Review

The biology of Australian weeds 43. *Polymeria longifolia* Lindl.

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Name

Polymeria longifolia Lindl., of the Convolvulaceae, is a native Australian species commonly known as either clumped or erect bindweed (Cunningham *et al.* 1981), polymeria, Peak Downs curse (Stanley and Ross 1986, Auld and Medd 1987) or polymeria take-all (Johnson *et al.* 2003). Wilson *et al.* (1995) make a distinction between two species commonly known as Peak Downs curse, *P. longifolia* and *Teucrium integrifolium* Benth., a member of the Lamiaceae. *Polymeria longifolia* is known as one of the 'take-all' weeds, because of its perennial rhizomatous habit, its ability to form dense competitive infestations that smother the ground and its ability to extract soil water and nutrients (Johnson 2002).

Description

Polymeria longifolia is an erect, perennial plant 7.5–25 cm tall (Figure 1) with stems branching from an extensive and deep rhizome system. The stems and leaves are usually covered with silky hairs, giving them a grey-green to silver appearance. The leaves are linear to linear-lanceolate or narrow-elliptic, 20–70 mm in length and 2–10 mm wide (Johnson 1992, Wilson *et al.* 1995). The leaf apex is acute and finely mucronate, while the base is abruptly rounded and auriculate or truncate, with the petiole generally less than 4 mm in length (Johnson 1992).

The inflorescences of *P. longifolia* are single-flowered and extend on axillary peduncles that are 15–60 mm long. The nearly equal sepals are narrow-ovate to oblong-elliptic, 5–9 mm long and 2–3.5 mm wide (Johnson 1992). The corolla is 10–20 mm long and commonly pale pink, mauve or white with a yellow centre (Stanley and Ross 1986, Auld and Medd 1987, Johnson 1992). Flowering occurs throughout the year, but mainly from spring to autumn (Stanley and Ross 1986, Johnson 1992). The capsule is globose and 6–8 mm in diameter with a single, rarely two, pubescent seeds (Johnson 1992).

There are two species of *Polymeria* that are common summer cropping weeds, *P. longifolia* and *P. pusilla* R.Br. (Figure 2). Both species grow on heavy clay soils and in areas that may be seasonally flooded (Williams 1988, Johnson 1992). The main difference between the two species is that while *P. longifolia* has an erect habit, *P. pusilla* has trailing stems that root at the nodes (Johnson 1992). The leaves of *P. pusilla* are oblong to ovate (10–30 mm long and 7–20 mm wide) and the flower is 6–12 mm long. This is opposed to the longer and narrower leaves of *P. longifolia*. The fruit of *P. pusilla* may be borne on a downturned pedicel and may or may not be buried. Fruit can be produced both above and below ground in this case. The fruits

Figure 1. A flowering *Polymeria longifolia* plant.

of *P. longifolia* are always aerially produced (Cunningham *et al.* 1981, Johnson 1992). Cunningham *et al.* (1981) outline another species, *Polymeria* sp. (aff. *ambigua*) that they record as a weed of western New South Wales (NSW). This species is, in fact, *P. pusilla* (Johnson 1992).

Polymeria longifolia is morphologically variable across geographic locations. Specimens collected from northern Queensland (Qld) and the Northern Territory (NT) have a much narrower leaf (2–5 mm) and smaller flower (up to 6 mm), compared with those collected from southern Qld and NSW (R. Johnson personal communication). Bentham and Mueller (1866) originally described this northern Australian biotype as a separate species (*Polymeria angusta* F.Muell.) but noted that this species may well be a variety of *P. longifolia*. Similar morphological variation has also been observed in southern Australian populations (Johnson 2000).

Figure 2. A comparison between *Polymeria longifolia* (on the left) and *Polymeria pusilla* (on the right).

