Chapter 5
Fallows

Compiled by Annie Johnson and Robert Thompson

Photo: A. Johnson

Standing stubble in a fallow paddock.

Fallows are an inherent part of farming in lower rainfall areas. The term 'fallow' used here refers to a paddock where no crop or pasture is growing. Fallows are a risk management tool that is used when low stored soil moisture or dry forecasts increase the risk of crop failure.

The main function of a fallow is to conserve moisture and nutrients for the following crop. Fallows can also reduce the carry over of disease and the number of weeds into the next crop. The benefits of a fallow are only attained when the weeds in the fallow are controlled.

A long fallow is traditionally the time between the pasture and cropping phases and is started in early winter 9–12 months before the next winter crop is sown. In higher rainfall areas long fallows are less critical for storing moisture but fallows are still important for weed management and a disease break prior to cropping. Fallows in higher rainfall areas start in early spring before annual grass weeds set seed.

A short fallow is the period over summer between two winter crops. Summer weeds are controlled to prevent them using soil moisture and nutrients.

Risk management

Fallows are a risk management tool in the farming system. When there is not enough moisture to sow a crop the paddock can be fallowed until there is enough moisture to plant another crop which can be a period of 16 to 18 months. The use of a fallow more often depends on the climate and crop prices than as a fixed part of the rotation. Deep drainage can occur during a long fallow and where shallow water tables or saline subsoils are present this can accelerate dryland salinity problems. In these situations research has found that when there is enough soil moisture to grow a crop, that moisture should be utilised to prevent deep drainage.

Fallows as an IWM tool

Fallows can be used as an IWM tool which can target cropping weeds such as the annual grasses. Weeds such as barley grass, vulpia and brome grass are difficult to manage in cereal crops.

Weeds need to be controlled early in and throughout the fallow for three reasons. First, the earlier the fallow commences and weeds are controlled the greater the moisture retention and yield of the following crop (Table 5.1).

Second, prevention of seed set for just one year can significantly reduce problem grass weeds such as barley grass, annual phalaris and annual ryegrass (Figure 5.1). Broadleaf weeds have a longer seed dormancy, therefore have only a small reduction in the seed bank after just one year.

Finally, during dry periods, plant residues that host the disease pathogens decompose slowly. To prevent the carry over of disease from the pasture phase grass weeds need to be controlled in the seedling phase before they can host significant levels of disease pathogens and to allow a longer period for plant residues to break down.

Table 5.1 Timing of fallow start and wheat yield near West Wyalong.

Start of fallow	Wheat yield (t/ha) wheat crop sown			
	4 June 1993	12 June 1994	8 May 1996	Mean
June	3.93	1.02	2.99	2.65
September	3.69	0.98	2.17	2.28
October	2.88	0.66	0.88	1.47

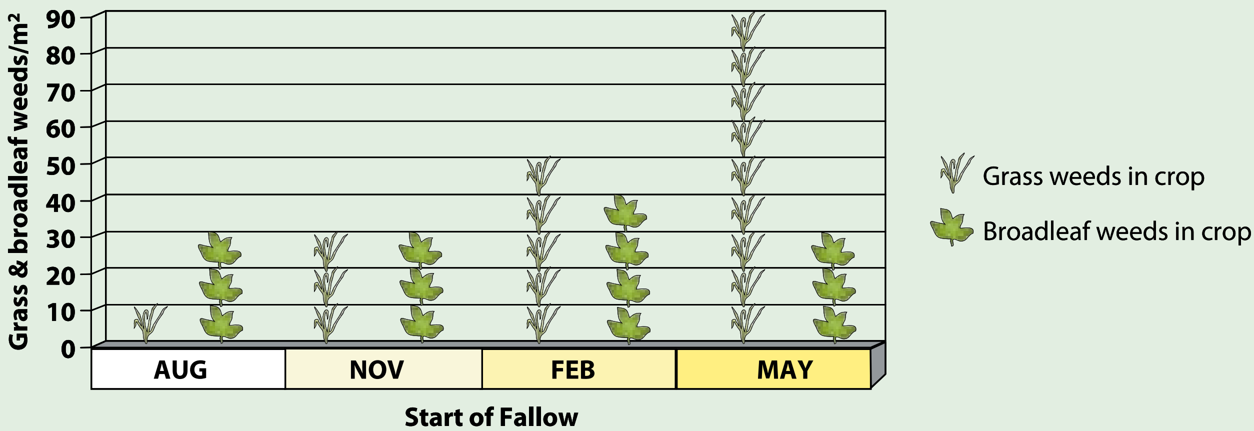
Source: Thompson and Milne, 1996.

