Review

The biology of Australian weeds
51. *Heliotropium europaeum* L.

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Name

Heliotropium europaeum L. – 'Helios' means sun, and 'trope' means turning to, thus giving the meaning of turning to the sun (Greek); 'europaeum' means from Europe or related to the European continent (Latin). The accepted common name within Australia is common heliotrope (Anon. 1953, Hartley 1979). However, common names within Australia also include Barooga weed, caterpillar weed, Bishop's beard, European heliotrope, wild heliotrope, potato weed, tomato weed, blue weed and Wanderrie curse (Moore 1956, Parsons and Cuthbertson 2001, Hunt 2006).

Description

Common heliotrope is a summer growing herbaceous annual belonging to the family Boraginaceae. Walsh and Entwisle (1999) describe it as having an erect habit up to 0.4 m in height with an indumentum of tubercle-based greyish hairs. The leaves are elliptic to ovate, 15 to 70 mm in length and 5 to 30 mm wide with an obtuse apex, cuneate base, flat margins and hairs on both sides. They are connected to the stems by petioles that are up to 30 mm long. Inflorescences are usually branched, sepals are lanceolate, 2.5 to 3.5 mm long, acute, shortly connate and do not elongate. The corolla is 4 to 5 mm long with a yellow, glabrous throat and is white and hairy outside. The anthers are acute, the apices free and the style very short. The stigma is about 0.75 mm long and papillate. The seeds are four dry, brownish mericarps per flower. Seeds can be glabrous or pubescent, are rugose and fall at maturity. Figures 1a–f show common heliotrope at various stages of its development.

Common heliotrope is not the only member of its genus that is a weed of economic significance in Australia, although it is by far the most important. The other four species of *Heliotropium* accorded economic significance occasionally cause localized, but generally not severe problems (Delfosse and Cullen 1980). Blue heliotrope (*Heliotropium amplexicaule* Vahl), a native of South America, is a perennial weed of roadsides, fallows and degraded pastures in southern Queensland, South Australia and northern New South Wales, where in some shires it is classified as noxious (Harden 1992, Parsons and Cuthbertson 2001). Smooth heliotrope (*Heliotropium curassavicum* L.) is also native to South America and occurs on saline flats and wet areas in all mainland states (Harden 1992, Walsh and Entwisle 1999). Another European species, creeping heliotrope (*H. supinum* L.), is very similar in appearance to *H. europaeum* except for its prostrate habit. It is also a summer weed, but is restricted to heavy clay soils in the Mediterranean semi-arid regions of Australia (Harden 1992, Walsh and Entwisle 1999). Rough heliotrope (*Heliotropium asperrinum* R.Br.) is a native species restricted to damp, sandy situations (Harden 1992, Walsh and Entwisle 1999).

History

There has been some contention as to whether common heliotrope is native to southern Australia (Moore 1956, Kloot 1983, Sheppard *et al.* 1996). The controversy centres on a specimen collected at the head of Spencer's Gulf by Robert Brown in 1802, which he named *Heliotropium glandulosum* (Moore 1956). Bentham (1869) later cited this specimen as *H. europaeum*, and argued that the plant was native, as there was no known European contact with South Australia prior to the voyage of Mathew Flinders, in which Brown took part (Kloot 1983). However, Black (1909) considered Brown's specimen to be of another species, the native *H. eichwaldii*, and Kloot (1983) cites personal communication from D.E. Symon to the effect that the specimen in question is very poor in quality and its identity uncertain. In comparing Australian specimens to those from the Northern Hemisphere, Bentham (1869) stated that no characters could be found to distinguish Australian specimens from European material. Moore (1956) cites comparative studies undertaken by the Kew Botanic Gardens, which concluded that Australian specimens from a wide range of localities were similar to European specimens, whilst those from Asiatic countries differed more widely from the European specimens than did those from Australia. All things considered, it seems most likely that common heliotrope was introduced to southern Australia during the 19th century from France or Italy (Moore 1956, Delfosse and Cullen 1980, Kloot 1983, Walsh and Entwisle 1999).

Distribution

Common heliotrope is native to the Middle East, East Asia and the region surrounding the Mediterranean Sea (Bentham 1869, Cunningham *et al.* 1981, Sheppard *et al.* 1996, Walsh and Entwisle 1999, Parsons and Cuthbertson 2001). It has been recorded in all states of Australia except Tasmania and the Northern Territory (Figure 2), being most abundant in southern New South Wales and Victoria inland of the Great Dividing Range, and in southern South Australia (Everest 1981, Harden 1992, Walsh and Entwisle 1999, Parsons and Cuthbertson 2001).