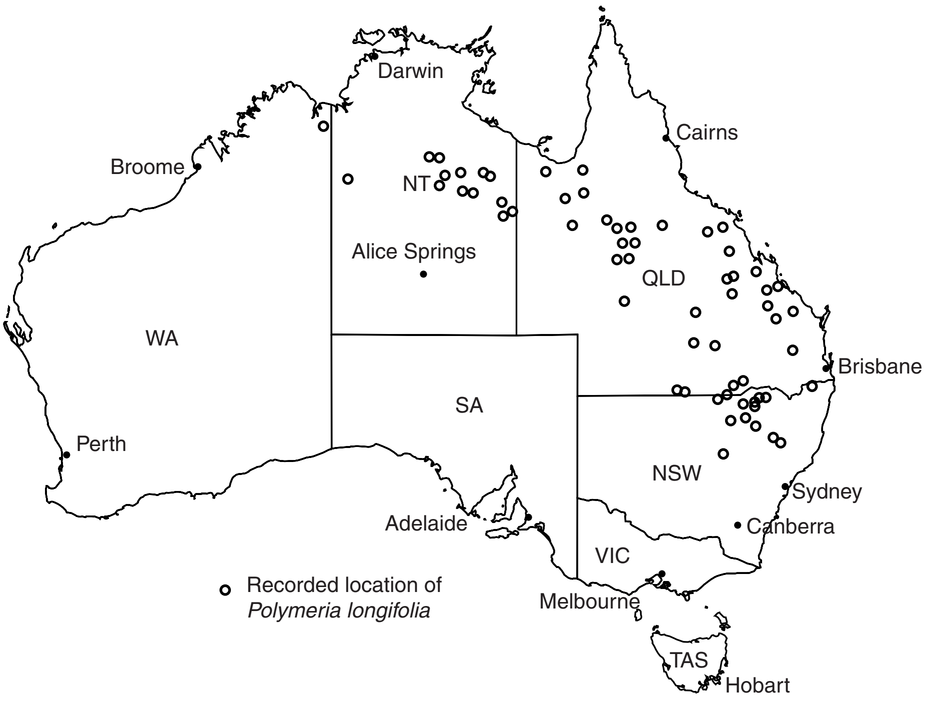

Figure 3. The distribution of *Polymeria longifolia* according to Australian herbarium records and collections made by the senior author. The southern-most recorded instance was in the Macquarie Valley (NSW) and the northern-most in the Kimberley area of Western Australia.

History

The botanist John Lindley first recorded *P. longifolia* prior to 1848 (Mitchell 1848, in Chapman 1991). Kleinschmidt and Johnson (1977) recorded that *P. longifolia* emerged in 'quantity' when the black soils of the Peak Downs area (near Capella in central Queensland, 23°05'S, 148°02'E) were broken up for cultivation in the early 1950s. As early as 1960, Queensland Herbarium records indicated that it was a 'troublesome weed in cultivation'. This continues to the present day, and particularly in cotton crops.

Distribution

Six of the seven species of *Polymeria* found in the world are endemic to Australia (Johnson 1992). *Polymeria longifolia* has been recorded in four Australian states (Figure 3). In NSW, it is commonly found north of Gunnedah, particularly on the north west slopes and plains (Cunningham *et al.* 1981, Hnatiuk 1990), but has been observed as far south as Warren in central NSW.

In Queensland, *P. longifolia* has been recorded in all major pastoral districts except three (Anon. 1994). Stanley and Ross (1986) noted that this species was common in the Burnett and Darling Downs districts of south-eastern Qld. *Polymeria longifolia* is present in two pastoral regions in the NT (Hnatiuk 1990), while a single observation has been made in the Kimberley area of Western Australia near Kununurra (Johnson 1992, Wheeler *et al.* 1992).

Habitat

Climatic requirements

The climatic requirements of *P. longifolia* appear to be quite broad, since the species occurs over a wide geographic area in NSW, Qld and the NT. In general, these areas receive a mean annual rainfall of between 400–900 mm year^{-1} and have average annual minimum and maximum temperature ranges of 9–21°C and 24–36°C, respectively.

Polymeria longifolia emerges rapidly in spring, often around the time of cotton planting, which occurs at or after the soil temperature has reached a minimum of 14°C at 10 cm soil depth just after sunrise on three consecutive days (Constable and Shaw 1988). It grows actively from October until at least April.

Although perennial, *P. longifolia* may disappear in winter in many cultivated fields. This disappearance may be linked to frost damage (G. Charles personal communication) but is more than likely a result of cultivation destroying shoot growth. Both McMillan (1988) and Williams (1988) suggested that *P. longifolia* is dormant during the winter and responds to the onset of rain, but other observations in uncultivated areas suggest that the plant continues to grow all year round, albeit slowly (Johnson 2000).

