# SECTION 6
# WEEDS
## Profiles of common weeds of cropping

INTEGRATED WEED MANAGEMENT
IN AUSTRALIAN CROPPING SYSTEMS

# SECTION 6: PROFILES OF COMMON WEEDS OF CROPPING

## WEED 1: ANNUAL RYEGRASS (*Lolium rigidum*)

### Common names

Annual ryegrass, Wimmera ryegrass, ryegrass, rigid ryegrass.

### Distinguishing characteristics

Annual ryegrass (*Lolium rigidum*) is hairless and has bright green, narrow leaves which are shiny, especially on the back of the blade. Annual ryegrass has a wide ligule and long auricles, and the emerging leaf is folded. The base (below ground) is often reddish purple, and seedlings exude a clear sap when crushed.

Mature plants are erect and up to 900 mm in height. The inflorescences (flowering stems) are flat and up to 300 mm in length. Spikelets have three to nine flowers and the husk is almost the same length as the spikelet.

Seeds are relatively flat, 4 to 6 mm long, 1 mm wide and straw-coloured, with the seed embryo often visible through the outer layers. They are held securely to the flower stem, and significant force is needed to detach them either as individual seeds or as part of the flower stem.

### Other weeds that can be confused with annual ryegrass

Perennial ryegrass (*Lolium perenne*) is very similar to annual ryegrass. However, the two species can be differentiated at the flowering to seeding stage.

Annual ryegrass has three to nine flowers in each spikelet, and the husk on the outer edge of the spikelet is generally a similar length to the spikelet. Perennial ryegrass has four to 14 flowers, and the outer husk is approximately half the length of the spikelet.

Paradoxa grass (*Phalaris paradoxa*) and lesser canary grass (*P. minor*) can sometimes be mistaken for annual ryegrass at the seedling stage. Both *Phalaris* species have a reddish purple pigmentation at the base of the plant but they lack the shiny surface on the back of the leaf blade. Rather, the leaves tend to be a dull silver-green. If the base of paradoxa is pinched at the one- to two-leaf stage the resultant sap will be red, unlike the clear sap in annual ryegrass.

Annual ryegrass can also be confused with silver grass (*Vulpia* spp.), bulbous meadow grass (*Poa bulbosa*) and toad rush (*Juncus bufonius*) at the seedling stage. Annual ryegrass has a shiny back to the leaf while both silver grass and bulbous meadow grass have the same shine on both leaf surfaces. Bulbous meadow grass leaves end in a hood. Toad rush is not a grass and can be distinguished by the absence of a ligule.

### Factors that make annual ryegrass a major weed

Annual ryegrass is one of the most serious and costly weeds of annual winter cropping systems in southern Australia.

#### Annual ryegrass produces an extremely high number of seeds per plant.

Survivors of control measures (in-crop and in pastures) can tiller well and produce high numbers of viable seed. This rapidly leads to large seedbanks and, subsequently, high weed numbers at emergence. Dense stands (greater than 100 plants/m$^2$) can produce up to 45,000 seeds/m$^2$ under ideal conditions.

#### Annual ryegrass is highly competitive.

When annual ryegrass emerges before or with the crop it can compete for nitrogen as early as the two-leaf crop stage, and appears to have a greater competitive advantage in later sown crops.

Conversely, there is good evidence to suggest that annual ryegrass plants that germinate after the crop are poor competitors and far less likely to influence crop yield.

### Annual ryegrass is a host for the bacteria *Clavibacter* spp. that causes annual ryegrass toxicity (ARGT).

ARGT is a serious disease that causes sheep and cattle death in southern Australia.

### Annual ryegrass can be infected by ergot fungus.

Ergot fungus can infect the heads of annual ryegrass in coastal regions, leading to contamination of grain. Ergot is toxic to both livestock and humans.

### Many populations of annual ryegrass have developed resistance to both selective and non-selective herbicides.

PHOTO: ANDREW STORRIE

Figure W1.1 Mature plant of annual ryegrass.

In 2013 in Australia annual ryegrass had developed resistance to seven herbicide mode-of-action (MOA) Groups (A, B, C, D, L, M and Q). Repeated use of herbicides from the same MOA group (particularly the high-risk Groups A and B) is likely to select for herbicide resistant individuals that will produce large numbers of seeds and quickly become a serious and significant weed problem.

There are many populations of annual ryegrass resistant to glyphosate (Group M) on the Liverpool Plains of northern New South Wales. These populations formed following repeated use of glyphosate for winter fallow weed control. Populations resistant to glyphosate are now found from New South Wales to Western Australia and at the time of writing there were 574 documented cases. (For details see the reference to the Australian Glyphosate Sustainability Working Group under ‘Further information’ in *Section 2 Herbicide resistance*, page 27).

## Environments where annual ryegrass dominates

Since its deliberate introduction as a pasture species in the early 1900s annual ryegrass has become widespread across the temperate areas of southern Australia. Its distribution has increased northward and westward in New South Wales to become a serious problem in winter cropping.

Annual ryegrass is considered a weed of winter fallows and crops due to its soil moisture preference and effect on crop yield loss. It is well adapted to most soil types in the winter rainfall regions of southern Australia, which are characterised by hot, dry summers and mild, wet winters.

## Seasonal conditions that favour annual ryegrass

Annual ryegrass is a winter to spring growing weed that can emerge from late autumn through to early spring. The number of emergence flushes and the density of plants that emerge are related to initial seedbank levels and frequency and amount of rainfall.

## Conditions that favour germination and establishment

Newly formed seeds of annual ryegrass are typically dormant, with seeds losing dormancy during the first six months after dispersal. Ideal conditions for germination of annual ryegrass include a significant autumn to winter rain event of at least 20 mm, and seeds located at a depth of 20 mm in the soil. Germination reduces with increasing depth of seed, ceasing at about 100 mm.

The optimum temperature for germination of annual ryegrass is much lower for buried seeds in darkness (11°C) compared with seeds in the light (27°C).

The majority of shallow buried seed will germinate in autumn and early winter, when undisturbed conditions are most favourable for seedling survival. The peak germination (80 per cent of seeds) occurs at the break of season after the first two falls of rain that exceed 20 mm. Seed burial (darkness) can trigger a secondary state of dormancy for 10 to 20 per cent of the seed.

Annual ryegrass seeds are mostly dormant when they develop, and slowly lose dormancy over the summer. However, some can still be dormant at the break, which limits the proportion of the seedbank that can emerge.

Emergence at the break the following year will be greater if:

1. Spring (when the seeds were produced) has above average temperatures, and even better if conditions are dry. These conditions produce seeds with less dormancy than usual.
2. Summer is very hot, and even better if there are also several heavy rainfall events. These conditions result in faster dormancy release.
3. There is a late break to the growing season. This gives the seeds more time to lose dormancy and be ready to germinate when the rains begin.

If the above factors occur in combination, then the proportion of the annual ryegrass seedbank that will germinate at the break of season will be greater.

If all three conditions have occurred, then this is the year in which delaying seeding to allow maximum annual ryegrass germination and kill pre-sowing will be the most beneficial in terms of reducing seedbank numbers.

PHOTO: ANDREW STORRIE

Figure W1.2 Seedling of annual ryegrass.

**TABLE W1.1** Tactics that should be considered when developing an integrated plan to manage annual ryegrass (*Lolium rigidum*).

| Annual ryegrass (*Lolium rigidum*) | | Most likely % control (range) | Comments on use |
|---|---|---|---|
| *Agronomy 2* (page 61) | Improving crop competition | 50 (20–80) | Optimum sowing rates essential. Row spacing >250 mm to reduce crop competitiveness. Sow on time. |
| *Tactic 1.1* (page 92) | Burning residues | 50 (0–90) | Avoid grazing crop residues. Use a hot fire back-burning with a light wind. |
| *Tactic 1.3* (page 101) | Inversion ploughing | 95 (80–99) | Bury seed greater than100 mm deep. Use of skimmers on the plough is essential for deep burial. |
| *Tactic 1.4* (page 105) | Autumn tickle | 15 (0–50) | Only effective on last year's seedset. Use in conjunction with delayed sowing (see *Tactic 1.5 Delayed sowing*, section 4, page 109). |
| *Tactic 2.1* (page 113) | Fallow and pre-sowing cultivation | 60 (0–90) | Cultivation may lead to increased ryegrass in the crop. Use in combination with a knockdown herbicide. Use cultivators that bury seed. |
| *Tactic 2.2a* (page 124) | Knockdown (non-selective) herbicides for fallow and pre-sowing control | 80 (30–95) | Avoid overuse of the one herbicide MOA group. Wait until ryegrass has more than 2 leaves. |
| *Tactic 2.2b* (page 128) | Double knockdown or 'double knock' | 95 (80–99) | Reduces the likelihood of glyphosate resistance. Use glyphosate followed by paraquat or paraquat + diquat 3 to 10 days later. |
| *Tactic 2.2c* (page 133) | Pre-emergent herbicides | 70 (50–90) | Note incorporation requirements for different products and planting systems. |
| *Tactic 2.2d* (page 139) | Selective post-emergent herbicides | 90 (80–95) | Apply as early as possible after the ryegrass has 2 leaves to reduce yield losses in cereals. |
| *Tactic 3.1a* (page 172) | Spray-topping with selective herbicides | 80 (60–90) | Apply before milk dough stage of annual ryegrass. |
| *Tactic 3.1b* (page 174) | Crop-topping with non-selective herbicides | 70 (50–90) | Note stage of crop compared to stage of annual ryegrass. Often not possible to achieve without crop yield loss. Most likely to occur with quick finish to season. |
| *Tactic 3.2* (page 184) | Pasture spray-topping | 80 (30–99) | Graze heavily in spring to synchronise flowering. |
| *Tactic 3.3* (page 190) | Silage and hay – crops and pastures | 80 (50–95) | Most commonly used where there is a mass of resistant annual ryegrass growth. Follow up with herbicides or heavy grazing to control regrowth. |
| *Tactic 3.4* (page 195) | Manuring, mulching and hay freezing | 90 (70–95) | Most commonly used where there is a mass of resistant annual ryegrass growth. Follow up with herbicides or heavy grazing to control regrowth. |
| *Tactic 3.5* (page 202) | Grazing – actively managing weeds in pastures | 50 (20–80) | Graze heavily in autumn to reduce annual ryegrass plant numbers. Graze heavily in spring to reduce seedset. |
| *Tactic 4.1* (page 212) | Weed seed control at harvest | 65 (40-80) | Best results when crop is harvested as soon as possible before ryegrass lodges or shatters |
| *Tactic 5.1a* (page 229) | Sow weed-free seed | 85 (50-99) | Reduces the risk of introducing resistant annual ryegrass to the paddock with crop seed |

## Seed survival in the soil

### Seed survival in the soil is reduced if the soil is not disturbed, whereas deep cultivation prolongs seed life.

In undisturbed soil less than 1 per cent carryover of viable residual seed remains after late winter, indicating that the seed is relatively short-lived. In a Western Australian study viable annual ryegrass seed persisted in undisturbed soil for at least four years, but the rate of decline was as much as 70 to 80 per cent per annum.

## Contributors

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# WEED 2: BARLEY GRASS (*Hordeum* spp.)

## Common names

Barley grass is a widely used name for *Horduem glaucum* and *H. leporinum,* although *H. glaucum* is referred to as northern barley grass in Western Australia. Until recently *H. glaucum* was described as a subspecies of *H. leporinum*. Accurate differentiation between *H. glaucum* and *H. leporinum* requires the use of a microscope and taxonomic skills.

*H. leporinum* is referred to as common foxtail and hare barley in some localities. *H. marinum* is widely referred to as sea barley grass around the world, and *H. hystrix* is known as Mediterranean barley grass.

Given the confusion that exists with common names for individual species and the recent differentiation between certain species, in the following text the scientific name will be used when referring to one species or another, while the term 'barley grasses' will be used where the information applies to several or all species.

## Distinguishing characteristics

Barley grasses are annual species renowned for rapidly germinating in autumn to provide valuable stock feed soon after breaking rain. This speedy establishment is a useful clue for early identification.

PHOTO: CUNNINGHAM *ET AL* 1992

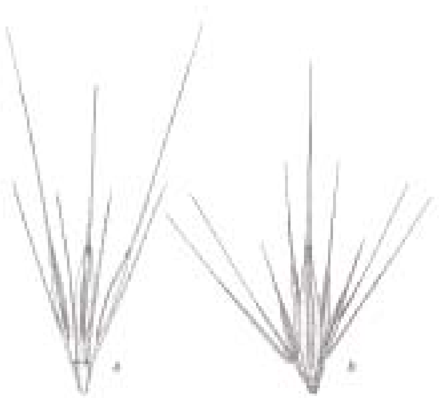

Figure W2.1 Spikelet groups of barley grass (a) *H. leporinum* and (b) *H. marinum*.

Small barley grass seedlings can be identified by looking for remnants of the seed, which can often be found attached to the root system.

Both *H. glaucum* and *H. leporinum* have very prominent auricles and a membranous ligule. Auricles are absent in *H. marinum* and *H. hystrix.*

Leaves are 1.5 to 12.0 mm wide and up to 200 mm long. They are sparsely covered with soft hairs and taper to a point. Leaves tend to be a paler green than other common annual grasses. Barley grasses grow to about 450 mm in height.

The inflorescence is a cylindrical spike-like panicle that is often partly enclosed by the sheath of the flag leaf. The spikelet is made up of three florets, the central one being fertile and the lateral ones sterile.

Glumes and awns are rough and sharp. When they are ripe the spikelets fall off the plant as units.

*H. marinum* is a common indicator plant for shallow clay and/or saline soil conditions.

## Other weeds that can be confused with barley grass

Barley grasses are unlikely to be confused with other grasses once they reach the boot (floral stages) and later stages of development. However, they can be confused with other grasses such as brome grasses (*Bromus* spp.), wild oats (*Avena* spp.) and volunteer cereals in early stages of development.

A few simple identifying features can be used to help distinguish barley grasses from other grass species in the early stages of growth. These are:

- Seeds germinate rapidly after the autumn break.
- Seed remnants are often still attached to the roots after germination, frequently with the characteristic multiple awns clearly visible.

- Leaf colour tends to be a lighter green than other species such as great brome (*Bromus diandrus*), which tends to be a darker green with a dull purplish tinge.
- Leaves tend to be quite twisted in growth, and the leaf tips often show signs of frost damage.
- Auricles are present.

## Factors that make barley grasses a major weed

### Barley grasses act as an alternate host for a number of cereal diseases

Rapid germination of the species after rainfall gives barley grasses the potential to act as a 'green bridge' for cereal root diseases. They are major hosts of the disease take-all (*Gaeumannomyces graminis* var. *tritici*), with possible yield losses up to 80 per cent under ideal conditions. Barley grasses harbour scald and net blotch of barley, and also host a type of stripe rust, although it is not yet clear what impact this rust may have on cereals.

### Seeds of barley grasses cause stock health problems

The seeds are a problem in pasture, hay and silage, causing eye injuries to sheep, reduced live-weight gains and reduction in wool quality.

### Post-emergent herbicide control is limited in cereals

There is a limited range of post-emergent herbicides available for the control of barley grasses in wheat and other cereals. However, pyroxasulfone (Sakura®) is an effective pre-emergent herbicide in wheat.

### Barley grasses are readily dispersed

The seeds can be carried on animals and fabric, and are a common contaminant of hay and feed grains.

### Populations of barley grasses can develop resistance to herbicides

There have been reports of barley grasses being resistant to paraquat and diquat and to several Group A 'fop' herbicides. Some populations have cross-resistance to the Group A 'dim' herbicides.

## Environments where barley grasses dominate

Barley grasses tend to be more dominant in the winter rainfall (southern) areas of the cropping belt. They flourish on a wide range of soil types, particularly in lightly grazed, fertile, ley pasture paddocks.

Barley grasses are commonly a problem in low rainfall cropping environments where cereals are grown in long succession and dry sowing is routinely practised. In these environments barley grasses are becoming more problematic as an increasing number of populations have evolved increased seed dormancy. This enables barley grasses to escape knockdown herbicides pre-sowing and they can germinate in-crop where there are limited herbicide options.

PHOTO: ANDREW STORRIE


Figure W2.2 Mature barley grass (*Hordeum leporinum*) seed head.

The range of barley grass species has the potential to be most problematic in ley pasture crop systems, especially when the pasture phase is more than three years. Without intervention, barley grasses tend to build up as fertility increases. While low grazing pressure leads to increased density, high stocking rates can be used to reduce levels of the weed in a pasture. A higher stocking rate of merinos (4.9 compared to 2.5 wethers/ha) at Trangie, New South Wales, resulted in a decline in *H. leporinum* density.

PHOTO: SHELDON NAVIE

Figure W2.3 Barley grass plant (*Hordeum leporinum*) flowering.

## Seasonal conditions that favour barley grasses

Increasing soil fertility is a commonly recognised factor favouring barley grasses, as can be seen by their prevalence in animal camp areas. Their presence is favoured by bare soil such as that which is found in thinning lucerne stands.

In fact, barley grasses have been shown to establish on a bare surface more rapidly than annual ryegrass (*Lolium rigidum*). In cropping systems low disturbance disc systems favour barley grasses compared with knife point and conventional sowing systems that have increased soil disturbance, which is the opposite situation to annual ryegrass. While stock will enthusiastically graze the weed in its vegetative phase, under low grazing pressure they will avoid it almost completely once the early boot stages begin. Therefore, in good spring conditions barley grasses can produce large amounts of seed.

## Conditions that favour germination and establishment

Barley grasses will germinate at a wide range of temperatures (7°C to 32°C) although the optimum range is 10°C to 15°C. The seeds germinate more rapidly in response to autumn rain than other grasses (such as *Lolium* spp.) and are able to establish before the soil surface dries out. Slightly saline conditions favour establishment mainly because barley grasses have a greater tolerance to higher osmotic potentials at germination than most other pasture species. They have low levels of hard seed and most of the seed formed in the spring will germinate in the following autumn.

PHOTO: DI HOLDING

Figure W2.4 Seedling of barley grass (*Hordeum leporinum*).

Since a very high proportion of barley grasses will germinate on the autumn break, it is unusual for further significant germinations to occur during the year. Populations from cropping systems possess increased seed dormancy compared to those from non-crop situations. Seed dormancy in these populations is broken by exposure to cold stratification. Therefore, seeds of these cropping populations tend to germinate in late autumn to early winter when conditions are moist and temperatures are cooler.

## Seed survival in the soil

There is no evidence indicating that barley grasses produce a persistent seedbank. Over 99 per cent of seeds germinate in the first year after seedset. Where activities such as pasture spray-topping are correctly timed, field observations indicate that control (as evidenced by autumn germinations) will be very high.

## Contributors

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**TABLE W2.1 Tactics that should be considered when developing an integrated plan to manage barley grass (*Hordeum* spp.).**

| Barley grass (Hordeum spp.) | | Most likely % control (range) | Comments on use |
|---|---|---|---|
| *Agronomy 1* (page 54) | Crop choice and sequence | 85 (0-95) | Avoid planting barley in infested areas. |
| *Agronomy 3* (page 74) | Herbicide tolerant crops | 80 (40-95) | Triazines and imidazolinone herbicides provide useful control in triazine and imidazolinone tolerant crops respectively. |
| *Tactic 1.1* (page 92) | Burning residues | 50 (0–75) | Dropping chaff and straw into windrows improves control. |
| *Tactic 1.3* (page 101) | Inversion ploughing | 90 (70–99) | Use skimmers to ensure deep burial. |
| *Tactic 1.5* (page 109) | Delayed sowing | 60 (50–90) | Level of control depends on break. Use in combination with *Tactic 2.2a Knockdown (non-selective) herbicides for fallow and pre-sowing control* (section 4, page 124). |
| *Tactic 2.1* (page 113) | Fallow and pre-sowing cultivation | 50 (30–80) | Requires dry weather following cultivation. |
| *Tactic 2.2a* (page 124) | Knockdown (non-selective) herbicides for fallow and pre-sowing control | 80 (50–90) | Works best if delayed until the 2- to 4-leaf stage after good opening rains. |
| *Tactic 2.2b* (page 128) | Double knockdown or 'double knock' | 80 (60–95) | Works best if delayed until the 2- to 4-leaf stage after good opening rains. |
| *Tactic 2.2c* (page 133) | Pre-emergent herbicides | 85 (75–99) | Pyroxasulfone provides good control in wheat. |
| *Tactic 2.2d* (page 139) | Selective post-emergent herbicides | 90 (80–95) | Several 'fop' herbicides provide good control in broadleaf crops. Sulfosulfuron provides suppression in wheat. |
| *Tactic 3.1b* (page 174) | Crop-topping with non-selective herbicide | 80 (50–90) | Timing is aimed at maximising weed seed kill and minimising effect on the crop. |
| *Tactic 3.2* (page 184) | Pasture spray-topping | 60 (50–90) | Graze heavily or winter-clean with 'fop' herbicides to induce more uniform emergence of heads. Timing is critical. Graze or spray regrowth. |
| *Tactic 3.3* (page 190) | Silage and hay – crops and pastures | 50 (30–80) | Silage provides better control than hay making. Heavily graze or spray regrowth. |
| *Tactic 3.4* (page 195) | Manuring – green and brown, mulching and hay freezing | 75 (50–90) | Graze heavily to induce more uniform emergence of heads. Timing is critical. Graze or spray regrowth. |
| *Tactic 3.5* (page 202) | Grazing – actively managing weeds in pastures | 30 (0–50) | Use high stocking rates early in the season to reduce numbers, and late in the season to reduce seedset on infested paddocks. |

# WEED 3a: BARNYARD GRASS (*Echinochloa* spp.)

Of the top five weeds considered to be most troublesome to world agriculture, two belong to the genus *Echinochloa*: awnless barnyard grass (*Echinochloa colona*) and barnyard grass (*E. crus-galli*).

## Common names

Awnless barnyard grass, barnyard grass, water grass, jungle rice, wild millet.

Due to the confusing similarity of the first two common names, in the following text the scientific names will be used when referring to one species or the other, while the term 'barnyard grasses' will be used where the information applies to both species.

## Distinguishing characteristics

*E. colona* is a smooth, tufted annual, 300 to 750 mm high, with an inflorescence of short spikes in an alternate arrangement on the main axis. It grows erect or sometimes lying along the ground, enabling rooting at lower nodes.

Purple-tinged leaf sheaths and blades (often), awnless spikelets (usually) and absence of a ligule are distinguishing characteristics of the species.

It is the flowers that principally distinguish *E. colona* from *E. crus-galli*. The flowering part and branches of *E. colona* are shorter, and the sharp pointed spikelets do not end in a bristle. The spikelets of *E. colona* are crowded on the stem in two to four regular rows, rather than being irregularly arranged.

## Other weeds that can be confused with *E. colona*

*E. crus-galli*, prickly barnyard grass (*E. muricata* var. *microstachya*) and hairy millet (*E. oryzoides*) can be confused with *E. colona*.

## Factors that make *E. colona* a major weed

*E. colona* is an important weed in five of the world's major crops. In Australia it is a serious weed in rice, sugarcane, maize, sorghum and summer fallow.

### *E. colona* germinates over a range of soil temperatures and grows rapidly

*E. colona* has the ability to germinate from September to March in southern Australia and at any time in northern Australia. Multiple cohorts will establish in any one season assuming sufficient rainfall. *E. colona* can establish under winter crops in spring. Most seed produced in one season will not germinate until the next season.

*E. colona* grows rapidly when air temperatures are greater than 24°C and there is sufficient soil moisture.

### *E. colona* is a very competitive plant

Prostrate growth habit in early seedling stages (rooting at the nodes to gain space and assuming an erect posture when light is limited) make it a very competitive weed in most crops.

PHOTO: ANDREW STORRIE

Figure W3.1 Inflorescence of *E. colona*.

PHOTOS: ANDREW STORRIE

Figure W3.2 Inflorescence of *E. crus-galli*.

Figure W3.3 Seedlings of *E. colona*.

### One plant may produce up to 42,000 seeds

The seeds are readily spread by irrigation or river water and often enter rice fields with crop seeds or transplants. In Australia it is suspected that wild ducks may have been important in the initial distribution of the weed.

### *E. colona* hosts a number of diseases

It is an alternate host for the viruses that produce mosaic diseases.

### *E. colona* has evolved resistance to herbicides

In 2007 glyphosate resistance was documented in populations of *E. colona* in New South Wales. At the time of writing there are 98 documented glyphosate resistant populations of *E. colona* in New South Wales, Queensland and Western Australia. All of the glyphosate resistant weed populations have occurred in situations where there has been intensive use of glyphosate, often over 15 years or more, where few or no other effective herbicides or other weed control practices have been used.

Overseas research has reported that *E. colona* has evolved resistance to a number of herbicides with different modes-of-action (MOAs) including Groups A, B, C and I.

## Environments where *E. colona* dominates

*E. colona* is a significant cropping weed in northern, central and southern New South Wales, southern and central Queensland, Northern Territory and the Ord River Irrigation Area in Western Australia.

*E. colona* is more widespread than *E. crus-galli* and is common along streambanks, levees and irrigation channels, around waterholes and in gilgai country (land surface with irregular mounds and depressions, usually in grey to black vertisols).