Habitat

Climatic requirements

Common heliotrope's distribution is limited to areas of winter dominant rainfall, principally between the 300 and 500 mm isohyets (Moore 1956). Despite the bulk of annual rain in the species' range falling in the winter, a significant amount of rainfall arrives over the summer months (around 20% in the Victorian Mallee), principally in the form of sporadic and intense thunderstorms. Warm summer temperatures, bare earth and sufficient rain constitute ideal conditions for the germination and emergence of common heliotrope (Moore 1956), and frequently landscapes are turned pale blue by its ensuing growth.

Substratum

Common heliotrope grows on a wide range of soil types, principally loams but ranging from sands to clays (Cunningham *et al.* 1981, Sheppard *et al.* 1996, Parsons and Cuthbertson 2001). Moore (1956) and Sheppard *et al.* (1996) both observed that common heliotrope does not appear to

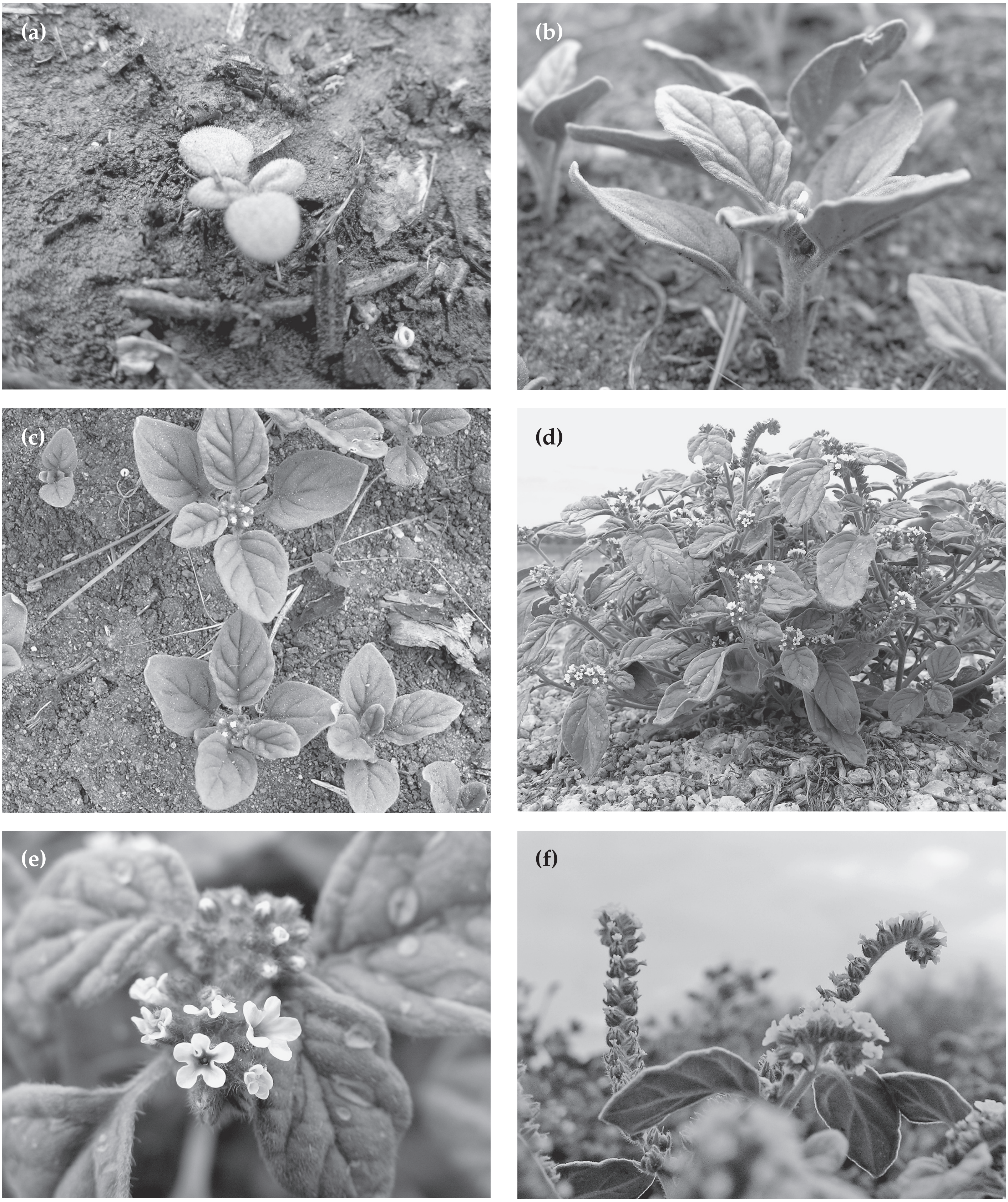

Figure 1. (a) A seedling of common heliotrope several days old showing cotyledons and emerging first true leaves.
(b) A young common heliotrope plant 2–3 weeks old with three pairs of true leaves about to commence flowering and axillary growth.
(c) Common heliotrope plants 2–3 weeks old and starting to show signs of drought stress (upturned leaves, retarded development).
(d) A mature common heliotrope plant.
(e) Flowers of common heliotrope in an inflorescence (cyme) early in development.
(f) A well developed inflorescence (cyme) of common heliotrope illustrating indeterminate nature of flowering. Note un-opened flower buds at the top, and immature seeds at its bottom.

show any marked preference for soil type. Hunt (2006) observed that infestations were more prominent on lighter soils, and used a model of soil water and temperature flux to illustrate that conditions suitable for germination persist for longer in lighter textured and coloured soils. This results in a greater number of seeds germinating on lighter as opposed to heavier soil types following rainfall events marginal for germination. Similarly, Vasconcelos and Sa (1988) observed that light textured alkaline soils were best for propagation of the plant. However, following large or extended rainfall events where water availability is not limiting, infestations are largely independent of soil type. Under these conditions, soil-surface conditions (i.e. pasture composition and conditions, degree of litter accumulation, crop/stubble conditions) are more important than soil type in determining the occurrence of the plant (Moore 1956, Delfosse and Cullen 1980, Sheppard *et al.* 1996).

