Chapter 2
Weeds

Compiled by Annie Johnson, Karen Roberts and Robert Thompson

Photo: A. Johnson

Saffron thistle.

The most prevalent weeds of Central West crops, pastures and fallows (Table 2.1) and their management are individually reviewed in this chapter. Other weeds which are increasing in occurence are also included.

Species Shift

When the dominant species of weeds in a paddock are suppressed through management or environmental factors, other weeds often fill the gap and become dominant. Regular use of cultivation, a certain herbicide or a change in environment can cause a "species shift".

Any method of managing weeds is going to result in 'selecting' weeds that are tolerant of that management tool and as a result those weeds become dominant. An example of species shift is where heliotrope was once uncommon in cultivated fallows and is now becoming more common in chemically managed fallows. Some farms where annual ryegrass is suppressed now have problems with barley, silver or brome grasses.

Species shift is **not** herbicide resistance. Herbicide resistance is where a population of a certain species was susceptible but is now immune to a herbicide mode of action.

Table 2.1 The most prevalent weeds in the Central West cropping zone nominated in farmer surveys in 2001 and 2003.

Cropping weeds	Pasture weeds	Fallow weeds
1. Annual ryegrass (***Lolium rigidum)***	1. Saffron thistle (***Carthamus lanatus***)	1. Camel melon (***Citrullus lanatus***)
2. Wild oats (***Avena fatua*** and ***Avena ludoviciana***)	2. Paterson's curse (***Echium plantagineum***)	2. Prickly paddy melon (***Cucumis myriocarpus***)
3. Saffron thistle (***Carthamus lanatus***)	3. Capeweed (***Arctotheca calendula***)	3. Skeleton weed (***Chondrilla juncea***)
4. Capeweed (***Arctotheca calendula***)	4. Barley grass (***Hordeum leporinum***)	4. Saffron thistle (***Carthamus lanatus***)
5. Skeleton weed (***Chondrilla juncea***)	5. Horehound (***Marrubium vulgare***)	5. Common heliotrope (***Heliotropium europaeum***)

For a full list of the survey results see Appendix 1 pages 91–92.

Integrated Weed Management

It is important to vary the practices that are used to control weeds to avoid a species shift to undesirable weed types. Integrated Weed Management (IWM) looks at all the weeds in the paddock rather than targeting individual species.

Planning for IWM requires knowing how each species reacts to each type of management. For example, 'will it grow back when cultivated?' or 'is it herbicide tolerant when mature?'.

Not all IWM tools will fit into every farming system. Choose rotations, herbicides and timing that are best for each weed spectrum.

Using multiple IWM tools will minimise unwanted results such as species shift.

Photo: A. Johnson

Capeweed flower.

The following four headings are used at the start of each species section. These points about the biology and ecology of individual weed species are highlighted to help make specific choices in the management of these weed species.

Seeding

Seeding indicates the number of viable seeds that these weeds can produce each year per square metre or per plant.

Seed bank life span

The life span is the length of time that seeds usually remain viable in the soil (the seed bank). Long term control of weeds involves preventing seed set for years to exhaust the soil seed bank.

Seeds can be lost from the seed bank when they germinate, die before germinating or are attacked by disease or predators like ants. The seed bank "half life" indicates the length of time for the loss of half the seeds remaining in the seed bank (Table 2.2).

Herbicide resistance / tolerance

Herbicide resistance and herbicide tolerance are different.

Some weed species are naturally tolerant to some herbicides.

Some weed populations have developed resistance to herbicides. Many populations of weed species are susceptible to herbicides but have the potential to develop resistance.

This section will decribe whether the species is already naturally tolerant to herbicides or if it has the potential to develop herbicide resistance.

Spread

Spread refers to the vectors by which seed and propagating material can move about the farm or from one farm to another. This information can sometimes be used to prevent new weeds from arriving on the farm and prevent small infestations spreading to other parts of the farm.

Table 2.2 Example of the reduction in a seed bank that has a half life of 6 months.

Months since (10 000) seeds enter soil seed bank	6	12	18	24
Number viable seeds remaining in the soil seed bank*	5000	2500	1250	625

** This assumes no additions (seed set).*

Annual Phalaris

Phalaris paradoxa

Seeding	From 3 500 to 21 500 seeds per plant (120 000 /m^2 in severe infestations).
Seed bank life span	4 –12 months*.
Herbicide Resistance/Tolerance	High risk for Group A (selective grass) resistance. One case of resistance to Group A has occured in NSW.
Spread	Easily caught in and spread by machinery, hay, feed grain, pasture and crop seed. Easily spread by flood water.

