeds can be dispersed by biotic vectors, particularly agricultural livestock. Up to 700 viable *M. parviflora* seeds can be passed daily through a horse with recovery from manure peaking three to five days after seed consumption and gradually declining until 13 days, when

no further seeds are recovered (St John-Sweeting and Morris 1990). Hardseeded viable seeds (~20% of total consumed) can be passed intact through sheep, with the majority being excreted within three days, although some seeds were recovered up to seven days after initial seed digestion (Michael *et al.* 2006c). As livestock are regularly moved within and between individual farms and agricultural regions, the potential dispersal of seeds is vast. Seeds can also be dispersed long distances by birds (Proctor 1968), although no Australian studies have been conducted.

Physiology of seeds and germination

The main type of dormancy impeding germination in *M. parviflora* seeds is physical dormancy, i.e. an impermeable seedcoat that prevents seeds from imbibing water (Michael *et al.* 2006a). The tissue responsible for physical dormancy (also known as hardseededness) in Malvaceae seeds is a layer of palisade cells that develops from the exotegmen, the outer epidermis of the inner integument (Corner 1976). In the field, dormancy release occurs during the summer months in response to natural fluctuations in temperature. Replication of summer temperatures in the laboratory confirms that these fluctuations are important, as dry seeds lose dormancy under alternating 50/20°C but not under constant temperatures (Michael *et al*. 2006a). Scanning electron microscopy of the seed coat shows structural differences in the chalazal region of permeable and impermeable seeds, indicating the importance of this region in the physical dormancy breakdown of *M. parviflora* seeds (Michael *et al.* 2006a). The structure of this chalazal region, a slit-like discontinuity, is consistent with that observed in other species belonging to the Malveae group of Malvaceae, confirming the significance of the chalazal region in regulating physical dormancy of seeds within the *Malva* genus. Bypassing natural dormancy release is possible by physical scarification of the seedcoat using tweezers (Sumner and Cobb 1967, Chauhan *et al.* 2006a, Michael *et al.* 2006a) or a scalpel (Sumner and Cobb 1967, Chauhan *et al.* 2006a) to allow imbibition. Chemical scarification has variable results on germination of hardseeded *M. parviflora.* Placing seeds in 71% sulphuric acid or 5% sodium hypochlorite for up to 18 hours does not enable imbibition, but 95% sulphuric acid for 60 minutes or boiling seeds in water for 5–10 seconds followed by immersion in ice water is partially effective (Sumner and Cobb 1967).

In addition to physical dormancy, minor physiological dormancy is observed in freshly matured *M. parviflora* seeds, as scarified seeds are slow to germinate (Sumner and Cobb 1967, Michael *et al.* 2006a). Release of physiological dormancy naturally occurs after a short period of after-ripening (Michael *et al.* 2007). Physiological dormancy can also be partially overcome using growth promoters, with 5 mM of KNO_3 increasing germination by 18% and 1 mM GA_3 by 13% (Chauhan *et al.* 2006a), in seeds scarified with 95% sulphuric acid for 60 minutes. Physiological dormancy occurs in other Malvaceae species (Egley and Chandler 1978, Warwick and Black 1985, Baskin and Baskin 1998) and in conjunction with physical dormancy is known as combinational dormancy (Baskin and Baskin 2004).

Non-dormant seeds are able to germinate over a wide range of temperatures (3.3–37°C) and a range of pH (pH 4–10) and have no light requirement (Chorbadjian and Kogan 2004, Chauhan *et al.* 2006a, Michael *et al.* 2006a). Germination, however, is optimal at temperatures typically associated with winter rainfall in Mediterranean-type climates (15–20°C) (Muniz 2000, Chorbadjian and Kogan 2004, Michael *et al.* 2006a). Germination declines as NaCl concentration increases; however, a small number of seeds can germinate at 160 mM NaCl (Chauhan *et al.* 2006a), indicating the potential for salt tolerance in some populations. Germination is completely inhibited at osmotic potentials of −0.6 to −1 MPa, suggesting moderate sensitivity to osmotic stress (Chauhan *et al.* 2006a).