Plant associations

According to Sheppard *et al.* (1996), who compared the demography of common heliotrope populations in Australia and southern France, frequency and intensity of infestations and magnitude of seed production are much greater in Australia than in its native habitat (Table 1). They concluded that this was largely due to differences in cultural practices between Australia and southern France. Common heliotrope establishes in late spring and early summer in bare areas after sufficient rainfall when temperatures are high enough to allow germination (Moore 1956, Sheppard *et al.* 1996). The farming systems in the pertinent regions of Australia principally utilize annual species for production, and leave much land devoid of vegetation over the summer months. In the plant's native range, perennial species are dominant, leaving less bare earth during summer.

As a weed of pastures, common heliotrope becomes established in areas previously dominated by winter annuals such as barley grass (*Hordeum leporinum* L.), silver grass (*Vulpia bromoides* (L.) S.F.Gray), subterranean clover (*Trifolium subterraneum* L.), musky crowfoot (*Erodium moschatum* (L.) L'Hérit) and capeweed (*Arctotheca calendula* (L.) Levyns) (Moore 1956, Everest 1981). Common heliotrope rarely establishes successfully in the presence of other living plants. Moore (1956) observed that common heliotrope was in lower densities in areas where saffron thistle (*Carthamus lanatus* L.) was a prominent constituent of pastures and was not present in undisturbed areas dominated by native perennial grasses (e.g. *Stipa* spp. and *Danthonia* spp.).

Common heliotrope is by no means the only summer weed within its range, but is often found in mixed infestations of summer annual dicotyledons such as caltrop (*Tribulus terrestris* L.), prickly paddy melon (*Cucumis myriocarpus* Naudin), camel melon (*Citrullus lanatus* (Thunb.) Matsum. & Nakai var. *lanatus*), quenna (*Solanum esuriale* Lindl.) and the annual grasses witchgrass (*Panicum capillare* L.) and stinkgrass (*Eragrostis cilianensis* (All.) Vignolo ex Janchen).