Photo: T. McNee

Wheat heavily infested with barley grass.

Grass weeds are a problem due to their ability to host many cereal diseases during the pasture phase. Along with winter cleaning (page 55), a long fallow (9–16 months) can be used to provide the the disease break between the pasture and cropping phases or between two cereal crops. Research has shown that the earlier these grasses are removed in the fallow the greater reduction in disease in the cereal crop the following year (Case studies 4.1 and 5.1).

Figure 5.1 Number of grass and broadleaf weeds in crop after various lengths of fallow period.



Source. Fettel, 1980.

IWM in fallows

A variety of weed control method are needed in fallows to prevent herbicide resistance or species shift. Rotation of herbicide modes of action and timing of weed control is very important to have effective control of weeds in fallow and hence obtain the full benefit of having a fallow. Be flexible with fallow management options in this chapter including considering a strategic cultivation if herbicide tolerant weeds are becoming a problem.

Herbicides

Herbicides are the main means of managing fallows today, with glyphosate the most commonly used herbicide. There are a range of herbicides that can be used in fallow and it is important to rotate the herbicide mode of action used in fallows. Fallows managed with a single herbicide mode of action have seen a species shift towards more herbicide tolerant weeds such as those listed in Table 5.2. Herbicide mixtures with different modes of action should be used for weed control in fallow to control a broader range of weed species.

Summer weed control and herbicide tolerance

Weed tolerance to herbicides increases as plants increase in size and when they are suffering from moisture or heat stress. Weed control in summer can be difficult as weeds grow very quickly. In warm temperatures when there is adequate moisture weeds can rapidly grow to a size where they can become difficult to control. Many of the weeds listed in Table 5.2 are easily controlled when they are quite small, but become more tolerant as their size increases even to higher rates of herbicide.

Weeds can emerge within five days of rain and with another 10 days they can be moisture stressed and cease active foliage growth. Weeds are most susceptible to herbicides in the two- to four-leaf stage which can occur within 14 days of germinating rain.

The right spraying conditions (e.g. temperature and wind speed) can be rare in summer. Water rates, droplet size and spray additives are very important factors on warm days (≥30˚C) with low humidity. Hot days (≥35˚C) cause many problems with herbicide volatility and no spraying should be done.


Photo: S. Johnson

Fleabane.

Table 5.2 Weeds species that become more tolerant to herbicides as size increases.

Glyphosate tolerant species	
Asphodelus (onion weed)	native millet
Bathurst burr	nutgrass
bladder ketmia	pigweed
black bindweed	sida
common heliotrope	skeleton weed
couch	small flowered mallow
dead nettle	stagger weed
fleabane	tarvine
corn gromwell	vulpia
lippa	windmill grass
lucerne	wireweed
Camel and paddy melon	
Chlorsulfuron tolerant species (post-emergent application)	
annual phalaris	skeleton weed
annual ryegrass	sowthistle
barley	St Barnabys thistle
paddy melon	wheat
saffron thistle	

Source: A. Storrie and T. Cook, 2006, pers. comm.

See Chapter 8 for more on herbicide use and weather.

Cultivation

Weed control in fallows may require a cultivation under certain conditions. Considering a cultivation does not mean returning to old techniques and machinery. For example, a shallow cultivation can be used to control seedling weed growth under hot, dry and dusty conditions when herbicides are generally not as effective (Table 5.3).

A cultivation is often used during the fallow, after a pasture phase to reduce soil compaction caused by stock. Hard setting red clay soils are often cultivated early in the fallow to increase the infiltration rate.

A strategically targeted cultivation is also a very effective IWM tool, especially when used in rotation with herbicides to prevent a build-up of herbicide tolerant weeds. Combining herbicide use with cultivation also reduces the risk of degrading the soil structure and increasing erosion through excessive cultivation.

When comparing cultivation and herbicides, research trials showed no difference in the grain yield of the next crop when weeds were controlled by either method. The timing of weed control in the fallow, however, had a significant impact on grain yield.

Table 5.3 Factors to consider for weed control in fallow.