Changes in seed germinability and dormancy during development on the parent plant have been comprehensively studied in *M. parviflora* (Michael *et al.* 2007). Seed moisture content decreases as seeds develop, whereas fresh (maximum 296 mg) and dry weight (maximum 212 mg) increase to a peak at 12–15 and 21 days after flowering (DAF) respectively. Thus, physiological maturity occurs at 21 DAF, when seed moisture content is 16–21%. Seeds are capable of germinating early in development, reaching 63% at 9 DAF, but germination declines as development continues, presumably due to imposition of physiological dormancy. Physical dormancy develops at or after physiological maturity, once seed moisture content declines below 20%. Seeds are able to tolerate desiccation from 18 DAF; desiccation hastens development of physical dormancy and improves germination, indicating that weed control measures imposed after flowering are unlikely to prevent viable seeds entering the soil seed bank.

*Malva parviflor*a seeds can remain viable for many years in soil without germination if their physical dormancy is retained. Seeds of *M. parviflora* were discovered in bricks of adobe buildings built between 1769 and 1837 in California and New Mexico, a dry environment with reduced temperature fluctuation and microbial activity (Spira and Wagner 1983). Seeds extracted from these bricks and placed on agar for 19 days did not germinate, but a third of the seeds were viable according to tetrazolium staining. However, the seed coat was apparently not artificially scarified so physical dormancy may still have been present. Alternatively, as embryos become less vigorous with increasing age, there may have been insufficient time allowed for germination or they may not have been able to exert sufficient force to emerge from the seed coat. Further information on the longevity of *M. parviflora* is lacking but viable seeds of *M. rotundifolia* have been unearthed after 100 years (Kivilaan and Bandurski 1981) and 120 years (Telewski and Zeevaart 2002) of burial in moist aerated soil, confirming the extensive persistence of species within the *Malva* genus. This suggests that *M. parviflora* could potentially have seed bank persistence of several decades in the event that fluctuations in temperature are not enough to break physical dormancy.

Hybrids

A hybrid between *M. neglecta* and *M. parviflora* was recorded in 1932, but there is no other record of this crossing nor of any since (Dalby 1975). Dalby (1968) reported the existence of other *Malva* hybrids between *M. pusilla* × *M. neglecta*, *M. alcea* L. × *M. moschate* L. and *M. sylvestris* × *M. neglecta* in Europe. Yet again, there are no other records of these crossings and it is not stated whether these were natural or artificial. Dalby (1968) suggested that the apparent variability of some *Malva* species is due, at least in part, to hybridization. However, due to the lack of other records of natural *Malva* hybrids, it is unclear as to whether these 'hybrids' were real or a case of misidentification. In experiments with artificial *Malva* crosses, no spontaneous hybrids occur, though some artificial crosses produce slightly fertile offspring (i.e. *M. pusilla* × *M. neglecta*, *M. parviflora* × *M. neglecta*) (Kristofferson 1926). There is no evidence for hybridization in Canadian collections of *Malva* species (Makowski and Morrison 1989). *Malva sylvestris* pollen placed on the stigma of *Gossypium* L. (cotton) does not germinate at all (Kamalova 1985) indicating that intergeneric hybrids are also very unlikely. Furthermore, as *M. parviflora* is predominantly inbreeding, with self-pollination occurring prior to flower opening, hybrids are not expected to form easily (Michael *et al.* 2006b).

Population dynamics

Malva parviflora is morphologically variable between geographical locations. Plants collected from northern populations within the wheatbelt of WA (north of 29°22'S) flower earlier, have shorter calyxes, are narrower at flowering and have heavier seeds at senescence than populations from more southern populations (Michael *et al.* 2006b). Two populations from the western side of the wheatbelt (Mingenew and Wagin), which has

higher rainfall, lose physical dormancy more slowly than populations from the eastern side (Morawa and Hyden), which has lower rainfall (Michael *et al.* 2006a). In South Australia, pedicel length varies considerably between plants (Barker 1977). In Jordan, growth is dependent on the climatic region in which plants grow (Eideh and Elkarmi 2005). Plants growing in the cool region grew taller in preference to increasing stem width, leaf length, leaf width and petiole length, whilst plants growing in the warm region exhibited the opposite, with plant height increase being lower.