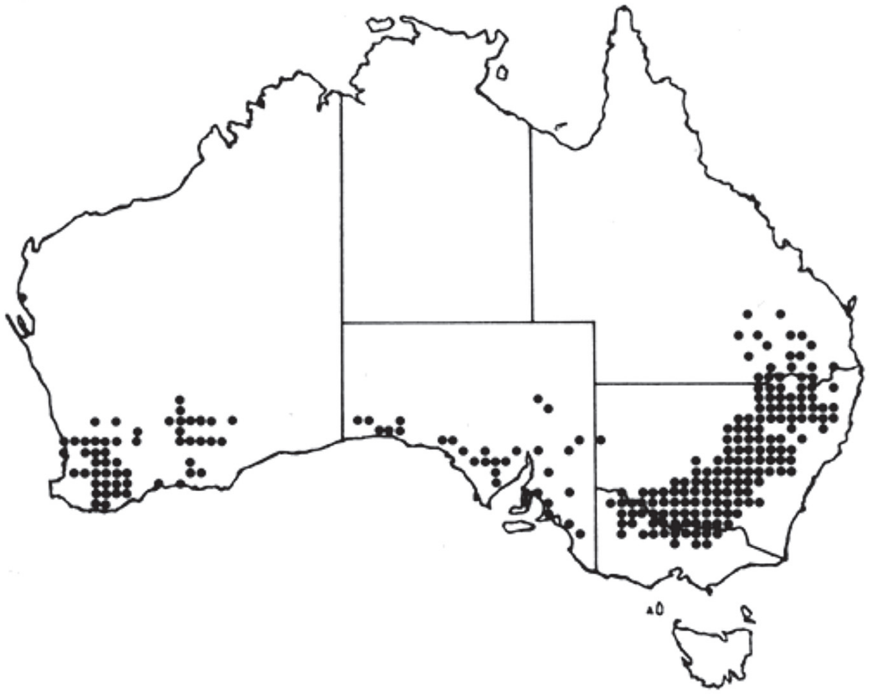

Figure 2. The distribution of common heliotrope within Australia (image taken from Parsons and Cuthbertson 2001).

Table 1. Mean (range) values for different population parameters measured from France and Australia by Sheppard *et al.* (1996).

Parameter	France 1992 and 93 (9 sites)	Australia 1991/92 and 92/93 (11 sites)
Seedling density m^{-2}	15 (0.3–700)	125 (20–892)
Flowering plant density m^{-2}	14 (0.3–700)	120 (20–892)
Plant dry weight (g)	(0.5–8.6)	(0.3–7.5)
Cymes plant^{-1}	64 (0.5–170)	23 (8–48)
Fruits plant^{-1}	628 (1.2–1104)	234 (32–755)
Seed rain m^{-2}	78 323 (17–235 200)	271 183 (187–1 456 101)
Seed bank (autumn) m^{-2}	21 759 (17 408–43 478)	177 852 (71 627–426 100)
Seed bank (spring) m^{-2}	9950 (1325–40 242)	119 251 (31 224–251 384)

Growth and development

Following emergence, development of above-ground parts is rapid. Plants flower as little as three weeks after germination (Moore 1956) and can produce ripening seed by six to eight weeks after germination (Parsons and Cuthbertson 2001). Moore (1956) states that after emergence, common heliotrope develops an extensive root system, and once established, it will withstand periods of drought provided there is sufficient sub-soil moisture. Through laboratory and field measurements of root growth, Hunt (2006) found that rate of root depth growth was relatively low (5.6 to 5.9 mm day^{-1}, Figures 3 and 4, Table 2) compared to temperate annual species that exhibited elongation rates of up to 21.6 mm day^{-1} under similar temperatures (Shrestha *et al.* 1999). Far from quickly developing a long tap root, root architecture appeared to methodically explore regions in which water was currently available before moving deeper (Figure 5). Established plants can rapidly grow a profusion of roots from the main stem just below the soil surface in response to rainfall (Figure 6). This allows them to use water arriving in small rainfall events that would not otherwise reach the plant's root system established

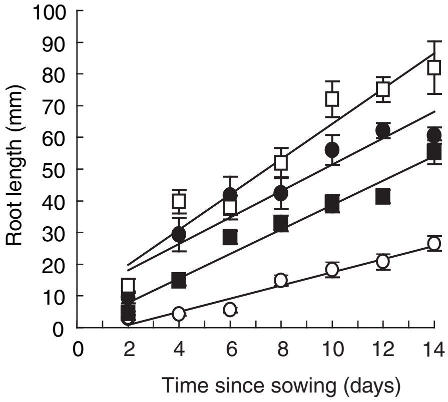

Figure 3. Root depth growth of pre-germinated seeds of common heliotrope over time at 17.1 (○), 20.3 (■), 26.5 (●) and 31.8°C (□) and regression lines for each temperature. Error bars are ± the standard error of the mean.

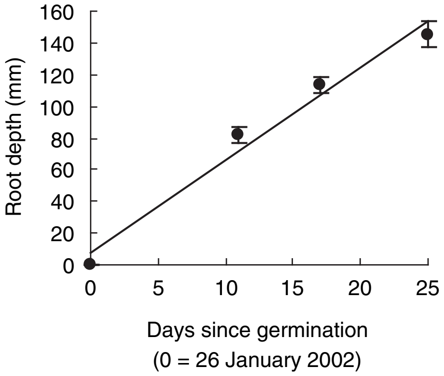

Figure 4. Root depth growth of common heliotrope (●) over time in the field near Birchip in north-west Victoria following a germinating rainfall of 28 mm on 22 January 2002. Error bars are ± the standard error of the mean. Linear equation is y = 5.9x + 7.6 (R^2 = 0.98).