Conditions	Cultivate	Spray
Herbicide tolerant weeds present	✓	
Weeds small and fresh		✓
Weeds large and moisture stressed	✓	
Ground too wet		✓
Windy weather	✓	
Soil too dry		✓
Little time (for labour)		✓
Expensive herbicide needed	✓	
Nearby herbicide sensitive crops	✓	
Need to germinate weeds	✓	
Slope of landscape >3%		✓

Source: Adapted from Wiltshire et al. *1999.*

Depleting the soil seed bank (autumn tickle)

At the end of a long fallow which has been managed with herbicides, a shallow cultivation can be useful. This cultivation, about eight weeks prior to sowing, can be used to stimulate weed emergence of dormant weed seed if large numbers of seed are known to be present. These weeds can then be controlled prior to sowing.

This technique, sometimes referred to as an 'autumn tickle' is a useful technique for reducing the soil seed bank and delaying the development of herbicide resistant weed populations.

Stimulating germination by cultivation is useful for species such as wild radish. For some species this is not a useful tool, for example wild oats has an extended germination period regardless of the tillage system.

Grazing

If the aim of the fallow is to preserve soil moisture then weeds should not be allow to grow to a size where they can be grazed. Heavily grazed swards still use moisture especially during summer when evapotranspiration ≥10 mm/day.

If grazing when there is no alternate feed available check for weeds that may threaten animal health. Some weeds such as skeleton weed can be grazed, but many other weeds can pose a threat to animal health. Weeds such as common heliotrope can cause liver damage in stock. If in doubt about grazing certain weeds species seek advice from your Rural Lands Protection Board veterinary officer.

Burning stubble on a short fallow

Stubble burning is a tool used for the control of disease and many weeds. Burning stubble must be weighed against the increased risks of nutrient loss and damage to the soil structure that can occur in a hot fire. High levels of ash can sometimes reduce the effectiveness of herbicides.

Burning for weed control must be practical and timely. The fire should aim to destroy weed seeds on the soil surface rather than burning fresh weed growth.

Burning to reduce some weed seeds on the soil surface requires a hot fire, while for others a cool burn is sufficient. Seeds that are still attached to the parent plant and have not fallen to the ground are easier to burn. Research has found that while burning standing stubble temperatures were often hot enough to destroy annual ryegrass seed but not wild radish seed on the soil surface. Wild radish required 500˚C for 10 seconds; annual ryegrass only required 400˚C for the same period.

Header trails after harvest comprise a higher stubble concentration relative to the rest of the paddock as well as a greater concentration of weed seed. Burning these trails therefore, produces a hotter and longer burn and enables both the removal of the crop residues and concentrates the fire where the weed seed burden also is highest (Table 5.4).

Table 5.4 Ryegrass control by burning stubble.

Straw at harvest	Dry matter	Ryegrass seeds killed by burning
Spread by harvester	2.3 t/ha	82 %
Windrowed	15 t/ha	99 %

Source: Walsh et al. *2005*

Burning windrows (higher concentration of material) can produce temperatures that are hot enough for a sufficient period to kill wild radish seed on the soil surface. Where there has been summer rain, windrows can hold the moisture making them difficult to burn in autumn despite the higher level of stubble.

Photo: T. McNee

Camel melon.

Burning problem weeds

When wireweed gets away in wet springs the crop can be given a salvage harvest spray (usually with 2,4-D). The stubble is later burnt to reduce the mat of dead wireweed 'tendrils'. This reduces the need for a number of cultivations prior to sowing.

Severe horehound infestations can sometimes be controlled by burning. Old bushes and up to 80% of the seedbank can be destroyed by a low intensity fire in autumn.

Case Study 5.1 Strategic use of fallows in a continuous farming system. By Annie Johnson and Greg Brooke

Name	Judy, Michael, Hayden, Stuart, Nigel Wass and families.
Property	The Plains, Nyngan (10 360 ha – 2360 ha native vegetation).
Enterprise	Continuous cropping, wheat, barley, pulses, canola.
Landscape and soil	Flat landscape. 2000 ha of duplex grey clay floodplain and 8000 ha of sandy red brown earths.
Rainfall	444 mm non seasonal.

Introduction

In 1999 the Wass family sold the last of their cattle to focus their time on cropping. Conservation cropping including minimum tillage and stubble retention, controlled traffic and rotational cropping has turned former scalded claypans into productive soils and made all farm operations easier and more efficient and improved crop yields.

Average farm yields have been increasing which has been accredited to soil structure improvements, better moisture conservation, and improved timeliness of sowing and weed control as well as better disease and nutrition management.