Cunningham *et al.* (1981) reported that *P. longifolia* was generally uncommon except in 'seasons of abundant summer rainfall when it may form mats over small localized areas'. Records from the Queensland Herbarium also indicate that abundance is enhanced by rainfall.

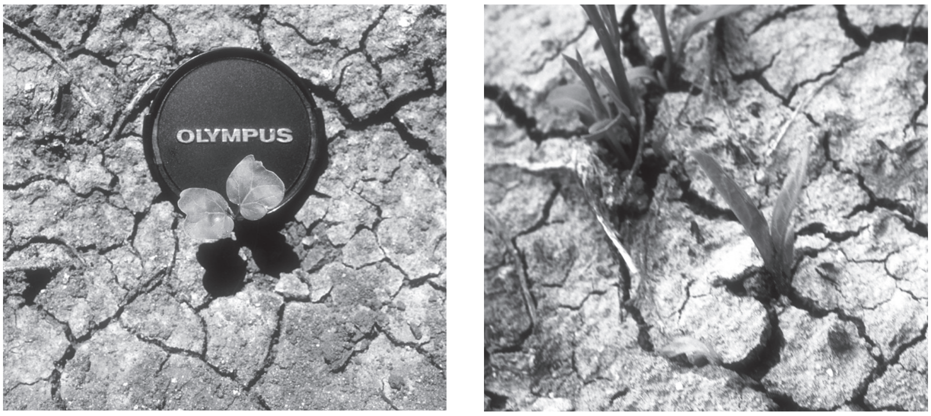

Figure 4. A comparison between the cotyledon leaves of *Polymeria longifolia* (on the left) and the leaves of new vegetative shoots (on the right). These plants had emerged less than one week before photographing.

Plant associations and substratum

Polymeria longifolia is a diagnostic species of the cracking clay soils that support the Mitchell grasslands (*Astrebla* spp.) (Connors *et al*. 1996, R. Johnson personal communication). In addition, it is commonly found in a range of plant communities including the bluegrass grasslands (*Dichanthium sericeum* (R.Br.) A.Camus) and the coolibah (*Eucalyptus microtheca* F.Muell.) and brigalow (*Acacia harpophylla* F.Muell. ex Benth.) woodlands (Kleinschmidt and Johnson 1977, Cunningham *et al.* 1981, Johnson 1992). Nelder (1992) also includes *Chenopodium auricomum* Lindl. (bluebush) dominated associations that include swamp, claypan and ephemeral lake vegetation. Many of these communities are associated with flood plains, watercourses, drainage lines and localized wet areas and, almost without exception, are on red, black, brown or grey cracking clays.

In general, *P. longifolia* grows in areas that receive a comparatively larger amount of run-off or drainage moisture, often in shallow depressions or floodways (Cunningham *et al.* 1981, Williams 1988, R. Johnson personal communication) and may be moderately tolerant of flooding. One Queensland herbarium record indicated that *P. longifolia* plants were unaffected by 30 cm of water covering them for two weeks.

Growth and development

Morphology

The cotyledons of *P. longifolia* are distinctly rounded and notched at the tip, in contrast to the long and narrow true leaves (Figure 4). Seedlings develop rapidly over the summer months, flowering and producing rhizome material below-ground during their first season of growth.

Polymeria longifolia is able to extract soil water from at least 80 cm soil depth, indicating active rhizome and root growth in this profile (Johnson 2000). In one study, 80% of rhizomes and 65% of roots of *P. longifolia* in the top metre of the soil were found in the top 40 cm of the profile, with a number of these rhizomes (49%) and roots (37%) in the 10–30 cm layer (Johnson 2000). While rhizomes and roots were found to a depth of 150 cm, less than 3% of rhizomes and 14% of roots were found deeper than 100 cm.

Although the stems of *P. longifolia* rarely grow higher than 25 cm, they may compete for light early in the development of crop seedlings. In some situations the stems of *P. longifolia* may grow taller and climb, not twine like other Convolvulaceae, up the branches of taller crop plants such as cotton.

Individual rhizomes of *P. longifolia* grow more than 1 m in length (Johnson 2000). The rhizomes in the upper soil profile can be classified into three functional categories: i) vertical rhizomes which bear aerial shoots, ii) horizontal rhizomes which grow parallel to the soil surface but 10–40 cm underneath it, and iii) vertical rhizomes which are attached to the horizontal rhizomes but penetrate deep into the soil (Figure 5, Johnson and Sindel 2003). Whether these vertical rhizomes surface to produce aerial shoots elsewhere, or whether their sole function is the acquisition of resources for plant growth is not known. True roots arise from nodes along the rhizomes.