The species is found on a wide range of soils, particularly heavy grey and black soils that are periodically flooded.

## Seasonal conditions that favour *E. colona*

*E. colona* is an annual species that grows rapidly during the spring to autumn period in southern Australia and all year in northern Australia. Flowering occurs during summer and autumn, particularly in response to rain.

## Conditions that favour germination and establishment of *E. colona*

Emergence of *E. colona* occurs mainly from September to February. The grass germinates in a number of flushes in response to rain of at least 20 mm. Most emergences will come from seed in the soil surface (0 to 20 mm), with little (1 per cent) below a burial depth of 100 mm.

## Seed survival in the soil

Seed burial trials conducted on the Darling Downs, Queensland, have shown that seeds of *E. colona* remained viable after 12 months' burial, with 13 per cent of seeds viable at 0 mm, 25 per cent at 50 mm, and 40 per cent at 100 mm.

# WEED 3b: *Echinochloa crus-galli*

## Common names

Barnyard grass, wild millet, Japanese millet, barnyard millet, swamp barnyard grass. See comment under *Weed 3a Barnyard grass Echinochloa spp.* (page 258) about the confusion of common names and the reason for therefore using the scientific name here.

## Distinguishing characteristics

*E. crus-galli* is a tall erect annual with thick roots and stout spongy stems. It has no ligule and has numerous racemes that are spreading, ascending or branched. Seed-heads are often purplish and consist of crowded spikelets with large seeds. The awns may be absent or present up to 25 mm long.

*E. crus-galli* is an extremely variable species which frequently has been split into different varieties and forms.

## Other weeds that can be confused with *E. crus-galli*

*E. crus-pavonis* and *E. colona* can be confused with *E. crus-galli*.

## Factors that make *E. crus-galli* a major weed

### *E. crus-galli* causes crop failures and yield reductions

*E. crus-galli* reduces crop yield and causes forage crops to fail by removing up to 80 per cent of the available soil nitrogen. The high levels of nitrates it accumulates can poison livestock. In Australia, infestations of this weed in rice have caused yield reductions of 2 to 4 t/ha.

### *E. crus-galli* can produce over 40,000 seeds per plant

Seed production is highly variable and relates to growing conditions.

### *E. crus-galli* has evolved resistance to a range of herbicides

In 17 countries around the world *E. crus-galli* has evolved resistance to MOA groups A, B, C, D, I, J and K, including a number of populations resistant to multiple MOAs. There were no resistant populations confirmed in Australia at the time of writing.

### *E. crus-galli* can cause problems at harvest

Heavy infestations can interfere with mechanical harvesting.

### Contaminated seed is probably the most common dispersal method

Water, birds, insects, machinery and animals will also spread *E. crus-galli*.

### *E. crus-galli* is a disease host

*E. crus-galli* acts as a host for several mosaic virus diseases.

### *E. crus-galli* is difficult to control as a mature plant

Pre-emergent herbicides are most effective since the plants are highly susceptible at the seedling stage, whereas established plants are difficult to control with most selective herbicides. Post-emergent herbicides are often ineffective due to a combination of poor herbicide coverage and/or moisture or heat stress at the time of spraying.

## Environments where *E. crus-galli* dominates

Photoperiod is one of the most important factors governing the distribution and competitive ability of *E. crus galli*. It flowers quickly in response to shortening day length, and when given favourable growing conditions and increasing day length it will produce very large competitive plants which eventually flower and produce many seeds.

It tolerates a wide variety of soil types. Commonly occurring along roadsides, in ditches and in disturbed areas, *E. crus-galli* can also invade riverbanks and the shores of lakes and ponds. It is a principal weed in many agricultural crops including rice, cotton, maize, sorghum, vegetables and sugar cane, and in summer fallow.

The species can also continue to grow when partially submerged, making it a major weed of lowland rice.

## Seasonal conditions that favour *E. crus-galli*

*E. crus-galli* grows rapidly during the spring to autumn period. Flowering occurs during summer and autumn, particularly in response to rain.

## Conditions that favour germination and establishment

Warm summer days and abundant soil moisture are required for *E. crus-galli* to germinate. The optimum temperature for germination is in the range 27°C to 31°C, but seeds will also germinate from 13°C to 40°C. Compacted soil favours germination and emergence.

## Seed survival in the soil

New seeds are dormant. Dormancy is often broken by exposure to low winter temperatures, alternating spring temperatures or spring flooding, but some seeds remain dormant much longer. Deeply buried seeds (over 80 mm) lose no viability for three years, and some seeds remain viable for up to 13 years.

**TABLE W3.1 Tactics that should be considered when developing an integrated plan to manage barnyard grass (*Echinochloa* spp.).**

| Barnyard grass (*Echinochloa* spp.) | | Most likely % control (range) | Comments on use |
|---|---|---|---|
| *Agronomy 1* (page 54) | Crop choice and sequence | 90 (40–99) | Avoid grass summer crops such as sorghum. Choose a competitive broadleaf crop such as mungbeans where a range of herbicide MOAs can also be used. Short season of mungbeans allows use of other tactics. See *Tactic 2.2a Knockdown (non-selective) herbicides for fallow and pre-sowing control* (section 4, page 124) and *Tactic 2.2b Double knockdown or 'double knock'* (section 4, page 128) to control spring and early summer cohorts before planting. Wide row summer crops will allow the use of bipyridil herbicides or cultivation along the inter-row area. |
| *Tactic 2.2a* (page 124) | Knockdown (non-selective) herbicides | 95 (70–100) | Target small weeds (2 to 3 leaves). |
| *Tactic 2.2b* (page 128) | Double knockdown or 'double knock' | 95 (90–100) | Use with dense populations or where you suspect glyphosate resistant populations. Ideally suited to treating plants no larger than the early tillering stage. Look at tank mixing pre-emergent herbicides for fallow use with second knock, e.g. Flame®. |
| *Tactic 2.2c* (page 133) | Pre-emergent herbicides | 90 (50–100) | Atrazine mixed with metolachlor gives more reliable control than atrazine alone. Reliant on good soil moisture. |
| *Tactic 2.2d* (page 139) | Selective post-emergent herbicides | 90 (70–99) | Follow label directions carefully, especially on plant growth stages. Be mindful of herbicide resistance risks as these herbicides have a greater tendency for selecting resistant individuals. Ensure surviving plants do not produce seed. |
| *Tactic 2.5* (page 158) | Weed detector sprayers | 99 (90–100) | Use in fallow (*Tactic 2.1 Fallow and pre-sowing cultivation*, section 4, page 113) with high rates of herbicide to 'spot' out larger survivors. |

## Contributors

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# WEED 4: BROME GRASS (*Bromus* spp.)

The most common species in the genus *Bromus* in southern Australia are *Bromus diandrus* and *B. rigidus* (both short- and long-awned varieties). A less common species, red brome (*Bromus rubens*), was confirmed to have one population resistant to glyphosate in Western Australia at the time of writing.

## Common names

*B. diandrus* is commonly called great brome but may also be known as ripgut brome, ripgut grass, giant brome, slands grass, jabbers, Kingston grass, spear grass and brome grass.

*B. rigidus* is usually known as rigid brome but sometimes ripgut brome, ripgut grass, spear grass, brome grass and also great brome, which causes confusion between the two species.

As a result, in the following text the scientific names will be used when referring to one species or the other, while the term 'brome grasses' will be used when the information applies to both species.

## Distinguishing characteristics

It is difficult to distinguish between the two species (Table W4.1, below) because both have erect seedlings with dull, hairy leaves that display reddish purple stripes following the leaf veins.

**TABLE W4.1** Distinguishing characteristics of *Bromus diandrus* and *B. rigidus.*

| Character | *B. diandrus* | *B. rigidus* |
|---|---|---|
| Leaf appearance | 10 mm wide leaves, which are rough and have some long hairs. The hairs on the leaf blade point upwards. There are usually prominent purple stripes on the leaf sheath. | 10 mm wide leaves with sparse hairs and very erect panicle branches. |
| Inflorescence appearance | The inflorescence is loose and nodding and spikelet branches are longer than the spikelets. | The inflorescence is compact and stiff. Spikelets are often heavily pigmented with reddish to black colouring. The spikelet branches are shorter than the spikelets. |
| Seed appearance | The hardened scar on the seed is rounded. | The hardened scar on the seed is acute. |

## Other weeds that can be confused with brome grasses

Brome grasses are difficult to distinguish from other brome species at the seedling or vegetative stage as they are very similar.

At the seedling stage brome grasses may be confused with wild oats (*Avena* spp.) because both possess hairs on the leaves and stems and have large ligules and no auricles at the base of the leaf blade.

Figure W4.1 *Bromus diandrus* seedling showing seed in root system. This helps determine whether the plant is brome or wild oats.

Figure W4.2 Ligule of *Bromus diandrus*. This is slightly shorter than in wild oats. Both species do not have auricles.

PHOTOS: ANDREW STORRIE

PHOTOS: ANDREW STORRIE

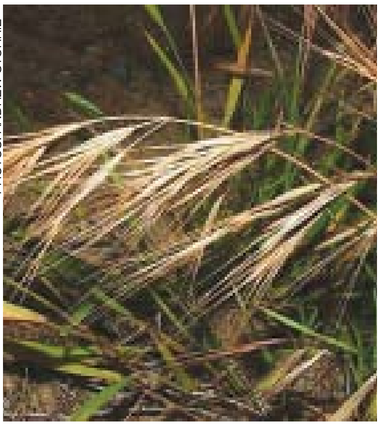

Figure W4.3 Mature plant of *Bromus diandrus*.

Figure W4.4 *Bromus diandrus* seed.

## Factors that make brome grass a major weed

### Both *B. diandrus* and *B. rigidus* compete against pasture and crop species for nutrients and water

*B. diandrus* and wild oats were found to be the most competitive grass weeds in wheat. Research in Western Australia demonstrated that wheat yields decreased exponentially with increasing densities of *B. diandrus.* One hundred *B. diandrus* plants/m$^2$ reduced wheat yields by 30 per cent.

Brome grasses show drought tolerance, better tolerance of phosphorus deficiency and better responsiveness to nitrogen than wheat. For this reason, addition of nitrogen to a crop can aggravate a brome grass problem.

### Brome grasses produce large numbers of seeds

Seed production can range from 600 to more than 3000 seeds per plant. The ability to shed a large proportion of seed before crop harvest is another important characteristic that makes brome grasses a major weed.

### Seeds of brome grasses cause contamination problems

In cropping situations brome grasses contaminate grain. In pastures the seeds contaminate wool, damage hides and meat and cause injury to livestock by entering the eyes, mouth, feet and intestines.

### Both *B. diandrus* and *B. rigidus* act as alternate hosts to cereal diseases

Left uncontrolled in fallow or pasture phases, brome grasses will host and carry over cereal diseases and pests to new crops. Diseases include ergot (*Claviceps purpurea*), take-all (*Gaeumannomyces graminis*), powdery mildew (*Erysiphe graminis*), septoria glume blotch (*Leptosphaeria nodorum*), black stem rust (*Puccinia graminis*), brown rust (*Puccinia recondita*), barley net blotch (Pyrenophora teres), sharp eyespot (*Rhizoctonia solani*), bunt (*Tilletia caries*) and cereal yellow dwarf virus. Pests include cereal cyst nematode (*Heterodera avenai*) and root-knot nematodes (*Meloidogyne* spp.).

### Brome grasses are developing herbicide resistance

At May 2014 there are populations of *B. diandrus* resistant to Groups A, B and M, *B. rigidus* to Group A and *B. rubens* to Group M.

## Environments where brome grasses dominate

A widely distributed problem weed across southern Australia, brome grasses occur between latitudes 23°S and 44°S in areas of mean annual rainfall greater than 250 mm and at least four months of growing season with a mean July temperature of less than 15°C. In drier areas of Australia *B. diandrus* and *B. rigidus* are replaced by *B. madritensis* and *B. rubens*.

Both *B.diandrus* and *B.rigidus* have a diverse habitat range including croplands, pastures, fallows, wastelands, roadsides, hilltops, coastal sand dunes, national parks and reserves.

*B. diandrus* is spread from south-eastern Queensland to south-western Western Australia and tolerates a wide range of soil types (acidic or alkaline, sandy to loamy).

*B. rigidus* is more commonly found on calcareous, sandy soils along coastal areas (mostly limited to Geraldton, the Eyre Peninsula and a strip from Adelaide to the Victorian Mallee).

Brome grasses are frequently found on fallows and in cropping rotations that contain high numbers of cereal crops.

Brome grasses appear to proliferate in no-till crops. Seeds do not germinate until shallow burial by the sowing operation, prompting a larger in-crop flush of brome grasses. There are few selective in-crop herbicides effective against brome grasses, which can dominate under reduced competition situations that arise when other weeds are selectively controlled.

## Seasonal conditions that favour brome grasses

Brome grasses germinate quickly after the autumn break, causing significant problems of reduced tillering in cereals sown at low densities in low rainfall areas.

Moisture is the main requirement for the germination of brome grasses, as seed will germinate over a wide range of temperatures. Rainfall therefore plays a prominent role in determining germination flushes, and the first flush following the opening rains in autumn to early winter is always the most prominent. In a dry start to the season, a greater proportion of the seeds show staggered germination which may continue until as late as August.

## Conditions that favour germination and establishment

The seeds of brome grasses have an initial period of dormancy. Usually by the end of summer seeds move out of their dormant phase and many germinate with the autumn break. The release from dormancy is generally much slower in *B. rigidus* than in *B. diandrus*. However, recent unpublished research has identified populations of *B. diandrus* with similar dormancy to *B. rigidus* which appears to be under strong hormonal control in the seed embryo. These populations appeared to be responsive to chilling, meaning that in the field dormant seed requires both moisture and a period of colder temperatures to germinate. As a consequence, large germinations of brome grasses are not expected until cooler moist conditions in late autumn and early winter.

This high dormancy and chilling requirement enables brome grasses to avoid knockdown herbicides and germinate in-crop where control options are far more limited.

Due to protracted germination and emergence from various soil depths, seedlings establish as cohorts throughout the season.

Seedlings can emerge from seeds buried up to 150 mm deep, although their establishment rate is reduced at that depth. The best depth for germination and emergence is 10 mm.

PHOTO: ANDREW STORRIE

Figure W4.5 *Bromus diandrus* seedling.

*B. rigidus* germination appears to be strongly inhibited by exposure to light. However, seed germination resumes upon release from innate dormancy and placement in complete darkness caused by tillage or sowing operations.

*B. diandrus* establishment is more rapid and uniform when emerging from under wheat stubble than on bare soil and higher if seed is mixed with the soil by shallow cultivation.

## Seed survival in the soil

A high proportion of dormant seeds survives hot, dry summers. Seed viability is lost within a year or two if exposed to a humid environment.

Seeds of *B. diandrus* can remain viable in the surface soil layer for two to three years, but little dormancy was found in *B. diandrus* in the southern areas of Western Australia.

Persistence of *Bromus* species could be prolonged on non-wetting soils, with high levels of seedbank carryover (30 per cent) from one season to the next. Greater persistence of brome grass seeds means that control must be undertaken over successive years to deplete the weed seedbank.

**TABLE W4.2 Tactics that should be considered when developing an integrated plan to manage brome grass (*Bromus* spp.).**

| Brome grass (*Bromus* spp.) | | Most likely % control (range) | Comments on use |
|---|---|---|---|
| *Tactic 1.1* (page 92) | Burning residues | 70 (60–80) | Sufficient crop residues are needed. |
| *Tactic 1.4* (page 105) | Autumn tickle | 50 (20–60) | Depends on seasonal break. Seed burial through shallow cultivation enhances seed depletion through germination, especially in *B. diandrus* with its shorter dormancy and faster germination. |
| *Tactic 1.5* (page 109) | Delayed sowing | 70 (30–90) | Best results with early seasonal break. |
| *Tactic 2.1* (page 113) | Fallow | 80 (70-90) | Start the chemical fallow before weeds set seed (i.e. early spring). |
| *Tactic 2.2a* (page 124) | Knockdown (non-selective) herbicides for fallow and pre-sowing control | 80 (30–99) | If possible delay spraying until full emergence and youngest plants have 2 leaves. |
| *Tactic 2.2c* (page 133) | Pre-emergent herbicides | 80 (40–90) | Follow label directions, especially on incorporation requirements of some herbicides. |
| *Tactic 2.2d* (page 139) | Selective post-emergent herbicides | 90 (75–99) | Apply when weeds have 2 to 6 leaves and are actively growing. |
| *Tactic 3.2* (page 184) | Pasture spray-topping | 75 (50–90) | Spray before viable seedset. Respray or graze survivors. Use this technique 2 years before going back to crop. |
| *Tactic 3.3* (page 190) | Silage and hay – crops and pastures | 60 (40–80) | Silage is better than hay. Graze or spray regrowth. |
| *Tactic 3.4* (page 195) | Manuring, mulching and hay-freezing | 90 (75-95) | Manuring works well if done before seed set. Any regrowth must be controlled. |
| *Tactic 3.5* (page 202) | Grazing – actively managing weeds in pastures | 50 (20–80) | Graze infested areas heavily and continuously in winter and spring. |
| *Tactic 4.1* (page 212) | Weed seed control at harvest | 70 (10–75) | Works best on early harvested crops before weeds drop their seeds |

## Contributors

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# WEED 5: FEATHERTOP RHODES GRASS (*Chloris virgata*)

## Common names

Feather finger grass, feather windmill grass, feathertop chloris, hairy Rhodes grass, windmill grass, woolly-top Rhodes grass.

## Distinguishing characteristics

Feathertop Rhodes grass (*Chloris virgata*) is a tufted annual grass up to 1 m tall with erect and semi-prostrate branched stems capable of rooting at the joints. Leaf blades are bluish green, 5 to 25 cm long and 3 to 6 mm wide. The seed-heads or panicles have seven to 19 feathery, white-silver spikes that are 3 to 9 mm long. The feathery appearance comes from the stiff white hairs and awns arising from the seeds.

Unlike common Rhodes grass (*C. gayana*), feathertop Rhodes grass panicles tend to remain unsplayed and pointing upwards. Seedlings are erect but with flattened stem bases, and this flattening becomes more obvious in older tillers. Leaf blades have tufts of hairs along the margins and where the blade joins the sheath. The stem joints are hairless and sometimes very dark.

## Other weeds that can be confused with feathertop Rhodes grass

In the early growth stages, feathertop Rhodes grass can be easily confused with awnless barnyard grass (*Echinochloa colona*).

## Factors that make feathertop Rhodes grass a major weed

### Feathertop Rhodes grass has displayed tolerance to glyphosate

When using glyphosate alone to control feathertop Rhodes grass it is often difficult to achieve high levels of control, particularly after the early tillering stage. The prolonged use and reliance on glyphosate in the fallows of northern New South Wales and Queensland cropping systems has assisted this species to become very common. For the same reason, feathertop Rhodes grass has also recently become an issue in glyphosate tolerant cotton systems.

### Seeds readily germinate unless buried

With minimal disturbance the seeds remain near the soil surface, which is ideal for emergence and perpetuation of the weed.

PHOTO: ANDREW STORRIE

Figure W5.1 Inflorescence of feathertop Rhodes grass showing shedding of seed.

PHOTO: VIKKI OSTEN

Figure W5.2 A feathertop-Rhodes-grass-infested sorghum crop.

## Environments where feathertop Rhodes grass dominates

Previously a weed of roadsides, fencelines and wasteland areas, feathertop Rhodes grass has now become an issue in cropping country, particularly where minimum or zero tillage has been practised for several years.

Feathertop Rhodes grass is a major weed in broadacre cropping systems in Central Queensland, the Darling Downs and Western Downs regions of southern Queensland, the coastal and northern Queensland cropping areas and northern New South Wales. In addition it is a problem in the vineyards and orchards of South Australia and in parts of the Western Australian grain region.

## Seasonal conditions that favour feathertop Rhodes grass

A number of below average rainfall years have made management difficult, allowing seedbank build-up. Very wet seasons have been associated with substantial field population increases.

## Conditions that favour germination and establishment

Seeds germinate between temperatures of 20°C to 30°C but a preference is shown for 25°C and above with exposure to light.

The seeds have innate dormancy, requiring an after-ripening period of approximately six to 10 weeks. While pre-chilling assists in breaking dormancy, it is not essential.

The majority of seedlings emerge from seed at 0 to 2 cm depth. In a central Queensland experiment 47 per cent of seed buried near the surface germinated, compared with 5 per cent at 5 cm and nil at 10 cm depths over 12 months. The majority of plants emerged within the first seven months.

PHOTO: ANDREW STORRIE

Figure W5.3 Feathertop Rhodes grass dominating the road shoulder near Conargo, NSW.

While feathertop Rhodes grass has a preference for lighter textured soils, it will also survive on heavier clay soils.

## Seed survival in the soil

Seed appears to be short-lived (about seven to 12 months) irrespective of burial depth, suggesting short field persistence in central Queensland. Seed exhumed from depth after being buried for 12 months did not germinate even after several dormancy breaking mechanisms were applied. Seedbank dynamics in southern Australia have not been researched at the time of writing.

**TABLE W5.1 Tactics that should be considered when developing an integrated plan to manage feathertop Rhodes grass (*Chloris virgata*).**

| Feathertop Rhodes grass (*Chloris virgata*) | | Most likely % control (range) | Comments on use |
|---|---|---|---|
| *Agronomy 1* (page 54) | Crop choice and sequence | 95 (75–99) | Choose rotation with summer legume crop such as mungbeans to allow use of grass selective herbicides combined with crop competition. |
| *Tactic 1.3* (page 101) | Inversion plough | 75 (70-80) | Deep burial of seed will prevent emergence. |
| *Tactic 2.1* (page 113) | Fallow and pre-sowing cultivation | 90 (50–100) | This is an effective option under dry conditions. |
| *Tactic 2.2a* (page 124) | Knockdown (non-selective) herbicides for fallow and pre-sowing control | <50 (0–70) | Glyphosate alone is unreliable and usually ineffective, especillay once tillering has commenced. The use of paraquat alone can be effective, however, larger plants may regrow. |
| *Tactic 2.2b* (page 128) | Double knockdown or 'double knock' | 90 (80–95) | Can be effective when applied to early tillering weeds, however, unreliable once flowering has commenced. The interval between the first and second knock should be around 7 days. Using glyphosate as the first knock followed by a bipyridil is highly variable but may control very small weeds under ideal conditions. A double knock of a grass selective (such as haloxyfrop) followed by paraquat delivers consistent results on early tillering weeds under good application conditions. |
| *Tactic 2.2c* (page 133) | Pre-emergent herbicides in fallow | 90 (80–95) | The use of pre-emergent herbicides (ie isoxaflutole) applied in spring, after harvest and before germination of weeds, can provide effective summer fallow management. |
| *Tactic 2.2d* (page 139) | Selective post-emergent herbicides | 90 (75–99) | Target pre-tillering weeds in mungbeans, cotton or sunflowers. |

## Contributors

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# WEED 6: LIVERSEED GRASS (*Urochloa panicoides*)

## Common names

Liverseed grass, urochloa, urochloa grass.

## Distinguishing characteristics

Liverseed grass (*Urochloa panicoides*) is a stoloniferous (runner-forming), summer-growing annual grass. The leaves are broad (to 15 mm) with wavy margins, loosely to densely hairy on both sides. The leaf blade is rolled in bud, and the ligule is a rim of short hairs. Seedling leaves, 20 to 100 mm long, are pale green and very broad with numerous hairs on margins and sheaths.

Adult leaves are similar; however, the leaf margins are slightly wavy or crinkled. As plants mature, the stems (tillers) become prostrate on fallow ground or more erect in crops. Prostrate stems can form roots at the nodes. Mature plants can sometimes form a mat-like ground cover in dense populations.

The seed-head is approximately 100 mm long and has two to seven spikes, 10 to 70 mm long, that branch off the main stem. Seeds are produced in two rows along one side of each spike.

## Other weeds that can be confused with liverseed grass

Young liverseed grass seedlings can be confused with panic grass (*Panicum* spp.) and sweet summer grass (*Brachiaria eruciformis*). Most *Panicum* species can be distinguished by having slightly hairy and, once the plant matures, generally much longer leaves (150 to 500 mm) than those of liverseed grass (100 mm). Adult plants usually have an erect habit in fallows, and their seed-heads are described as open panicle, at least 200 mm long. Liverseed grass is also distinguished from sweet summer grass by leaf colour. Sweet summer grass leaves are much darker green and have reddish purple tinges particularly around the leaf margin and sheath. For a more detailed description refer to *Weed 9 Sweet summer grass (page 278)*.

## Factors that make liverseed grass a major weed

### Liverseed grass emerges in one major flush

This flush occurs in response to sufficient rainfall (over 20 mm). However, liverseed grass will continue to occur after the main flush but this represents a small proportion of the overall seedbank. Controlling the major flush of weeds may result in significant seedbank declines. This cannot be done without considering the seed production potential of the later season plants as substantial seed production per plant may easily refill the seedbank.

### Liverseed grass produces a large number of seeds

A large plant can produce up to 3000 seeds under favourable conditions.