Importance

Detrimental

There has been little research into the competitive effects of *M. parviflora*; however *Malva* species are very good competitors with both agricultural (Makowski and Morrison 1989, Makowski 1995) and horticultural crops (Agamalian and Kurtz 1989, Abusteit and Shehata 1993) as well as other weed species such as wild oats (*Avena ludoviciana* Durieu) (Bilalis *et al.* 2001). In particular *Malva* species are especially competitive in minimum tillage systems where tap roots are allowed to grow freely. *Malva pusilla* has been studied extensively in this regard. It is listed as a noxious weed in Canada (Makowski and Morrison 1989), where it is a major weed of less competitive field crops such as lentil and flax (Makowski and Mortensen 1992). It doubled in abundance on cultivated land between 1980 and 1985 in Alberta, Canada (Makowski 1995). It is capable of substantially reducing crop yields and quality, particularly if it emerges before the crop (Friesen *et al.* 1992). In Canada, wheat yields are reduced by 30% at densities of 139 plants m^{-2} and densities of 39 plants m^{-2} reduce the yield of flax by more than 90% (Makowski and Morrison 1989). *Malva pusilla* remains green in the autumn and causes problems by interfering with both the threshing and cleaning processes of the harvester (Makowski and Morrison 1989). It is also a problem as a crop seed contaminant. The highly competitive nature of *Malva* species throughout the world suggests that *M. parviflora* also has the potential to cause significant detriment to agricultural systems within Australia.

Consumption of *M. parviflora* can be harmful to livestock. In Australia there is evidence that ingestion of very large quantities of *M. parviflora* (1.4–5.5 kg day^{-1}) in addition to hard driving can cause 'staggers' in sheep, horses and cattle (Dodd and Henry 1922, Hurst 1942, Everist 1974, Main and Butler 2006). Affected animals cannot walk and display trembling and quivering of the limbs, shallow breathing and rapid pulse (Everist 1974). If the animal is allowed to rest, the condition will pass and it will recover in a few hours. So although potentially toxic, *M. parviflora* poses only a small risk to livestock if the 'staggers' condition is recognized early. However, if the animal is continuously pushed it may die. It is not known what causes 'staggers' although researchers have suggested that plant nitrate content may be a contributing factor (Webb 1948, Gardner and Bennetts 1956, Kingsbury 1964, Everist 1974). Consumption of *M. parviflora* can also be detrimental to poultry. Sterculic and malvalic acid, fatty acids found in *M. parviflora* plants (Shenstone and Vickery 1959, Ahmad *et al.* 1984), produce the typical symptoms of 'pink-white condition' in the whites of poultry eggs. The disorder produces a mottled, discoloured yolk, a pasty condition when eggs are kept at low temperatures, and higher than normal yolk water content (Shenstone and Vickery 1959). This condition has severe commercial consequences through a reduction in overall egg quality.

Malva parviflora acts as host for many pests and diseases including the South African cassava mosaic virus (Berrie 2001), the faba bean necrotic yellow virus (Al-Nsour *et al.* 1998), cotton tipworm (*Crocidosema plebejana* Zell.) (Hamilton and Gage 1986), rust fungus (*Puccinia malvacearum* Bertero ex Mont.) (Elarosi *et al.* 1974), the thrip *Frankliniella occidentalis* Perg. (Bautista *et al.* 1995) and root lesion nematodes (*Pratylenchus neglectus* L. and *P. thornei* L.) (Vanstone and Russ 2001). As the weed can emerge all year round (Chorbadjian and Kogan 2002), it is likely to be able to host biotrophic fungi, such as powdery mildew and rusts. An Egyptian study recorded the presence of 39 different fungal species from 20 genera on a single *M. parviflora* plant (Abdel-Hafez and El Naggar 2001). These pests compound the consequences of *M. parviflora* infestation.