Polymeria longifolia is very drought tolerant. This tolerance can be attributed in part to the deep seated rhizomatous/root system and the large number of trichomes on the leaf surface that reduce water loss from transpiration (Johnson 2000). These trichomes give the leaves their common grey/green to silver appearance.

This perennial weed often forms patches that are irregular in size and shape under uncultivated conditions, but commonly circular or oval shaped in cultivated fields and up to 100 m in diameter. It is widely believed that oval shaped patches appear as a result of cultivation machinery dragging plant fragments along permanent beds (Johnson *et al.* 1998). Scattered plants may also be found in cultivated fields.

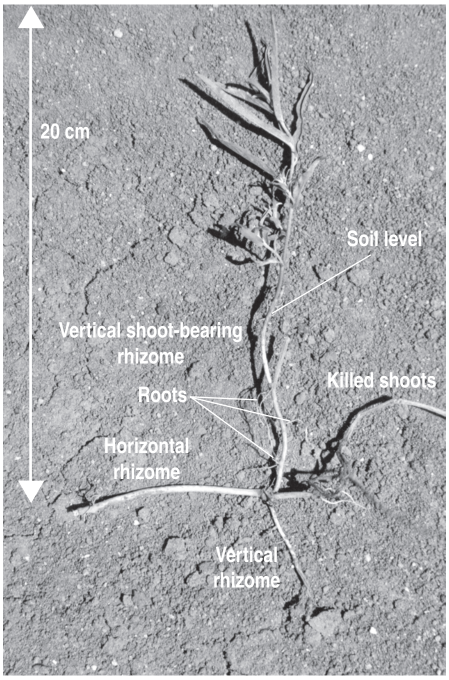

Figure 5. A typical shoot and part of the rhizome system of *Polymeria longifolia*. The vertical rhizome arises from a node on the horizontal rhizome and penetrates deep into the ground. Two shoots that have been previously killed are still attached. Fibrous roots, responsible for water and nutrient uptake, can be found at all nodes and at other points along the rhizomes.

Perennation

Although there are no data available on the perennation of *P. longifolia*, it is probable that plants are long-lived and produce shoot and rhizome material throughout the year. New shoot recruitment is more prolific after rainfall or irrigation events (Johnson *et al.* 1999). In disturbed environments such as roadside edges, continued shoot defoliation will result in the thickening of rhizomes in the upper soil profile. Defoliation causes resprouting from the next undamaged node along the shoot-bearing rhizome (Johnson and Sindel 2003).

Shoots are not usually observed in cultivated fields over the winter. New shoots emerge in the spring from existing rhizome material. There is some storage of carbohydrates in the pith and cortex of the rhizomes during autumn (Johnson 2000).

Physiology

There have been no studies on the physiology of *P. longifolia*.

Phenology

Seedlings emerge between November and March, with the development of true leaves within two weeks (Johnson 2000). Seedlings are able to produce rhizomes within their first season of growth. Vegetative shoot recruitment begins as soil temperatures rise in spring and continues from October until April, although it can continue all year round in uncultivated areas. The density of stems within patches of *P. longifolia* is variable, with a maximum of 220 stems m^{-2} recorded (Johnson 2000).

Flowering and seed production generally occur throughout the year, peaking during late summer/early autumn. Seeds mature in approximately 30 days and are commonly shed within 15 days of maturity. The death of individual stems after flowering and seed set is common, particularly towards the end of the season. Reshooting may occur from the base of these senescent stems, or from nearby.

As temperatures begin to fall in mid autumn, leaf loss from the lower half or two-thirds of the stems is common. This also occurs during periods of extreme water stress. New leaf growth occurs after a more favourable soil water balance is restored.

There is no information on the growth pattern of the rhizome system of *P. longifolia*.

Mycorrhiza

There is no information available on the presence or absence of mycorrhizae for *P. longifolia*.