Rotations

Wheat, barley, canola, lupins, chickpeas and field peas are grown in rotation.

"Weed burdens in paddocks determine crop choice more than seasonal outlook and the most desirable rotation".

Lucerne was grown for several years after the last cattle were sold to build up soil nitrogen and provide competition for the weeds.

Now long fallows (≥12 months) are used to build up moisture, control cropping weeds and provide a disease break.

There is no fixed rotation sequence. Crop choice is on the basis of paddock history, weeds and market prices. The preference would be to never grow a crop in its own stubble. However if back-to-back cereal crops need to be grown a disease tolerant variety is selected.

Photo: A. Johnson

Stubble retention prevents erosion and helps retain soil moisture.

Photo: A. Johnson

Hayden and Stuart Wass.

The worst weed problems have been when no herbicide control was available for weeds that germinated in crop. Herbicide availability for weeds in each paddock determines which crops are grown.

With long fallows, moisture availability is less of a limiting factor; weeds are the most limiting factor. The Wass's have begun to experiment with cover crops before a long fallow to determine if more ground cover is needed to prevent erosion and help retain moisture.

Crop choice considers sowing time and length of season of the crop. Fast maturity crops and varieties allow time for an extra knockdown herbicide spray pre-sowing for better weed control.

The varying crop lengths give competition to weeds at different times which can be used to prevent seed set of certain weeds.

Agronomy

Crops are planted late if possible to allow time for one or two (double knock) pre-sowing sprays of knockdown herbicides.

Sowing with the disc seeder gives a very even crop establishment. Crop competition against weeds is managed through an even plant density rather than a high seeding rate. The even plant density also gives a closed canopy faster, reducing weed germination.

Table 5.5 Sowing rates used for various crops.

Sowing rates	kg/ha
Wheat	25–30
Lupins	80
Field peas	80–100
When soil nutrition and moisture are high the optimal plant density is 35–55 plants/m^2.	

Controlled traffic

Controlled traffic with autosteer and selling the cattle was a lifestyle and management decision. The level of labour to manage the farm has been dramatically reduced. The level of erosion on the more fragile soil and compaction on the clay soils has been reversed.

Photo: A. Johnson

Wheat crop on "The Plains".

Controlled traffic has evened out the ground so the speed of sowing can increase with reduced power requirements, giving large fuel savings. The autosteer saves about 5% overlap giving better weed control and crop density. There are less gaps which in the past become weedy areas that reinfested the rest of the paddock.

Controlled traffic has allowed changes to farm operations that were not possible previously. This includes rapid dry sowing when rain is forecast, night spraying and spraying shortly after rain. The more timely weed control has made herbicides more effective and allows less weed escapes.

Stubble retention

The main operations are sowing with the disc seeder and spraying. The autosteer guidance and using a disc seeder gives the accuracy to plant each crop between the rows of the previous crop. Sowing between the rows gives a better germination and puts the seed away from the roots system of the previous crop which can be a source of disease especially crown rot.

Standing stubble gives some protection to the seedling crop as well as reducing soil moisture evaporation. This is important and since this practice has been used there has been less crown rot and reduced weed germination in the crop.

Planting field peas into standing stubble allows the plants to climb up the stubble on either side of the row which improves the harvesting of the peas.

Spray coverage is smoother with the tramlines (less movement on the boom) and there are no gaps or overlaps by the boom.

Putting in tramlines and autosteer in the spray rig has also allowed better spraying. Retaining the stubble also results in less dust when spraying.

Minimum tillage

The only other cultivation that has taken place in recent years has been with harrows in autumn on the odd paddock where the ground was cloddy. This operation evens out the ground in preparation for sowing.

This is also a way to reduce the soil seed bank if there were escapes in the previous season as the harrows stimulate germination of many weeds. The paddock is then sprayed out while the weeds are small.

Weed species shift

The change to stubble retention and controlled traffic has resulted in changes in the weed population across the farm. Some weeds are under control while others are now emerging problems.

It is often easier to control cropping weeds in fallow or pastures and fallow weeds with crop or pasture competition.

Photo: A. Johnson

Disc seeder and press wheels.

Table 5.6 Weed species shift after the change from mixed farming to fallow – cropping rotation.

Decreasing	Increasing
skeleton weed	Australian bindweed
saffron thistle	heliotrope
wild oats	fleabane
barley grass	spiny emex
annual phalaris	sowthistle
nightshades/quena	woody weeds

Weed Management

Grass weeds

Grass weeds (barley grass, phalaris and wild oats) were a problem in cereal crops. Control of grass weeds in crop was expensive so they were managed by controlling seed set over four years in pastures and fallow.