Beneficial

In certain countries, *M. parviflora* is a useful and valuable plant species. It has been used as feed for poultry (Asar *et al.* 1972), carp fish (Labib *et al.* 1994) and grazing animals (Guerrero 1999). *Malva parviflora* has chemical feed quality attributes comparable to alfalfa, with weed-infested paddocks in eastern California able to sustain more lamb grazing days and produce more kilograms of lamb gain per hectare of land than weed-free paddocks (Guerrero 1999). There is the opportunity for *M. parviflora* to be marketed as a livestock food source as long as the potential for 'staggers' is taken into account by ensuring livestock are not unduly exerted or pushed.

Malva parviflora is an important part of the human diet and provides essential nutrients for many underprivileged people in countries such as Morocco, where only the young shoots are eaten, (Tanji and Nassif 1995), Egypt (Badawi and El-Sahhar 1978), Mexico (Ranhotra *et al.* 1998) and the Mediterranean region (Abousabaa 2001). Analysis of *M. parviflora* leaves indicate that they are high in protein (36.2%), carbohydrates (12.4%) and soluble fibre (4.2%) (Ranhotra *et al.* 1998) and seeds contain considerable amounts of antioxidants (Abousabaa 2001). *M. parviflora* has also been used in traditional medicine for hundreds of years for its anti-bacterial properties (Grierson and Afolayan 1999). Recently it has been discovered that *M. parviflora* contains important anti-bacterial and anti-fungal proteins and genes for these could potentially be transferred to improve resistance of otherwise pathogen-sensitive plants (Wang and Bunkers 2000, Wang *et al.* 2001, Shale *et al.* 2004, 2005). Four potent anti-fungal proteins purified from seeds were found to severely inhibit the activities of *Fusarium graminearu* Schwabe and *Phytophthora infestans* (Mont.) de Bary (Wang and Bunkers 2000, Wang *et al.* 2001). Hexane, methanol and water extracts made from *M. parviflora* with a prostrate growth form inhibit the growth of Gram-positive and Gram-negative bacteria, while extracts made from plants with an upright growth form inhibit the growth of Gram-positive bacteria only (Shale *et al.* 2005). Antibacterial activity of *M. parviflora* (leaves and roots) initially increases with storage, with the highest inhibitory activity being measured after 3–6 months storage, after which activity gradually decreased (Shale *et al.* 2004).

Whilst *M. parviflora* is host to many pathogens and diseases, it also provides shelter, food and refuge to beneficial predators such as *Amblyseius victoriensis* Wom., a predatory mite found in peach orchards of NSW (James 1989, 1990) and *Coccinella arcuata* Fabr. (beetle), *Nabis capsiformis* Germ. (pale damsel bug) and *Deraeocoris signatus* Dist. (brown smudge bug) found in cotton fields of south-east Queensland (O'Brien 1978). So whilst caution should be exercised in its use, *M. parviflora* has many beneficial attributes.

Legislation

Malva parviflora is not currently a declared or noxious weed in any Australian state or territory (Australian Weeds Committee 2008) and there is no legislation governing its movement or control.

Weed management

Herbicides

There are currently 192 herbicide products containing 54 active ingredients registered for use on *M. parviflora*, including paraquat (135 g L^{-1}) and diquat (115 g L^{-1}), trifluralin (400 g L^{-1}), simazine (500 g L^{-1}), diuron (500 g L^{-1}) and glyphosate (450 g L^{-1}) (APVMA 2008). In order to be registered, herbicides must provide evidence of reasonable weed control. However, control of *M. parviflora* with selective herbicides and cultivation is often unsatisfactory (Blackshaw 1996),