* Within two years, 95–99% of seeds emerge or become non viable.

Annual phalaris is common on clay soils and flood plains. It is easily spread in flood water, therefore monitor flood plain areas for new infestations.

Annual phalaris has the ability to germinate and set seed in 90 days even under marginal conditions. Seed is set from mid September to November.

Annual phalaris seeds are dormant at maturity and this prevents them germinating during summer. The dormancy starts to break down the following autumn and is totally broken down within 12 months.

Management

Limit seed set in crops and fallows for two consecutive years to reduce annual phalaris populations.

Pasture

Annual phalaris can cause sudden death in horses but is not damaging to ruminants. *Phalaris minor* and *Phalaris aquatica* (separate species that are also found in the central west) do cause problems with stock.

Legume based pastures should have trifluralin applied pre-sowing. A perennial grass based pasture can suppress annual phalaris. Spray topping, winter cleaning or selective herbicides used for the control of other weeds can reduce seed set in annual phalaris.

Fallow

A long fallow is an effective tool for reducing large populations of annual phalaris. One winter of total weed control in fallow combined with good control in the previous pasture or following crop will significantly reduce the seed bank.

Annual phalaris is stimulated to germinate by cultivation. An autumn cultivation will result in emergence in May or June rather than in July or August after the crop is planted. The seedlings can be then controlled before planting.

Cropping

Annual phalaris is mostly a weed in winter cereals. It is very competitive with high yield losses in untreated crops (Table 2.3).

Annual phalaris is a very persistent weed in the cropping phase due to its high seeding rate and quick seed set.

Photo: A. Johnson

Annual phalaris seed head.

The application of a residual herbicide prior to sowing a winter cereal will reduce some competition to the seedling crop. Plants that germinate late are capable of setting seed prior to harvest.

Crop selection is important as only one product is registered for post-emergent annual phalaris control in barley, cereal rye and triticale and none for oats. Wheat crops are commonly sown with trifluralin and Glean® or Logran® (Group B) followed by a selective grass post-emergent herbicide (Group A). Clearfield® wheat and canola allow other products to be used. The general reliance on Group A and now Group B herbicides means that the potential for resistance is high.

Triazine (Group C) products can also be used in canola and pulses for the control of annual phalaris.

Table 2.3 Yield loss due to untreated annual phalaris.

Annual phalaris in wheat at Barmedman			
1986		1987	
Vasco Wheat	Yield t/ha	exp. wheat var.	Yield t/ha
Nil treatment	1.76	Nil treatment	1.05
Treated	3.85	Treated	2.54

Source: Milne 1986, 1987.

Case Study 2.1 Weed spectrum determining rotations By Annie Johnson and Karen Roberts

Name	Geoff McCallum (manager farming operations for Northparkes Mine).
Property	Northparkes Mine (6800 ha, 1630 mine lease, remainder is a buffer zone around the mine).
Enterprise	Continuous cropping, wheat, barley, canola, field peas and lupins.
Landscape and soil	Mainly flat landscape with clay to clay loam soils.
Rainfall	530 mm.
Advantages	No-till and controlled traffic has appeared to have a positive effect on reducing weed populations.
Key points	Crop and herbicide rotations are essential in continuous cropping systems, where other IWM options are limited. Farm hygiene and weed control in non-cropped areas is an important preventative measure.

Since 1997 the Northparkes Mine has owned farming land as a buffer zone which is managed by the mine as a financially independent enterprise. The farm has no stock and is managed using no-till on GPS guided tramlines on average paddock sizes of 200 ha. Environmental sustainability is an important target on farm and all mining and farming operations are subject to ISO 14001 certification.

Weed Spectrum

The most problematic weeds on farm are annual phalaris and some wild oats. Other weeds that commonly occur include ryegrass, hairy panic, Bathurst burr, saffron thistle and Paterson's curse.

No-till and species shift

The farm is managed on a no-till (stubble retention) basis to improve the soils, reduce erosion and increase organic matter in the soil. The most used equipment on farm is the 24-metre boom spray. The spray rig and tractors use GPS controllers to minimise gaps and overlap in the crop. This ensures savings on weed control and prevents costly weed escapes.

This system has been in place since 1998 and with three years of drought (2001–2004) it is difficult to determine if changes to the weed spectrum have been due to the no-till or the drought. However, Geoff has observed that generally less weeds are germinating with lower levels of annual phalaris and wild oats, and higher levels of sowthistle and fleabane.

Although there has been a reduction in grass weeds this has not yet equated to a reduction in chemical costs as overall weed levels still require control measures.