### Liverseed grass can develop resistance to herbicides

Repeated use of glyphosate puts liverseed grass at high risk of developing resistance. Three populations of liverseed grass in northern New South Wales were reported to have moderate levels of glyphosate resistance in 2008.

PHOTO: ANDREW STORRIE

Figure W6.1 Liverseed grass seed-head.

A fourth population with much higher levels of resistance than these initial populations was identified in northern New South Wales in late 2013. These populations developed resistance due to continuous winter cropping and over reliance on glyphosate as the summer fallow herbicide. These infestations have now been managed well with strategic cultivations and the use of pre-emergence herbicides. Alternative post-emergence herbicides have been substituted for glyphosate.

### It is a host for cereal diseases

Liverseed grass serves as an alternate host for cereal diseases, including barley yellow dwarf virus in south-eastern Queensland.

## Environments where liverseed grass dominates

Liverseed grass was introduced as a pasture grass and is naturalised in tropical and subtropical Australia. It is now a problem in northern New South Wales and southern and central Queensland. Liverseed grass appears to prefer lighter textured surface soils such as brigalow–belah country (brown to grey vertisols). In its native range in Africa it grows on sandy soil in damp areas.

## Seasonal conditions that favour liverseed grass

Liverseed grass is favoured by wet summers. The seedbank often increases dramatically during a forage sorghum–millet phase.

Poor control by herbicide is common when daytime temperatures exceed 35°C. A difficult to control weed of summer crops and fallow, liverseed grass quickly shows stress under low moisture conditions, often because there are only a few roots supporting a tillered plant. Herbicide efficacy declines as plants mature or are under stressed conditions. It is important to check for good root development accessing good soil moisture levels before applying herbicide.

## Conditions that favour germination and establishment

The seed of liverseed grass is able to emerge from as deep as 100 mm. However, emergence is maximised when seed is buried at a depth of 50 mm, with warm damp soil favouring emergence. After rain liverseed grass tends to emerge in one flush, compared with the prolonged emergence found with barnyard grass. Most seedlings found in cropping areas germinate from the soil surface or from shallow depths.

PHOTO: ANDREW STORRIE

Figure W6.2 Liverseed grass seedling.

## Seed survival in the soil

After 12 months' burial in southern Queensland, 24 per cent of the original seeds sown on the surface remained viable, and 10 per cent and 67 per cent remained viable when buried at 50 mm and 100 mm respectively. A very small percentage (less than 0.1 per cent) of liverseed grass seed persisted after four years when positioned in the top soil (0 to 2 cm depth) if the soil remained undisturbed. Five per cent remains in undisturbed soil at a depth of 10 cm. Soil disturbance is likely to increase the rate of seedbank decline as no seed persisted after four years between a depth of 0 and 8 cm with regular soil disturbance.

**TABLE W6.1 Tactics that should be considered when developing an integrated plan to manage liverseed grass (*Urochloa panicoides*).**

| Liverseed grass (*Urochloa panicoides*) | | Most likely % control (range) | Comments on use |
|---|---|---|---|
| *Agronomy 2* (page 61) | Improving crop competition | 40 (20–60) | Summer crops only have limited effect on liverseed grass as it grows under low light conditions. Summer crops (e.g. sorghum, maize, sunflowers) grown on wide rows are poorly competitive. |
| *Tactic 1.5* (page 109) | Delayed sowing | 95 (30–99) | Followed by knockdown non-selective herbicides (*Tactic 2.2a Knockdown (non-selective) herbicides for fallow and pre-sowing control*, section 4, page 124). Moisture stress often reduces level of control. Spray when plants are at 3-leaf stage. Adjuvants can improve level of control. |
| *Tactic 2.1* (page 113) | Fallow and pre-sowing cultivation | | Combine with delayed sowing (*Tactic 1.5 Delayed sowing*, section 4, page 109) to stimulate germination of grass and double knock (*Tactic 2.2b Double knockdown or 'double knock'*, section 4, page 128). |
| *Tactic 2.2a* (page 124) | Knockdown (non-selective) herbicides for fallow and pre-sowing control | 90 (70–99) | Optimum application growth stage is between 2 leaves and early tillering stage. Tolerance to glyphosate and bipyridyls increases with plant size and age. |
| *Tactic 2.2b* (page 128) | Double knockdown or 'doubleknock' | 98 (95–100) | Knocks of glyphosate followed by paraquat have resulted in nearly 100 per cent control on early tillering glyphosate susceptible plants. If treating glyphosate-resistant plants, consider using a bipyridil as first knock followed by cultivation or a grass-selective (ie haloxyfop) followed by paraquat. |
| *Tactic 2.2c* (page 133) | Pre-emergent herbicides | 95 (85–100) | Imazapic (Qld and northern NSW only) requires good rainfall to be effective and must be applied prior to the end of December if planning to plant cereals the following year. Group B and K herbicides are more effective than Group C or D. |
| *Tactic 2.2d* (page 139) | Selective post-emergent herbicides | 90 (75–95) | Must be applied to small actively-growing weeds. Poor results generally occur when spraying large or moisture-stressed plants. |
| *Tactic 2.3* (Page 146) | Weed control in wide-row cropping | 85 (75–95) | Suited to many summer crops such as sorghum, maize and sunflowers. Some survival of liverseed grass is inevitable as plants miss treatment in intra-row area. |

## Contributors

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# WEED 7: PARADOXA GRASS (*Phalaris paradoxa*)

## Common names

Paradoxa grass, annual canary grass, bristle-spiked canary grass, paradoxical canary grass, awned canary grass.

## Distinguishing characteristics

Paradoxa grass (*Phalaris paradoxa*) is an invasive, tufted, annual grass capable of producing a large number of tillers and it generally thrives in moist conditions growing to a height of 1.2 m. Paradoxa grass has distinct reddish purple colouring at the base of the stems and also around the nodes.

The leaf blade is flat, hairless and approximately 200 mm long. As with many grass species, identification during the vegetative stage is reliant upon correct recognition of the ligule and auricle characters. The ligule is translucent and thinly membranous, and there are no auricles. The seed-head is readily distinguishable although there is variation in the spikelet cluster.

PHOTO: ANDREW STORRIE

Figure W7.1 Inflorescence of paradoxa grass.

## Other weeds that can be confused with paradoxa grass

Paradoxa grass can be confused with lesser canary grass (*P. minor*), which has a seed-head that is more bristly and a unique spikelet arrangement. The seedlings are distinguishable from wild oats (*Avena* spp.), wheat and barley as they are more slender and have a red base.

## Factors that make paradoxa grass a major weed

Originating in the Mediterranean area, paradoxa grass has spread throughout 26 countries worldwide. It is present across the wheat growing regions of Australia, and is a major weed of the northern grain region where it has become the second most prominent grass weed in winter cereals.

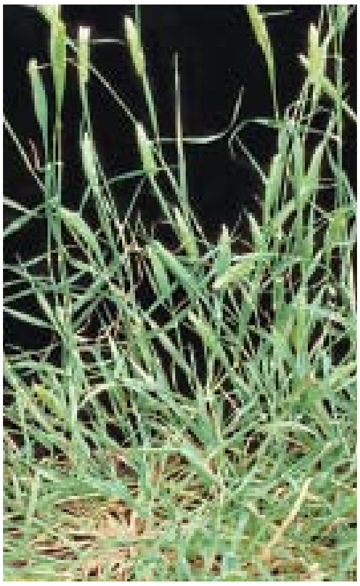

PHOTO: WILSON, *ET AL*

Figure W7.2 Mature plant of paradoxa grass.

### The success of paradoxa grass is attributable to its competitiveness and its ability to produce large numbers of seeds

Seed production ranges from 3500 to 21,500 seeds per plant. In severe infestations in favourable years up to 120,000 seeds/m$^2$ have been recorded. While paradoxa grass thrives in moist conditions, seedlings will still establish in marginal moisture conditions and plants will set seed. Yield losses due to paradoxa grass infestations in winter cereals have been known to exceed 40 per cent.

### Paradoxa grass can cause staggers in sheep

This weed is palatable to livestock and is often grazed by sheep as part of wheat–sheep rotations. As with other *Phalaris* species there have been reports of staggers in sheep that have grazed heavily on paradoxa grass.

### Paradoxa seed is a contaminant of winter cereals and may lead to reduced returns

It may also be a contaminant in seed of Toowoomba canary grass (*P. aquatica*), also known as 'grazing phalaris', which is a major pasture species in Australia.

### Seed heads of paradoxa grass tend to shatter when disturbed and drop seed in windy conditions

The spikelets at the top of the panicle are quite feathery but are not usually carried by wind. They will float and may be transported by water should they fall into creeks or streams. Because of the ability to shatter when disturbed, paradoxa grass seed is easily caught in harvesting equipment, and thorough decontamination is required to prevent seed dispersal to neighbouring fields or farms.

### Herbicide resistance is known in paradoxa grass

Some populations of paradoxa grass are known to be resistant to the Group A (ACCase inhibitor) herbicides in five countries including Australia, and more are at a high risk of resistance development. Paradoxa grass is also resistant to atrazine (Group C) along roadsides and rail lines in Israel. Hence, these herbicides should be used as part of an integrated weed management strategy.

PHOTO: ANDREW STORRIE

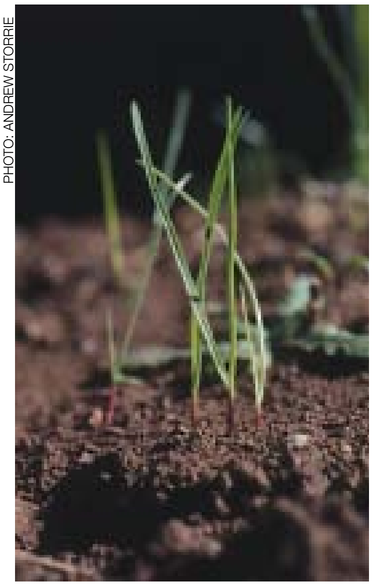

Figure W7.3 Paradoxa grass seedlings.

### Paradoxa grass thrives in a poorly competitive crop

In contrast, seed production can be greatly reduced by increasing the sowing densities of wheat and barley.

## Environments where paradoxa grass dominates

Paradoxa grass is a minor to moderate weed in Victoria, South Australia and Western Australia but has become particularly troublesome in northern New South Wales and southern Queensland.

It is a problem weed of winter cereals such as wheat and barley, and is also often seen in winter rotation crops such as faba beans and chickpeas. A common weed in fallows, it is easily controlled with non-selective herbicides and cultivation.

Although found on a variety of soil types, paradoxa grass favours the heavier black or grey clays that have greater water holding capacity.

Paradoxa grass is a weed in no-till, minimum till and conventional cultivation systems. Germination of the seed is stimulated by cultivation as it becomes sensitive to light after a period of burial in moist conditions. Control can therefore be enhanced by using an autumn tickle to stimulate emergence of paradoxa grass seedlings, allowing the use of knockdown herbicides prior to planting winter cereals.

## Seasonal conditions that favour paradoxa grass

Paradoxa seedlings first emerge with winter cereals beginning in May, while the majority of seedlings emerge in June and July. Timing of emergence can be altered through a light cultivation (autumn tickle) in March and April so that the majority of seedlings emerge in May and June, thus allowing control with a broad spectrum knockdown herbicide prior to planting. Seedset generally occurs from late October through November. Paradoxa grass is sensitive to photoperiod with floral initiation occurring with increasing day length. As the day length increases, late emerging seedlings will become reproductive shortly after emergence. If these seedlings are not controlled, late emerging plants will contribute to the soil seedbank and create further problems in the following season.

## Seed survival in the soil

Paradoxa grass seed is generally short-lived, with 95 to 99 per cent either emerging or becoming non-viable within two years. Seed is initially dormant when shed from the parent plant, preventing germination in the warmer months; however, these mechanisms break down rapidly with the majority of seeds germinating within 12 months. Typically, emergence is from seed buried 2.5 to 5 cm below the soil surface; however, seedlings can emerge from seed buried as deep as 10 cm. Seed buried from 5 to 15 cm generally remains viable for longer periods, so growers utilising inversion tillage techniques may inadvertently prolong the life of paradoxa seed in the seedbank.

**TABLE W7.1 Tactics that should be considered when developing an integrated plan to manage paradoxa grass (*Phalaris paradoxa*).**

| Paradoxa grass (*Phalaris paradoxa*) | | Most likely % control (range) | Comments on use |
|---|---|---|---|
| *Agronomy 2* (page 61) | Improving crop competition | 50 (25–95) | Barley is much more competitive than wheat in suppressing seed production. |
| *Tactic 1.4* (page 105) | Autumn tickle | 40 (10–60) | Use with an early break. Combine with delayed sowing. Follow with non-selective knockdown herbicide. |
| *Tactic 1.5* (page 109) | Delayed sowing | 85 (50–95) | Follow by knockdown non-selective herbicide (*Tactic 2.2a Knockdown (non-selective) herbicides for fallow and pre-sowing control*, section 4, page 124). Effectiveness depends on seasonal conditions. Late germinations often occur. Use in conjunction with an autumn tickle (*Tactic 1.4 Autumn tickle*, section 4, page 105) to promote seed germination. |
| *Tactic 2.2a* (page 124) | Knockdown (non-selective) herbicides for fallow and pre-sowing control | Up to 90 | Young seedlings offer a small target area. Sufficient number of droplets/$cm^2$ are required for high levels of control especially with dense infestations. |
| *Tactic 2.2c* (page 133) | Pre-emergent herbicides | 70 (60–90) | Dry conditions post-sowing will reduce herbicide efficacy. |
| *Tactic 2.2d* (page 139) | Selective post-emergent herbicides | 80 (70–95) | Spray young actively growing plants and repeat if necessary. Target small weeds. |
| *Tactic 3.1a* (page 172) | Spray-topping with selective herbicides | 80 (70–95) | Good potential in broadleaf crops |
| *Tactic 3.1b* (page 174) | Crop-topping with non-selective herbicides | 75 (60–90) | Useful in early sown short season pulse crops |
| *Tactic 3.1c* (page 178) | Wiper technology | 50 (40–70) | Good in short broadleaf crops such as lentils |
| *Tactic 3.3* (page 190) | Silage and hay – crops and pastures | 50 (40–70) | Spray with a knockdown herbicide or graze regrowth. |
| *Tactic 3.5* (page 202) | Grazing – actively managing weeds in pastures | 50 (40–80) | Graze heavily and continuously from winter until senescence. |

## Contributor

Ian Taylor

# WEED 8: SILVER GRASS (*Vulpia* spp.)

Silver grass is an annual grass occurring in cropping and grazing regions across Australia. There are several species, the most common being *Vulpia bromoides* and *V. myuros.* These species commonly occur together.

## Common names

Silver grass, vulpia, hairgrass, silkygrass. *V. bromoides* is known as squirrel-tail fescue and *V. myuros* as rat's tail fescue.

## Distinguishing characteristics

Silver grass is a slender annual grass with fine (0.5 to 3.0 mm wide) hairless leaves. It has a membranous ligule, no auricles and slender hairless stems. The seed-head is a narrow, one-sided panicle containing numerous seeds that have a straight terminal awn up to 14 mm long.

## Other weeds that can be confused with silver grass

In the early seedling stages of growth silver grass can be confused with annual ryegrass (*Lolium rigidum)* and toad rush (*Juncus bufonius*). Toad rush can be distinguished from silver grass by the absence of a ligule and by fleshy leaves that arise from the base of the plant. Annual ryegrass can be distinguished from silver grass because of the shiny lower surface of its leaf blade, larger wider leaves (especially when there are more than three leaves) and the presence of auricles.

The early growth of the perennial bulbous meadow grass (*Poa bulbosa*) is also often mistaken for silver grass, particularly in the tableland areas of Australia. However, the leaf stems of bulbous meadow grass have a distinctive pear-shaped swollen base.

Figure W8.1 Mature plant of *Vulpia bromoides.*

## Factors that make silver grass a major weed

### Silver grass competes with sown crops and pastures

Although less competitive than other annual grasses such as wild oats (*Avena* spp.), silver grass can severely reduce crop yields when present in high densities. This is most likely to occur in direct-drilled early sown crops. During perennial pasture establishment on the slopes and tablelands, silver grass can present a major problem by competing with the sown species.

### Silver grass residues can reduce crop establishment and growth

In paddocks where silver grass has been a heavy pasture contaminant, the degraded residues have been found to have an adverse effect on biomass and germination of a number of crops (including wheat, lucerne and 'grazing' phalaris, but not canola). This effect is most apparent after a dry summer and autumn period, where minimal soil disturbance maintains the residue on the soil surface. Heavy residues can be burnt in autumn to reduce the effect.

### Silver grass is an alternate host for cereal diseases

It acts as a host for a wide range of cereal root diseases including take-all, crown rot, rhizoctonia, bare patch and common root rot. Like other annual grasses, silver grass can be a host for the crop pest webworm *Hednota* species. It is also a host for the nematode that causes annual ryegrass toxicity.

### It is an undesirable component in pastures

Silver grass has low herbage production during autumn and winter, and low palatability and nutritive value in late spring and summer. Livestock avoid grazing silver grass after seed-heads emerge. In pastures on low fertility soils with low intensity set stocking, silver grass will quickly dominate.

### Silver grass causes animal health problems

The awned seeds of silver grass can seriously injure livestock by penetrating the skin and lodging in feet, eyes, ears and mouths. Seed present in hay can also cause livestock injury. The seeds and awns are a significant source of wool contamination.

## Environments where silver grass dominates

Silver grass occurs over a wide range of climatic conditions in Australia, from coastal to inland regions receiving between 200 to 1200 mm annual rainfall. It grows predominantly in areas with Mediterranean climates (cool winters and warm summers, absence of severe drought, dominant winter–spring rainfall). Due to shallow roots, silver grass plants are sensitive to drought and are therefore found mostly in the higher rainfall areas of southern Australia, including the major cereal and livestock regions.

Growing on a wide range of soil types from highly fertile loams to low fertility acid sands, silver grass is a bigger weed problem on low fertility soils (low in nitrogen and phosphorus). On higher fertility soils increased competition from other species reduces its impact.

Silver grass prefers low pH soils. It is not tolerant of cultivation and so is favoured by direct drilling. It is often a problem in pastures, particularly during establishment.

## Seasonal conditions that favour silver grass

Seed can germinate and emerge in the field at any time during the year, providing that the after-ripening dormancy has been broken and sufficient moisture is available. Silver grass is most likely to be present in paddocks that are cultivated before the autumn break. It is a minor species when cultivation occurs after the autumn break, as seedlings are destroyed by cultivation and any remaining viable seeds are buried.

## Conditions that favour germination and establishment

The seed of silver grass has an after-ripening period of two to three months in the field, after which germination can occur (given adequate moisture) over a wide range of temperatures. The seeds are intolerant of burial and germinate from the soil surface or to a depth of approximately 10 mm. Seeds buried at depths of greater than 50 mm are unlikely to germinate.

Silver grass emerges rapidly from cultivated soils. Field studies in northern New South Wales tableland pastures found that 21 per cent of the *V. myuros* and 46 per cent of the *V. bromoides* seedbank emerged in the first seven months. Total emergence was staggered over a 16 month period. At two sites in southern Western Australia, however, over 97 per cent of *V. myuros* and *V. fasiculata* emerged in the first few months of the first season after seedset, and the seedbank did not persist after that.

*Vulpia bromoides* and *V. myuros* are able to germinate under light and dark conditions over a range of temperatures (approximately 10°C to 30°C). However, light increases the germination rate.

## Seed survival in the soil

Large seedbanks of silver grass can develop and seed can persist for at least three years. However, given the right conditions most seed will germinate in the first year, with only a small percentage remaining dormant to germinate in following seasons.

**TABLE W8.1 Tactics that should be considered when developing an integrated plan to manage silver grass (*Vulpia* spp.).**

| Silver grass (*Vulpia* spp.) | | Most likely % control (range) | Comments on use |
|---|---|---|---|
| *Agronomy 1* (page 54) | Crop choice and sequence | 80 (70–95) | Rotate to a triazine tolerant or glyphosate resistant canola in heavily infested areas. |
| *Agronomy 3* (page 74) | Herbicide tolerant crops | 95 (90–99) | Using pre- and post-emergent applications of triazine herbicide in triazine tolerant crops will almost eradicate most species of *Vulpia*. |
| *Agronomy 4* (page 79) | Improving pasture competition | Variable | Reduces seed production, helping to maintain a low incidence of silver grass in a pasture. Winter clean with simazine. |
| *Tactic 1.1* (page 92) | Burning residues | 50 (30–70) | Use a hot fire back-burning into the wind. |
| *Tactic 1.3* (page 101) | Inversion ploughing | 90 (80–99) | Use a plough with skimmers to bury seed more than 75 mm deep. |
| *Tactic 1.4* (page 105) | Autumn tickle | 60 (50–80) | Requires an early break to the season. Combine with delayed sowing. |
| *Tactic 1.5* (page 109) | Delayed sowing | 75 (50–90) | Works well in most seasons. Tends to fail on non-wetting soils. |
| *Tactic 2.1* (page 113) | Fallow and pre-sowing cultivation | 70 (50–90) | Generally works well. Crop using full soil disturbance with late sowing to enable use of knockdown herbicides plus cultivation. |
| *Tactic 2.2a* (page 124) | Knockdown (non-selective) herbicides for fallow and pre-sowing control | Up to 95 | Ensure good herbicide coverage. |
| *Tactic 2.2b* (page 128) | Double knockdown or 'double knock' | 80 (70–95) | If this is required, pasture cleaning or spray-topping should have occurred 2 years before cropping. |
| *Tactic 2.2c* (page 133) | Pre-emergent herbicides | 80 (70–95) | Triazines are very good on most species of *Vulpia*. |
| *Tactic 2.2d* (page 139) | Selective post-emergent herbicides | Up to 95 | If silver grass is the main component of the pasture there will be a loss of winter fodder. The treated pasture should be resown in the following season or renovated to increase the component of desirable species. |
| *Tactic 3.2* (page 184) | Pasture spray-topping | Up to 85 | Timing is critical. Heavy grazing leading up to topping will induce uniform head emergence. Gives the ability to keep desirable pasture species while reducing the incidence of silver grass. Conduct two seasons before cropping. |
| *Tactic 3.3* (page 190) | Silage and hay – crops and pastures | Up to 90 | Cut for silage at commencement of flowering. Control regrowth. |
| *Tactic 5.1* (page 228) | On-farm hygiene | Variable | Contaminated hay should not be moved to clean areas. |

## Contributors

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## WEED 9: SWEET SUMMER GRASS (*Brachiaria eruciformis*)

### Common names

Sweet summer grass, sweet signal-grass. Sweet summer grass is the preferred common name in the subtropics and tropics of Queensland.

### Distinguishing characteristics

Sweet summer grass (*Brachiaria eruciformis*) is delicate and fine in appearance compared with the major subtropical summer grasses of cropping such as *Urochloa* and *Echinochloa* species.

It is distinguished by its colouring. The culms, leaf margins and leaf sheaths are strongly reddish purple, while the leaf blades are dark green. Leaves are 15 to 100 mm long by 2 to 6 mm wide.

Sweet summer grass tends to be a tufted annual grass that may root at the lower joints, giving a sprawling stoloniferous (stem-forming) appearance. The upright growth habit components of the plant reach 300 to 600 mm in height.

The flowering section of the stem is 10 to 80 mm long with three to 14 spikes of short (10 to 30 mm long) florets. Seed-heads do not have the typical 'signal' appearance of the other *Brachiaria* species as they do not droop, instead remaining upright and parallel with the stem. Seeds are purplish, elliptical and about 2 mm long.

### Other weeds that can be confused with sweet summer grass

Sweet summer grass is not easily confused with other summer growing grasses of cultivation. *B. eruciformis* is unique in appearance, although confusion does arise when growers refer to it as just 'summer grass', which reflects an incorrect use of common name terminology (summer grass is *Digitaria ciliaris*).

Some confusion could arise where it grows in conjunction with native members of the same genus such as velvet-leafed summer grass (*B. windersii*) and green summer grass (*B. subquadripara*). However, *B. eruciformis* can be easily distinguished from these other *Brachiaria* species by the architecture of the seed-heads and the higher degree of reddish purple colouring.

PHOTO: WILSON, *ET AL* 1995

Figure W9.1 Mature sweet summer grass plant and seed head.


Figure W9.2 Sweet summer grass infesting grain sorghum.

## Factors that make sweet summer grass a major weed

Little is known about sweet summer grass in terms of its ecology and biology, except that yields of summer crops are often severely depressed (30 to 60 per cent) by dense patches of the weed. Senesced plant material from the carpet of grass can also impede emergence of winter crops.

### Sweet summer grass can be competitive when it forms dense mats or carpets across areas of cultivation

The impact on crop yield is greatest when it emerges before or with the crop. Studies in central Queensland showed that sweet summer grass which emerged two to three weeks after the crop reduced sorghum yields by 10 to 20 per cent.

### Sweet summer grass creates a problem when the remnant plant material impedes emergence of winter crops

During cultivation the green and/or dead plant material tends to wrap around tynes, causing blockages and dragging across the paddock.

The plant is a short-lived summer weed dispersed by seed. Seeds fall very close to the parent plant and it is unknown whether they are further dispersed by insects or birds.