facilitating its spread once initial infestations become established. *Malva parviflora* is naturally tolerant to glyphosate (Group M) (Wu and Dasgheib 2001). Glyphosate is a non-selective, foliar applied herbicide which has been extensively used around the world for the past 20 years. It gives only partial control of *Malva* species (Dastgheib and Frampton 2000, Wu and Dasgheib 2001, Chorbadjian and Kogan 2002). It is well known that the activity of glyphosate can be antagonized by the presence of polyvalent cations (Stahlman and Phillips 1979, Nalewaja and Matysiak 1991) that lead to the formation of poorly soluble glyphosate salts that are less likely to be taken up by the plant. Microanalysis of the leaf surface of *Abutilon theophrasti*, from a closely related genus and a member of the Malveae group, indicates the presence of two antagonistic elements, magnesium and calcium (Hall *et al.* 2000). Further analysis led to the discovery of specialized trichomes (chalk glands) that secrete these cations. Therefore, the glyphosate tolerance of *M. parviflora* may be due to specialized structures, such as trichomes, and further investigation is required.

This tolerance to glyphosate can be reduced by the addition of certain herbicides, which when mixed together, produce a synergistic interaction that increases the efficiency of glyphosate or maintains its optimum activity at lower rates. Such herbicides include lactofen (Wells and Appleby 1992), a diphenyl ether herbicide that inhibits the production of protoporphyringogen oxidase (Group G), and fluroxypyr (Chorbadjian and Kogan 2002), which disrupts plant cell growth (Group I). Directed spray applications of undiluted ammonium nitrogen fertilizer cause 99% control at the 1–4 leaf stage and 77% at the 5–7 leaf stage (Agamalian 1991).

Other treatments

Malva parviflora plants have a substantial taproot and they are thus difficult to kill. Plants are able to regrow after being cut down or eaten to the crown area, though cultivation can kill *M. parviflora* if the taproot is severed below the crown (Chorbadjian and Kogan 2002). Mowing and grazing of *M. pusilla* will delay growth for a short time, followed by rapid recovery and increased branching below the injured area (Makowski and Morrison 1989).

Livestock have been used to control weeds for many years. The effect of animal digestion on *M. parviflora* seed viability has been examined for horses (St John-Sweeting and Morris 1990), sheep (Michael *et al.* 2006c) and birds (Proctor 1968); and for *M. pusilla* digestion by cattle (Blackshaw and Rode 1991). Many studies indicate seed survival with passage through animals is related to the degree of hardseededness in addition to seed size (Simao Neto and Jones 1987, Simao Neto *et al.* 1987, Norton *et al.* 1989, Gardener *et al.* 1993a,b, Squella and Carter 1996), with hardseeded small seeds most likely to survive digestion. The hardseededness of *Malva* species, as well as small size, allow a substantial proportion of seeds to survive mastication and digestion. Most (>92%) physically dormant seeds placed into a sheep rumen survive up to 48 hours of digestion, whilst only 1.4% of scarified non-physically dormant seeds survive digestion for 12 hours (Michael *et al.* 2006c). The hard, impermeable seed coat of *M. parviflora* protects the embryo from chemical and enzymatic scarification (Sumner and Cobb 1967), which enables seed survival during rumen digestion.

However, when dormant seeds were fed to sheep and faeces collected, the large majority (82%) were killed through mastication, digestion and gut passage (Michael *et al.* 2006c). The proportion of hardseededness within any *M. parviflora* weed population depends largely on plant and seed development stage (Michael *et al.* 2007) so the risk of spreading viable seeds is very low if sheep graze only on immature plants and seeds. The palatability of *M. parviflora* to sheep at different plant and seed development stages is unknown and research is needed.

Natural enemies

Whilst there has been little research on natural enemies of *M. parviflora* and thus the prospect of using biological control in Australia is unknown, the bioherbicide BioMal™ (derived from the fungi *Colletotrichum gloeosporioides* Penz.) is successfully used to control *M. pusilla* in Canada (Zimdahl 1999).

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