Rotations

Currently wheat is grown on 60% of the farm each year. Barley gives comparable gross margins to wheat, but the area is limited due to annual phalaris infestations which have no in crop control available.

Rotations are more determined by weed spectrum and herbicide availability than a set rotation.

Photo: A. Johnson

Geoff McCallum.

A rotation will generally include at least two years of cereals using disease tolerant varieties and then two years of broadleaf crops give a disease break before the cereal is grown again.

Cereals

Although annual phalaris seems to be decreasing it is still a major issue especially with herbicide selection in cereals. Glyphosate (Group M) is used as a knockdown prior to sowing and trifluralin (Group D) is applied at sowing and incorporated with knife points and press wheels. The stubble cover also provides some extra protection in reducing germination in the furrows. In crop sprays vary with the weeds present and are usually a Group A herbicide for phalaris and wild oat control or Glean® (Group B) for ryegrass, wild radish and other broadleaf weeds. If late season sprays are required usually Dicamba or MCPA (Group I) are used.

Broadleaf crops

Triazine tolerant canola is grown to help control wild radish. Wild radish only occurs in three paddocks on farm. These paddocks are always sown last to allow for knockdown control pre-sowing.

Canola and pulses are also sown with a residual herbicide and Group A herbicides are used in crop to control grasses.

Summer weeds

At harvest the stubble is cut short and spread from the harvester. This provides even coverage of the soil which prevents many weeds from germinating. The whole farm is then sprayed with glyphosate and 2,4-D amine (Group I) to control summer growing weeds that have germinated in the crop. During February and March paddocks are sprayed as needed, usually after rain. Atrazine (Group C) can be used in the summer fallows prior to growing TT canola. Glean can be used prior to growing cereals.

Tree lines

Across the farm, isolated patches of native vegetation are being joined together with six row wide tree lines. It is planned to one day have 10–15% of the farm under native vegetation.

The tree lines have to be carefully managed to prevent them from becoming a source of weed seed. Although weed growth is allowed, seed set is prevented through various physical and chemical methods. In the future a wick wiper will be used to apply herbicides to weeds to minimise any risk of damage to trees.

To prevent the trees becoming weeds by taking moisture from the crops the outside of the tree line is deep ripped to force the roots to grow down the profile rather than out into the adjoining paddocks.

Farm hygiene

Since, the majority of work on farm is carried out by external contractors, there is a high risk of new weeds being introduced. All machinery entering and leaving the farm is cleaned down. In paddocks where a particular weed problem exists (e.g. wild radish) all machinery is cleaned to prevent any seeds or plant material being moved to clean areas.

Herbicide resistance management

Herbicide mode of action groups are rotated with the different crops. Annual phalaris restricts herbicide choices and use of Group A herbicides to manage annual phalaris is an acknowledged weakness. Currently up to 70% of the farm is sprayed with a Group A each year (this is 20% higher than industry recommendations). A key management issue is to reduce the use of Group A herbicides.

Alternate winter weed controls that are being considered include a winter fallow once in every 10 years per paddock. Field peas grown and cut for hay to prevent seed set would also be another weed control option.

Fire is not used on farm as a weed management tool. It is believed that a fire hot enough to kill weed seed would also greatly reduce any organic material on the soil that becomes organic matter.

Photo: A. Johnson

Northparkes Mines wheat crop.

Annual Ryegrass

Lolium rigidum

Seeding	Over 1 000 seeds per plant (20 000/m^2).
Seed bank life span	Up to four years.*
Herbicide Resistance/Tolerance	Very high risk of resistance developing. Resistant to Group A, B, C, D and M in some areas and cross resistance between some of these groups has occurred.
Spread	In hay, feed grain, crop and pasture seed and machinery. Seed can pass through the gut of sheep and cattle and remain viable.

* 70–80% of ryegrass seed left in the seed bank germinates or becomes non viable within 12 months. The initial break in the season produces 40–80% of seedlings. The remainer (20–60%) can germinate in crop.

IWM is very important as ryegrass has the potential to develop resistance to many herbicides. It is estimated that 1 in 10 000 ryegrass plants are naturally resistant to Group A (selective grass) herbicides. Therefore, if there is one ryegrass plant per square metre then one plant per hectare could be naturally Group A resistant. Rotation of different herbicide modes of action as well as non herbicide methods (e.g. pasture) is critical.

Management

Control of seed set for two consecutive years will give a rapid decline in ryegrass populations. Management of herbicide resistant ryegrass requires the use of a variety of different methods to reduce the level of resistance in the population.