Reproduction

Floral biology

Although specific pollination studies have not been undertaken, there is evidence to suggest that *P. longifolia* is cross-pollinated (S. Johnson personal observations). For example, various pollinating insects have been observed visiting *P. longifolia* flowers. These included the honey bee (*Apis mellifera* L.) observed between December and January, with one visiting 15 flowers in 5.5 minutes. Small black *Carpophilus* spp. beetles, 3–4 mm in length, took shelter in open flowers from October to December. Although these beetles ate the corolla and damaged the stamens and stigma, pollen may have been spread between flowers. Other species that were observed in flowers included transverse ladybirds (*Coccinella transversalis* Fabricius), jewel beetles (Buprestidae) and small native bees with yellow and brown striped abdomens (Tipiidae). Additional evidence for cross-pollination can be drawn from the fact that the flowers of *P. longifolia* are large and brightly coloured, similar to those of other insect pollinated species from the same family (Elmore *et al.* 1990).

In general, the flowers open in the early morning, close before sunset and do not open the following day, unless the conditions are cloudy and overcast (S. Johnson personal observations). Flower opening time may be as short as two and a half hours under high temperatures (31–63°C) and low humidity (2–28%) (measured at 10 cm above soil level). However, flowers may open for up to six days under glasshouse conditions.

A maximum of 67 flowers m^{-2} day^{-1} and nine on a single stem have been observed in an irrigated cotton field (Johnson 2000). However, production was often less than 10 flowers m^{-2} day^{-1} throughout the spring and summer.

Seed production and dispersal

The capsule of *P. longifolia* commonly produces a single, and rarely two, seeds. There has been one observed instance of a pod with three seeds present in an irrigated cotton field (Johnson 2000). The maximum seed production observed was 142 seeds m^{-2} y^{-1}, with 23 seeds on a single stem in a dense infestation in a cotton field (Johnson 2000). In general, fewer than five seeds m^{-2} were produced during the summer in cultivated populations.

Although relatively few are produced, seeds may play a significant role in dispersal. The seed is covered in short hairs, allowing flotation for at least several minutes. The mean individual seed weight of *P. longifolia* was 48.3 ± 0.5 mg, which was lighter than the equivalent volume of soil (Johnson 2000). Conceivably, the roundness of the seed would help it to be rolled along by irrigation or runoff water over a short distance and the weight of the seed, with the hairs covering the seed coat, would help in long distance dispersal via irrigation or flood water. The movement of seed in mud on machinery is another probable means of dispersal.

Physiology of seeds and germination

Members of the Convolvulaceae are known to have hard seed coats and a corresponding high level of seed dormancy (Ballard 1973, Elmore *et al.* 1990). The one study on the dormancy of *P. longifolia* seed showed that seed stored for at least one month had only a 20% germination level (untreated) or a 30% germination level (nitric acid scarification) (Charles 1996). In addition, Johnson (2000) found that only 4.2% of seed planted for 1, 1.5 and 2 year periods established as seedlings, with seed burial to at least 1 cm required for establishment to occur. The viability of non-germinated seed recovered from the same trial ranged from 21–37%, decreasing as the time in the soil increased.

Seedling establishment for *P. longifolia* has not been observed before cotton planting, indicating that the minimum soil surface temperature for both crop and weed must exceed 14°C.

Vegetative reproduction

Polymeria longifolia is a serious weed of cultivated fields because of its potential for vegetative reproduction. There are two ways that this occurs.

New vegetative shoots are produced from *in situ* rhizome material, whether undisturbed, or after defoliation. New vegetative shoots are also produced when vegetative fragments are transplanted, particularly with cultivation. Vegetative regeneration can occur from shoot only, rhizome only and shoot and rhizome fragments under moist soil conditions in the glasshouse (Johnson *et al*. 1998). Regenerative success increases with fragment size, although a minimum rhizome size of 10 cm, or shoot only length of 5 cm is needed. It is likely that cultivation performed immediately before rainfall or irrigation events may spread this weed (Johnson *et al.* 1998). Since cultivation machinery is often not cleaned, new infestations are appearing in previously infested and uninfested fields (Johnson *et al*. 2003). In addition, the movement of vegetative fragments in mud on vehicles, or in infested soil in laser levelling machines has been shown to spread the weed (Johnson *et al.* 2000). However, defoliation of transplanted fragments within three weeks will prevent further fragment survival (Johnson 2000).

Hybrids

It is not known whether *P. longifolia* produces hybrids with closely related species.