### Anecdotal observations indicate that sweet summer grass is a prolific seeder

Under good growing conditions, a single plant is likely to produce around 4000 seeds/$m^2$.

### Sweet summer grass is not known to host insects or diseases

### Sweet summer grass has developed resistance to glyphosate

One population of sweet summer grass from central Queensland has been confirmed as resistance to glyphosate in mid 2014.

## Environments where sweet summer grass dominates

PHOTO: VIKKI OSTEN

Figure W9.3 Sweet summer grass seedling.

This plant is native to northern Africa, the Mediterranean and India, and was most probably introduced into Australia as a pasture species.

Sweet summer grass is mainly a weed of cropping, and is a major problem in central Queensland, particularly on the Central Highlands. It has been recorded as a moderately important weed of coastal and sub-coastal southern Queensland, extending through to the Darling and Western Downs regions.

Sweet summer grass shows a preference for heavy soil types, and does not grow well in saline conditions.

It is predominant in summer crops and summer fallows in environments that have warm to hot temperatures with summer dominant rainfall. In central Queensland it is a major weed in sorghum and sunflower cropping enterprises, and less so in dryland and irrigated cotton.

Being a summer annual, sweet summer grass emerges from mid-spring to early autumn. When autumn and winter are mild, emergence can occur later into the season if moisture is available, and it can then become a weed in winter crops. Since central Queensland has no winter grass issues per se, grass herbicides are not used in winter crops and late emerging sweet summer grass can create problems. However, as temperatures begin to drop the weed becomes far less competitive.

Anecdotal evidence over the past 20 years indicates that sweet summer grass favours zero or minimum tillage systems, since its occurrence and importance has dramatically increased with the wider adoption of reduced tillage practices.

## Seasonal conditions that favour sweet summer grass

Central Queensland research showed that sweet summer grass often becomes a problem after the first spring to summer rains. If these rains occur late when temperatures are greater than 30°C, it is very quick to complete its life cycle (within four to six weeks).

Several cohorts of emergence of sweet summer grass can occur between October and March if sufficient moisture is available. These emergences can be both in-crop and in-fallow occurrences, depending on paddock use at the time and whether residual grass-active herbicides have been used.

More often than not the weed will emerge on the same planting rains used for crop emergence, but other cohorts will emerge later with in-crop rains. The uncontrolled plants emerging with or before the crop create the biggest problems for the cropping phase. Uncontrolled sweet summer grass during the fallow, while using ‘stored’ water, has the greatest impact on soil nitrogen and the weed seedbank.

## Conditions that favour germination and establishment

Sweet summer grass germination is favoured by good soil water conditions, particularly in the surface and upper 50 mm, as well as warm to hot temperatures (greater than 30°C). Low stubble cover and smooth soil surfaces provide an excellent environment for seedlings to flourish.

## Seed survival in the soil

Seeds produced in summer are highly viable in the following summer. It is not known whether two generations can be produced per season, but it is likely as the weed is short-lived and ideal conditions (wet and hot) are often prolonged for several months.

Less than 7 per cent of seed emerges from below 20 mm soil depth, while 33 per cent of seed buried in the surface 20 mm emerges over a six-month period from the start of summer. This assists in explaining why minimum or zero tillage systems are the preferred environments for sweet summer grass, as minimal soil disturbance keeps the weed seed in the upper surface layer.

**TABLE W9.1 Tactics that should be considered when developing an integrated plan to manage sweet summer grass (*Brachiaria eruciformis*).**

| Sweet summer grass (*Brachiaria eruciformis*) | | Most likely % control (range) | Comments on use |
|---|---|---|---|
| *Agronomy 1* (page 54) | Crop choice and sequence | 95 (75–99) | Use when weed burden is moderate to high and select crops that allow use of Group A 'fop' and 'dim' chemistry. See *Tactic 2.2d Selective post-emergent herbicides* (section 4, page 139). |
| *Agronomy 2* (page 61) | Improving crop competition | 95 (75–99) | Increased competition results in lower weed pressure and reduces reliance on herbicides. |
| *Agronomy 6* (page 85) | Controlled traffic or tram-lining for optimal herbicide application | 95 (75–99) | See *Tactic 2.3 Weed control in wide-row cropping* (section 4, page 146). |
| *Tactic 1.5* (page 109) | Delayed sowing | 90 (75–99) | Best when used in conjunction with *Tactic 2.2a Knockdown non-selective herbicides for fallow and pre-sowing control* (section 4, page 124). Hold off as long as practically possible after sowing rains to allow weeds to emerge and use herbicide or full disturbance sowing. |
| *Tactic 2.1* (page 113) | Fallow and pre-sowing cultivation | 95 (90–100) | During the fallow prior to the grass forming dense mats |
| *Tactic 2.2a* (page 124) | Knockdown (non-selective) herbicides for fallow and pre-sowing control | 95 (75–99) | Best control when targeting small weeds |
| *Tactic 2.2b* (page 128) | Double knockdown or 'double knock' | 99 (95–100) | Target small weeds and apply the second knock within 5 days of the first. |
| *Tactic 2.2c* (page 133) | Pre-emergent herbicides | 95 (75–99) | Best control when applied prior to the germinating rains |
| *Tactic 2.2d* (page 139) | Selective post-emergent herbicides | 95 (75–99) | Target small weeds. Best used in conjunction with *Agronomy 1 Crop choice and sequence* (section 3, page 53), particularly if potential weed burden is going to be high. Group A selective grass herbicides can be used in sunflower, mungbean and cotton. |
| *Tactic 2.3* (page 146) | Weed control in wide row cropping | 95 (75–99) | Target small weeds. Best used in conjunction with *Agronomy 6 Controlled traffic farming or tramlining for optimal herbicide application* (section 3, page 85). Also presents opportunity to band pre-emergent herbicide over the crop row. |

## Contributor

Vikki Osten

# WEED 10: WILD OATS (*Avena* spp.)

## Common names

Wild oats, black oat.

In the following text most of the information applies to both species of wild oats (*Avena fatua* and *A. ludoviciana*) so the common name 'wild oats' will be used. The scientific names will be used only in the two instances where information applies to one species or the other.

## Distinguishing characteristics

Wild oats tend to grow in discrete patches at low to moderate densities (up to 100 plants/m$^2$).

The seedling leaves are twisted anticlockwise, the opposite direction to wheat and barley. Wild oats have a large ligule with no auricles, and the leaves tend to be hairy with a slight bluish hue. The emerging leaf is rolled.

Wild oats seeds are usually dark but can vary through to cream. Hairiness of seeds also varies.

PHOTO: ANDREW STORRIE

Figure W10.1 Wild oats ligule. Note the absence of auricles. Easily confused with brome grasses.

## Other weeds that can be confused with wild oats

In the seedling phase wild oats can be confused with all *Bromus* species which have tubular leaf sheaths and hairy leaves and sheaths. Wild oats exhibit a rolled sheath and few hairs on the leaves.

## Factors that make wild oats a major weed

### Wild oats are highly competitive

They have evolved closely with modern winter crop production. Plant for plant, wheat and wild oats are very close competitors. Competition for nutrients and water commences soon after emergence, leading to a reduction in wheat tillers. Left uncontrolled, wild oats have been shown to cause wheat yield losses as high as 80 per cent. Greatest yield loss occurs when the plants emerge before or at the same time as the crop.

### Wild oats produce a large number of seeds

The number of wild oats seeds produced is dependent on crop competitiveness, crop rotation and management techniques used. In northern New South Wales the maximum seedset is estimated to be approximately 225 seeds/plant for low densities and less than 50 seeds/plant for densities above 50 plants/m$^2$. Up to 20,000 seeds/m$^2$ can be produced by uncontrolled infestations.

### Wild oats can easily develop resistance to herbicides

Group A herbicide resistance has been present in Australian populations of wild oats since the mid 1980s. However, since 2003 Group A resistance has exploded in frequency and area, particularly in northern New South Wales.

The incidence of Group A 'dim' (e.g. Achieve®) resistance in wild oats continues to increase. In 2003 the first commercial case of Group Z (flamprop methyl) resistance was recorded in Australia. This population was also resistant to the Group A 'dim' herbicides. Much of the resistance to flamprop methyl appears to be cross-resistance from Group A resistance with one in three 'fop' resistant wild oats populations also having Group Z resistance.

The first case of Group B resistance in wild oats in Australia was identified in South Australia in 2005.


PHOTO: ANDREW STORRIE

Figure W10.2 Mature wild oats plant.


PHOTO: WILSON, *ET AL* 1995

Figure W10.3 Wild oats seedling.

Internationally, wild oats have developed resistance to Group A herbicides in seven countries, and resistance to multiple mode-of-action herbicides in Canada, Iran, Great Britain, South Africa and the USA.

### Wild oats avoid early herbicide applications through later germinations

Staggered germination is a mechanism of wild oats persistence, with the main cohort emerging in autumn to early winter and small numbers emerging through until spring. Later cohorts produce enough seed for the following season because they avoid the pre-emergent or early post-emergent herbicide applications relied on for control.

### Wild oats represent a large cost to cropping

The annual cost to the Australian wheat industry in 1999 was estimated to be $80 million, with $60 million being spent on herbicides and their application, and $20 million being accounted for by lost yield.

The level of grain contamination varies from year to year and depends on ripening and shedding of wild oats in relation to harvest. Australian grain receival tolerance levels are outlined in Table W10.1 (below).

**TABLE W10.1 Australian grain receival tolerance levels for wild oats contamination.**

| Varietal grade option | APH2 | H2 | APW1 | ASW1 | AGP1 | AUW1 | FEED |
|---|---|---|---|---|---|---|---|
| Allowable no. grains/half-litre | 50 | 50 | 50 | 50 | 50 | 150 | 400 |

### Wild oats are easily spread as contaminants of grain, hay and machinery

Up to 75 per cent of wild oats seed may be collected at harvest, with seeds being transported up to 250 m from the parent plant. Delaying harvest can reduce seed movement in the paddock and grain sample, as the delay means a greater proportion of the wild oats seeds will have shattered.

### Wild oats act as a host for a number of important cereal diseases and pests

They are one of the main hosts for cereal cyst nematode (*Heterodera avenae*), stem nematode (*Ditylenchus dipsaci*), root lesion nematode (*Pratylenchus neglectus*) and the root diseases rhizoctonia (*Rhizoctonia solani*) and crown rot (*Fusarium graminearum*).

## Environments where wild oats dominate

Both wild oats species are significant weeds wherever winter crops are grown. *A. ludoviciana* tends to be more prevalent in warmer areas of northern New South Wales and southern Queensland, while *A. fatua* dominates in southern areas. Most infestations are a mix of the two species.

Wild oats are the most important winter cropping weed in northern New South Wales and southern Queensland, second to annual ryegrass in most of the southern region, and the third most important weed in Western Australia.

Soil type doesn't greatly influence the weed's distribution although wild oats can emerge from a greater depth in lighter textured soils.

## Seasonal conditions that favour wild oats

Wild oats that emerge before or at the same time as the crop are more competitive than those emerging later. Most competition with the crop occurs in the first six weeks following cereal crop emergence. Competition with slower growing pulses (e.g. chickpeas) occurs during the period of rapid growth in spring.

## Conditions that favour germination and establishment

Opening autumn rains encourage germination of about 40 per cent of wild oats seeds, with a further 10 to 30 per cent germinating later in the season. This means that early planted crops are most likely to suffer from wild oats competition unless control methods are implemented. Dry sowing of crops without an effective pre-emergent herbicide is likely to suffer significant yield loss from wild oats.

Direct drilling retains most wild oats seed near the soil surface, resulting in a quicker seedbank turnover rate. Most of the seeds will emerge from the top 50 to 75 mm of soil.

## Seed survival in the soil

Despite common belief, the half-life of wild oats seed is about six months, equating to 75 per cent depletion in 12 months. Trial work in northern New South Wales in the 1990s has shown that once seed production has ceased, the seedbank can be depleted to extremely low numbers within three to five years. Deep burial of wild oats seed will increase survival times.

PHOTOS: ANDREW STORRIE

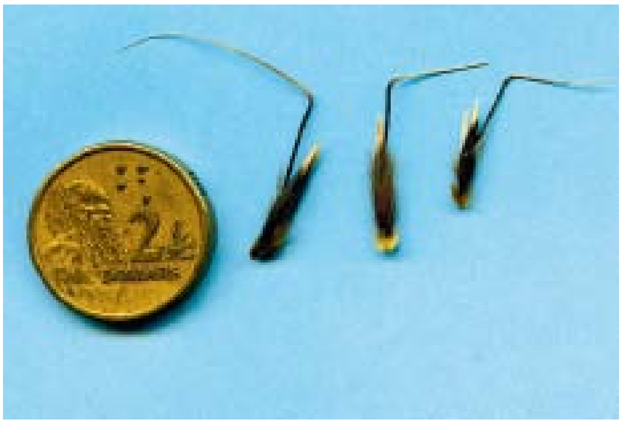

Figure W10.4 *Avena ludoviciana* seeds (right) and *Avena fatua* seed (left). Note that *A. ludoviciana* spikelets tend to hold together at maturity while *A. fatua* readily break into individual seeds.

**TABLE W10.2** Tactics that should be considered when developing an integrated plan to manage wild oats (*Avena* spp.).

| Wild oats (*Avena* spp.) | | Most likely % control (range) | Comments on use |
|---|---|---|---|
| *Agronomy 1* (page 54) | Crop choice and sequence | 95 (30–99) | Summer crop–winter fallow rotation is very effective; numbers build up in winter pulse crops. Maintaining a clean winter fallow is the key to success. |
| *Agronomy 2* (page 61) | Improving crop competition | 70 (20–99) | Competitive crops at optimum sowing rates are very effective. High levels of control are achieved with barley, much lower with wheat. |
| *Agronomy 3* (page 74) | Herbicide tolerant crops | 90 (80–99) | Good to excellent control achieved with glyphosate resistant and triazine tolerant crops |
| *Tactic 1.4* (page 105) | Autumn tickle | 40 (30–60) | Needs an early break to season. Combine with delayed sowing (*Tactic 1.5 Delayed sowing*, section 4, page 109). |
| *Tactic 1.5* (page 109) | Delayed sowing | 40 (30-60) | Must be used with *Tactic 1.4 Autumn tickle* (section 4, page 105) |
| *Tactic 2.2a* (page 124) | Knockdown (non-selective) herbicides for fallow and pre-sowing control | 80 (70–90) | Wait until youngest plants have 2 leaves if possible. Late germinations will not be controlled. |
| *Tactic 2.2c* (page 133) | Pre-emergent herbicides | 80 (70–90) | Works best when combined with competitive crops |
| *Tactic 2.2d* (page 139) | Selective post-emergent herbicides | 80 (70–90) | Test for resistance before spraying. Use in combination with competitive crops. |
| *Tactic 3.1a* (page 172) | Spray-topping with selective herbicides | 90 (60–99) | Flamprop methyl is very effective on flamprop susceptible wild oats. Best results with competitive crops, warmer conditions and at very early jointing stage of wild oats. Group Z resistance is common in many areas. |
| *Tactic 3.2* (page 184) | Pasture spray-topping | 80 (70–90) | Graze or spray survivors. Hay freezing works well. |
| *Tactic 3.3* (page 190) | Silage and hay – crops and pastures | 97 (95–99) | Harvest when wild oats are flowering. Control regrowth. |
| *Tactic 3.5* (page 202) | Grazing – actively managing weeds in pastures | 75 (60–80) | Graze heavily and continuously in spring. |
| *Tactic 4.1* (page 212) | Weed seed control at harvest | 70 (20–80) | Works well on early harvested crops before wild oats drop their seeds. |
| *Tactic 5.1a* (page 229) | Sow weed-free seed | 95 (0-100) | Only sow seed produced in wild oat-free paddocks. |
| *Tactic 5.1c* (page 232) | Clean farm machinery and vehicles | 80 (0-100) | Ensure harvesters are well cleaned before moving to clean property or paddock. |

## Contributor

Andrew Storrie

# WEED 11: WINDMILL GRASS (*Chloris truncata*)

## Common names

Windmill grass, umbrella grass, black windmill grass, creeping windmill grass, early chloris, star grass, blow-away grass.

## Distinguishing characteristics

Windmill grass (*Chloris truncata*) is an erect, hairless, warm season biennial or short-lived perennial to 0.5 m high, usually forming a dense low crown, sometimes with short, branched stolons. The leaf blade is 2 to 5 mm wide with a blunt (obtuse) and boat-shaped tip and has a ligule consisting of short hairs.

Flower spikes are usually six to nine in number, resembling fingers radiating horizontally and 4 to 20 cm long. Spikelets are arranged alternately in two rows on the underside of the spikes. Florets are black when mature and the seed is ovoid.

## Other weeds that can be confused with windmill grass

Tall windmill grass (*Chloris ventricosa*) and Rhodes grass (*C. gayana*) can be confused with windmill grass when young. Tall windmill grass however grows to at least 1 m high and has a drooping inflorescence (Figure W11.3, page 287). Rhodes grass has a compact and upright flowerhead.

## Factors that make windmill grass a major weed

### Windmill grass is difficult to control in no-till fallows and can reduce the yield of winter crops

Windmill grass can reduce winter crop yields by using stored soil moisture and nutrients over summer. Yield losses of up to 50 per cent have been recorded.

Field trials in central and northern New South Wales have shown that windmill grass is tolerant of glyphosate and a range of other herbicide modes-of-action (MOAs). Field trials in Western

PHOTO: ANDREW STORRIE

Figure W11.1 Mature windmill grass plants.

Australia have given higher levels of control with glyphosate and other herbicides than those achieved in New South Wales.

There are also limited herbicide registrations for windmill grass in fallow and in-crop.

### Windmill grass populations have evolved resistance to glyphosate

In a 2011 risk assessment undertaken in the northern grain region, windmill grass was identified as a moderate to high risk for glyphosate resistance in northern New South Wales farming systems. At the time of writing, 11 populations of windmill grass from New South Wales, Victoria and Western Australia have been confirmed resistant to glyphosate.

### Anecdotal observations indicate that windmill grass is a prolific seeder

Although the seed production of windmill grass has not been measured it is considered by rangeland managers to be a prolific seeder. Its ability to quickly respond to rain and flower and produce viable seed at almost any time of year means seedbanks can be continually replenished.

### Windmill grass is a host to cereal diseases

Anecdotal evidence suggests that something other than competition for moisture and nitrogen is reducing winter cereal yields. Windmill grass is a common host for barley yellow dwarf virus. Also windmill grass has been found to be a host for crown rot.

### Windmill grass seed-heads blow in the wind, enhancing its spread

An abscission layer forms at the base of each flowering stem on maturity. This allows the seed-head to break off and blow in the wind. Seed shatters easily as the heads tumble. Seed-heads often accumulate along fencelines and buildings.

## Environments where windmill grass dominates

Windmill grass is an Australian native found in temperate mainland Australia extending to central Australia, but it is absent from the Northern Territory. It is associated with dryland grasslands and woodlands on most soil types, ranging from grey cracking clays to light sandy soils. Windmill grass will grow on a range of soil types but shows a preference for lighter textured soils. In Australia it has been recognised as a useful pasture species and was introduced into California and South Carolina in the USA as a turf species.

Windmill grass is becoming a weed of no-till cropping and is a major problem in central-northern New South Wales. Removal of sheep from many farming systems since 2005 has seen an increase in the incidence of windmill grass in summer fallows.

PHOTOS: ANDREW STORRIE

Figure W11.2 Windmill grass in fallow.

Figure W11.3 Windmill grass showing its stoloniferous habit.

Anecdotal evidence over the past 20 years indicates that windmill grass favours zero or minimum tillage systems, since its occurrence and importance has dramatically increased with the wider adoption of reduced tillage practices.

## Seasonal conditions that favour windmill grass

Windmill grass will flower at most times of the year, thereby ensuring the seedbank is topped up with fresh seed. Seed drops about one month after flowering. Fresh seed has some dormancy; however, this is variable. Research on the north-west slopes of New South Wales shows that windmill grass will establish following significant rains (greater than 20 mm) from early summer until autumn.

## Conditions that favour germination and establishment

Windmill grass germination is favoured by good soil water conditions, particularly in the surface and upper 50 mm; however, the number of days until germination is not affected by lower soil moisture compared with many other native perennials. Windmill grass will germinate over a wide range of temperatures (15°C to 35°C).

Seeds of windmill grass will germinate in light. This fact combined with its tolerance of a wide temperature range and ability to germinate in a drying soil allow it to germinate on the soil surface. Research has found little successful recruitment (greater than 96 per cent mortality) in established native grass pastures over a two-year period, despite large numbers of seeds germinating. Any seedlings that did establish were in bare spaces between other plants and no new recruits flowered during this time.

## Seed survival in the soil

Seeds appear to lose viability after three years; however, this weed's ability to flower and set seed at most times of year ensures a constant supply of new seed.

**TABLE W11.1 Tactics that should be considered when developing an integrated plan to manage windmill grass (*Chloris truncata*).**

| Windmill grass (*Chloris truncata*) | | Most likely % control (range) | Comments on use |
|---|---|---|---|
| *Agronomy 1* (page 54) | Crop choice and sequence | 95 (75–99) | Use when weed burden is moderate to high and select broadleaf crops (summer) that allow use of 'fop' and 'dim' chemistry. See *Tactic 2.2d Selective post-emergent herbicides* (section 4, page 139). Alternatively, summer fallows will allow the use of full-disturbance cultivation. See *Tactic 2.1 Fallow and pre-sowing cultivation* (section 4, page 113). |
| *Agronomy 2* (page 61) | Improving crop competition | 50 (30–80) | Increased competition results in lower weed pressure and reduces reliance on herbicides. |
| *Tactic 2.1* (page 113) | Fallow and pre-sowing cultivation | 95 (70–100) | Several cultivations may be necessary. Grazing (*Tactic 3.5 Grazing – actively managing weeds in pastures, section 4,* page 202, and *Tactic 4.2 Grazing crop residues*, section 4, page 222) prior to cultivation often improves control.<br>Also glyphosate prior to cultivation dramatically improves control. |
| *Tactic 2.2a* (page 124) | Knockdown (non-selective) herbicides for fallow and pre-sowing control | 70 (55–85) | Best control when targeting weeds up to 4-leaf stage. High temperatures and moisture stress significantly reduce levels of control. |
| *Tactic 2.2b* (page 128) | Double knockdown or 'double knock' | 90 (80–100) | Target small weeds and apply the second knock (paraquat) at a robust rate within 7 to 14 days of the first. |
| *Tactic 2.2d* (page 139) | Selective post-emergent herbicides | 90 (75–99) | Target small weeds in mungbeans, cowpeas, cotton or sunflowers. Best used in conjunction with *Agronomy 1 Crop choice and sequence,* section 3, page 53, particularly if potential weed burden is going to be high. |

## Contributors

Andrew Storrie and Tony Cook

# WEED 12: BLACK BINDWEED (*Fallopia convolvulus*)

## Common names

Black bindweed (New South Wales), climbing buckwheat (Queensland), fallopia.

## Distinguishing characteristics

Black bindweed (*Fallopia convolvulus*) is an annual herb with twining stems to 1 m long. Cotyledons are narrow-clubbed with rounded tips. Arrow-shaped leaves are hairless to slightly 'mealy' with a prominent mid-vein. The leaf margin has small, shallow, rounded 'teeth'. Flowers are greenish white and the seed is dull black and tri-angled.

## Other weeds that can be confused with black bindweed

Black bindweed can be confused with the following three species.

*Muehlenbeckia gracillima* is a native climber usually found on riverbanks and the margins of wet sclerophyll forests. Its leaf margins are very finely toothed and slightly wavy. The seed is black and spherical rather than tri-angled.

Field bindweed (*Convolvulus arvensis*) is a vigorous dark green perennial twiner with stems to 2 m, arising from a deep taproot with horizontal roots and rhizomes. The leaves are elongated, arrow-shaped, two-lobed at the base and sparsely hairy.

*C. erubescens* is a hairy prostrate perennial with twining stems to 1 m and a thick rootstock.

**TABLE W12.1 Distinguishing characteristics of black bindweed compared with similar weed species.**

| Species | Leaf | Flower | Seed |
|---|---|---|---|
| *Fallopia convolvulus* | Arrow-shaped with prominent mid-vein. Small rounded teeth on margin. | Floppy spike-like inflorescence of greenish white flowers. | Dull black, tri-angled, 4 to 5 mm long. |
| *Muehlenbeckia gracillima* | Triangular with very finely toothed margin. | Spike-like inflorescence. | Black and spherical. |
| *Convolvulus arvensis* | Elongated and arrow-shaped with 2 lobes at base. Smooth margin. | White to pink funnel-shaped single flower to 25 mm diameter. | Hanging globular capsule with a small point. Brown to black. |
| *C. erubescens* | Variable in shape and size, but similar to *C. arvensis*. Smooth margin. | Tubular with fused petals, pink to white, ~20 mm wide when open. | Egg-shaped capsule. Brown to black. |

PHOTO: ANDREW STORRIE

Figure W12.1 *C. erubescens* in flower.

Figure W12.2 Black bindweed climbing wheat.

PHOTOS: ANDREW STORRIE

Figure W12.3 Black bindweed seedling.