Pastures

Ryegrass pastures provide good quality feed for stock, and can suppress vulpia and barley grass. Ryegrass is a host for some cereal diseases so it must be managed for at least a year prior to the return to cropping to provide a disease break (Case study 4.1 page 53). Winter clean or spray top and follow with a long fallow to prevent seed set for two years prior to the first crop.

Hay production also limits seed set if the pasture is cut before the ryegrass seed matures. Hay production has been used to reduce resistant ryegrass populations after a spray failure. Ryegrass should be tested if resistance is suspected.

Photo: K. Hertel

Hay production can prevent seed set.

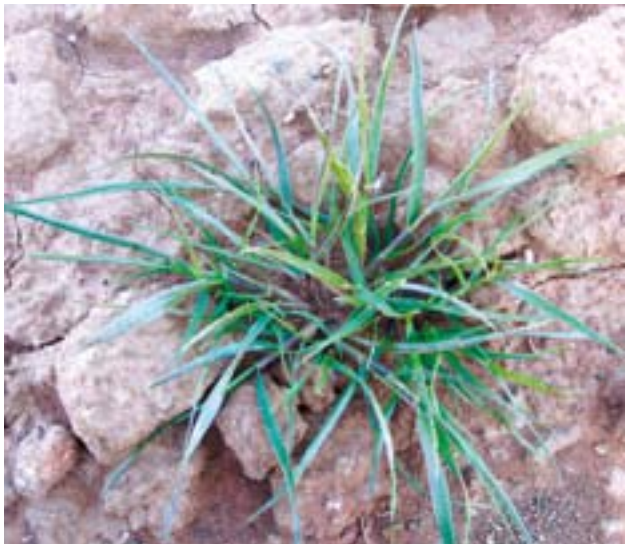

Photo: A. Johnson

Ryegrass plant.

Fallow

A long winter fallow is an effective IWM tool for managing annual ryegrass. The control of seed set in fallow will give one season where there is no seed produciton.

IWM needs to be employed during the fallow period to delay the development of resistance to knockdown herbicides.

Cultivation can increase the number of seedlings that emerge in autumn but only in the first year after seed set. Burning stubble can destroy annual ryegrass seeds (Case study 1.2 page 8) and significantly delay the development of herbicide resistance.

Cropping

Continuous cropping favours annual ryegrass. Rotate crops with fallows and pastures, and rotate herbicide modes of action.

An even crop density will enhance the effectiveness of other control methods. Increase crop competition with optimal plant populations. Cereal and canola

crops provide better competition to ryegrass than open canopied crops such as pulses, although pulses allow the use of alternative herbicide mode of actions.

Ryegrass reduces yield potential from the early stages of crop growth. For that reason, early season ryegrass control like pre-emergent knockdowns or residual herbicides and early post-emergent control is important for maintaining yield potential.

Ryegrass can be an alternate host for cereal diseases so it is important to keep broadleaf crops clean of ryegrass to make the most of the disease break.

Ryegrass can germinate over a long period. If there are large numbers of seeds in the soil, germination of ryegrass seeds will continue after pre-sowing knockdown herbicides and post-emergent herbicides have been applied.

Spray topping prevents the majority of seed set. Diquat can be used for spray topping in pulse crops although yield loss may occur.

Seed capture at harvest in Western Australia has been used and removes up to 80% of ryegrass seed if they have not already dropped to the ground. However, this is expensive and really only economical (in yields ≥ 4t/ha) when herbicide resistance is present.

There are a range of herbicide modes of action available to control ryegrass. Rotating these groups is important in delaying resistance development (Table 2.4).

Table 2.4 Mode of action groups available for annual ryegrass control.

Control measures	Modes of action available	Example products
Knockdown herbicide	Group M Group L	glyphosate paraquat, paraquat and diquat (Spray.Seed®)
Residuals	Group B Group C Group D Group E	triasulfuron (Logran ®) chlorsulfuron (Glean®) simazine, atrazine trifluralin tri-allate (Avedex XTRA®)
Post-emergent herbicides	Group A Group B	various for use in cereals and in broadleaf crops Glean®
Spray topping pulses	Group L	paraquat (Gramoxone®) Registered for use in peas, chickpeas, lupins, faba beans and vetch
Pastures	Group C Group K Group L Group M	diuron in lucerne, simazine in winter cleaning propyzamide (Kerb®) paraquat (Gramoxone®) in lucerne glyphosate in pastures

Photo: A. Johnson

Ryegrass growing in lucerne pasture.

