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GRDC GROWNOTES™

GRDC™ GRAINS RESEARCH & DEVELOPMENT CORPORATION

VETCH

SECTION 6

WEED CONTROL

Weed control

Key messages

- Broadleaf Weed control in vetch can be problematic as some herbicide options are limited.
- Hard seeded vetch varieties can also increase the risk of volunteer vetch in subsequent crop rotations.
- Spraying herbicides should be avoided when vetch is at the flowering stage, as it will severely affect yield. [1]
- Ensure to spray under good conditions and to always keep good paddock records to avoid potential herbicide damage to own paddocks and neighbouring crops. [2]
- Monitor crops for herbicide damage and keep an eye out for potentially resistant weeds (which should then be tested).
- Vetch offers a non-herbicide option for weed control when hay is made and weeds are removed.
- Green/brown manuring is a favoured use of vetch and another tool for resistant weed control.

The total cost of weeds (revenue loss plus expenditure) to Australian grain growers is estimated at $3,318 million. [3] Effective weed control is essential for good yields and to avoid the buildup of troublesome weeds in the rotation. Plan your weed control strategy before sowing.

Pulses grown in rotation with cereal crops offer farmers opportunities to easily control grassy weeds with selective herbicides that cannot be used in the cereal years, providng herbicide resistance is not an issue. An effective kill of grassy weeds in the pulse crop will reduce root disease carry over, such as brown rot, and provide a “break crop” benefit in the following cereal crop.

Weed management in vetch is problematic, with few herbicides registered for in-crop weed control. Management of broadleaf weeds is especially difficult, with limited post emergent herbicide options for broadleaf weed control. [4] The control of broadleaf weeds should be focused on pre-emergent options. Broadleaf weeds can compete strongly with the vetch, reducing the value of the crop and potentially leading to increased weed problems in later years. Several grass herbicides are available and most of these can be tank mixed with insecticides (check labels). Avoid herbicide spraying at flowering. [5]

A weed management program should be designed to make the most of opportunities to use selective herbicides in each crop in the rotation to reduce the weed problem in the following crop. Great care should be taken in planning a cropping rotation to avoid growing a crop which may become a “weed”, which cannot be controlled with selective herbicides, in the subsequent crop.

6.1.1 Volunteer vetch

Increasing numbers of wild vetch or tares is being viewed with alarm in some areas. Wild vetch has the potential to become a severe problem in the cropping systems of south eastern Australia (Photo 1). Once established, it is highly competitive in crops such as lupins.

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1 R Matic (2010) Vetch summary 2010. SARDI. Online Farm Trials. http://www.farmtrials.com.au/trial/14055

2 R Matic (2010) Vetch summary 2010. SARDI. Online Farm Trials. http://www.farmtrials.com.au/trial/14055

3 R Llewellyn, D Ronning, M Clarke, A Mayfield, S Walker, J Ouzman (2016) Impact of weeds on Australian Grain production. GRDC. https://grdc.com.au/__data/assets/pdf_file/0027/75843/grdc_weeds_review_r8.pdf.pdf

4 R Matic, S Nagel, G Kirby (2008) Common Vetch. Pastures Australia. http://keys.lucidcentral.org/keys/v3/pastures/Html/Common_vetch.htm

5 R Matic, S McColl (2013) Which vetch is my farming system? Online Farm trials. http://www.farmtrials.com.au/trial/16634

Wild Vetch is an autumn-germinating annual broadleaf weed. They have a high percentage of hard seeds which may survive indefinitely and germinate if conditions are favourable. Cultivation to bury the seed and prevent germination is not effective. Seed germination trials showed vetch has the ability to germinate from a depth of 250 mm.

Vetch is classified as a Class 7 contaminant in ASW standard wheat by the Australian Wheat Board. This means that no more than one vetch seed per 0.5 L grain sample is allowed. Contamination above this level would result in the grain being rejected.

Photo 1: *Vetch tares in a paddock.*

Photo: Peter Teasdale

Cultivated varieties of vetch are easier to control as they are not as hard-seeded as their wild relatives. Germination percentages of cultivated varieties are relatively high and with the correct timing of herbicide application can be well controlled. [6]

New common vetch varieties (Morava⒣ and Rasina⒣) are soft seeded varieties and have no potential to be a weed in subsequent crops. However, older varieties like Blanchefleur and Languenoc have 5–20% hard seeds and can potentially be a weed in the following 2–3 years.