Bad grass weed areas were left fallow for two years. The resulting reduction in grass weed populations has meant that no in crop control of wild oats has been needed for several years (Table 5.6).

Saffron thistle

Saffron thistle was once one of the most problematic weeds across the property and is now rarely seen. Saffron thistle has been controlled by rotating crops and pastures that have herbicide options to control it.

Lontrel® in canola, 2,4-D amine in wheat and spray topping in pastures prevented the seed set of saffron thistle for many years and reducing the seed bank to low levels.

Skeleton weed

Skeleton weed was best managed in fallows and with competition from lucerne.

Lucerne is extremely competitive against skeleton weed and competes all year round for moisture. The improved fertility of the soil through rotations and minimum tillage is also thought to have impacted on the level of skeleton weed.

In fallows a couple of glyphosate applications during the summer sometimes followed by a ripping controlled the root systems which were stressed from the herbicide. The herbicides selected for each crop (e.g. Lontrel® in canola) also control skeleton weed.

Quena

The reduction in cultivation is one of the main reasons for the reduction in quena. Timely fallow sprays while quena is at the seedling stage also helps reduce the population of this weed.

Growing problems

Spiny emex

Spiny emex has spread from only occurring in one patch in 1970 to across large parts of the farm today. The Wass brothers regret that it was not totally wiped out when it first appeared 30 years ago.

To prevent further spread across the farm, wheels of vehicles and machinery are checked and cleaned down before moving from spiny emex areas. They hope to develop a box to collect the spiny emex seeds as they come off the press wheel on the disc seeder to remove some seeds from the paddock.

Fleabane

Fleabane is currently controlled in the fallow. Fleabane is targeted at the seedling stage using glyphosate; if it is allowed to mature it is very difficult to control. Control during the winter cereal is very important to keep fleabane under control.

Woody weeds

Across the farm thousands of trees have been planted along the fence lines and individual trees from the centre of the paddocks have been removed. In these former tree sites woody weeds are an ongoing problem during the fallow period.

Currently fallow herbicides at high rates and a weed seeker are used to target woody weeds and to reduce chemical costs.

Photo: A. Johnson

Woody weeds like these acacias are an on going problem during the fallow period.

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Photo: K. Roberts

Uncontrolled weeds in fallow use up moisture and nutrients.

Chapter 6
Biological Control of Weeds

Compiled by Paul Sullivan

***Paterson's curse plants attacked and killed by the crown weevil* Mogulones larvatus.**

Biological control of weeds is the use of living organisms such as insects, mites, pathogens or fish to reduce a weed's abundance or to limit a weed's distribution. Biological control where available should be used as part of an integrated weed management strategy.

Weeds have been targeted by biological control programs since the mid 19th century when the cochineal insect *Dactylopius ceylonicus* was deliberately used in Sri Lanka to control smooth tree pear *Opuntia vulgaris*. Since then many biological control programs have targeted weeds. These efforts have ranged from being completely successful to being unsuccessful. Over the last 30 years there has been an acceleration in the number of biological control programs for weeds in Australia.

How does biological control work?

When plants are introduced to another country, their natural enemies are usually left behind. If conditions become favourable, introduced plants not accompanied by their natural enemies may increase and become much more numerous than they would in their native range. When this happens, they may spread aggressively and become widespread weeds.

Biological control attempts to re-establish a balance by using parasites, predators, pathogens and plant eating organisms to lower the target weed population. These natural enemies are referred to as control agents.

Types of biological control

Classical biological control is the most common type of biological control. Since the 1980's, inundative biological control has also become quite fashionable. Other biological control methods (not mentioned here) have limited application and are less common.

Classical biological control

Classical biological control is the introduction of control agents into a region to permanently suppress the target weed's population. These agents have traditionally been arthropods, mainly insects. Today, plant pathogens and mites are also being used, although any biological enemy, for example nematodes or herbivorous fish, may be used.

Classical biological control is environmentally friendly and in the long term economically advantageous. It allows all landholders to benefit as the agent seeks out all available plants without recognising property boundaries.

The disadvantages of classical biological control are the upfront expense and low funding availability. Biological control also takes many years to establish and the level of control in those first few years may be very low. The target weed is never eradicated by using biological control (Figure 6.1).