Barley grass

Hordeum leporinum

Seeding	Thousands per square metre.
Seed bank life span	Low, most seeds germinate the following autumn.
Herbicide Resistance/Tolerance	Medium risk of resistance developing. Resistance has developed to Group A (selective grass) and Group L (rare).
Spread	By seed in the coats of animals, in hay and feed grain, crop seed and machinery.

Management

Control of seed set for one year can substantially reduce a barley grass problem. Barley grass germinates and matures earlier than other grasses so earlier control is needed.

Pastures

Barley grass produces large quantities of feed in winter and early spring when many other species are slow growing or dormant. Barley grass is more drought resistant than some other annual pasture plants.

The long barbed awns on the seed heads can cause substantial injury to young livestock making this species undesirable in most pastures. In many areas, the general approach is to avoid stocking barley grass infested paddocks in late spring. In dryland pastures, severe defoliation of the barley grass by sheep between mid winter and early spring can delay the maturation of the barley grass and force the height of the seedheads closer to the ground where they may cause less damage to livestock.

In autumn, heavy grazing of seedlings may reduce populations. Heavy grazing in winter will not reduce the population size but increase tillering.

Feed tests at the vegetative stage and the very early flowering stage (a period of around ten days) show a significant decline in digestibility, protein and energy as the barley grass matures and the seed head emerges (Table 2.5).

Table 2.5 Quality decline in maturing barley grass at Parkes

	Vegetative	Early flowering
Digestibility	*76%*	*68%*
Protein	*23%*	*16%*
Metabolisable energy	*11.5 MJ/kg*	*10 MJ/kg*

Source: K. Roberts, pers. comm.

Photo: A. Johnson

Barley grass in head.

Spray topping of barley grass in spring can reduce seed set. Barley grass matures and sheds seed much earlier than other weeds and pasture plants which means that spray topping must be very timely to prevent seed set.

Fallow

Barley grass populations can be readily controlled by a long fallow. The short seed bank life span means that prevention of seed set for one year will leave very few seeds to germinate the following year.

Cropping

Barley grass seed can establish readily on the soil surface and therefore does not have a reduced germination under stubble retention systems.

Herbicide options are very limited in cereals. In pulses and canola a range of post-emergent selective grass herbicides are available. Reliance on selective grass herbicides (Group A) has lead to cases of herbicide resistance.

Clearfield® wheat and canola can also be used to manage barley grass.

Capeweed

Arctotheca calendula

Seeding	Up to 4 330 seeds per plant.
Seed bank life span	Medium.*
Herbicide Resistance/Tolerance	Medium resistance risk. Resistance identified to Group L in limited situations.
Spread	Seed spread by wind and water.

* Capeweed seeds are dormant at maturity. About 60% of seeds will have germinated after 18 months. Dormancy is affected by temperature and rainfall. The greater the depth in the soil and the lower the temperature the seed is exposed to, the longer the dormancy.

Management

Capeweed plants are best controlled from early autumn onwards when they are small rosettes (<6 cm diameter). Capeweed is more tolerant of herbicides and more expensive to control once flower buds begin to form.

Cropping

Capeweed is a problem in cereal and broadleaf crops. Capeweed is one of the earlier plants to germinate in autumn. This weed has a rapid growth rate and can be large and hard to kill by sowing time. The size of a capeweed plant can double in less than two weeks once the rosettes begin to form.

Control capeweed before sowing with a knockdown herbicide or cultivation. Do not reduce the rates of pre-sowing knockdown herbicides especially if transplants (cultivation survivors) are present. Savings at this stage may lead to expensive follow up post-emergent treatments and costly yield reductions (Table 2.6).

Pastures

Minimise capeweed by the use of strongly competitive pastures consisting of subclover, perennial grasses or lucerne. If grazing pressure is very low, stock will prefer to eat grasses and clover and allow capeweed to dominate. Overgrazing can create bare ground in the pasture where capeweed will later establish.

Table 2.6 Yield loss due to untreated capeweed.

Capeweed in wheat at Trundle 1986		**Capeweed in canola at Mirrool 1985**	
Osprey Wheat	Yield t/ha	Bunyip Canola	Yield t/ha
Nil treatment	2.03	Nil treatment	0.62
Treated	3.18	Treated	1.14

Source: Milne, 1985, 1986.