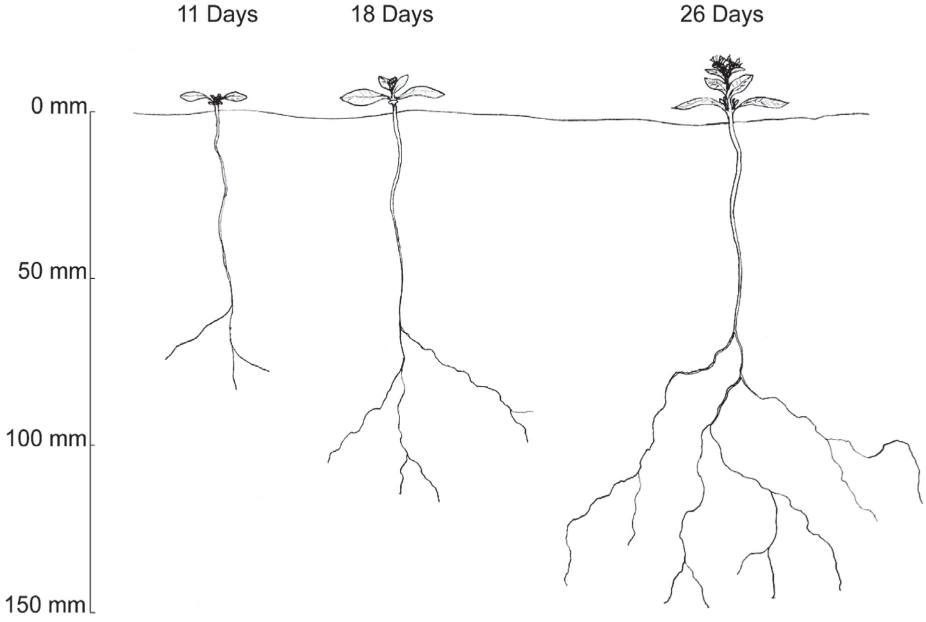

Figure 5. A scale drawing of development, root position and structure of common heliotrope plants in the field over 26 days following emergence at Birchip in January 2002.

Table 2. Growth rate of common heliotrope root depth at different temperatures estimated by linear regression for each temperature. Growth rates with a different letter are significantly different (P <0.05) as determined by analysis of parallelism.

Temperature (°C)	Growth rate (mm day^{-1})	R^2
17.1	2.1^{a}	0.96
20.3	3.9^{b}	0.96
26.5	4.2^{b}	0.90
31.8	5.6^{c}	0.94

at depth (Hunt 2006). The architecture of the above-ground parts of the plant concentrates rainfall around the main stem where it can be easily accessed by these opportunistic roots (Figure 7).

Reproduction

Seed production and dispersal

Flowering and seed production are both indeterminate and concurrent with growth, which occurs continuously throughout summer until plants are killed by drought or autumn frosts (Moore 1956, Sheppard *et al.* 1996). Reproductive effort can be enormous in favourable seasons and seed rain as high as 1.4 million seeds m^{-2} has been recorded in Australia (Sheppard *et al.* 1996). Although common heliotrope can reproduce upon the rainfall event which causes its germination, further access to moisture will result in massively increased reproductive output because its growth is indeterminate (Hunt *et al.* 2006). Seeds are small, light and have a rough seed coat which allows them to be dispersed by both wind and in the coats of animals. There is anecdotal evidence that seeds are also able to remain viable after passing through the digestive tract of ruminants, and can be spread in this manner.

Physiology of seeds and germination

Sheppard *et al.* (1996) suggested that 10 mm of rainfall may be sufficient to allow germination but that 25 mm is required to ensure population establishment. Fromm and Grieger (2000) suggested that successful germination and emergence requires the amount of rainfall necessary to wet the top 250 mm of soil. By fitting a rectangular hyperbolic function (y = a + b/(1 + dx)) to emergence data from a simulated rainfall experiment conducted at Normanville in north-west Victorian in January 2002, Hunt *et al.* (2006) found that 24 mm of rainfall was required for successful, albeit low density emergence (less than 1% of total seed bank) of common heliotrope. This figure corresponded to the amount of water required for minimal reproductive output of plants grown in lysimeters at Normanville in January 2003 (Hunt *et al.* 2006). The amount of rainfall required for successful germination and establishment of common heliotrope will vary with soil type, soil cover, weather conditions and time of year (Moore 1956, Hunt 2006), since both the amount and duration of soil water are the critical determinants of germination and emergence.