Population dynamics

Large variations in stem densities have been observed in uncultivated areas. Marked increases in stem density occur over spring and summer, followed by decreases during autumn (Johnson 2000). This pattern assumes a summer-dominant rainfall pattern, but when summer drought occurs, stem density will decrease. Similar trends for stem density have been observed in cultivated cotton fields over the same seasons (Johnson 2000). Density, dry weight and the number of flowers and seeds on a unit area basis was always greatest under irrigated field conditions when compared with uncultivated field sites, such as cleared grassland, coolibah woodland and along the edge of graded roads. This may be a result of the irrigation water and fertilizer applied to cultivated land, combined with the infrequent and shallow cultivation events that appear to stimulate stem production in cultivated fields (Johnson *et al.* 2000). Alternatively, competition from a cotton crop may be less than that from vegetation in native and disturbed plant communities.

The lifespan of individual stems is dependent on a number of factors, including intra-specific competition, climatic conditions and defoliation. For example, rapid vegetative growth of *P. longifolia* occurs under high soil moisture conditions even if the stems are in the reproductive phase, and significant stem mortality can occur as a result of cultivation damage. Individual stems of *P. longifolia* are indeterminate and can switch from a vegetative to a reproductive state, or vice versa, or simply remain in a vegetative state (Johnson 2000).

Importance

Detrimental

Polymeria longifolia has been recorded as a weed of many summer crops in NSW and Qld, including irrigated and dryland cotton (Johnson 2000), sorghum, sunflower and soybean (R. Johnson personal communication) and in winter crops such as wheat (Martin and McMillan 1984). It has not always been recorded in winter cropping surveys (Martin *et al.* 1988, Felton *et al.* 1994). However the species was reported as being among one of the ten major weeds of cotton in a NSW survey conducted in the 1988/89 season (Charles 1991, Table 1). Infestations of the weed currently cause major yield losses in cotton crops in the Gwydir, Namoi and Macintyre Valleys in NSW and in the St. George/Dirranbandi area in Qld (Johnson *et al*. 2003). For example, stem densities exceeding 100 stems m^{-2}, commonly found in weed patches, reduced cotton yield by more than 50% (Johnson 2000).

Beneficial

The only recorded benefit of *P. longifolia* is for grazing (Cunningham *et al.* 1981). However, given that it is a native plant, it has intrinsic conservation value in natural ecosystems.

Legislation

Polymeria longifolia is not declared noxious under any legislation in Australia.

Weed management

Herbicides

As a deep rooted rhizomatous plant, *P. longifolia* has traditionally been difficult to control. Many herbicides successfully kill the foliage of the species but fail to translocate further than 10 cm into the rhizome mass. Consequently, shoots resprout after rainfall or irrigation. Table 2 provides a summary of herbicide trial results for effective control of *P. longifolia*. No herbicides are currently registered for *P. longifolia* in either crop or fallow situations.

Because of the significant problems this weed causes in cotton crops, research has focused on herbicides. Poor control is often achieved with herbicides generally thought effective (Johnson 2000). The extent to which operator and application error causes these failures is unknown; it is likely to be significant. Many herbicides that are commonly applied for pre- or post-emergent weed control in cotton are ineffective on *P. longifolia*, for example, fluometuron and prometryn (Group C herbicides, Table 2). Although the phenoxy group, for example, 2,4-D amine, 2,4-D ester, and fluroxypyr (Group I herbicides), are not used in cotton, they are more effective against *P. longifolia*, but only at rates exceeding 1 L ha^{-1} (Strachan 1983). One reason for the apparent success of Group I herbicides may be that these are artificial auxins that inhibit the initiation of shoot buds from rhizome tissue (Raven *et al.* 1987). Because of the potential for spray drift with these herbicides, and the residual nature of fluroxypyr, care is needed in their application. Atrazine, a Group C herbicide, is the only other herbicide that has been shown to be effective in controlling *P. longifolia* growth, as distinct from other herbicides from this group, such as cyanazine, diuron, fluometuron, methazole and prometryn.