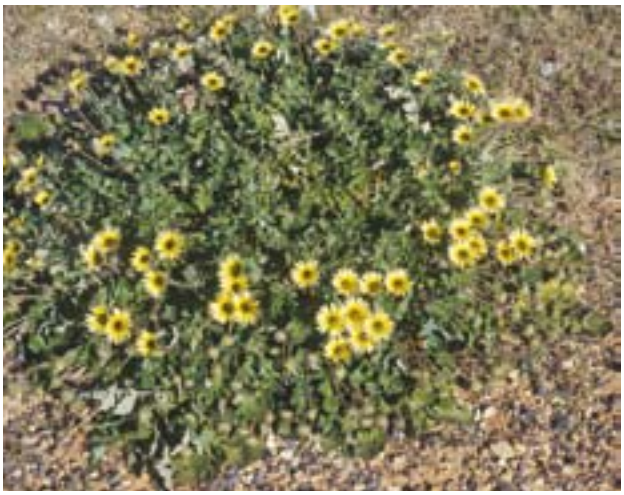

Photo: S. Johnson

Capeweed plants in flower.

Although stock will eat capeweed during early flowering, it is of lower nutritional value than many good pasture species. Capeweed can cause scouring in sheep. Nitrate poisoning can occur when starved and stressed animals graze high volumes of capeweed.

A range of herbicides are available to control capeweed in pastures. Capeweed is difficult to control once flower buds begin to form although glyphosate can reduce seed set. Spot spraying is effective for reducing small infestations. The continuous use of paraquat (Group L) in permanent pastures and some wheat paddocks in Victoria and South Australia has lead to resistance.

Fallow

Capeweed has a medium seed bank life span. A long fallow combined with good seed set control in pastures will reduce capeweed populations.

Cultivation promotes the germination of capeweed seedlings. Traditional cultivation (with discs or equivalent) will only kill capeweed if the roots are exposed and allowed to dry out. If conditions are wet after the soil is cultivated these plants may survive as transplants in the emerging crop. Capeweed transplants are extremely robust. Herbicide rates for controlling seedling capeweed will not control these transplants.

Common heliotrope

Heliotropium europaeum Also called white or annual heliotrope

Seeding	300 000 per square metre.
Seed bank life span	Three to five years.*
Herbicide Resistance/Tolerance	Established heliotrope plants are tolerant to most herbicides.
Spread	Seed transported by wind, water, machinery, hay and grain, or on coats of animals. Can survive the digestive tract of sheep.

* Dormancy is soil depth dependant, that is, there is higher dormancy at greater depth. One dormancy study showed that >50% of all seed remained viable after two years.

Heliotrope flourishes on bare ground and is mostly a weed in summer fallows. It is also a weed of winter dominant pastures where no summer growing species are present. Heliotrope germinates once temperatures reach 24˚C and germination is staggered through summer. Heliotrope has the ability to flower within three to five weeks of germination and set seed quickly.

Established heliotrope has a well developed tap root and will grow under conditions dry enough to stunt or kill most other plants. Seed production is continuous through summer.

Management

Heliotrope is susceptible to herbicides until the third node stage and established heliotrope plants are very tolerant to most herbicides. Spot spraying seedlings that grow around old sheep camps and other isolated patches can prevent heliotrope establishing larger areas of infestation.

Fallow

To control heliotrope, spray plants early at two to three nodes. Established heliotrope plants are tolerant to herbicides.

Photo: S. Johnson

Heliotrope seedling.

Photo: K. Roberts

Common heliotrope in flower.

Heliotrope can be actively growing during hot and dry conditions when herbicide application is difficult. Other control options such as cultivation need to be considered.

Cultivation can effectively control heliotrope as it does not regrow from plant fragments. Cultivation will stimulate germination of more heliotrope seeds which will require follow up treatment.

Cropping

Competitive summer crops are very useful in suppressing seedling heliotrope. Heliotrope is not a weed of winter crops but its use of soil moisture will reduce winter crop yields.

Pastures

Pure lucerne pastures and summer active perennial grasses are very competitive against heliotrope. Heliotrope flourishes when pure annual winter legume pastures (subclover and medics) die back in late spring.

Viable seed can be spread around the property through the digestive tract of grazing animals if eaten.

Heliotrope is not very palatable. Sheep, cattle and horses can all suffer from poisoning when grazing heliotrope dominant pastures or fallows. Grazing heliotrope in subsequent years has a cumulative effect causing liver damage.

Fleabane

***Conyza* spp.**

Seeding	Can produce up to 110 000 seeds per plant (80% viable).
Seed bank life span	About 12 months but increases with depth.*
Herbicide Resistance/Tolerance	Established plants are naturally tolerant to glyphosate.
Spread	Seed carried on animals, machinery, hay, grain and wind.

* The seeds have no dormancy but only germinate under the right conditions. When on the surface only 5% of fleabane seeds remain viable after 12 months. At 5 and 10 cm, seed survival after 12 months was 10 and 15%.