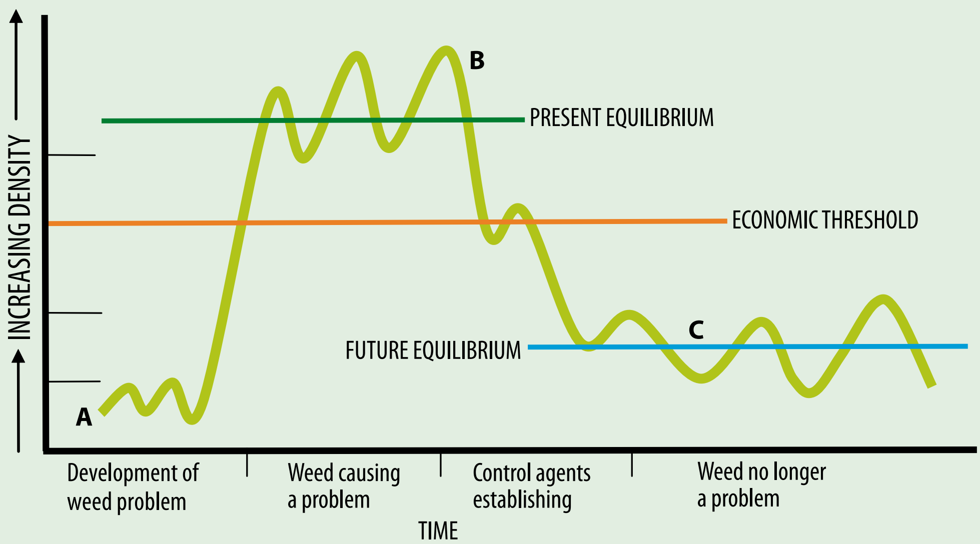
Inundative biological control

Inundative biological control occurs when a control agent is mass reared and released to get immediate short term control of the weed. Inundative biological control agents for weeds are usually host specific plant pathogens (e.g. virus, mycoplasma, bacterium or fungi). These pathogens are often called mycoherbicides. This method targets a single weed species usually in a high value crop where the weed has escaped other control methods. Inundative control has a high success rate but is a short term strategy with control seldom lasting more than one season.

Photo: P. Sullivan

***The horehound clear wing moth* Chamaesphecia mysiniformis.**

Figure 6.1 Theoretical effects of classical biological control



A: Weed is at low numbers and not a problem.

B: The weed increases, spreads rapidly and becomes a problem. Biological control is researched and, if possible, agents are released.

C: Long term, biological control agents and weed density balance has stabilised.

After: KLS Harley and IW Forno, 1992.

Biological control of weeds

Although biological control agents can be found for use against most weeds, research resources are limited. Priority is given to weeds that are causing the greatest economic loss or the greatest environmental degradation, and where there is a reasonable expectation that biological control will succeed. Table 6.1 gives a summary of steps to be followed in a classical biological control program.

Table 6.1. A summary of steps followed in a classical biological control program.

Step	Uses
1.	Identify the weed. See Case study 6.1.
2..	Study the weed within its original range.
3.	Select damaging species (the agent). To gain the maximum damaging effect, a complex of agents is usually introduced. See Case study 6.2 and 6.3.
4.	Check host specificity. Normally only agents that reproduce exclusively on the target weed and possibly its close relatives are considered for use as biological control agents.
5.	Screen agents for disease, predators and parasites.
6.	Seek approval to release agents from the Australian Quarantine and Inspection Service and Environment Australia.
7.	Breed and release biological control agents.
8.	Monitor target weed before and after release of biological control agent to see if further action needs to be taken.

Propagating biological control agents

Insectary propagation is labour intensive, expensive and the quality of agents is questionable. This may be overcome by establishing field nurseries. A field nursery is an area of the weed where the agent is released, and where, after the agent multiplies, it is harvested for distribution to other release sites.

The field nursery should be kept free from damage by human and animal interference and be easily accessible. This method is unsuitable for some insects, while other insects are ideally raised this way.

Distributing and establishing control agents

It is usually better to release large numbers of agents at a few sites than a few agents at many sites. Hundreds rather than tens are best.

Sometimes agents are established by releasing adults into field cages placed over clumps of the target weed. Field cages are removed after egg laying, or after one to several generations. This method is particularly useful if the numbers of agents available for release are low, or if their behaviour is such that they disperse rapidly. The cages need to be big enough to enclose sufficient numbers of weeds to meet food requirements and to meet any special requirements that the agent may have. For example, some insects only mate when in flight.