## Factors that make black bindweed a major weed

### Black bindweed is competitive in crops

In Oklahoma, USA, 32 black bindweed plants/m$^2$ reduced wheat yield by 50 per cent.

### Black bindweed produces a large number of seeds

In Oklahoma it produced up to 2500 seeds/m$^2$ per season, with up to 1000 seeds per plant.

### The twining habit of black bindweed causes problems of blockages in tillage equipment and contamination in grain samples

If black bindweed is permitted to grow in summer fallows, the vine wraps around cultivator tynes, causing blockages in equipment and slowing operations. It readily becomes a grain contaminant; in milling grades of wheat up to 50 seeds per half-litre is permitted. Black bindweed can also be dispersed in contaminated seed and feed grain.

### Black bindweed is tolerant of many herbicides, particularly once it has more than two true leaves

This fact, together with the adoption of wider winter cereal row spacings (greater than 250 mm) for improved sowing into stubbles which reduces the competitive ability of the crop, has made black bindweed a more significant problem weed. These wider row spacings often mean that full crop ground cover is never achieved, or is achieved late in the season, allowing the black bindweed to establish and develop into large twining plants.

### Black bindweed resistance to Group B herbicides was first recorded in 1993

In studies west of Goondiwindi, Queensland, sites had five to 10 years' use of chlorsulfuron (e.g. Glean®). However, at the time of writing no other resistant populations have been identified in Australia. Populations of black bindweed have evolved resistance to triazine herbicides (Group C) in Austria and Germany.

## Environments where black bindweed dominates

Black bindweed is found to some degree in all mainland states and territories. However, it is only considered a weed problem north of Parkes, New South Wales, and through southern and central Queensland. In Western Australia it is considered a garden escape around Perth. Although adaptable to a wide range of environmental conditions, it prefers self-mulching clay soils but will also grow on loam soils. It is unclear why it is not a problem in winter crops in more southerly areas with clay soils.

Black bindweed is a weed of winter crops, particularly in pulses where no effective herbicides are available for its control. Germinating in mid-winter to spring, black bindweed avoids early post-emergent herbicide applications and survives harvest. With sufficient soil moisture it will continue to grow into summer, creating problems in fallows and no-till summer crops.

## Seasonal conditions that favour black bindweed

In northern New South Wales and southern Queensland black bindweed germinates from July to September. Flowering commences late in spring and continues into summer. Plants will grow up to 1 m long during a wet summer.

A wet spring followed by a wet summer favours the weed. In farming systems where wide row spacings (greater than 300 mm) are used and where cereal plant density is suboptimal, the black bindweed problem is intensified.

A wet spring decreases the period of residual control given by picloram (e.g. Tordon® 242).

## Conditions that favour germination and establishment

Black bindweed tends to germinate when the soil temperature at 50 to 100 mm depth reaches 11°C to 13°C. It is speculated that there is a cyclical dormancy, which is released in late winter and then reinstated as a secondary dormancy when temperatures begin to rise. Only 2.5 per cent of the seed germinates each year. New seed is thought to have a primary dormancy that is broken by a period of low temperatures. Research in North Dakota, USA, in the 1980s found that temperatures between 2°C and 10°C for two months were required to break this primary dormancy.

Due to the lack of control options available in pulse crops, the black bindweed seedbank often increases dramatically when pulse crops are grown.

## Seed survival in the soil

The survival of black bindweed seed in Australian soils is unknown. However, work in Alaska showed that less than 1 per cent of seed was viable 10 years after burial.

**TABLE W12.2 Tactics that should be considered when developing an integrated plan to manage black bindweed (*Fallopia convolvulus*).**

| Black bindweed (*Fallopia convolvulus*) | | Most likely % control (range) | Comments on use |
|---|---|---|---|
| *Agronomy 1* (page 54) | Crop choice and sequence | 85 (0–95) | Do not sow pulses where black bindweed is a problem. Summer crop–winter fallow allows use of knockdown non-selective herbicides to control black bindweed. |
| *Agronomy 2* (page 61) | Improving crop competition | 90 (10–95) | Optimum sowing rates are essential. Row spacings >250 mm in winter cereals reduce crop competitiveness. |
| *Tactic 2.2d* (page 139) | Selective post-emergent herbicides | 95 (40–99) | Must be used with competitive crops and higher sowing rates. |
| *Tactic 3.5* (page 202) | Grazing – actively managing weeds in pastures | 90 (0–95) | Unmanaged pastures are a major source of crop weed problems. |
| *Tactic 5.1a* (page 229) | Sow weed-free seed | 95 (0-100) | Ensure seed for sowing comes from black bindweed free areas or has been well graded. |

## Contributor

Andrew Storrie

# WEED 13: BLADDER KETMIA (*Hibiscus* spp.)

## Common names

Bladder ketmia, narrow-leaf bladder ketmia (*Hibiscus tridactylites*), wide-leaf bladder ketmia (*H. verdcourtii*), lantern hibiscus, flower-of-an-hour, rose mallow, wild gooseberry, Venice mallow (commonly used outside Australia).

## Distinguishing characteristics

There are two species of bladder ketmia. The cotyledons of both species are similar in shape, with one leaf circular to broadly oval and the other circular with a slightly flattened base. The two species can be distinguished by a number of characteristics (Table W13.1, below). Wide-leaf bladder ketmia has two forms generally distinguished by the colour of the centre of the flower.

**TABLE W13.1 Characteristics of the two species of bladder ketmia.**

| | Wide-leaf bladder ketmia | Narrow-leaf bladder ketmia |
|---|---|---|
| Scientific name | *Hibiscus verdcourtii* (formerly *H. trionum* var. *vesicarius*). | *Hibiscus tridactylites* (formerly *H. trionum* var. *trionum*). |
| Introduced/native | Native | Previously thought to be introduced, but likely to be native |
| Plant height and habit | Always erect and up to 1.8 m high | Semi-prostrate to erect and up to 1.3 m high |
| Leaf appearance | Waxy and mid to dark green | Leaves less waxy, often with purple-tinged edges |
| | Leaves have 3 lobes, not deeply divided. | Leaves have 3, sometimes 5 lobes, deeply divided. |
| | Margins not toothed (entire) | Margins are toothed. |
| Flower appearance | Cream petals with either yellow or crimson-red centres | Yellow-cream petals with deep purple centres |
| Cotyledon size (length x width) | 20 x 18 mm (yellow-centred)<br>18 x 16 mm (red-centred) | 14 x 14 mm |
| Leaf size (max. length x width) | 138 x 94 mm (yellow-centred)<br>101 x 72 mm (red-centred) | 90 x 95 mm |
| Time to flowering (glasshouse average) | 37 days (yellow-centred)<br>40 days (red-centred) | 30 days |
| Seed-head appearance | Straw-coloured and rough in texture with raised ribs. Not see-through at maturity. | Light grey and papery with soft, raised purple ridges. Nearly see-through at maturity. |
| Seed appearance | Larger and black | Smaller and light to mid-grey |
| Total number of seeds/plant | 2300 (range 50 to 7800) | 5600 (range 1500 to 15,900) |

## Other weeds that can be confused with bladder ketmia

Wide- and narrow-leaf bladder ketmia are easily confused. The seedlings of bladder ketmia are also similar in appearance to native rosella (*Abelmoschus ficulneus*), a common broadacre weed in Queensland.

PHOTO: ANDREW STORRIE

Figure W13.1 Mature plant of narrow-leaf bladder ketmia.

PHOTO: ANDREW STORRIE

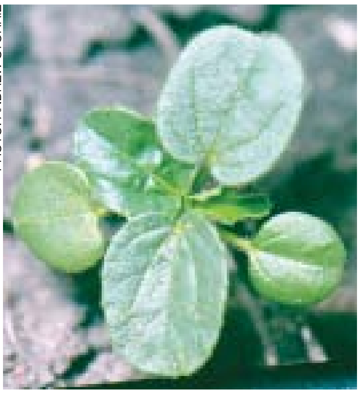

Figure W13.2 Wideleaf bladder ketmia seedling.

PHOTO: STEVEN JOHNSON

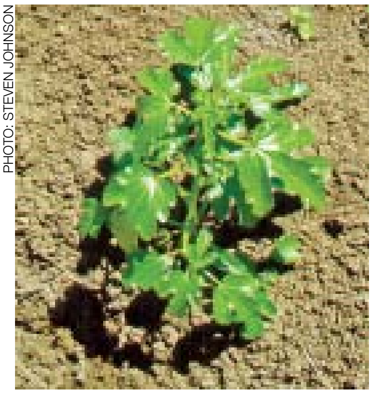

Figure W13.3 Wide-leaf bladder ketmia plant.

PHOTO: STEVEN JOHNSON

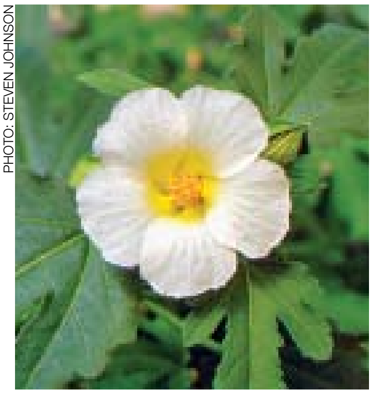

Figure W13.4 Wide leaf bladder ketmia flower (yellow centre form).

The various common names of ketmia may lead to some confusion with the *Physalis* species commonly called Chinese lantern or Chinese gooseberry.

## Factors that make bladder ketmia a major weed

Bladder ketmia is an annual weed of summer crops and disturbed areas.

### Both species of bladder ketmia are able to produce a large number of seeds

Between approximately 2000 and 5500 seeds are produced on medium sized plants (Table W13.1, page 292).

### Strong seed dormancy and a number of dense seedling flushes throughout spring and summer make bladder ketmia difficult to control

While plants are generally killed by frost, narrow-leaf bladder ketmia will grow in sheltered stubble and fallow situations during winter.

### Narrow-leaf bladder ketmia is tolerant of glyphosate

Lower rates of glyphosate are ineffective on narrow-leaf bladder ketmia seedlings, especially where there is moisture and/or heat stress. As the plants get larger their tolerance of glyphosate increases.

### Dense stands of bladder ketmia can cause localised yield loss

Individual plants are not overly competitive.

### The weed, which may be easily spread through poor farm and machinery hygiene, is a crop pathogen host

Bladder ketmia is an alternative host to many insect pests.

## Environments where bladder ketmia dominates

### Bladder ketmia is a problem in summer crops, particularly in cotton and grain sorghum

It is a common weed in the northern grain zone and a minor weed in other areas.

Narrow-leaf bladder ketmia is common on the slopes, tablelands and coastal areas of New South Wales, and on the Darling Downs and coastal areas of southern Queensland.

Wide-leaf bladder ketmia is more common in the western areas of the plains in New South Wales and the Darling Downs in Queensland. The yellow-centred form of this species is common south of the Darling and Western Downs of Queensland where it coexists with the red-centred form, which is more common in central and western Queensland.

Bladder ketmia is common on heavy cracking clay soils.

## Seasonal conditions that favour bladder ketmia

Both wide- and narrow-leaf bladder ketmia seedlings emerge in successive flushes after rainfall (at least 10 mm is needed) or irrigation throughout spring, summer and autumn. Narrow-leaf bladder ketmia is also able to emerge during winter.

Plants produce seeds within 46 to 61 days, depending on variety (Table W13.1, page 292). Only narrow-leaf bladder ketmia has been recorded as producing seed over winter.

## Conditions that favour germination and establishment

Cultivation increases the number of narrow-leaf bladder ketmia seedlings that emerge by two to four times over uncultivated situations. Narrow-leaf bladder ketmia can emerge from at least 5 cm in depth but this decreases to less than 1 per cent emergence at 10 cm.

Rainfall or irrigation before spring planting generally produces an early season flush that may be controlled by a knockdown herbicide. Periodic spring and summer showers encourage good seedling establishment.

## Seed survival in the soil

Narrow-leaf bladder ketmia seed has a relatively long viability in the soil. Summarising seedbank studies on vertisols, 70 to 80 per cent of seed is viable after one year, decreasing to 40 to 70 per cent after two years and 30 per cent after three years. In contrast, wide-leaf bladder ketmia seed viability was 50 per cent after one year and 15 per cent after two years. Seed viability decreased with depth of burial.

**TABLE W13.2 Tactics that should be considered when developing an integrated plan to manage bladder ketmia (*Hibiscus* spp.).**

| Bladder ketmia (*H. tridactylites* and *H. verdcourtii*) | | Most likely % control (range) | Comments on use |
|---|---|---|---|
| *Tactic 2.1* (page 113) | Fallow and pre-sowing cultivation | 95 (90–99) | Shallow cultivation may stimulate seedling emergence, followed by knockdown non-selective herbicides. |
| *Tactic 2.2c* (page 133) | Pre-emergent herbicides | Variable | Dependent on herbicide used and available soil moisture for activation |
| *Tactic 2.2d* (page 139) | Selective post-emergent herbicides | Variable | Dependent on herbicide used. Target small weeds. |

## Contributor

Stephen Johnson

# WEED 14: CAPEWEED (*Arctotheca calendula*)

## Common names

Capeweed, cape dandelion.

## Distinguishing characteristics

Capeweed (*Arctotheca calendula*) is a prostrate, stemless, sprawling annual herb that germinates during autumn and winter. It has hairless, club-shaped cotyledons. The first two leaves grow as a pair, are spear-shaped and may be scalloped. Subsequent leaves grow singly and are deeply lobed with a rounded apex. Leaves are succulent; the upper surface is hairy and the lower surface is covered with a mat of white hairs.

The solitary daisy-like flower heads have brilliant yellow ray florets with blackish purple central disc florets. Seeds are covered in pinkish brown, fluffy, woolly hairs.

## Other weeds that can be confused with capeweed

During vegetative stages capeweed may be confused with dandelion (*Taraxacum officinale*), flatweed (*Hypochoeris radicata*), smooth catsear (*Hypochoeris glabra*), skeleton weed (*Chondrilla juncea*), fleabane (*Conyza* spp.), hawkbit (*Leontodon taraxacoides*), ox tongue (*Helminthotheca echioides*), prickly lettuce (*Lactuca serriola*), sowthistle (*Sonchus oleraceus*), prickly sowthistle (*Sonchus asper*), slender thistle (*Carduus* spp.), brassica weeds such as wild radish (*Raphanus raphanistrum*), and white arctotis (*Arctotis stoechadifolia*), a coastal sand-stabilising perennial weed.

PHOTO: ANDREW STORRIE

Figure W14.1 Comparison of the underside of capeweed (left) and wild radish (right) leaves

## Distribution

A native of southern Africa, capeweed is found in all Australian states and territories.

## Factors that make capeweed a major weed

### Capeweed is a competitive plant

It competes with crops (cereals, pulses, canola) for water, nutrients and probably light, resulting in yield reduction. Plants emerging in early autumn become large before the crop is sown and compete strongly with the crop. A capeweed plant at rosette stage can reach 600 mm in diameter and can out-compete other plants. Such large plants are difficult to control with herbicides. They are often transplanted during the planting operation, and their re-emergence with crop plants can lead to population levels that decrease crop yield. In New South Wales 76 per cent of cereal crops had capeweed infestations. In Western Australia seven to 90 capeweed plants/m$^2$ may reduce wheat yield by 28 to 44 per cent and net return by up to 76 per cent.

### A capeweed plant growing under favourable conditions can produce up to 4300 seeds

Seeds may be dispersed by human activity, animals, wind, water and movement of hay.


PHOTO: ANDREW STORRIE

Figure W14.2 Mature capeweed plant.

## Capeweed is persistent

Capeweed rapidly dominates overgrazed or poorer pastures. Capeweed seed will pass through the gut of rabbits and remain viable. Continuous high stocking rates will lead to capeweed dominance in annual pastures.

## Capeweed can develop resistance to herbicides

Capeweed has evolved resistance to diquat and paraquat (Group L) in lucerne hay crops in Victoria.

## Capeweed can cause animal health problems

It is often associated with scouring in sheep. Capeweed can also cause nitrate and nitrite poisoning of livestock, particularly sheep and cattle. This occurs more frequently in starved animals given access to potentially toxic plants, in stressed animals (during mustering, droving or other handling), or due to lack of acquaintance or adaptation. It can also occur under normal grazing in some seasons. Toxic levels of nitrate are only likely to be present in plants growing in high fertility soils, particularly around stock camps or in stockyards. In practice, capeweed growing on medium to light textured soils is unlikely to contain toxic levels of nitrate. Horses develop skin allergies to the pollen which they come across through contact when grazing and/or eating the weed.

Stock deaths may also occur after spraying with hormones and other herbicides that elevate nitrate content in the capeweed. This usually occurs from early season spraying, when temperatures are higher and overcast weather follows. Nasal granuloma may occur in cows that inhale air with high concentrations of capeweed pollen for long periods. Woolly seeds in unopened buds may cause hair balls and death in sheep. In humans capeweed can cause contact dermatitis and hay fever.

## Capeweed is an alternate host for insects and diseases

Capeweed is an alternate host for light brown apple moth and the larvae of 10 other species of Lepidoptera, as well as green peach aphid, blue green aphid, cowpea aphid and red-legged earth mite. It also carries the thrip-transmitted tomato spotted wilt virus and the aphid-transmitted cucumber mosaic virus.

## Environments where capeweed dominates

Capeweed is a serious weed of cultivation across southern Australia.

In pasture the status of this species as a weed is less clear-cut. For example, in drier parts of the Western Australian wheatbelt capeweed is a useful forage plant, but in wet areas it is viewed as a weed because it occupies the area of more valuable and beneficial pasture species. In pastures it may have both positive and negative effects on both the pasture and stock production.

## Seasonal conditions that favour capeweed

This species is favoured by 'false breaks'. These low rainfall events can favour capeweed germination before other species because the woolly seed cover attracts moisture and reduces desiccation. It can also survive periods of drought better than most crops and pastures, so a dry period following good germinating rains increases the proportion of capeweed.

## Conditions that favour germination and establishment

Autumn rains induce germination of capeweed if the soil surface remains wet for a few days. Subsequent rain and residual soil moisture continue to support growth of seedlings, and these will persist through winter crops if not killed prior to crop sowing. The woolly hair around the seed assists early germination.

Seeds are usually dormant at maturity, with an after-ripening period of two to three months. Dormancy is rapidly overcome by summer temperatures around 40°C.

Secondary dormancy, a combination of embryo and seed coat-based dormancy, may be initiated by low winter temperatures. Long-term dormancy is dependent on regional adaptation. In Western Australia greater than 95 per cent of capeweed seed from the southern agricultural area germinated on the soil surface at the break of the season. Only 5 per cent of seed from the northern agricultural area germinated in the first year and 75 per cent in the second season, with 20 per cent remaining dormant for more than two years. Dormancy cycled to favour an autumn germination.

Capeweed seeds kept in the dark or buried will remain dormant for longer than those exposed to light. Again, this appears to be ecotype dependent as seeds in Portugal showed almost complete germination at 15°C in continuous darkness, whereas in Australia seed burial prevented germination.

Optimal diurnal temperatures for germination were between 10°C and 15°C in research conducted in South Africa, but higher (25°C) in Western Australian research. Germination is very low at temperatures above 30°C.

PHOTOS: ANDREW STORRIE

Figure W14.3 Capeweed seedling.

Figure W14.4 Pasture dominated by capeweed in Western Australia.

All these results were recorded in strong autumn flushes of germination in Mediterranean environments.

## Seed survival in the soil

The survival of capeweed seed in the soil is likely to be very strongly influenced by the ecotype or location and by the degree of burial that occurs. In Western Australia survival ranges from almost no carryover of seed from one season to the next, to in excess of 20 per cent of seedset being carried over for at least two years.

A number of species have potential as biological control agents but the importance of capeweed as a pasture species means they are not likely to be introduced until alternative pasture species are developed.

**TABLE W14.1 Tactics that should be considered when developing an integrated plan to manage capeweed (*Arctotheca calendula*).**

| Capeweed (*Arctotheca calendula*) | | Most likely % control (range) | Comments on use |
|---|---|---|---|
| *Agronomy 3* (page 74) | Herbicide tolerant crops | 90 (80–95) | Good control can be achieved in triazine, imidazolinone and glyphosate resistant crops. |
| *Tactic 1.3* (page 101) | Inversion ploughing | 90 (50–98) | Use skimmers to ensure deep burial of seed. Not suitable for some soil types. |
| *Tactic 1.5* (page 109) | Delayed sowing | 60 (50–90) | Works best on undisturbed paddocks |
| *Tactic 2.1* (page 113) | Fallow and pre-sowing cultivation | 60 (20–95) | Requires drying conditions following cultivation. Transplants are common in wet conditions. Burial of seed will lead to dormancy. |
| *Tactic 2.2a* (page 124) | Knockdown (non-selective) herbicides for fallow and pre-sowing control | 80 (70–99) | Good control of actively growing unstressed weeds. Poor control of early germinated weeds that have lost leaves due to early season drought. |
| *Tactic 2.2b* (page 128) | Double knockdown or 'double knock' | 90 (80–99) | Better control of hard-to-kill plants and those in dense infestations |
| *Tactic 2.2c* (page 133) | Pre-emergent herbicides | 75 (70–85) | Diuron and picloram provide good control. |
| *Tactic 2.2d* (page 139) | Selective post-emergent herbicides | 90 (80–99) | Clopyralid, florasulam, florasulam+isoxaben, pyroxsulam and terbutryne provide good control, especially of hard-to-kill plants. Limited control options in leguminous crops. Spray-grazing is good for pastures. |
| *Tactic 3.2* (page 184) | Pasture spray-topping | 70 (30–90) | Graze heavily in winter to ensure uniform flower emergence. Graze or respray survivors. |
| *Tactic 3.4* (page 195) | Manuring, mulching and hay freezing | 90 (80–99) | Graze heavily in winter to ensure uniform flower emergence. Graze or respray survivors. |
| *Tactic 3.5* (page 202) | Grazing – actively managing weeds in pastures | 50 (30–80) | Rotationally graze pastures and use spray-grazing with MCPA or 2,4-D while terbutryne gives excellent control in clover based pastures. Flumetsulam plus diuron provides reasonable control in many other legume based pastures. |

## Contributors

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# WEED 15: COMMON SOWTHISTLE (*Sonchus oleraceus*)

## Common names

Common sowthistle, annual sowthistle, sowthistle, milk thistle.

## Distinguishing characteristics

The cotyledons of common sowthistle (*Sonchus oleraceus*) are spoon-shaped and often have a greyish powdery film on their surface. Leaves are bluish green and predominantly net-veined.

Adult leaves are characterised by their serrated appearance and are commonly deeply lobed with a major triangle-shaped lobe at the tip of the leaf. Adult leaves are characterised by auricles that clasp the stem, and the leaf margins are never spiny.

Stems are hollow and exude a milky sap when broken.

Seeds are flat and possess a wrinkled surface at maturity and a fine white pappus.

PHOTO: ANDREW STORRIE

Figure W15.1 Prickly sowthistle plant.

## Other weeds that can be confused with common sowthistle

Common sowthistle can be confused with rough or spiny sowthistle (*Sonchus asper*). However, the leaves of spiny sowthistle are thicker and spiny at the margins, and its seeds are broader and lack the cross wrinkles present on common sowthistle seeds.

## Factors that make common sowthistle a major weed

### Common sowthistle is a major weed of fallows and uses vital stored soil moisture

The weed is not seen as competing heavily with crops. However, in a poorly competitive crop common sowthistle contributes to green matter at harvest and can lead to grain quality problems.

PHOTOS: ANDREW STORRIE

PHOTOS: WILSON *ET AL.* 1995

Figure W15.2 Common sowthistle seedling (left) and prickly sowthistle seedling (right).

### Common sowthistle is a prolific producer of seed

It can produce up to 68,000 seeds/$m^2$ in a fallow. In addition, the seeds possess a fine pappus that helps them disperse readily. The seeds possess no innate dormancy and are therefore able to germinate once dispersed from the parent plant.

### Common sowthistle is difficult to control

There are several populations of the weed in northern New South Wales and southern Queensland that are resistant to Group B herbicides.

At May 2014 four populations of sowthistle from northern New South Wales were confirmed resistant to glyphosate.

There are populations of *S. asper* that have evolved resistance to Group B herbicides in Canada and the USA and to Group C herbicides in France.

### Common sowthistle is an alternate host for insects

Common sowthistle is an alternate host for *Helicoverpa* species, and for aphids which can transmit viral diseases to economically important crops.

## Environments where common sowthistle dominates

Although ubiquitous across Australia, common sowthistle is a major weed of cropping only in the northern grain region from central Queensland to northern New South Wales. The weed is most common in zero or reduced tillage systems and occurs in both fallow and cropped areas.

Common sowthistle can be found on most soil types but is favoured in soils with a high water-holding capacity.

The weed is a problem in many different production enterprises including dryland and irrigated broadacre cereal production, horticultural crops, vineyards and tree crops. Also common in non-crop areas, it is frequently found on roadsides and in nature reserves.

## Seasonal conditions that favour common sowthistle

Common sowthistle has long been considered a winter annual. However, it is common all year round in the northern region and capable of producing several generations in a favourable year. For this reason a high level of diligence is required to control this weed.