Fleabane grows rapidly, flowers and sets seed over many months. It is relatively tolerant to herbicides due to its hairy leaves and stems. Resistance has also developed with the continuous use of glyphosate.

Fleabane is a poor seedling competitor but it is quick to establish on bare ground. Fallows are susceptible to invasion.

Management

Fleabane needs to be controlled early (prior to seed set) when it is relatively susceptible to herbicides. Control needs to be effective as a small number of survivors can produce enough seed to maintain high population numbers. Spot spray or chip isolated plants before they have a chance to spread.

Fallows

Cultivation will control fleabane plants. Cultivation stimulates seedlings to germinate. Fleabane does not regrow from plant fragments. Control prior to the small rosette stage is essential.

Fleabane is a growing problem in fallows managed with glyphosate. Fleabane is tolerant to glyphosate past the seedling stage and at least one population of glyphosate resistant fleabane has been found.

Photo: H. Wu

Mature fleabane.

Photo: H. Wu

Fleabane seedlings and rosettes.

Rotate to paraquat+diquat (Spray.Seed®) to prevent herbicide resistance.

The hairy surface of the leaf can reduce herbicide uptake. High water volumes and spray additives are important to improve herbicide efficacy on fleabane seedlings.

Cropping

Fleabane is a weed of summer fallows, however control needs to take place in crop. Herbicide application may have to occur before wheat harvest to enable control at the small rosette stage when it is most susceptible to herbicides. Control of large plants post-harvest is difficult and expensive.

Aim to control young flushes of seedlings that emerge in autumn.

Pastures

Fleabane flourishes when pure annual legume pastures (subclover and medics) die back in warm weather. Summer active perennial grasses in pasture provide competition during this time.

Pure lucerne pastures are very competitive against fleabane.

Fumitory

***Fumaria* spp.**

Seeding	800 seeds per plant.
Seed bank life span	Three to five years on the soil surface, more than 10 years at depth.
Herbicide Resistance/Tolerance	Some species are naturally tolerant to trifluralin (Group D). Medium risk for resistance developing to Group B herbicides.
Spread	Easily in seed lots, particularly canola and small seeded legumes such as subclover. Ants also spread seed.

There are seven different species of fumitory present in Australia but the most common species in NSW are bastard's fumitory (*Fumaria bastardii*), wall fumitory (*F. muralis*) and dense flowered fumitory (*F. densiflora*). *Fumaria bastardii* and *F. muralis* has mauve flowers and *F. densiflora* has dark pink flowers. A variety of *F. bastardii* has distinctly blue–green waxy leaves which reduce the efficacy of some post-emergent herbicides.

Management

Due to the natural herbicide tolerance (Case study 2.2) of *Fumaria* species, a combination of cultivation and herbicides should be used.

Cropping

Fumitory is a problem in winter crops. It is tolerant to some herbicides (Group B, C and I) and there is lack of in crop control options in crops like conventional canola and pulses.

Choose crops where there are post-emergent herbicide options for the control of fumitory such as cereals or herbicide tolerant canola. Fumitory germinates over a long period of time therefore some form of residual post-emergent control is needed on later emerging plants.

Triazines can be used in triazine tolerant canola and pulses.

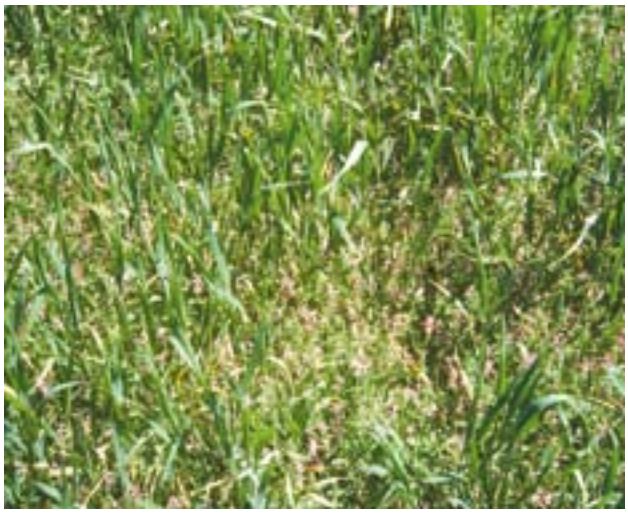

Photo: B. Trounce

Fumitory in wheat.

Photo: J.J. Dellow

Fumitory in flower.

Fallow

Cultivation increases fumitory emergence. An 'autumn tickle' stimulates fumitory emergence for pre-sowing herbicide control.

Pasture

Fumitory can outcompete establishing pastures. There is possibly an allelopathic effect (inhibits the growth of) some species.