The success of an agent depends on several factors including its ability to reach and colonise its host, as well as the amount of damage it can cause. Some agents disperse very quickly. For example, the stem galling moth *Epiblema strenuana*, an agent for control of parthenium weed, travelled 150 kilometres in one year. Other agents disperse slowly. The cochineal insect *Dactylopius ceylonicus*, an agent for control of smooth tree pear, dispersed only 45 metres in three years.

To promote rapid establishment and control, agents that disperse slowly may need to be released at many locations. Employing this strategy for agents that disperse quickly may be a waste of limited resources. These agents often have well developed abilities to search for weed infestations.

Agents that may need to be bred and released over a number of years are those that breed slowly, are hard to establish or disperse slowly.

Evaluating biological control agents

Field release sites of agents also need to be monitored for evidence of establishment of the agent. This evidence will consist of presence a year after release, reproduction and increase in the population of the agent. Agents will also need to be monitored to see how rapidly they spread from the release site. Rapid spread suggests that further releases should be made at sites many kilometres apart.

Case study 6.1 – Identifying the species

Skeleton weed (*Chondrilla juncea*) originated in the Mediterranean and Asia minor regions and was first found in Australia in 1913. There are three distinct forms of the weed in Australia. They are known as the narrow-leaf form, the intermediate-leaf form and the broad-leaf form.

The highly specialised rust *Puccinia chondrillina* was released for control of skeleton weed in Australia in 1971. The rust was successful in controlling the common narrow-leafed form but it did not damage either of the two other forms of the weed. Now the broad-leaf form is becoming more common and poses an increasing problem through the wheat belt. It is a larger more erect plant and also appears to be more competitive than the narrow-leaf form.

Table 6.2. Currently available biological control agents for weeds in Central West NSW.

Host	Agent	
	scientific name	common name
Paterson's curse	*Mogulones larvatus*	crown weevil
	Mogulones geographicus	root weevil
	Phytoecia coerulescens	stem borer
	Meligethes planiusculus	pollen beetle
	Longitarsus echii	flea beetle
Bridal creeper	*Zygina* sp.	leaf hopper
	Puccinia myrsiphylli	rust
	Crioceris sp.	leaf beetle
Horehound	*Wheeleria spilodactylus*	plume moth
	Chamaesphecia mysiniformis	clear wing moth
Common pear	*Dactylopius opuntiae*	cochineal
Tiger pear	*Dactylopius austrinus*	cochineal
Rope pear	*Dactylopius tomentosus*	cochineal
Blue heliotrope	*Deuterocampta quadrijuga*	beetle

Note: These are more agents available in Australia but mostly for weeds which do not occur in this region.

For more information contact a NSW DPI biological control officer listed below:

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Gary Grimshaw	Dubbo	02 6881 1258
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Case Study 6.2 Prickly Pear

The control of common pest pear, *Opuntia stricta* varieties, by *Cactoblastis cactorum* is a classical example of biological control. Two varieties of pear, *O. stricta* variety *stricta* and *O. stricta* variety *dillenii*, were involved.

In 1900 *O. stricta* occupied around 4,000,000 hectares. Although chemical and mechanical control methods were attempted, neither was successful and, by 1926, the weed occupied at least 24,000,000 hectares. Half of this area was so densely covered that it was useless for production and the land had been abandoned by the owners.

Investigations into organisms attacking cacti in North and South America and in the West Indies were begun in 1920. About 150 cactus feeding forms were studied, and of these, 52 were selected as suitable for release. Nineteen of the 52 suitable species were successfully bred up in large numbers for field release. However, only nine became permanently established. Some of the first insects approved and released were the cochineal insects *Dactylopius opuntiae* and *Dactylopius confusus*. *Dactylopius opuntiae* was first released in 1921 and appeared to be controlling the common pest pear in brigalow and belah scrub by 1927. However *D. opuntiae* numbers declined in the following years due to wet summers combined with the destruction of food plants by the South American moth *Cactoblastis cactorum*. This moth was released in 1926. By 1928 *Cactoblastis* had established so well in the field that eggs were able to be collected directly from the field. The period between 1930 and 1932 saw the collapse of most *O. stricta* infestations due to the feeding of *Cactoblastis* combined with the effects of micro-organisms causing the remains of the plants to rot. Following the weeds demise, properties previously abandoned were reclaimed and brought back into production.