6.2 Integrated weed management

Weeds present one of the largest costs to grain growers and are one of the biggest influences on the management of cropping systems. Their impact is multifaceted; they affect yield and management across all seasons, and sometimes crop price. In addition, the weed challenge faced by growers is constantly evolving, with changes in weed types and their characteristics, such as herbicide resistance, requiring the ongoing adaptation of management.

The Grains Research and Development Corporation (GRDC) supports integrated weed management. Download the Integrated Weed Management Manual.

Integrated weed management (IWM) is a system for managing weeds over the long term, particularly the management and minimisation of herbicide resistance. There is a need to combine herbicide and non-herbicide methods into an integrated control

6 A Chambers in GRDC. Groundcover Issue 16: All vetches aren't equal. https://grdc.com.au/resources-and-publications/groundcover/ground-cover-issue-16/all-vetches-arent-equal

MORE INFORMATION

Weed management as a key driver of crop agronomy

program. Given that there are additional costs associated with implementing IWM, the main issues for growers are whether it is cost-effective to adopt the system and whether the benefits are likely to be long-term or short-term in nature.

The manual looks at these issues and breaks it down into seven clear sections, assisting the reader to make the development of an integrated weed management (IWM) plan a simple process.

Successful weed management requires a field by field approach. Knowledge of weeds and weedbank status, soil types as relevant to herbicide use as well as cropping and pasture plans are all critical parts of the picture. Knowledge of paddock history and how much summer and winter weeds have been subjected to selection to resistance (and to which herbicide modes of action) can also assist.

When resistance has been identified, knowledge of which herbicides still work becomes critically valuable information.

The following 5-point plan will assist in developing a management plan in each and every paddock.

1. Review past actions and history
2. Assess current weed status
3. Identify weed management opportunities
4. Match opportunities and weeds with suitably effective management tactics
5. Combine ideas into a management plan. Use of a rotational plan can assist [7]

An integrated weed management plan should be developed for each paddock or management zone.

In an IWM plan, each target weed is attacked using tactics from several tactic groups (see links below). Each tactic provides a key opportunity for weed control and is dependent on the management objectives and the target weed's stage of growth. Integrating tactic groups reduces weed numbers, stops replenishment of the seedbank and minimises the risk of developing herbicide-resistant weeds.

IWM tactics

- Reduce weed seed numbers in the soil
- Controlling small weeds
- Stop weed seed set
- Reduce weed seed numbers in the soil
- Hygiene - prevent weed seed introduction
- Agronomic practices and crop competition

Successful weed management also relies on the implementation of the best agronomic practices to optimise crop growth. Basic agronomy and fine-tuning of the crop system are the important steps towards weed management.

There are several agronomic practices that improve crop environment and growth, along with the crop's ability to reduce weed competition. These include crop choice and sequence, improving crop competition, planting herbicide tolerant crops, improving pasture competition, using fallow phases and controlled traffic or tramlining. [8]

6.2.1 Monitoring weeds

Record the key broadleafed and grass weed species for summer and winter and include an assessment of weed density, with notes on weed distribution across the paddock (Photo 2). Include GPS locations or reference to spatial location of any key weed patches or areas tested for resistance.

7 GRDC. Integrated weed management hub. https://grdc.com.au/Resources/IWMhub

8 DAFWA. (2016). Crop weeds: Integrated Weed Management (IWM). https://www.agric.wa.gov.au/grains-research-development/crop-weeds-integrated-weed-management-iwm

Include any data, observations or information relating to the known or suspected herbicide resistance status of weeds in this paddock. Add this information to paddock records.

Photo 2: *Scout for weeds throughout the year so that control can be applied at the optimal times.*

Source: Take Action

6.2.2 IWM in the Northern region

Broad-scale herbicide resistance is continuing to spread through the GRDC Northern Region. Growers can choose from a range of chemical and non-chemical integrated weed management tactics that delay or prevent resistance developing or control herbicide resistant weeds.

Major weeds of the northern grains region include feathertop rhodes grass, windmill grass, flaxleaf fleabane, awnless barnyard and liverseed grasses, common sowthistle, wild oats, wild radish and annual ryegrass.

Weeds cause economic losses in various ways, usually by reducing crop yields or contaminating harvested grain. Weeds use soil moisture during a fallow or cropping period, resulting in less moisture being available for the following crop.