This species can emerge following minimal rainfall (5 mm). However, larger flushes emerge following significant falls of rain (greater than 25 mm).

The weed is common in crops and fallows but most prevalent in fallows. In fallows, and prior to planting, it is common for this weed to be present at different stages of growth.

In a poorly competitive crop common sowthistle plants will grow and produce seeds. Escapees of the weed in such crops are most likely to set seed toward the end of the crop, or once the crop has been harvested.

Following harvest common sowthistle will regrow and flower, and at this stage it is difficult to control with commonly used rates of fallow herbicides.

PHOTO: ANDREW STORRIE

Figure W15.3 Flowering common sowthistle.

A competitive crop such as barley will suppress common sowthistle and the number of plants reaching maturity will be dramatically reduced. On the Darling Downs in southern Queensland, common sowthistle was fully controlled in the absence of herbicides by growing barley at a density of 75 plants/m$^2$ at either 250 mm or 500 mm row spacing. By comparison, it readily grew in wheat, even at a density of 150 plants/m$^2$ when grown in 500 mm rows.

## Conditions that favour germination and establishment

The seed of common sowthistle can germinate at temperatures in the range 5°C to 35°C. Germination is ultimately determined by moisture availability, as a moist environment is preferred.

Emergence is favoured under zero and reduced tillage systems where seeds remain close to the soil surface (top 20 mm). No seedlings emerge from below a depth of 20 mm.

## Seed survival in the soil

The duration of seed persistence will depend on the depth at which the seed is buried. Generally, the seed of common sowthistle is short-lived in the surface soil (20 mm), with up to 99 per cent gone after eight months in the absence of replenishment. Burial below this depth promotes seed persistence for up to 30 months.

**TABLE W15.1 Tactics that should be considered when developing an integrated plan to manage common sowthistle (*Sonchus oleraceus*).**

| Common sowthistle (*Sonchus oleraceus*) | | Most likely % control (range) | Comments on use |
|---|---|---|---|
| *Agronomy 2* (page 61) | Improving crop competition | 95 (75–99) | Increased competition results in lower weed pressure. Competition improves herbicide efficacy. |
| *Tactic 2.1* (page 113) | Fallow and pre-sowing cultivation | 80 (30-90) | Cultivation or full disturbance sowing buries seeds and prevents their germination. |
| *Tactic 2.2a* (page 124) | Knockdown (non-selective) herbicides for fallow and pre-sowing control | 95 (75–99) | Better control is achieved when treating small weeds. A reduction in herbicide efficacy occurs when 2,4-D is tank-mixed with glyphosate due to antagonism within the plant. |
| *Tactic 2.2d* (page 139) | Selective post-emergent herbicides | 95 (75–99) | Better control is achieved when treating small weeds. |
| *Tactic 3.1a* (page 172) | Spray-topping with selective herbicide | 95 (75–95) | Seed reduction of escapes. Timing is critical to avoid crop damage. |
| *Tactic 4.2* (page 222) | Grazing crop residues | 95 (up to 100) | To control escapes in fallow before seedset. Common sowthistle is very palatable and is preferentially grazed. |

## Contributor

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# WEED 16: DOUBLEGEE (*Emex australis*)

## Common names

Doublegee, spiny emex, three-cornered jack, cat-head, prickly jack, giant bull head, Tanner's curse, bindii, Cape spinach.

## Distinguishing characteristics

Doublegee (*Emex australis*) is a vigorous annual herb with a strong tap root and a long, fleshy, hairless stem. The cotyledons are hairless, elongated and club-shaped. Subsequent leaves are alternate, hairless and triangular with undulating margins.

Ovate leaves form a prostrate rosette at early stages of growth but can assume a semi-erect habit in dense crop or pasture.

Round, ribbed stems branching from the centre of the rosette may grow up to 600 mm in length. Clusters of very small, inconspicuous white flowers produce hard woody achenes with three sharp spines radiating from the apex.

## Other weeds that can be confused with doublegee

Doublegee is easily confused with *E. spinosa*, an uncommon weed found at a few sites in the northern wheatbelt of Western Australia and also in some areas of southern Australia. This has more erect stems but the fruits and achene spines of *E. spinosa* are half the size of those of *E. australis*.

## Factors that make doublegee a major weed

As a significant weed of agriculture in temperate Australia, doublegee causes a loss of $20 million annually over an estimated one million hectares of crops and one million hectares of pastures in Western Australia alone. *E. australis* was brought to Australia in 1830 as the vegetable called Cape spinach.

### Doublegee competes against crops and reduces yield

A presence of eight to nine doublegee plants/m$^2$ can reduce wheat yield by up to 50 per cent.

PHOTO: ANDREW STORRIE

Figure W16.1 Mature doublegee plant with flowers and fruits.

### Doublegee produces a large number of seeds

One doublegee plant growing under ideal conditions in the absence of competition may spread up to 1 m in diameter and produce as many as 1100 seeds.

### Doublegee can contaminate grain, leading to a rejection of grain deliveries

It is very difficult to separate doublegee achenes from the seeds of pulses. Although it is relatively easy to separate the achenes from cereal and canola seeds, additional cleaning post-harvest may be required. In pedigree and bulk seed production programs of any crop, it is necessary to achieve nil contamination, which is extremely difficult.

### Doublegee seed dispersal in agriculture is diverse

Mechanisms for the easy dispersal of seeds include movement in rubber tyres on farm vehicles or on shoes, transport with crop seed, silage or fodder, and animal movement.

### Doublegee can cause animal health problems

The plants contain oxalate at levels that may not be toxic in small quantities but may poison sheep if eaten in large quantities. The spiny fruits of doublegee can injure animals and people walking barefoot, and are robust enough to puncture bicycle tyres.

### Doublegee has evolved resistance to herbicides

One case of metsulfuron-methyl (Group B) resistance has been confirmed in doublegee in the Western Australian wheatbelt.

Both glyphosate and paraquat + diquat are effective on doublegee seedlings. A range of selective herbicides from groups B, C, F, G, I and L can effectively control this weed in cereal crops. There are few options to control doublegee in pulse crops.

As for biological control, two weevils (*Perapion antiquum* and *Lixus cribricollis)* and red apion (*Apion miniatum*) were released in the 1980s and 1990s but failed to establish due to prolonged dry summers in Australia.

## Environments where doublegee dominates

Doublegee is widespread throughout the agricultural areas of temperate mainland Australia and on Flinders Island off Tasmania.

It is a weed of concern in cereals, lupins, pulses and canola in South Australia, Western Australia, central and northern New South Wales, south-eastern Queensland, the Murray River irrigation areas of Victoria and roadsides in the Northern Territory.

PHOTO: ABUL HASHEM

Figure W16.2 Doublegee seedling.

PHOTO: ANDREW STORRIE

Figure W16.3 Close-up of doublegee fruits.

It is a weed in agricultural, horticultural, pastoral, industrial, wasteland, grassland and conservation areas but is not usually found in natural ecosystems.

Doublegee prefers soil types from sand to clay loam where pH is neutral to slightly alkaline.

## Seasonal conditions that favour doublegee

Doublegee seeds mainly germinate in autumn and winter although germination may occur any time during the year.

In Western Australia and northern New South Wales where summer rainfall is likely, and in seasons where summer rainfall occurs in temperate climates, germination may occur in late February and seedlings are likely to persist into winter crops.

## Conditions that favour germination and establishment

Germination of doublegee seed occurs over a wide range of temperatures (day and night temperatures from 5°C to 35°C) but more quickly at higher temperatures. The emergence of seedlings usually starts in autumn after sufficient rain. Summer rains can germinate some doublegee seeds and these plants can successfully complete development.

Seedling emergence is higher in heavier soil types than in sandy soils. Unburied seed has low germinability and very few seeds germinate from deeper than 50 mm.

## Seed survival in the soil

Doublegee achenes may remain viable in soil for more than seven years.

An autumn cultivation will stimulate emergence of the seedlings, and if these seedlings are killed the level of viable seeds in the soil will decrease rapidly.

After two growing seasons about 15 per cent of seed remains viable in the soil, and less than 2 per cent remains viable after eight growing seasons.

**TABLE W16.1 Tactics that should be considered when developing an integrated plan to manage doublegee (*Emex australis*).**

| Doublegee (*Emex australis*) | | Most likely % control (range) | Comments on use |
|---|---|---|---|
| *Agronomy 1* (page 54) | Crop choice and sequence | 80 (0-95) | Cheaper and easier to control in cereals. Avoid crops that don't have good herbicidal control options. |
| *Agronomy 3* (page 74) | Herbicide tolerant crops | 90 (50–95) | Very useful for non-cereal phase of rotations |
| *Tactic 1.3* (page 101) | Inversion ploughing | 90 (80–99) | Use once on intractable infestations only, and then don't deep cultivate for at least 10 years. |
| *Tactic 1.4* (page 105) | Autumn tickle | 40 (20–60) | Depends on seasonal break. Use in conjunction with a follow-up herbicide treatment or cultivation. |
| *Tactic 2.2a* (page 124) | Knockdown (non-selective) herbicides for fallow and pre-sowing control | 75 (50–80) | Use robust rates. |
| *Tactic 2.2c* (page 133) | Pre-emergent herbicides | 75 (50–80) | Can be variable depending on season. Subsequent crop choice may be limited after treatment. |
| *Tactic 2.2d* (page 139) | Selective post-emergent herbicides | 90 (70–95) | Spray small and actively growing weeds. Repeat if required. |
| *Tactic 3.5* (page 202) | Grazing – actively managing weeds in pastures | 50 (30–70) | Doublegee is palatable to stock until formation of the spiny achenes. Useful for suppression and reduction of seed production, enabling favourable pasture species to actively compete. |

## Contributors

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# WEED 17: FLEABANE (*Conyza* spp.)

There are three main species of fleabane in Australia: flaxleaf fleabane (*Conyza bonariensis*), tall fleabane (*C. sumatrensis*) and Canadian fleabane which comprises two varieties (*C. canadensis* var. *canadensis* and *C. canadensis* var. *pusilla*). Of the three species, flaxleaf fleabane is the most common across Australia particularly in cropping and fallow paddocks.

## Common names

Flaxleaf fleabane, Canadian fleabane, tall fleabane, fleabane, hairy fleabane, cobbler's peg (New South Wales coast only).

## Distinguishing characteristics

Flaxleaf fleabane can grow up to 1 m tall and has deeply indented leaves. It has the narrowest leaves at rosette stage when compared with other *Conyza* species. Its branches often grow taller than the main plant axis.

Tall fleabane can grow up to 2 m tall. Its leaves are less indented than flaxleaf fleabane and its branches do not grow taller than the main plant axis.

Both flaxleaf and tall fleabane have flower-heads of approximately 10 mm when pressed. By comparison, Canadian fleabane has smaller flower-heads of 5 mm when pressed.

The two varieties of Canadian fleabane also differ, with var. *canadensis* possessing very hairy leaves and var. *pusilla* having virtually hairless leaves.

Flaxleaf fleabane has a smoothly pitted receptacle while tall fleabane has a roughly pitted receptacle.

Each of the fleabane species is characterised by the production of fluffy cream seed-heads that possess a pappus. They also produce a very long taproot that can grow up to 350 mm in length.

PHOTOS: ANDREW STORRIE

Figure W17.1 Comparison of mature plants of the three fleabane species: (from left) tall fleabane, flaxleaf fleabane and Canadian fleabane.

## Other weeds that can be confused with fleabane

Fleabane can be confused with bushy starwort (*Aster subulatus*). (See Figure W17.2, right).

The main confusion, however, arises from the use of common names, because cobbler's peg is the common name generally used for *Bidens pilosa* and other *Bidens* species, whereas in New South Wales 'cobbler's peg' is the common name for fleabane in particular.

PHOTO: ANDREW STORRIE

Figure W17.2 Bushy starwort is a much finer plant than fleabane and usually grows in wetter areas.

## Factors that make fleabane a major weed

### Fleabane is a prolific seed producer, each plant producing up to 110,000 seeds

Of these seeds, up to 80 per cent can be viable. The seeds do not possess dormancy so they can germinate whenever temperature and moisture requirements are met. Prevention of seedset is vital for control.

### Fleabane is a major weed of fallows, summer and winter crops and pastures

Fleabane competes for the vital resource of soil water in crop and fallow phases. It severely affects fallow efficiency in northern New South Wales and Queensland and pasture production, particularly in degraded pastures, in southern New South Wales and southern Western Australia.

PHOTO: ANDREW STORRIE

Figure W17.3 Seed production by fleabane.

### Fleabane is very difficult to control with herbicides

Inconsistent control is often obtained with herbicide treatments, especially once plants exceed a diameter of 50 mm, have dense infestations and high stubble levels. Where fleabane becomes a problem in fallows, weed control costs can increase by up to 80 per cent due to the difficult nature of control (such as double knock: e.g. glyphosate + 2,4-D followed seven to 10 days later by paraquat).

### Fleabane is capable of developing herbicide resistance

It has already evolved resistance to herbicide Groups C, L and M overseas. Repeated applications of glyphosate are often applied in an attempt to control the weed in fallow. In 2010, eight fleabane populations resistant to glyphosate were confirmed in northern New South Wales and southern Queensland. At May 2014 there were 58 populations of fleabane confirmed resistant to glyphosate across Australia (see AGSWG website glyphosateresistance.org.au for latest information).

### Flaxleaf fleabane emerges throughout most of the year

The pappus on the seed enables it to be dispersed long distances by high intensity summer storms, through a combination of strong winds and surface run-off, and through the water movement in irrigation channels and waterways. This suggests that the spread of fleabane across an agricultural landscape could be very rapid. The majority of the seed, however, falls within 3 to 5 m of the parent plant. Fleabane invades and flourishes in areas lacking competition.

## Environments where fleabane dominates

Flaxleaf fleabane occurs in all states of Australia. It was first identified as a major crop weed problem in northern New South Wales and southern Queensland, but has now spread widely into southern and western states. It is a serious problem in lucerne stands in New South Wales and fallows and pastures in northern New South Wales, Queensland, Victoria, South Australia and southern Western Australia.

As the most common fleabane species in South Australia, flaxleaf fleabane is a frequent weed of pastures and is relatively unpalatable to stock.

Canadian fleabane and tall fleabane are also weeds in every state.

Each of these three fleabane species is common on roadsides and disturbed wetlands and wastelands in Western Australia from Perth to Kununurra. Flaxleaf fleabane and tall fleabane have rapidly increased their distribution in southern Western Australia between 2008 and 2013.

Fleabane is more common on lighter soils but can also flourish in heavy textured soils. It is poorly competitive in-crop but grows very well in bare fallows, cropping gaps, wide rows and weakly competitive crops.

It is also largely a weed on zero and reduced tillage systems. The increased presence of fleabane has forced some growers to use cultivation.

## Seasonal conditions that favour fleabane

In the northern grain region of Australia fleabane appears to be an all year-round weed with peak growth periods in autumn, spring and summer. It survives winter with slow vegetative growth while developing a strong taproot.

Significant rainfall events which keep the soil surface moist for three to four days are required for germination of a major flush of seedlings.

Often fleabane germinates under a winter crop after the normal application time for post-emergent herbicides. The plants develop unobserved until harvest, when they begin to elongate for flowering. The harvest machinery cuts the tops off the plants but they survive in the summer fallow as woody, deep-rooted plants with little leaf area to absorb herbicides. These established plants are difficult to control in the following summer fallow. However, if left unchecked, they continue to produce seed through the summer.

## Conditions that favour germination and establishment

Fleabane prefers cool and moist conditions for germination. Emergence of fleabane in northern New South Wales and Queensland occurs predominantly in late autumn to early and late winter. However, in southern New South Wales, fleabane has its major emergence over winter, continuing into spring. Hot summers discourage fleabane emergence.

Fleabane is a small-seeded weed species. Seedlings only emerge from (or near) the soil surface. For this reason the occurrence of fleabane is more common in zero and reduced tillage systems, where the majority of seed remains in the soil surface and increased stubble cover keeps the soil surface wet for longer.

Although very limited emergence occurs in mid-winter in northern New South Wales and Queensland, young autumn or early winter seedlings actively grow during winter despite cold and dry conditions. Surprisingly, even where there does not seem to be much growth above ground, root growth progresses. The building of such a strong root system during winter provides sufficient food reserves for rapid growth during the following spring. Over-wintering fleabanes are very difficult to control.

PHOTO: ANDREW STORRIE

Figure W17.4 Fleabane seedling.

## Seed survival in the soil

Fleabane emergence is very sensitive to soil burial. Seedlings emerge only from the soil surface or in the top 5 mm. No emergence occurs below 20 mm of burial depth. The depth of burial also affects seed survival of fleabane. Seed viability declines rapidly to less than 15 per cent after 12 months of burial, followed by a steady but slow decline over an extended period. When sown on the surface, less than 2 per cent of the seed remains viable after three years. After burial at 50 mm and 100 mm for three years about 9 per cent of buried seed remains viable.

**TABLE W17.1 Tactics that should be considered when developing an integrated plan to manage fleabane (*Conyza* spp.).**

| Fleabane (*Conyza* spp.) | | Most likely % control (range) | Comments on use |
|---|---|---|---|
| *Agronomy 2* (page 61) | Improving crop competition | 50 (30–70) | Avoid wide row cropping in weedy paddocks. |
| *Tactic 2.1* (page 113) | Fallow and pre-sowing cultivation | | Small actively growing fleabane can be controlled with robust rates of glyphosate. Pre-sowing cultivation or full disturbance sowing will reduce likelihood of fleabane establishing in-crop. |
| *Tactic 2.2b* (page 128) | Double knockdown or 'double knock' | 95 (60-100) | Glyphosate + Group I herbicide followed 7 to 10 days later by robust application of a bipyridil herbicide (Group L) gives very high levels of control in fallow on heat- and moisture-stressed weeds. |
| *Tactic 2.2c* (page 133) | Pre-emergent herbicides | 90 (85–99) | Long-term control applied pre- or post-planting. Use higher recommended rates for better control. |
| *Tactic 2.2d* (page 139) | Selective post-emergent herbicides | 90 (85–99) | Target small weeds; timing is critical. Rely on mixtures at sufficiently high rates, especially in fallow. Target in-crop germinations with late post-emergent herbicides in cereal crops. |
| *Tactic 2.4* (page 156) | Spot spraying, chipping, hand roguing and wiper technologies | 90 (80–99) | Very effective to reduce potential populations where there are small numbers of survivors. Plants must be cut off below ground. |
| *Tactic 2.5* (page 158) | Weed detector sprayers | 99 (90-100) | Properly calibrated detect sprayers can give extremely high levels of control of large fleabane plants in fallows. |

## Contributors

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# WEED 18: FUMITORY (*Fumaria* spp.)

## Common names

Fumitory, also known as carrot weed, is the widely used name for several species of *Fumaria*. Worldwide there are about 50 species of which eight are recorded in Australia. Their distribution in Australia is shown in Table W18.1 (below).

**TABLE W18.1 Distribution of eight *Fumaria* species in Australia.**

| Species | Distribution in Australia |
|---|---|
| *F. bastardii* | All states and Australian Capital Territory |
| *F. capreolata* | All states and Australian Capital Territory |
| *F. densiflora* | All states, but rarely Northern Territory |
| *F. indica* | All states (except Tasmania) and Northern Territory |
| *F. muralis* | All states and Australian Capital Territory |
| *F. officinalis* | Queensland, New South Wales, South Australia and Tasmania |
| *F. parviflora* | All states (except Tasmania) and Northern Territory |
| *F. vaillantii* | South Australia |

A comprehensive survey in 1997 found that most species were associated with winter cropping practices. Only *F. capreolata* was not associated with disturbed soils and was found mainly in gardens. *F. densiflora* and *F. bastardii* are the most widespread and abundant species while *F. officinalis* is the rarest.

**TABLE W18.2 Distinguishing characteristics of the seven more widespread *Fumaria* species naturalised in Australia.**

| Species | Flower colour | Leaves |
|---|---|---|
| *F. parviflora* | Light to mid pink | < 1 mm wide |
| *F. indica* | Light to mid pink | 1 to 2 mm wide, 10 mm long |
| *F. densiflora* | Dark pink | 1 to 2 mm wide, 5 mm long |
| *F. officinalis* | Dark pink | > 2 mm wide |
| *F. muralis* | Mauve | > 2 mm wide |
| *F. bastardii* | Mauve | > 2 mm wide |
| *F. capreolata* | White | > 2 mm wide |

## Distinguishing characteristics

Fumitory is an autumn and winter growing annual, glabrous (hairless) herb with a semi-erect climbing habit. Leaves are alternate, divided, deeply lobed and light green to bluish-green. Stems are irregularly five-angled, are brittle, may be reddish and contain a watery, greenish latex. The flowers are arranged in racemes and colour ranges from white to mauve depending on species. The plants vary greatly in their morphology depending on the growing conditions but also within species, particularly for *F. bastardii*. This variability leads to difficulty in the correct identification of the species.

## Factors that make fumitory a weed

Fumitory is not considered a serious weed globally and so these species have not been intensively studied from a weeds perspective. However, recent experience in Australia has identified increased incidence of fumitory in winter crops. In the 1960s fumitory was found in less than 4 per cent of crops in southern New South Wales and Victoria, albeit with occasional serious infestations, but by the early 1990s such proportions had risen to more than a third of cereal crops and over 40 per cent of canola crops. It is likely that this substantial increase is due in part to the increase in importance of canola in winter cropping areas.

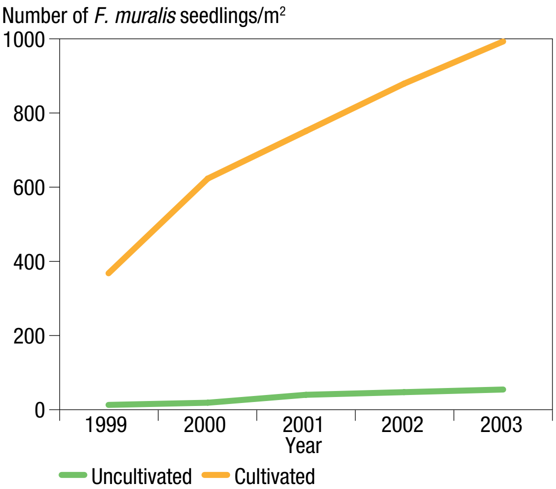

Figure W18.1 Seedling *Fumaria* spp.

Two main factors help explain the change: firstly there are limited herbicide options registered for selective removal of fumitory from canola, and secondly where fumitory seed is harvested together with canola, its similar size precludes the complete decontamination of the canola seed-lot. This scenario indicates that canola seed-lots are a likely means of spreading fumitory further across the cropping zone.

## Fumitory has a long-lived seedbank

Seeds have been known to remain viable for up to 20 years, with a seedbank half-life of 10 years. Extended pasture phases might not have any effect on fumitory populations. Soil disturbance can stimulate seedling emergence. A seedbank persistence study at Mount Barker, Western Australia, found that cultivation after a pasture phase stimulated *F. muralis* seedling emergence every year and increased the seedbank decline rate from negligible levels to over 65 per cent. The stimulatory effect of tillage occurred every year for five years.

**FIGURE W18.1 The cumulative number of *F. muralis* seedlings emerging over 5 years at Mount Barker, Western Australia, either tilled or left uncultivated (mean of 6 replicates). No seedset was allowed.**




## Fumitory has the ability to germinate over a range of temperatures

Fumitory will continue to germinate after sowing and late-emerging weeds will miss post-emergent herbicide applications.

## Fumitory is genetically variable allowing adaption to different conditions

Fumitory species are able to grow in a wide range of conditions varying from season to season.

## Fumitory species have varying susceptibility to herbicides

Some tolerance of trifluralin is found in all species. Two populations of *F. densiflora* have evolved resistance to trifluralin following 15 years of continuous use.

PHOTO: ANDREW STORRIE

Figure W18.2 Flowering *Fumaria muralis*.

There is no residual control from triasulfuron and chlorsulfuron at recommended rates.

Bromoxynil gives good control of *F. bastardii* only. No fumitory species are controlled by 2,4-D, 2,4-DB and MCPA herbicides.

## Conditions that favour fumitory

A survey in the late 1990s showed that most of these *Fumaria* species, like true agricultural weeds, occurred almost exclusively in regularly disturbed sites. The exception was *F. capreolata* which was found in non-disturbed sites. *F. bastardii* and *F. densiflora* were found over a range of soil textures and rainfall giving them widespread and overlapping occurrence. *F. densiflora* presence was largely unaffected by the amount of autumn rainfall, being more influenced by soil texture, either sandy loams or heavy alkaline clays. *F. bastardii* was present equally on all soil types, although it occurred more frequently in areas of higher April rainfall.

*F. muralis* was significantly affected by both soil texture and rainfall during autumn, most notably during May when it was often flowering. In agricultural sites it preferred the medium to heavier textured soils with higher rainfall, while in non-agricultural environments it also occurred on lighter soils, provided they were high in organic matter and in higher rainfall areas. *F. muralis* was commonly found with *F. bastardii* but less commonly with *F. densiflora*.