Good stands of established lucerne will compete reasonably well. Fumitory seed is able to persist in the soil for many years. An extended pasture phase does not significantly reduce the seed bank.

Case Study 2.2 Fumitory tolerance to herbicides

Surveys have found plants with some tolerance to trifluralin (Group D) in all species. Some resistance to trifluarin has been detected in *F. densiflora*, with cross resistance to pendimethalin (Group D). Susceptibility to trifluralin and pendimethalin increased under warm moist conditions.

There were also plants with some tolerance to Logran® (Group B) and unsatisfactory control by MCPA amine (Group I). *Fumaria densiflora* was tolerant to bromoxynil (Group C). Repeated use of these herbicides has increased the level of tolerance.

Source: Bowcher and Holding, 2004.

Horehound

Marrubium vulgare

Seeding	Mature plants produce over 20 000 seeds per year.
Seed bank life span	7–10 years in the soil (anecdotal). The majority of seeds remain near the surface and have a lower survival.
Herbicide Resistance/Tolerance	Horehound is very tolerant to many herbicides, especially during summer and winter.
Spread	By seed which can attach to the coats of animals, can pass through the digestive tract of horses, be carried by water and on machinery.

Horehound is a weed of pastures and non arable land. Horehound is opportunistic, germinating from autumn to spring when there is enough moisture. Young seedlings are not very competitive, but once established, have rapid growth.

Spring seedlings do not survive the first summer if there is a lack of follow up rainfall. Horehound mostly flowers in spring with burrs and seeds appearing in early summer. Horehound will flower all year if there is enough rainfall. Seedlings can flower in their first year.

Management

An IWM plan that includes a good cropping rotation or pasture improvement program is likely to give the best long term control of horehound.

Extensive infestations are best tackled progressively by cultivation or burning. Small areas of horehound should be quarantined and controlled to prevent spread. Solitary plants can be chipped out or spot sprayed.

Fallow

Horehound does not persist under cultivation. Repeated cultivations with tyned implements may be necessary when the soil is moist as partially buried plants continue to grow. Consider using a disc plough where practical. Summer cultivation is preferred because the disturbed plants are readily killed by the heat.

Some control on non-arable areas and fallow can be achieved by fire in autumn. Burning will destroy old bushes and can significantly reduce the seed bank by up to 80% or more.

Seeds that are not destroyed by fire will often germinate shortly after and these seedlings can then be controlled by grazing or herbicide. Crop or pasture competition will also reduce the likelihood of plants returning after fire.

Target new growth and seedlings in autumn with herbicides. Apply when the plants are actively growing.

If horehound plants are suffering from moisture stress at the time of herbicide application poor results are likely.

Photo: J. Edwards

Horehound.

Cropping

Horehound seedlings are weak and are easily displaced by competitive cereal crops. MCPA, dicamba and paraquat+diquat can be used to control seedlings prior to planting crops. 2,4-D and MCPA are very effective on horehound when used post-emergent in cereals.

Pasture

Overgrazing often favours horehound by creating gaps in which horehound seedlings can later establish without competition from other pasture species.

Horehound is generally unpalatable to sheep but they may eat it when it is lush in spring or if food is scarce. Heavy grazing pressure will do little to suppress large horehound plants but can be effective for controlling seedlings. Temporary tainting of meat will result from browsing on horehound.

MCPA can be used in pastures to control established horehound plants without damaging grasses, however subclover may be injured while medics, lucerne and rose clover will be killed. Use high water rates and a wetting adjuvant as horehound is a difficult plant to wet.

Maintain competitive pastures to prevent the establishment of seedlings. Horehound seedlings seldom establish in dense pastures where perennials and summer growing annuals can outcompete them. Mature plants rarely persist with strong competition from pastures but can become a significant problem if pastures thin out due to stress, disease or heavy grazing.

Slashing can prevent seed production and limit the spread of horehound but this is only a temporary measure. Slashing is unlikely to achieve a rapid reduction of infestations. Clean down slashers as they may spread seed to uninfested areas.

Horehound seeds can be spread by sheep when caught in wool. Ensure sheep are free of horehound before grazing clean pastures.

Biological control

Biological control agents are available and include the horehound plume moth and the horehound clearwing moth. Biological control agents are especially useful if non arable land or reserves are infested.

Biological control is a long term control option that can be used as part of an IWM plan especially for non-arable land or reserves. Refuges (non control areas) must be provided for biocontrol agents to feed on when other controls are being implemented.

➢ **See also biological control agents page 72.**

Photo: A. Johnson

Horehound leaves.