Within each growing season, there may be numerous germination flushes which follow suitable rainfall events. This necessitates multiple control operations. Following each event, emergence commences within a few days, but may take several weeks to conclude (Hunt 2006).

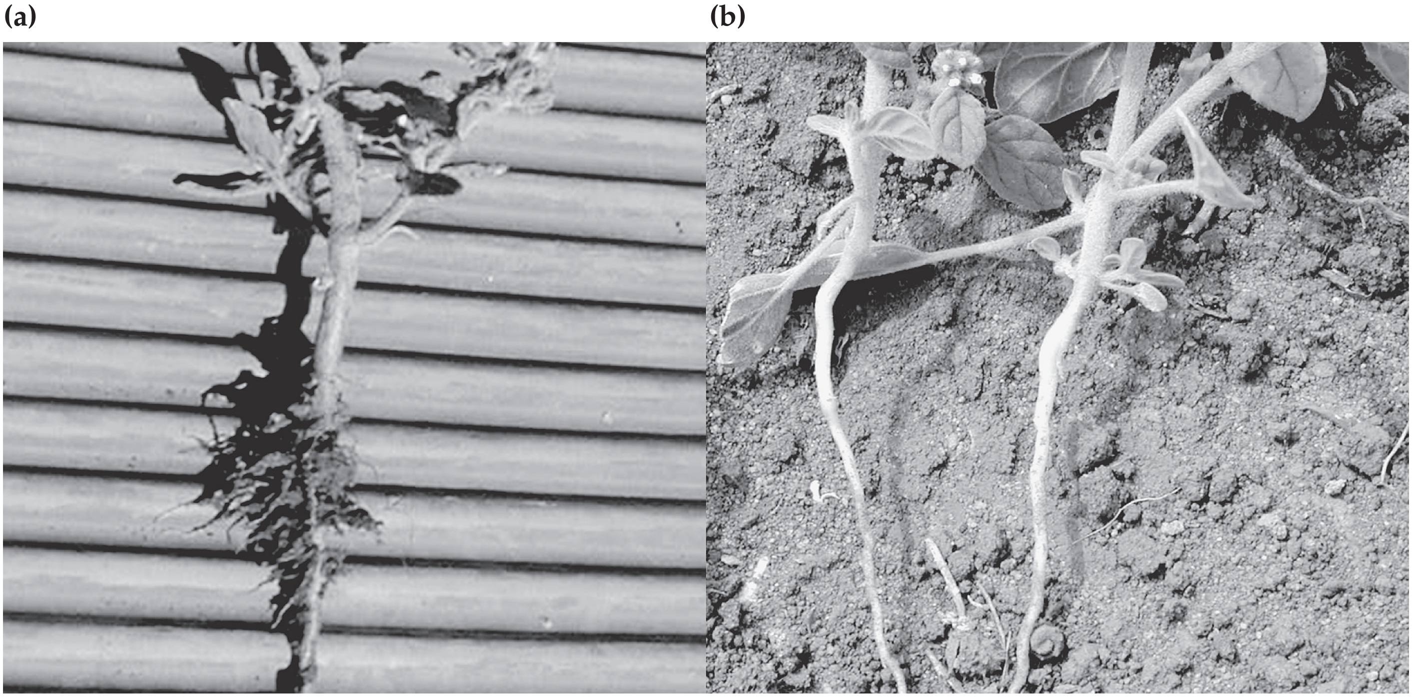

Figure 6. Plants of common heliotrope growing in the open (a) and under a rain shelter (b). There is a profusion of new roots below the root collar in the plants growing in the open, but not in those growing under a rain shelter. The opportunistic roots grew in response to a 6 mm rainfall event at Normanville in March 2001.

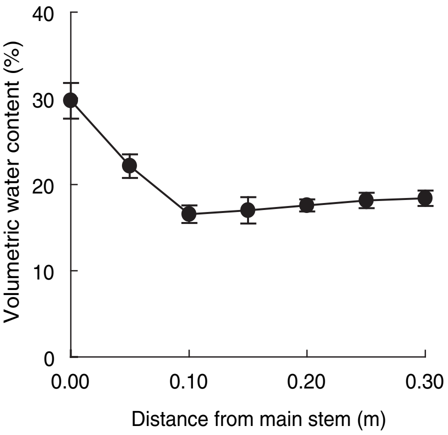

Figure 7. Mean volumetric soil water content (%) at increasing distances from the main stem of seven plants of common heliotrope approximately 12 hours after 9 mm of rain fell at Normanville in March 2001. Error bars are ± the standard error of the mean.