Today *Cactoblastis* controls *O. stricta* infestations over most of its range. However, *D. opuntiae* is also used in the colder areas where *Cactoblastis* is not quite as effective.

Photo: J. Hosking

Common pear cochineal insects Dactylopius opuntiae.

Case Study 6.3 Biological Control of Paterson's Curse

Biological control was first suggested for Paterson's curse in 1928, however it was not until 1972 that the CSIRO began surveying the western Mediterranean region for the plant's natural enemies. The first agent, a small leaf-mining moth (*Dialectica scalariella*) was released in 1980, but did not establish because of drought and grasshoppers.

Shortly after the moths were released, two beekeepers and two graziers obtained an interim injunction from the High Court preventing further releases. An eight-year legal battle followed resulting in the *Biological Control Act* 1984. The Act prevents further legal problems for biological control programs where the majority good is circumvented by legal challenges. All state and territory governments passed complementary biological control legislation between 1986 and 1988. The injunction was lifted on 17 November 1988.

Of the many insects found damaging Paterson's curse in Europe, seven were approved by Australian Quarantine and Inspection Service for release in Australia (see Table 6.3). These insects attack the weed during all stages of growth.

All these insects have been released and are established in the field except for the root hair flea beetle (*Longitarsus aeneus*) which was released but did not establish.

The leaf-mining moth (*Dialectica scalariella*) was re-released by NSW Agriculture between 1988–1991 at more than 900 sites throughout New South Wales. It is now widespread and common on Paterson's curse and viper's bugloss. Larvae of this moth feed within the leaves to form mines (mainly on the lower side). These mines turn to blisters as the larvae increase in size. Leaves are attacked from spring to autumn and this may reduce the competitiveness of Paterson's curse when moths are present in high numbers.

The second agent released was the crown weevil (*Mogulones larvatus*) in 1992. Adult weevils emerge in spring and feed on leaves producing circular-to-oval shaped holes before entering a summer inactive period. Feeding, mating and egg-laying recommence early autumn and continue until spring. Young larvae initially feed inside leaf stalks moving down into the root crown. Most damage is caused by larvae feeding in the crown during autumn, winter and spring. Plants under heavy attack may die before seeds can be produced. Crown weevils are established at hundreds of sites in NSW.

The root weevil (*Mogulones geographicus*) was first released in 1993. This weevil attacks the plants in a similar way to the crown weevil except that root weevil larvae feed more in the tap root than the root crown. It has a similar life cycle to the crown weevil. Root weevils are established at more than 30 sites in NSW.

Two flea beetle species have also been released. Adult *Longitarsus aeneus* feed on rosette leaves while larvae feed on root hairs. It was released directly into the field but did not establish. Adults of the other flea beetle (*Longitarsus echii*) emerge in winter. Adults feed on rosette leaves and larvae feed inside the main root. Flea beetles are established at more than 20 sites in NSW.

Stem beetles (*Phytoecia coerulescens*) emerge in late spring and lay eggs that hatch a week later. Larvae feed inside larger stems and move to lower plant parts where they remain until the following spring. These beetles are cannibalistic with usually only one survivor emerging from each plant. Stem beetles have established at several sites in southern NSW.

The flower-feeding beetle (*Meligethes planiusculus*) was the last of the insects to be released into the field. Eggs are laid in the terminal flower buds in spring. Larvae quickly emerge and feed on flower buds, flowers and developing seeds. After flowering finishes, the adult flower beetle remains fairly inactive through the remainder of summer, autumn and spring. Flower feeding beetles have established at several sites in southern NSW.

Photo: CSIRO

The Paterson's curse flea beetle **Longitarsus echii.**

Photo: CSIRO

The Paterson's curse crown weevil **Mogulones larvatus.**

Table 6.3. Agents currently approved for the biological control of Paterson's Curse.

Species	Agents common name	Plant part attacked	Generations per year
Dialectica scalariella	Leaf-mining moth	Leaf, below stem surface	5–7
Mogulones larvatus	Crown weevil	Leaf, crown, leaf stalks	1
Mogulones geographicus	Root weevil	Leaf, root, leaf stalks	1
Longitarsus aeneus	Root hair flea beetle	Leaf, root hairs	1
Longitarsus echii	Tap root flea beetle	Leaf, inside tap root	1
Phytoecia coerulescens	Stem beetle	Leaf, stem	1
Meligethes planiusculus	Pollen beetle	Flower bud, flower, developing seed	1–2