*F. parviflora* was commonly found in lime-rich environments, particularly in South Australia and north-western Victoria. The scarcity of these soils in New South Wales explains the rarity of the species in that state. *F. parviflora* is more likely to be found with *F. densiflora*.

## Seed survival in the soil

Seedling emergence varies with species, season, soil type, seed burial depth and soil disturbance. It is greater in heavy than in light soils and in disturbed soils. There is a high proportion of seedling emergence from shallow seed sources, whereas more deeply buried seeds remain dormant and long-lived with a half life estimated at 10 years.

Seed dormancy is due to an immature embryo, a physiological block commonly removed by high summer temperatures. There are also seed-covering structures, namely a lignified seed wall (pericarp) and a phenol-containing seed coat (testa), that may control germination and emergence.

In Australia ants are the natural dispersal agents with seeds removed to ant nests or 'granaries' where there is a concentration of seedlings at germination time. Such granaries also commonly contain significant quantities of other seeds such as annual ryegrass although strong grass seedling emergence is rarely seen in granaries where fumitory is growing. While clumping of seedlings via this process is likely to reduce seedling survival, the spread of seed from the granaries by cultivation implements is likely to lead to greater populations surviving over larger patches.

Management of fumitory infestations therefore becomes more important. Changing tillage practices to no-till will reduce the spread of the weed by confining populations to ant granaries. Minimising the use of contaminated seed for sowing is common sense, particularly sourcing canola seed from non-fumitory fields. Other appropriate agronomic practices include growing competitive crops and cultivars to reduce fumitory seed production.

**TABLE W18.3 Tactics that should be considered when developing an integrated plan to manage fumitory (*Fumaria* spp.).**

| Fumitory (*Fumaria* spp) | | Most likely % control (range) | Comments on use |
|---|---|---|---|
| *Agronomy 1* (page 54) | Crop choice and sequence | 85 (0–99) | Avoid crops with no post-emergent herbicide options. Minimise canola in the rotation. |
| *Agronomy 2* (page 61) | Improving crop competition | 65 (10–80) | Establish vigorous crops on the narrowest row spacing practical. No-till reduces seed spread from ant granaries. |
| *Agronomy 3* (page 74) | Herbicide tolerant crops | 80 (0–95) | Clearfield® for *F. densiflora* only and TT canola. Roundup Ready® canola can be effective. |
| *Tactic 1.4* (page 105) | Autumn tickle | 85 (10–90) | Use at early break. Cultivation greatly stimulates germination. Combine with delayed sowing. |
| *Tactic 1.5* (page 109) | Delayed sowing | 95 (90–99) | Combine with autumn tickle. Follow with non-selective herbicides (*Tactic 2.2a Knockdown (non-selective) herbicides for fallow and pre-sowing control*, section 4, page 124) targeting small weeds. |
| *Tactic 2.2a* (page 124) | Knockdown (non-selective) herbicides for fallow and pre-sowing control | 90 (50–95) | Use robust rates. Late germinations are not controlled. |
| *Tactic 2.2c* (page 133) | Pre-emergent herbicides | 85 (50–95) | Trifluralin can give good control except in *F. bastardii* and *F. muralis*. Look out for resistant populations. |
| *Tactic 2.2d* (page 139) | Post-emergent herbicides | 90 (80–99) | Wider range for use in wheat and barley. |
| *Tactic 5.1a* (page 229) | Sow weed-free seed | 100 | Only sow seed grown in fumitory-free areas, especially in canola and small seeded pastures. |

## Contributors

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# WEED 19: INDIAN HEDGE MUSTARD (*Sisymbrium orientale*)

## Common names

Indian hedge mustard, wild mustard, mustard, hedge mustard, oriental hedge mustard, oriental mustard, eastern rocket.

## Distinguishing characteristics

Indian hedge mustard (*Sisymbrium orientale*) is an erect annual. It is branched and grows up to 1 m tall. Young plants form a rosette with deeply lobed, pointed leaves up to 110 mm long. Upper leaves are alternate and spear-shaped. Flowers are pale yellow and 6 to 10 mm long. The pod is 60 to 100 mm long, two-celled, slender and cylindrical, and opens when ripe.

## Other weeds that can be confused with Indian hedge mustard

Indian hedge mustard may be confused with hedge mustard (*Sisymbrium officinale*); however, the latter has pods only 10 to 20 mm long which are pressed to the stem, and smaller flowers (petals 2 to 4 mm long).

It can also be confused with wild radish (*Raphanus raphanistrum*), buchan weed (*Hirschfeldia incana*), sand rocket (*Diplotaxis tenuifolia*) and muskweed (*Myagrum perfoliatum*).

## Factors that make Indian hedge mustard a major weed

### Indian hedge mustard produces very large numbers of seeds

Up to 30,000 seeds/m$^2$ are shed in early summer.

### Indian hedge mustard causes problems at harvest

Coarse fibrous stems cause problems by wrapping around header parts.

### There are populations resistant to Group B and I herbicides

The first cases of Group B resistance were confirmed in the early 1990s in North Star, northern New South Wales, and Wallaroo, South Australia. Subsequent Group B resistant populations were discovered in the district of Goondiwindi in southern Queensland. These collections were growing in continuously cropped wheat paddocks where chlorsulfuron had been applied for between six and 10 years. A further six collections in surrounding districts of Goondiwindi were found to be resistant to chlorsulfuron in later testing.

Random weed surveys across western South Australia, on the Eyre Peninsula in 2009 and western Victoria in 2010 revealed that 52 per cent and 35 per cent of Indian hedge mustard populations were resistant to chlorsulfuron respectively, and that 57 per cent and 38 per cent of the samples were also resistant to metosulam. Screening with 2,4 D revealed no resistance of any population from either district.

The first case of 2,4 D resistance in Indian hedge mustard was identified in 2007 from Port Broughton in the South Australian mid-north. Subsequent

PHOTO: ANDREW STORRIE

Figure W19.1 Mature Indian hedge mustard plant.

PHOTO: WILSON, *ET AL.* 1995

Figure W19.2 Indian hedge mustard seedling.

directed surveys in this region identified 12 Indian hedge mustard populations occurring on seven farms with resistance to both 2,4-D and Group B herbicides. Resistance to Group B and I herbicides is of particular concern as it limits weed control options.

### The small seeds of Indian hedge mustard can cause grain contamination

It is one of the species of weed seed contaminants which make up the 'small foreign seeds' fraction of the grain delivery standards. There is a limit in wheat of 0.6 per cent or 1.2 per cent by weight depending on wheat grade.

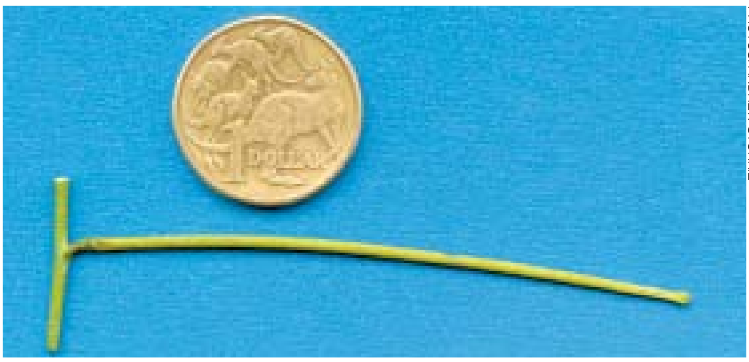
## Environments where Indian hedge mustard dominates

Indian hedge mustard is a widespread introduced weed of the cereal growing regions of Western Australia, western and northern New South Wales and southern Queensland. It is a weed of crops, pastures, rangelands, open woodlands, roadsides, disturbed sites and waste areas. It is sometimes found in grazed woodlands and is spreading along roadsides and disturbed areas in the arid zone.

Soil type does not greatly influence the presence or absence of Indian hedge mustard.

## Seasonal conditions that favour Indian hedge mustard

Because its seeds have a relatively short innate dormancy and germinate more readily in seasons with good rainfall, Indian hedge mustard germinates during autumn to winter. In these seasons effective control can be achieved by pre-sowing knockdown herbicides. However, in seasons



PHOTOS: ANDREW STORRIE

Figure W19.3 Close-up of seed head (left) and close-up of individual pod (right).

when opening rains are late, there can be a serious infestation of Indian hedge mustard in sown crops as it continues to emerge after post-emergent herbicides have been applied.

## Conditions that favour germination and establishment

An initial germination flush follows cultivation at the start of the winter growing season. Subsequent germinations of Indian hedge mustard occur sporadically after rain at any time over a period of several years. Germination in autumn is stimulated by high summer temperatures.

## Seed survival in the soil

Little is known about the survival of Indian hedge mustard seed. However, persistence in soil is usually from one to several years.

**TABLE W19.1 Tactics that should be considered when developing an integrated plan to manage Indian hedge mustard (*Sisymbrium orientale*).**

| Indian hedge mustard (*Sisymbrium orientale*) | | Most likely % control (range) | Comments on use |
|---|---|---|---|
| *Agronomy 1* (page 54) | Crop choice and sequence | 85 (0-99) | Avoid crops with no post-emergent herbicide options. |
| *Agronomy 3* (page 74) | Herbicide tolerant crops | 80 (0-95) | Very useful for non-cereal portions of the rotation |
| *Tactic 1.4* (page 105) | Autumn tickle | 25 (10–50) | Use with early breaks to the season and combine with delayed sowing. |
| *Tactic 1.5* (page 109) | Delayed sowing | 95 (90–99) | Follow by knockdown with non-selective herbicides (*Tactic 2.2a Knockdown (non-selective) herbicides for fallow and pre-sowing control*, section 4, page 124) targeting small weeds. |
| *Tactic 2.2a* (page 124) | Knockdown (non-selective) herbicides for fallow and pre-sowing control | 75 (50–80) | Use high rates to control biennial plants. Tank-mixing with phenoxy herbicides improves control in absence of Group I resistance. Late germinations are not controlled. |
| *Tactic 2.2c* (page 133) | Pre-emergent herbicides | 75 (50–80) | Dry conditions post-sowing reduces herbicide efficacy. |
| *Tactic 2.2d* (page 139) | Selective post-emergent herbicides | 80 (60–90) | Spray young actively growing plants and repeat if necessary. Be aware of resistance status. |
| *Tactic 3.1a* (page 172) | Spray-topping with selective herbicides | 95 (85–99) | Be aware of resistance status. The control range assumes no Group B resistance. |
| *Tactic 3.1c* (page 178) | Wiper technology | 80 (60–95) | Useful tactic in lentils |
| *Tactic 3.5* (page 202) | Grazing – actively managing weeds in pastures | 70 (50–80) | Rotationally graze. Use spray-grazing with herbicide suited to pasture species present. |
| *Tactic 4.1* (page 212) | Weed seed control at harvest | 50 (10–70) | Useful on early harvested crops |

## Contributors

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# WEED 20: MUSKWEED *(Myagrum perfoliatum)*

## Common names

Muskweed, 'Round Island' spinach (localised to the southern Liverpool plains, New South Wales), mitre cress (in the United Kingdom).

## Distinguishing characteristics

Muskweed (*Myagrum perfoliatum*) cotyledons are broad and club-shaped, making them different from any other brassica species. Leaves are a waxy blue-green, hairless and without petioles. They also have distinctive white veins. Rosettes grow to 450 mm in diameter and are very flat to the ground, somewhat like capeweed and unlike other brassica weeds such as wild radish. The flowers are small and pale yellow. The pods are hard, wedge-shaped, 5 to 7 mm long and 4 to 5 mm wide, and they stick out from the stem.

## Other weeds that can be confused with muskweed

Muskweed can be confused with turnip weed (*Rapistrum rugosum*) when in pod and at the end of flowering, and common sowthistle (*Sonchus oleraceus*) when at the seedling stage.

It can also be confused with prickly lettuce (*Lactuca serriola*) and willow lettuce (*Lactuca saligna*) when at the seedling stage and when elongating.

## Factors that make muskweed a major weed

### Muskweed has staggered germination

It is able to emerge from April to October, which makes timing of control difficult.

### Muskweed produces a large number of seeds

An average plant is thought to produce about 1000 seeds, with seedbanks of up to 3000 seeds/m$^2$.

Seed is thought to survive at least five to 10 years.

### Muskweed is competitive

It is particularly damaging to pulse yields, with reports of up to 50 per cent yield losses in chickpeas and lentils. It can also completely smother patches of cereal and canola.

PHOTOS: ANDREW STORRIE

Figure W20.1 Flowers (left) and pods (right) of muskweed.

PHOTOS: ANDREW STORRIE

Figure W20.2 Mature muskweed plant.

Figure W20.3 Muskweed seedling.

### Muskweed creates a problem at harvest

It slows harvest due to the bulk of material and it will 'ball' in front of the comb. Although muskweed rarely reduces canola yield most of the pods will exit with the chaff and straw in a properly adjusted harvester.

### Herbicide control options are limited

Only a few herbicides are registered for the selective control of muskweed in cereals and none are registered for pulses. The poor competitive ability of pulses compounds the problem. There are no herbicide control options in conventional canola.

### Muskweed is a serious grain contaminant

The pods are the same size as wheat and barley grains. When muskweed is present in canola and pulse grain, additional seed cleaning is often required before delivery.

### Muskweed is dispersed by harvesting equipment and in grain and hay

Plants also tumble across paddocks, dispersing seed.

## Environments where muskweed dominates

Muskweed is a major weed of chickpeas, lentils, lupins, field peas, faba beans and canola in western Victoria and South Australia. It is also a weed of winter cereals and lucerne.

Reduction in the use of long fallow and the trend toward continuous cropping with the inclusion of broadleaf crops have led to an increase in muskweed levels. The high intensity of pulse cropping in the Wimmera district of Victoria and parts of South Australia has been the major reason for its proliferation.

Muskweed prefers alkaline clay-loam and clay soils.

## Seasonal conditions that favour muskweed

Muskweed will germinate and establish from April to October with soil temperatures between 4°C and 29°C. Most plants emerge from the top 50 mm of soil.

It can commence flowering from late July through to mid-October, with seed production from mid-August to early December.

## Conditions that favour germination and establishment

Germination of muskweed occurs as the seed pod deteriorates. Warm wet summers will speed deterioration of the pod increasing the percentage of the seedbank to germinate the following autumn.

## Seed survival in the soil

Little is known about the survival of muskweed seed in the soil but it is thought to survive at least five to 10 years. It is likely that muskweed would show similar seedbank longevity to that of wild radish.

**TABLE W20.1 Tactics that should be considered when developing an integrated plan to manage muskweed (*Myagrum perfoliatum*).**

| Muskweed (*Myagrum perfoliatum*) | | Most likely % control (range) | Comments on use |
|---|---|---|---|
| *Agronomy 1* (page 54) | Crop choice and sequence | 90 (0–95) | Easier to control in competitive cereal crops. Controlled effectively in winter fallow and in long pasture phases. |
| *Agronomy 3* (page 74) | Herbicide tolerant crops | 90 (80–95) | Imidazolinones, glyphosate and triazines provide good control in imidazolinone, glyphosate and triazine resistant crops respectively. |
| *Tactic 2.2c* (page 133) | Pre-emergent herbicides | 90 (50–99) | Chlorsulfuron is effective in competitive wheat crops. Few options in other cereals, pulses and canola. |
| *Tactic 2.2d* (page 139) | Selective post-emergent herbicides | 90 (75–95) | Hormone and sulfonylurea herbicides provide good control in cereals. Few options for other pulses or conventional canola. |
| *Tactic 3.1b* (page 174) | Crop-topping with non-selective herbicide | 60 (40–90) | Must use a short-season crop. Picks up later germinations and reduces viability of partly filled weed seeds. |
| *Tactic 3.1c* (page 178) | Wiper technology | 65 (20–99) | Effective in short pulse crops, e.g. lentils. Time treatment according to weed growth stage. |
| *Tactic 5.1a* (page 229) | Sow weed-free seed | 100 | Muskweed range is still expanding rapidly and transport of weeds in crop seed is the likely source of introduction in clean areas. |
| *Tactic 5.1c* (page 232) | Clean farm machinery and vehicles | 99 | Contaminated machinery is a likely source of weed seed introduction in clean areas. |

## Contributors

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# WEED 21: TURNIP WEED (*Rapistrum rugosum*)

## Common names

Turnip weed, rapistrum, turnip, wild turnip, giant mustard, bastard cabbage.

## Distinguishing characteristics

As an erect annual or biennial, turnip weed (*Rapistrum rugosum*) grows to a height of 1 m and is covered in short, stiff hairs. The upper leaves have a petiole, and the flower petals are yellow with dark veins.

Turnip weed is difficult to distinguish from other brassica species until pods form. Pods are 5 to 10 mm long and consist of two segments. The lower segment is 2 to 5 mm long, often with no seeds, while the upper segment is globular, wrinkled and ribbed with a conical beak, usually containing a single seed. The pods do not split upon ripening.

## Other weeds that can be confused with turnip weed

Turnip weed is easily confused with other brassica weeds until pods form. It is similar to the following three species.

Charlock (*Sinapis arvensis*) is often found in the same environment. The leaves on the upper stem are attached directly to the stem (i.e. no petiole) and the pod is elongated, 20 to 60 mm long, with a flattened beak.

Wild turnip (*Brassica tournefortii*) tends to prefer red, lighter textured soils. It has erect pods 30 to 70 mm long that are constricted between the seeds.

Buchan weed (*Hirschfeldia incana*) is usually found along roadsides and in wastelands, as well as in declining pasture and lucerne stands. It has pods up to 20 mm long that are held close to the stem and have a swollen beak containing one seed.

## Factors that make turnip weed a major weed

### Turnip weed is very competitive

This weed reduced barley yields in southern Queensland by an average of 8 per cent and wheat yields by an average of 17 per cent over 10 trials in the 1980s. In chickpeas, with average crop plant populations, no herbicide and turnip weed populations of 10 or 40 plants/m$^2$, yield reductions were 17 per cent and 50 per cent respectively.


Figure W21.1 Turnip weed and charlock are often confused. Note that charlock stemleaf (right) has no petiole (leaf stalk).

PHOTO: WILSON, *ET AL* 1995

PHOTO: ANDREW STORRIE

Figure W21.2 Mature turnip weed plant (left) and turnip weed pods (right).

### Turnip weed produces a large number of seeds

Plants can produce up to 8000 seeds/$m^2$.

### Turnip weed causes problems at harvest

Large plants slow harvest operations and can lead to drum chokes. There is a limit of 50 seeds/half-litre in Australian milling grade wheats.

### Turnip weed is readily dispersed in agriculture

It is spread in crop seed, fodder and machinery.

### Turnip weed can develop herbicide resistance

Like other brassica weeds, there are numerous populations of turnip weed across eastern Australia that have evolved resistance to several Group B herbicides. Group B resistance has also been found in turnip weed in Iran.

### Turnip weed can have an impact on other farm enterprises

Infestations have been implicated in the failure of curly Mitchell grass to re-establish in north-western New South Wales, while turnip weed seeds in the feed have been found to reduce pig growth rates in Queensland by 1.5 per cent. Turnip weed is also known to taint the meat of animals grazing the pastures it dominates and this can cause the rejection of carcasses at the abattoir.

## Environments where turnip weed dominates

Turnip weed is found across a range of environments but is better adapted to hotter and drier environments compared with most brassica weeds (except charlock, with which it is often found in mixed infestations in northern New South Wales). It favours clay soils but will grow on sandy loams.

Although widespread in New South Wales and southern Queensland, turnip weed is only of minor concern in Victoria and South Australia. It has the potential to extend its range in all Australian states, including Western Australia.

It is a significant weed of pulses, and a lesser weed in cereals due to its susceptibility to phenoxy and sulfonylurea herbicides.

Tillage systems do not affect the abundance of turnip weed. Although it tends to be a winter weed, it will continue into the summer if sufficient soil moisture is available.

## Seasonal conditions that favour turnip weed

The optimum temperature range for germination is 10°C to 25°C, so turnip weed will germinate during autumn to early summer, with the main period in autumn. Dormancy is broken by high temperatures (approximately 35°C).

In northern New South Wales and southern Queensland flowering can commence in early August, with viable seed being produced by early September. Frost will limit the timing of seedset in cooler areas.

Turnip weed is most competitive when chickpeas are flowering, possibly due to shading of the crop by the bolting weed plants. In most other crops competition will begin earlier in the development of the crop.

## Conditions that favour germination and establishment

A wet autumn following a dry summer favours establishment of turnip weed, particularly in poorly competitive crops and pastures.

PHOTO: ANDREW STORRIE

Figure W21.3 Turnip weed seedling.

## Seed survival in the soil

Seed removed from pods appears to have a short half-life, whereas it is thought that the presence of entire pods will prolong the life of the turnip weed seedbank. A no-till seedbank study in southern Queensland found 36 per cent of turnip weed seed persisted after two years, and 7 per cent remained after four years in the top 10 cm of soil.

**TABLE W21.1 Tactics that should be considered when developing an integrated plan to manage turnip weed (*Rapistrum rugosum*).**

| Turnip weed (*Rapistrum rugosum*) | | Most likely % control (range) | Comments on use |
|---|---|---|---|
| *Agronomy 1* (page 54) | Crop choice and sequence | 80 (40–99) | Pulses are poor competitors; winter fallow–summer crop is a good choice. |
| *Agronomy 2* (page 61) | Improving crop competition | 80 (50–99) | Competitive crops at optimum densities, row spacing and nutrition greatly reduces crop yield loss and reduces weed seedset. |
| *Agronomy 3* (page 74) | Herbicide tolerant crops | 90 (75–99) | Very useful for broadleaf crop phase of the rotation |
| *Tactic 1.4* (page 105) | Autumn tickle | 40 (20–60) | Effectiveness depends on seasonal conditions. Combine with delayed sowing (*Tactic 1.5 Delayed sowing*, section 4, page 109). |
| *Tactic 1.5* (page 109) | Delayed sowing | 60 (30–80) | Provides reasonable control in most seasons |
| *Tactic 2.1* (page 113) | Fallow and pre-sowing cultivation | 50 (25–75) | Encourages germinations which can be controlled pre-planting |
| *Tactic 2.2c* (page 133) | Pre-emergent herbicides | 70 (60–90) | Control varies depending on seasonal conditions, with poorer results in dry starts. |
| *Tactic 2.2d* (page 139) | Selective post-emergent herbicides | 90 (20–99) | Very good in cereals, but limited range in pulses and canola. |
| *Tactic 3.1a* (page 172) | Spray-topping with selective herbicides | 80 (60–90) | Logran® good for cereals and Eclipse® in some pulses for Group B susceptible populations |
| *Tactic 3.1b* (page 174) | Crop-topping with non-selective herbicides | 70 (60–80) | Good for early planted short-season pulses |
| *Tactic 3.1c* (page 178) | Wiper technology | Variable | Potentially useful in short pulse crops such as lentils where all the weeds are the same development stage and height |
| *Tactic 3.2* (page 184) | Pasture spray-topping | 50 (30–70) | Graze heavily over winter to induce a more uniform flowering. Graze or respray survivors. |
| *Tactic 3.5* (page 202) | Grazing – actively managing weeds in pastures | 75 (0–95) | Unmanaged pastures are a major source of crop weed problems. Rotational heavy grazing in combination with spray-grazing gives good control. |
| *Tactic 4.1* (page 212) | Weed seed control at harvest | 60 (50–70) | Use on early harvested crops. |

## Contributor

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# WEED 22: WILD RADISH (*Raphanus raphanistrum*)

## Common names

Wild radish, white weed, white charlock, wild charlock, cadlock, wild kale, wild turnip, jointed radish.

## Distinguishing characteristics

Wild radish (*Raphanus raphanistrum*) is generally a winter and spring growing annual which may grow up to 1.5 m high. The cotyledons are heart-shaped and hairless with long stems. The first true leaves are irregularly lobed around the edges with one or more completely separated lobes at the base of the leaf blade.

The seedling develops into a flat rosette, the leaves of which do not have a distinct stalk. Erect branches covered with prickly hairs arise from near the base as the plant matures. The rosette of lobed leaves does not persist.

Lower stem leaves are covered with prickly hairs and deeply lobed, with a rounded terminal lobe. When crushed these leaves have a strong turnip-like odour. Upper stem leaves become narrower, shorter and often undivided.

Flowers are in clusters on the ends of stem branches. They have four petals which alternate with four sepals. The petals may vary in colour; yellow or white petals are more common than purple, pink or brown. Petals often have light or dark distinct veins.

The seed pod is constricted between the seeds and does not split lengthwise. It breaks up into distinct segments when ripe, and during threshing it is often broken up into single-seeded segments. Each pod usually has three to nine seeds, ovoid to almost globular, yellowish to reddish brown, and covered with white bran-like scales. There is no seed in the beak of the pod.

## Other weeds that can be confused with wild radish

Wild radish may be confused with wild turnip (*Brassica tournefortii*), charlock (*Sinapis arvensis*), turnip weed (*Rapistrum rugosum*) or garden radish (*Raphanus sativus*). In the seedling stage it can also be confused with capeweed (*Arctotheca calendula*).