Relatively high temperatures are required for common heliotrope to germinate (Moore 1956, Hunt *et al.* 2006). Moore observed that no seeds germinated in three weeks at 19°C, but when the temperature was increased to 24°C and 35°C, percentage germination increased to 22% and 30% accordingly; germination did not occur in the field until mean air temperatures of around 18–24°C occurred. Hunt *et al.* (2006) found through controlled temperature and water potential treatments that optimum temperature for common heliotrope germination was around 35°C, and optimum water potential 0 MPa. Under these conditions, close to 100% of the viable seed population will germinate. They also observed that optimal conditions are rarely met in the field, and that the percentage of seeds that germinate at sub-optimal conditions changes seasonally and between Australian populations.

Moore (1956) found that pre-treatment of seeds kept moist at 0°C for 24 hours and 10°C for one week also gave a significant increase in percentage germination when compared to untreated controls. However, Hunt (2006) found that germination percentage was not increased by pre-treatment of seeds at colder temperatures, and attributed the disparity in results between his and Moore's study to differences in seed maturity due to different harvesting methods. Hunt (2006) also found that seeds of common heliotrope do not have a light requirement for germination.

Seeds of common heliotrope appear to have considerable longevity. In a letter published in the Gardener's Chronicle and Agricultural Gazette, Charles Darwin cites an example from 19th century France, where seeds of common heliotrope were germinated after being buried in Gaulish tombs for approximately 1500 years (Barrett 1977). Within Australia there are numerous, if less impressive, anecdotes of common heliotrope germinating *en masse* in favourable seasons when it has been absent for many years under less favourable conditions. Such anecdotes aside, Vasconcelos and Sa (1988) studied the longevity of seeds of common heliotrope buried at different depths and found that more than 50% remained viable after two years, excluding those stored at the soil surface.

Importance

Common heliotrope is an economically important weed of both crops and pastures in Australia (Delfosse and Cullen 1980, Lazarides and Hince 1993). It is thought to infest 10 million ha of agricultural land (Culvenor 1985) and is reputed to cost Australian agriculture over $46 million in bad years (Cullen and Delfosse 1990). Common heliotrope growing over the summer months can significantly decrease the yield of subsequent winter crops (Table 3), particularly in dry years (Delfosse and Cullen 1980, Fromm and Grieger 2000, van Rees and Smallwood 2000). It does this by transpiring water and accumulating nitrogen during summer that could otherwise be used by ensuing crops (van Rees and Smallwood 2000). Hunt (2006) found that from 1976 to 2002, summer rainfall in the Mallee region of Victoria on average accounted for 27% of the region's average potential wheat yield, and that uncontrolled common heliotrope could potentially account for as much as $84 million in lost yield. It has also been observed that on soils with chemical constraints to crop growth at depth (e.g. salinity, excessive boron), common heliotrope is able to extract more water than most crops (D.

Roget personal communication). Under such circumstances, paddock soil water can be in deficit when crops are planted, and considerable rainfall is required before any water will be available to a crop.

There is evidence that the remains of common heliotrope plants may have an allelopathic effect on the growth of crop plants (Table 3, van Rees and Smallwood 2000). The weed can also be a host for crop pathogens, including cucumber green mottle mosaic virus (Boubourakas *et al.* 2004), Pepino mosaic virus (Cordoba *et al.* 2004), cereal root lesion nematodes (Vanstone and Russ 2001), black rot (Mahiar and Khlaif 1999) and beet mosaic potyvirus (Katis *et al.* 1997). Under certain environmental conditions, common heliotrope seeds and foliage may be harvested with grain and become a contaminant (Gaul *et al.* 1994, Hill *et al.* 1997, Anon. 1999). This is a problem, as the above-ground parts of common heliotrope contain high levels of pyrrolizidine alkaloids (O'Dowd and Edgar 1989), which are well established as hepatotoxins in animals and humans (Huxtable 1989). The frequently lethal toxaemic effects of the pyrrolizidine alkaloids found in common heliotrope on sheep, cattle, pigs and poultry are well documented, and include wasting caused by failure of body functions, jaundice and photosensitization – all the result of liver damage (Bull *et al.* 1956, Walker 1966, Kinnaird *et al.* 1968, McLennan and Dodson 1972, Everest 1981, Harper *et al.* 1985, Gaul *et al.* 1994). Common heliotrope pollen has also been identified as a source of pyrrolizidine alkaloids in samples of commercially available honey (Edgar *et al.* 2002, Beales *et al.* 2004).

Table 3. Soil water, available nitrogen and subsequent wheat yield under controlled (cultivated) and uncontrolled (plant remains left and plant remains removed) common heliotrope on a fallow at Charlton in central Victoria in 1998/99. Table taken from van Rees and Smallwood (2000).