Glyphosate (a Group M herbicide) provides moderate control but generally only at high rates. Similarly, moderate control is achieved by the Group L herbicides paraquat and diquat, probably at somewhat lower rates. Representative chemistry from herbicide Groups B, F, G, K and N is ineffective, and although results for pendimethalin and trifluralin, (both Group D herbicides) and s-metolachlor (Group K) have not been recorded, these herbicides are commonly applied for weed control before cotton planting (Johnson and Spora 2002) and have not effectively controlled *P. longifolia* growth in the past. Chemistry from the herbicide Groups E and H has not been tried on this species.

Table 1. Weed species that growers identified as important problems in NSW cotton growing areas (from Charles 1991). Means and their standard errors have been presented.

Weed species	Percentage of properties affected	Weed importance[A]	Percentage of area affected	Trend in incidence[B]
Xanthium occidentale	87	6.6 ± 0.5	44 ± 6	-3.6 ± 1.1
Cyperus spp.	79	5.3 ± 0.5	15 ± 3	7.1 ± 0.8
Xanthium spinosum	60	4.7 ± 0.6	34 ± 6	-1.5 ± 1.0
Physalis spp.	46	3.2 ± 0.6	18 ± 4	-1.7 ± 1.2
Ipomoea lonchophylla	42	3.1 ± 0.6	20 ± 4	-1.8 ± 0.9
Hibiscus trionum	40	2.9 ± 0.6	22 ± 5	-2.9 ± 1.2
Datura spp.	38	2.6 ± 0.5	14 ± 4	-3.3 ± 1.0
Tribulus spp.	37	2.5 ± 0.5	16 ± 4	-2.5 ± 1.0
Haloragis glauca	37	1.8 ± 0.4	4 ± 2	4.2 ± 0.9
Polymeria longifolia	23	1.5 ± 0.4	3 ± 2	3.3 ± 1.3
Sesbania cannabina	25	1.4 ± 0.4	4 ± 2	6.3 ± 1.1
Echinochloa crus-galli	21	1.1 ± 0.3	10 ± 4	-3.3 ± 1.3
Salvia reflexa	17	1.1 ± 0.4	5 ± 1	-2.5 ± 1.4

[A] Weed importance was ranked from 10 to 1, where a 10 indicated that all growers considered the weed to be the most important.
[B] Trend in incidence was ranked with 10 indicating a rapid increase, 0 a stable incidence and -10 a rapid decrease.

It has been suggested that repeated applications of effective herbicides are needed to manage this weed (Kleinschmidt and Johnson 1977). Likewise, herbicide application is more likely to be successful when *P. longifolia* is actively growing, particularly after rainfall or irrigation. For this reason, infestations are commonly treated in summer fallows. Shielded 'spot' spraying technology may allow specific areas of *P. longifolia* to be treated at lower cost. Acknowledging these facts, promising research has indicated that split applications of glyphosate during late spring and summer, applied to actively growing *P. longifolia*, may hold the key to successful management (Charles and Johnson 2002).

Other treatments

Cultivation. Severely disruptive cultivation of the upper soil profile where the rhizomes of *P. longifolia* are located, for example by a rotary hoe, can reduce the growth of the weed (Johnson 2000). Likewise, cutting *P. longifolia* rhizomes and shoots into small pieces during cultivation can prevent fragment regrowth (Johnson *et al.* 1998). The evidence so far indicates that persistent soil disturbance by cultivation may be a likely key to controlling *P. longifolia*. However, because cultivation machinery can spread *P. longifolia* fragments, cultivation for control has only been recommended within patches of the weed, preferably not before rainfall or irrigation, so that fragments have a chance to dry out and die (Johnson *et al.* 2000).

Chipping. Hand-chipping or hoeing, while commonly employed against other weeds in cotton crops, does not effectively control *P. longifolia*. Evidence suggests that shallow chipping once a month for four months actually stimulated the growth of *P. longifolia* (Johnson *et al.* 2000).

Field hygiene. Good field hygiene in cultivated fields is essential to prevent the movement of vegetative fragments or seed from infested to uninfested areas. This involves removing mud from cultivation machinery used in infested fields and

Table 2. A summary of herbicides evaluated to control *P. longifolia*.