Despite both species having heart-shaped cotyledons and similarly shaped rosette leaves, wild radish can be distinguished from wild turnip at the seedling stage. Both have deeply-lobed leaves except that in wild radish the margins of individual lobes are uniformly serrated, whereas those of wild turnip are irregularly serrated. The leaves of wild turnip carry 'warts' on the upper surface and are broader in relation to their length. The basal rosette of leaves in wild turnip persists until late in the growing season, unlike that of wild radish. Wild turnip has very few stem leaves.

PHOTO: ANDREW STORRIE

Figure W22.1 Wild radish flowering.

PHOTOS: ANDREW STORRIE

Figure W22.2 Wild radish can have a range of flower colours.

The flowers of wild turnip are similar to charlock (rather than wild radish) in colour, shape and size. The seed pods of wild turnip split lengthwise to release the seeds when ripe. Wild radish pods do not split lengthwise; instead, the seed remains in the pod, which breaks into segments.

Wild radish that displays yellow flowers can sometimes be confused with charlock in the absence of fruit. Wild radish has larger flowers, with longer and narrower petals that do not touch or overlap and are a paler yellow. The sepals of wild radish are pressed against the back of the petal, while in charlock the sepals are widely spreading.

Separating wild radish and charlock at seedling stage is extremely difficult; however, charlock has smoother and rather shiny leaves, with less deeply impressed veins.

Wild radish and capeweed look similar when young but the underside of the capeweed leaf is white with fine fur. There is similarity in colour on both sides of the wild radish leaf (see *Weed 14 Capeweed Arctotheca calendula,* page 295).

At the seedling stage wild radish may be confused with turnip weed because the cotyledons are very similar. However, the mature plants are quite different, with turnip weed having only yellow flowers. The one- to three-seeded pod of turnip weed is often pressed to the stem, and when mature usually breaks into upper and lower segments. The lower segment is cylindrical and contains up to two seeds, whereas the upper segment is globular with one seed and a beak (see *Weed 21 Turnip weed Rapistrum rugosum,* page 319).

Figure W22.3 Mature wild radish pods showing how they break into cereal grain-size segments.

PHOTOS: ANDREW STORRIE

Figure W22.4 Garden radish pods look very similar to wild radish, but don't break into small segments.

Garden radish is similar to wild radish in the above-ground parts but the flowers are purplish, pink or white, never yellow. Garden radish seed pods are spongy, lack distinct joints and split in various ways at maturity (not into segments containing single seeds).

## Factors that make wild radish a major weed

### The ease of dissemination of wild radish has resulted in its widespread occurrence

It is easily distributed as an impurity in hay, chaff and grain. Wild radish pods often break into segments similar in size to wheat seed, and removal of the contamination can be quite difficult. It is important to ensure that all crop seeds for sowing, and all hay purchased, are not contaminated with wild radish seed. Livestock, wind, water and machinery also spread wild radish seed.

### Wild radish is very competitive because of the rapid establishment of its seedlings and the relatively fast growth rate

Competition is further increased due to the introduction of modern crop cultivars that are shorter in habit. Yield response following spraying is often four to five times higher for wild radish killed early at the three-leaf stage than for control after tillering (Table W22.1, below).

The trend to wider row spacings with direct sowing also reduces the ability of cereal crops to compete with weeds such as wild radish.

Yield losses are even more significant in alternate crops (Table W22.2, below). The impact on yield depends on the density of wild radish plants and the timing of emergence compared to the crop plants.

**TABLE W22.1 Effect on wheat yields of early and late spraying of wild radish in central west of New South Wales.**

| Treatment | Wheat yield (t/ha) |
|---|---|
| Unsprayed | 0.14 |
| Sprayed late (wheat tillered) | 0.36 |
| Sprayed early (3-leaf wheat) | 1.66 |

**TABLE W22.2 Effect of wild radish population on crop yield reduction.**

| | Wild radish plant density (plants/m$^2$) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 2–4 | 10 | 25 | 50 | 64 | 75 | 100 | 200 |
| Crop | Crop yield loss (%) | | | | | | | |
| Wheat | - | - | 11 | 20 | - | 26 | 33 | 50 |
| Canola | 11 | - | - | - | 91 | - | - | - |
| Lupin | 15 | 28 | 56 | 81 | - | 92 | - | - |
| Faba bean | - | 36 | - | - | - | - | - | - |
| Field pea | - | 36 | - | - | - | - | - | - |
| Lentil | - | 42 | - | - | - | - | - | - |
| Chickpea | - | 49 | - | - | - | - | - | - |

### Lupin, wheat, field pea and barley grains rapidly lose their viability during storage when contaminated with green wild radish pods

This is due to the toxic substances released by the wild radish pods and seeds. Research in Western Australia showed the degree of sensitivity to the wild radish toxins depends on storage temperature, level of pod contamination, time of exposure and crop type. Damage to lupin seed began at 5 per cent by weight contamination and a storage period of three days. All lupin seed was killed after 5 days exposure to 8 per cent contamination.

PHOTOS: ANDREW STORRIE

Figure W22.5 Wild radish seedling showing distinctive heart-shaped cotyledons (left) and wild radish rosette showing deeply lobed leaves (right).

### The fibrous stems of wild radish can make harvesting difficult by choking the header comb

It is now uncommon to see crops left unharvested due to the smothering effect of wild radish and the difficulty of harvesting heavily infested crops. Improvements in harvester design have overcome these problems.

### Moisture levels of harvested grain can be affected

In years with late rains, when wild radish continues to grow and remains green after crop maturity, the moisture squeezed from the wild radish stems during harvest often raises the grain moisture content above acceptable storage levels.

### Wild radish can cause animal health problems

When eaten by dairy cows wild radish has caused milk taint. In some cases poisoning occurs if the seeds (the most toxic part of the plant) are consumed in considerable quantities. Generally, mortality due to wild radish poisoning is rare.

### Wild radish has allelopathic activity

Its extracts and residues can suppress germination, emergence and seedling growth of some crops and weeds.

### Wild radish is an alternate host for a number of pests and diseases

The more common plant pests and diseases found on wild radish are thrips, flea beetles, club root of brassica species, tobacco streak virus and cucumber mosaic virus.

### Wild radish produces abundant seeds

In Western Australia wild radish is a more prolific seeder than wild turnip, doublegee, annual ryegrass and brome grass. Early emerging plants produce more seeds than the later emerging cohorts. In a Western Australian lupin crop, cohorts emerging later than 21 days after crop emergence failed to reproduce altogether.

Failure of later cohorts to reproduce has also been confirmed in other crops such as wheat and canola in Western Australia. However, wild radish plants that emerged 10 weeks after canola (in New South Wales) and wheat (in Victoria) managed to produce some seeds.

As the density of wild radish increases, seed production per plant decreases. Victorian research has shown that seed production ranged from 292 seeds/m$^2$ at a density of 1 plant/m$^2$ to 17,275 seeds/m$^2$ at 52 plants/m$^2$ in a wheat crop.

PHOTO: ANDREW STORRIE

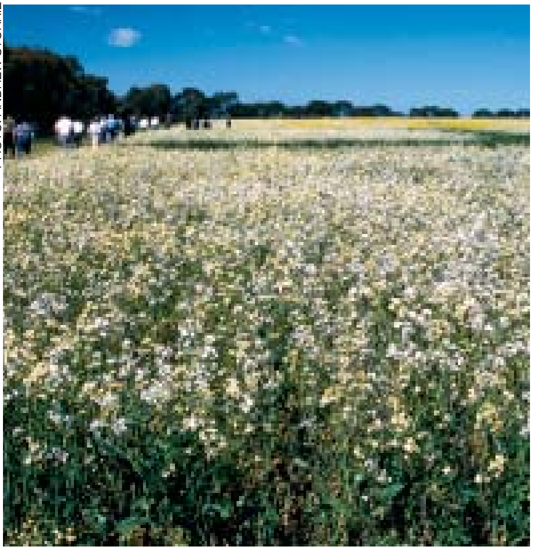
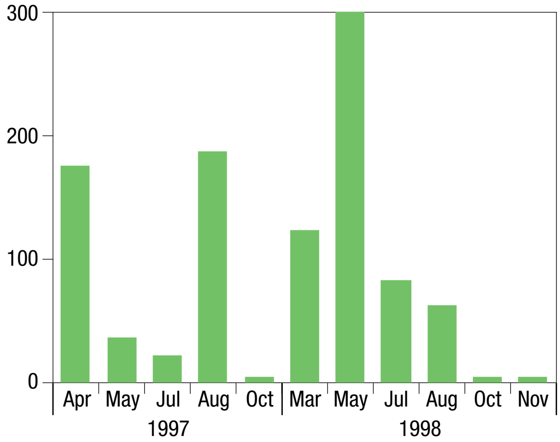


Figure W22.6 Wild radish dominating a crop of canola.

FIGURE W22.7 Emergence patterns of wild radish following seed rain in late 1996.




SOURCE: AFTER PELZER 2004

In order to achieve long-term control of wild radish, seed production must be prevented or at least minimised.

## Complex seed dormancy is one of the most important characteristics that enables wild radish to persist as a weed of cropping

Wild radish seeds are dormant at maturity and as many as 70 per cent of the seeds are still dormant at the start of the next cropping season. Many seeds will not germinate until the second season after their formation (about 18 months later). Research conducted on field populations of wild radish at Mount Barker, Western Australia, showed the highest emergence of radish seedlings occurred two seasons after seed-rain (Figure W22.7, above). This emergence pattern fits perfectly with the wheat–lupin rotation that was favoured in the northern Western Australian wheatbelt.

Seeds enclosed by pods have much slower emergence than naked seeds. In addition to the role of the seed-coat in controlling dormancy, there is also embryo dormancy in wild radish. As a result there is a cycling of dormancy in the field which in turn determines the ability of the seed to germinate at various times during the season.

Dormancy breakdown is enhanced by shallow burial of the seed in early summer, which can be achieved through trampling by livestock.

Geographic location and temperature also influence wild radish dormancy. For example, seeds from Western Australia's warmer northern agricultural region have lower dormancy levels than seeds from the cooler southern region.

Dormancy is further complicated by flower colour. Seeds of purple-flowered forms are more dormant than those of the white and yellow forms. It follows that purple-flowered forms of wild radish have a greater likelihood of avoiding control by early herbicides because they tend to germinate after the time of application.

The dormancy factor is also influenced by the time of seedling emergence. Early emerging plants produce more seeds with greater dormancy as they commence flowering and forming seed in winter when conditions are favourable to producing a thicker pod. Pods produced on the same plant in spring when it is hotter and dryer will have lower levels of dormancy than those produced earlier.

The overall dormancy behaviour of wild radish is therefore complex and has played a significant role in the persistence of this weed.

### Wild radish can germinate at any time of the year given sufficient soil moisture

Germination is possible under widely fluctuating temperatures from 5°C to over 35°C, with optimal diurnal fluctuation of 25°C to 10°C.

### The flexible flowering patterns of wild radish, requiring less than 600 degree-days to flower, indicate that wild radish has the capacity to grow and set seeds in most areas of southern Australia

Temperature is the major factor controlling development up to flowering, while day length as well as temperature influence the duration of flowering.

### Wild radish seed persistence is greatest when seed is buried at depths greater than 40 mm

Although the decline in the number of viable seeds is greatest in the top 10 mm of soil, any measures taken to completely exhaust the seeds in the top 100 mm of soil (with the prevention of input of fresh seeds) would need to be applied for at least a minimum of six years (Table W22.3, below).

Tillage, besides stimulating emergence, also affects wild radish seed longevity through the placement of seed at different depths.

**TABLE W22.3 Percentages of wild radish seed remaining viable after burial at various depths.**

| | Duration of burial (years) | | | | | |
|---|---|---|---|---|---|---|
| | 0.5 | 1 | 2 | 3 | 4 | 6 |
| Depth of burial (mm) | Viable wild radish seed after burial (%) | | | | | |
| 0 | 43 | 19 | 5 | 4 | 5[a] | 0 |
| 10 | 10 | 12 | 16[a] | 5 | 3 | 1 |
| 50 | 55 | 47 | 52[a] | 27 | 21 | 7 |
| 100 | 75 | 57 | 53 | 44 | 43 | 0 |

a Apparent increases in viability with time due to variation between samples

### Wild radish sheds pods before crop harvest, enabling it to persist in cropping systems

In a Victorian study, between 50 and 60 per cent of wild radish pods had shed prior to harvest, while the remainder fell during the harvest process. Environmental conditions (e.g. hot dry spells, severe wind, rainfall) close to crop harvest can cause the seed pods to shed. Nevertheless, early windrowing of crops such as canola and pulses may capture the green wild radish pods and prevent return of the seeds to the soil.

### Through its genetic and phenotypic variability, wild radish has managed to adapt well to varied crops, environments and control tactics

This variability in wild radish is also evident in its flower colour variations; more than 12 different forms have been differentiated based on colour and venation pattern on the petal.

### Being an outcrossing species, wild radish has sufficient genetic variability and biochemical adaptability to evolve resistance to the commonly used herbicides in cropping systems

Populations (mostly in Western Australia) have developed resistance to herbicides in the mode-of-action (MOA) Groups B, C, F, I and M. Group B resistance is the most common, followed by Group F.

A major concern is the increasing frequency of wild radish populations that are developing resistance to atrazine (Group C) and 2,4-D amine (Group I). It is common to find populations that have developed multiple resistance across several MOAs. Resistance to herbicides in up to three

MOA groups has been documented in individual populations. Resistance to Group C herbicides (e.g. atrazine) is maternally inherited. This means that these genes do not move with the pollen, so containment of these Group C resistant populations is feasible.

At May 2014 three Western Australian populations of wild radish was confirmed resistant to glyphosate.

## Environments where wild radish dominates

Wild radish is a cosmopolitan weed. Regarded as being native to Europe and through the Mediterranean region to central Asia, it is now naturalised in most temperate countries of the world. In southern Australia it is one of the most widespread and troublesome weeds of cereal and pulse crops. It occurs in pastures and is a common weed of roadsides and wastelands.

The worst wild radish problem is encountered in Western Australia, especially on the sand plain soils of the northern wheatbelt.

Although wild radish has a preference for slightly acidic soils, it grows well over a range of soil types in southern Australia, and flourishes in fertile nitrogenous soil. In New South Wales and southern Queensland it is found on lighter textured acidic soils.

The planting of pulse crops (other than lupins) has the potential to worsen the wild radish problem due to limited in-crop herbicide choices against wild radish in these crops, and the poor competitive ability of pulses.

While the introduction of triazine tolerant canola cultivars initially resulted in improved wild radish management, the dependence on triazine herbicides is selecting for resistance to this MOA. Several atrazine failures were observed in 2011 and atrazine resistance was confirmed in at least four populations of wild radish. The long term 1:1 rotation of lupin–wheat practised in the northern wheatbelt of Western Australia for many years has encouraged the build-up of the wild radish seedbank and increased the risk of the weed developing herbicide resistance.

## Seasonal conditions that favour wild radish

Wild radish can emerge at any time of the year providing there is sufficient soil moisture although the majority of seed germinates in autumn and winter. It has an ability to produce seed in a very short time from germinations late in spring or during summer.

## Conditions that favour germination and establishment

Greatest emergence occurs from wild radish seeds at depths of 10 to 20 mm following autumn shallow cultivation; seedlings rarely emerge from depths greater than 50 mm. Autumn stimulation with cultivation is achievable only when the temperature of the surface soil is below 20°C and there is sufficient soil moisture.

The fact that buried wild radish seeds need exposure to light and surface seeds prefer darkness for germination partially explains the stimulation by cultivation. Cultivation changes the position of seeds in the soil and therefore access (or not) to light. Seeds left on the soil surface without soil disturbance have poorer emergence, as do seeds buried at greater than 40 mm.

The presence or absence of trash may also determine wild radish germination in the field. Organic trash increases the moisture level of the soil as well as lowering soil temperatures. Consequently, the germination window for the surface and buried seeds is increased. If trash must be removed to allow the crop to be sown, it should be done only after allowing maximum germination of the wild radish followed by appropriate control measures.

## Seed survival in the soil

Deep burial extends wild radish seed viability, and subsequent cultivation must be shallow to avoid relocating buried seed close to the surface where it could germinate.

Seed longevity is also affected by tillage at different depths by different implements, with longer survival of seed placed at greater depths (Table W22.3, page 328).

Other factors such as soil microbes, frequency of soil disturbance, soil temperature and soil moisture can vary seed survival from six to over 10 years.

**TABLE W22.4 Tactics that should be considered when developing an integrated plan to manage wild radish (*Raphanus raphanistrum*).**

| Wild radish (*Raphanis raphanistrum*) | | Most likely % control (range) | Comments on use |
|---|---|---|---|
| *Agronomy 3* (page 74) | Herbicide tolerant crops | 90 (80–99) | If growing canola in a wild radish infested area it is essential to use a herbicide resistant cultivar and associated herbicide package. |
| *Tactic 1.1* (page 92) | Burning residues | 70 (20–90) | In concentrated windrows. Burn when conditions are conducive to a hot burn. |
| *Tactic 1.3* (page 101) | Inversion ploughing | 98 (20-100) | Plough must be correctly 'set up' and used under the right conditions. Must use skimmers. |
| *Tactic 1.4* (page 105) | Autumn tickle | 45 (15–65) | Follow-up rain is needed for better response. |
| *Tactic 2.2a* (page 124) | Knockdown (non-selective) herbicides for fallow and pre-sowing control | 80 (70–90) | Add a reliable herbicide spike for more reliable control. Late germinations will not be controlled. |
| *Tactic 2.2d* (page 139) | Selective post-emergent herbicides | 90 (70–99) | Apply to young and actively growing weeds. Repeat if necessary to control late emerging weeds or survivors. |
| *Tactic 3.1a* (page 172) | Spray-topping with selective herbicides | 80 (70–95) | Wild radish may regrow if there are late rains. Good for seedset control. Spray before embryo development for best results. |
| *Tactic 3.1c* (page 178) | Wiper technology | 70 (50–80) | Has potential in low growing pulses such as lentils. |
| *Tactic 3.3* (page 190) | Silage and hay – crops and pastures | 80 (70–95) | Cut before embryo formation in developing wild radish seed (21 days after first flower). Graze or spray regrowth. |
| *Tactic 3.4* (page 195) | Manuring, mulching and hay freezing | 95 (90–100) | Brown manuring more efficient than green manuring and more profitable. Grazing before spraying to open sward will improve results. Hay freezing works well and is the most profitable manuring option in most cases. |
| *Tactic 3.5* (page 202) | Grazing – actively managing weeds in pastures | 70 (50–80) | Rotationally graze and use spray-grazing. Can also use slashing to improve palatability and reduce pasture growth rate in spring. |
| *Tactic 4.1* (page 212) | Weed seed control at harvest | 75 (65–85) | Most reliable in early harvested paddocks. |
| *Tactic 5.1a* (page 229) | Sow weed-free seed | 95 (90-100) | Very important as resistance in wild radish is increasing and introduction via crop seed is increasingly likely. |

## Contributors

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# WEED 23: WIREWEED (*Polygonum* spp.)

## Common names

Wireweed, hogweed, knotweed, prostrate knotweed, sand wireweed (*P. arenastrum*).

## Distinguishing characteristics

There are two similar species of wireweed: *Polygonum aviculare*, which has branch leaves about half the size of stem leaves, and *P. arenastrum* in which all leaves are of similar size.

Wireweed is an autumn to early summer germinating annual or biennial. Cotyledons are spear-shaped with a pointed apex, hairless, 7 to 15 mm long and blue-green.

Mature plants have a prostrate habit with branches up to 1.2 m long and a long fibrous taproot. Leaves are blue-green and occur alternately on the stems. Leaves have a short petiole and up to five flowers can be present in the leaf axils. Stems can root at the nodes.

The flowers are small and pinkish white. There is evidence to suggest that considerable variation exists within this species, with fruit dimension and shape the best characters to determine the different taxa.

Wireweed seeds are 1 to 2 mm in length and rusty brown.

## Other weeds that can be confused with wireweed

Wireweed can be confused with *P. bellardii* (tree hogweed), which also has spear-shaped leaves. However, tree hogweed has a red stem and is an erect weed, growing up to 100 cm in height.

At the seedling stage wireweed is similar to *Plantago lanceolata* (ribwort) and *P. coronopus* (bucks-horn plantain), neither of which have a sheathing membrane at the base of the true leaves.

## Factors that make wireweed a major weed

### Delayed germination makes wireweed hard to control

Wireweed often germinates and emerges during or after crop or pasture establishment. This is due to its physiological requirement for low soil temperatures to break the innate dormancy of fresh seed.

### Wireweed competes for moisture and nutrients

It can reduce crop and pasture yields by extracting nutrients, but generally has minimal impact on winter cereal crop yields due to it delayed emergence.

PHOTOS: ANDREW STORRIE

Figure W23.1 Mature plant of *Polygonum arenastrum* (left) and flowering *P. aviculare* (right).

### Wireweed often causes problems with machinery

The long, tough branches of wireweed become tangled in cultivation equipment, causing blockages and spreading the weed. It can also interfere with harvesting operations because of lengthy branching.

### Wireweed has phytotoxic properties

These phytotoxic chemicals inhibit the establishment of other plant species, especially medic and lucerne. It also affects rhizobium bacteria required for legume nodulation.

Wireweed is not readily managed through grazing because of its low forage quality and relative unpalatability. It can be toxic to horses, with deaths having been recorded in New South Wales.

## Environments where wireweed dominates

Both species of wireweed are natives of Europe and Asia and distribution is listed as cosmopolitan. Both are widespread weeds of cultivation in Australia, particularly in cereal crops, canola and field peas, and are also serious weeds of lucerne and establishing pastures.

Wireweed is tolerant of atrazine and is often a weed of triazine tolerant canola. Wireweed tolerates a wide range of environmental conditions and soil pH (5.6 to 8.5), although increasing salinity can reduce germination.

## Seasonal conditions that favour wireweed

Wireweed is a problem when its germination coincides with that of crop or pasture seed. As wireweed requires a period of low soil temperature to germinate, there is an opportunity to establish crop and pasture prior to its germination peak, given appropriate moisture conditions.

With a long taproot wireweed often survives throughout the dry summer months in south-eastern Australia and occasionally in south-western Australia. This may present problems for perennial pasture systems such as lucerne because of additional competition for water and nutrients and contamination of the feed supply.

## Conditions that favour germination and establishment

Current knowledge suggests that wireweed germination is favoured by low soil temperature in late autumn and early winter, and by cultivated seedbeds. Soil disturbance until June in South Australia favoured the emergence of wireweed.

A wireweed infestation depends on more than the simple cultural system used by the grower. Direct drilling is reported to discourage germination of the weed compared with full cultivation. Under a semi-arid agro-ecosystem in central Spain there was more wireweed in plots with conventional tillage than those with no tillage. However, studies in the United Kingdom showed

Figure W23.2 Wireweed seedling.

PHOTOS: ANDREW STORRIE

Figure W23.3 Wireweed choking a crop of durum wheat.

increased levels of wireweed in minimum tillage paddocks and reduced levels in continuous winter wheat after shallow cultivation.

## Seed survival in the soil

Wireweed seed is hard-coated and adapted for medium-term survival in the soil environment. The seeds produce a large dormant seed pool. Seed dormancy can be broken if seeds are exposed to low temperatures (2°C to 4°C) and light.

Under specific management the annual decline of the seedbank is estimated to be about 30 per cent per year, with many seeds germinating but not surviving through to reproduction.

Research from the United Kingdom estimated a period of four to seven years is required to exhaust the wireweed seedbank.

**TABLE W23.1** **Tactics that should be considered when developing an integrated plan to manage wireweed (*Polygonum* spp.).**

| Wireweed (*Polygonum* spp.) | | Most likely % control (range) | Comments on use |
|---|---|---|---|
| *Agronomy 1* (page 54) | Crop choice and sequence | 80 (0–50) | Avoid continuous cereals or broadleaf crops where control is difficult. Avoid growing pulses in heavily infested paddocks. Wireweed increases in triazine tolerant canola. |
| *Agronomy 3* (page 74) | Herbicide tolerant crops | 90 (50–95) | Some imidazoline herbicides provide useful control in legume and imidazoline tolerant crops. Glyphosate will provide good control in glyphosate tolerant crops. |
| *Agronomy 5* (page 81) | Fallow phase | 80 (0–80) | Control early in the fallow to reduce vining (i.e. kill small plants). |
| *Tactic 1.3* (page 101) | Inversion ploughing | 90 (80–95) | Use once to bury resistant seed deeply then avoid bringing that seed back to the surface for at least 10 years. |
| *Tactic 2.2a* (page 124) | Knockdown (non-selective) herbicides for fallow and pre-sowing control | 90 (75–90) | Glyphosate, dicamba and some sulfonylurea herbicides are the most effective. |
| *Tactic 2.2c* (page 133) | Pre-emergent herbicides | 90 (50–80) | Trifluralin, pendimethalin, chlorsulfuron and triasulfuron provide good control, but are dependent on rain after application. |
| *Tactic 2.2d* (page 139) | Selective post-emergent herbicides | 90 (75–90) | Metsulfuron and dicamba provide good control. Target small weeds for better control. Few options exist in broadleaf crops. |
| *Tactic 3.4* (page 195) | Manuring, mulching and hay freezing | 90 (50–80) | Good for controlling late germinations and reducing problems in summer fallow. |

## Contributors

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