	Controlled	Uncontrolled	
	(cultivated)	(plants left)	(plants removed)
Total soil water at sowing (mm)	210	140	140
Available nitrogen (kg ha^{-1})	78	45	45
Subsequent wheat yield (t ha^{-1})	3.68	2.17	2.46

Animals grazing on pastures dominated by common heliotrope are susceptible to pyrrolizidine alkaloid poisoning. Culvenor (1985) estimated the total annual loss from pyrrolizidine alkaloid poisoning by common heliotrope in south-eastern Australia as $A7.5 million.

Legislation

Common heliotrope is proclaimed noxious in Tasmania and in the Albany, Augusta-Margaret River, Boyup Brook, Bridgetown-Greenbushes, Broomehill, Bunbury, Busselton, Capel, Cranbrook, Dardanup, Denmark, Donnybrook-Balingup, Gnowangerup, Kojonup, Manjimup, Nannup, Plantagenet, West Arthur, Woodanilling, Dumbleyung, Katanning, Tambellup and Wagin regions of Western Australia (Parsons and Cuthbertson 2001, Department of Agriculture and Food 2007). Common heliotrope is not specifically legislated for in other states and territories of Australia.

Weed management

Within Australia, common heliotrope is largely controlled by cultivation and a combination of knockdown herbicides (e.g. glyphosate, paraquat and diquat) and residual herbicides (e.g. sulfonylureas and triazines). Cultivation is only effective on younger plants, causes erosion and is damaging to soil structure (Delfosse and Cullen 1980, Anon. 1999, Parsons and Cuthbertson 2001). Effective control with herbicide can be difficult to achieve under summer conditions (Leys *et al.* 1990, Fromm and Grieger 2000, van Rees and Smallwood 2000). If a cohort of common heliotrope establishes following rain and is successfully controlled by either cultivation or knockdown herbicide, further rain will result in another cohort emerging which will also require control (Moore 1956, Delfosse and Cullen 1980, Dellow and Seaman 1987, Parsons and Cuthbertson 2001). This re-treatment can make the cost of controlling common heliotrope very high. Ironically, control of common heliotrope, particularly by cultivation, creates a disturbed habitat ideal for the growth of future cohorts of the species.

Analysis of long term summer rainfall data from the Victorian Mallee indicates that there is potential for reducing the cost of controlling common heliotrope by using residual pre-emergent sulfonylurea or triazine herbicides, instead of the traditional post-emergent herbicides or cultivation (Hunt 2006). Economic benefits would have to be weighed up against the rotational constraints resulting from long plant-back periods for broad leaf crops following application of such herbicides. Economic analysis of the likely benefits of controlling each emerging cohort of common heliotrope could also lead to reduced control costs (Hunt 2006).

Other treatments

It has been shown that common heliotrope may be completely controlled with dense stands of lucerne (*Medicago sativa* L.) in a grazing context (Delfosse and Cullen 1980, Dellow and Seaman 1987). Moore (1956) suggested that common heliotrope could be controlled in wetter areas by maintaining pastures of phalaris (*Phalaris tuberosa* L.) and subterranean clover (*Trifolium subterraneum* L.) or perennial native grass species in drier areas. Control of common heliotrope by maintenance of competitive pasture species is not suitable in cropping systems, as the pasture species will indirectly compete with ensuing crops in exactly the same manner as common heliotrope. Control by grazing is of limited value due to the plant's toxicity (Moore 1956). However, some farmers use flocks of ageing merino wethers for this purpose (A. Sheppard personal communication).

Natural enemies

The inadequacy of conventional control methods prompted interest in a biological control program, and in 1950 the Commonwealth Scientific Research Organisation (CSIRO) began searching for possible organisms throughout the weed's native range. Accounts of this program, which concluded in 1994, may be found in Delfosse and Cullen (1980) and Sheppard (1994). Despite the release and establishment of the flea beetle *Longitarsus albineus* Foudras in 1982/83 and 87/88, and rust fungus *Uromyces heliotropii* Sredinski in 1991–1994 across southern Australia, these biological control agents have not contributed to the control of common heliotrope (Cullen and Delfosse 1990, Sheppard 1994). It is thought that this is largely due to the ephemeral nature of common heliotrope populations which does not allow populations of biological control agents to increase with sufficient speed to reduce the weed's impact (A. Sheppard personal communication).

Acknowledgments

Research was funded by Grains Research and Development Corporation project No. DAS293. We would like to thank Michael Moerkerk, DeAnne Price, Dennis O'Dowd and the Victorian Department of Primary Industries for their contribution to this project.

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