'Effectiveness' (reduction in shoot growth)	Active ingredient/s of herbicide	Herbicide Group	Rate (where known) ha^{-1}	Reference[A]
Effective (90%+)	2,4-D amine (225 and 300 g L^{-1})	I	2.0 L	2, 3, 4, 5
	2,4-D ester (800 g L^{-1})	I	1.25 L	2
	fluroxypyr (300 g L^{-1})	I	2.0 L	3, 5, 6, 7
	picloram (50 and 75 g L^{-1}) and 2,4-D amine (200 and 300 g L^{-1})	I	1.4/3.0 L	2, 3, 6
	picloram (100 g L^{-1}) and triclopyr (300 g L^{-1})	I	2.0 L	6
Moderately	atrazine (500 g L^{-1} and 900 g kg^{-1})	C	5.0-10.0 L	4, 6
effective	dichlorprop (600 g L^{-1})	I	–	3
(75%-90%)	glyphosate (360 g L^{-1})	M	8.0+ L	1, 3, 4, 6
	glyphosate (450 g L^{-1})	M	2.4–6.0 L	6, 7
	imazapyr (250 g L^{-1})	B	2.0 L	6
	paraquat (125 g L^{-1}) and diquat (100 g L^{-1})	L	–	4
	MCPA (500 g L^{-1})	I	1.0–2.0 L	3, 5
Ineffective (>75%)	amitrole (250 g L^{-1}) and ammonium thiocyanate (220 g L^{-1})	F	5.6 L	2, 3
	chlorsulfuron (750 g kg^{-1})	B	30–60 g	2, 3, 6
	cyanazine (500 g L^{-1})	C	3.5 L	3, 5
	dicamba (200 and 500 g L^{-1})	I	1.4 L	2, 3, 6
	diuron (500 g L^{-1} and 900 g kg^{-1})	C	–	3
	fluometuron (500 g L^{-1} and 900 g kg^{-1})	C	–	3
	glufosinate-ammonium (200 g L^{-1})	N	3.0 L	3, 5, 6
	methazole (800 g kg^{-1})	C	2.7 kg	3, 5
	metsulfuron-methyl (600 g kg^{-1})	B	10–30 g	3, 4, 6
	MSMA (800 g L^{-1})	K	–	3
	norflurazon (800 g kg^{-1})	F	2.5 kg	5
	oxadiazon (20 g kg^{-1})	G	4.0 L	5
	oxyfluorfen (240 g L^{-1})	G	4.0 L	3, 5
	prometryn (500 g L^{-1} and 900 g kg^{-1})	C	–	3
	pyrithiobac-sodium (850 g kg^{-1})	B	120–240 g	6
	triclopyr (600 g L^{-1})	I	0.1–0.3	6

[A]References: 1. Scarsbrick *et al.* (1979), 2. Strachan (1983), 3. McMillan (1988), 4. Harvey (1989), 5. McMillan and Cook (1989), 6. Johnson (2000) and 7. Charles and Johnson (2002).

avoiding moving infested soil during laser levelling (Johnson *et al.* 2000).

Prevention. *Polymeria longifolia* is present in many of the plant communities that have been, and continue to be developed for crop production, especially around Walgett (NSW) and St. George and Dirranbandi (Qld), and particularly in irrigated cotton production. It has been recommended that *P. longifolia* infestations be identified prior to land development. Care can then be taken to isolate large existing patches and prevent fragments being spread over a wide area. If necessary, these areas can be left out of production.

Natural enemies

The beetle, *Carpophilus* sp. appears to feed on the pollen and corolla of open flowers in spring, while 10–30% of all maturing seed was destroyed by *Helicoverpa* spp., all common summer cropping pests (Johnson 2000).

The root knot nematode *Meloidogyne* sp. has been positively identified on the roots of *P. longifolia* grown in pot culture, but has not been seen in the field.

Various *Puccinia* rusts have been collected on *P. longifolia* on at least five separate occasions, but remain unidentified to species level, probably because the species have not been previously described (J. Walker personal communication). There was strong evidence that the *Puccinia* were not *Puccinia dichondrae* Mont. in Gay, the only other widespread rust on plants in the Convolvulaceae. A hyper-parasite fungus *Sphaerellopsis filum* (Biv.-Bern. ex Fr.) Sutton heavily parasitized *P. longifolia* during wet summers and a slime mould fungus *Physarum cinereum* (Batsch) Pers. was also identified after it moved up the plant stems to sporulate.

Species of *Puccinia* rust are unlikely to hold significant prospects for long-term biological control because they have not been aggressive enough to cause serious damage in the past. Moreover, most rust fungi cannot be cultured *in vitro* and inoculum must be produced on live plants.

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