Weed competition for moisture may result in poor crop establishment and growth, therefore reducing crop yield potential. For example, chickpea seedlings are poor competitors and even relatively low densities of Group A-resistant wild oats in chickpeas can reduce yields significantly.

Weed seed contamination of harvested grain can result in either seed grading being required or discounts on contaminated grain.

Tactic Group 1 – Deplete weed seed in the soil seedbank

Burning residues, insect predation, inversion ploughing, autumn tickle, delayed sowing.

Tactic Group 2 – Kill weeds (seedlings)

Fallow cultivation, herbicides (knockdown, double-knock, pre-emergent, post-emergent), wide rows (band spraying, inter-row cultivation), spot spraying, wick wipers, chipping, weed detector spraying, biological control.

Tactic Group 3 – Stop weed seed set

In-crop weed management (spray-topping, crop-topping, wick wipers, desiccation and windrowing), pasture spray topping, silage and hay, manuring, mulching, hay freezing, grazing.

Tactic Group 4 – Prevent viable weed seeds being added to the soil seedbank

Weed seed control at harvest (narrow header trail, chaff cart, bale direct), grazing residues.

MORE INFORMATION

GRDC Integrated Weed Management hub

Costs of key Integrated Weed Management tactics in the Northern region

VIDEOS

WATCH: Double knock application – a Grower's Experience.

WATCH: IWM: Double knock – Northern region

Tactic Group 5 – On-farm hygiene

Sow weed-free seed, manage weeds in non-crop areas, clean machinery, livestock movement, monitoring following flood events. [9]

6.2.3 Double knock

A double knock approach is generally a fallow operation where two weed control tactics with different modes of action are applied within a period of usually four to 14 days to a single flush of weeds to control survivors from the first application, thereby stopping seed set. The second tactic, or knock, may also include cultivation, heavy grazing or burning as an alternative to a herbicide. This tactic is commonly used in fallow situations, but could be used in-crop.

The most common double knock approach is to apply a systemic herbicide (for example, Groups A, I or M) when conditions are favourable for maximum translocation, followed by a contact herbicide (for example, Group L). The intervals for maximum effectiveness will depend on the type of herbicide used, weed species being targeted, the size and age of weeds, temperature and moisture conditions. Higher water rates are often used for the second knock (100 L/ha). Double knock is more expensive than a single herbicide application and may not need to be applied every year. Conduct a paddock herbicide resistance risk assessment first.

Advantages:

- Minimises seed set.
- Delays the development of glyphosate and other mode of action herbicide resistance.
- Reduces the number of glyphosate resistant weeds to be controlled in-crop.
- May improve pre-sowing weed control, very useful for minimum or zero tillage systems.

Practicalities:

- Translocated herbicide should be applied first, followed by paraquat or a paraquat and diquat mixture.
- Time between applications will vary with the main target weed species.
- Identify the weed species being targeted to determine the most cost-effective chemistry. [10]

6.2.4 Herbicides explained

Herbicides should be regarded as part of an integrated weed control strategy within the cropping rotation as it is generally easier, more effective and cheaper to use selective herbicides to remove grassy weeds in broadleaved crops and broadleaved weeds in cereal crops.

When selecting a herbicide, it is important to know crop growth stage, weeds present and plant-back period. For best results, spray weeds while they are small and actively growing. Herbicides must be applied at the correct stage of crop growth, or significant yield losses may occur. Check product labels for up-to-date registrations and application methods.

Residual and non-residual

Residual herbicides remain active in the soil for an extended period (months) and can act on successive weed germinations. Residual herbicides must be absorbed through the roots or shoots, or both. Examples of residual herbicides include imazapyr, chlorsulfuron, atrazine and simazine.

9 F Scott, T Cook. (2016). Costs of key integrated weed management tactics in the Northern region. NSW DPI. http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0010/678997/Costs-of-key-iwm-tactics-in-the-northern-region.pdf

10 F Scott, T Cook. (2016). Costs of key integrated weed management tactics in the Northern region. NSW DPI. http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0010/678997/Costs-of-key-iwm-tactics-in-the-northern-region.pdf

The persistence of residual herbicides is determined by a range of factors including application rate, soil texture, organic matter levels, soil pH, rainfall/irrigation, temperature and the herbicide's characteristics. Persistence of herbicides will affect the enterprise's sequence (a rotation of crops). Non-residual herbicides, such as the non-selective paraquat and glyphosate, have little or no soil activity and they are quickly deactivated in the soil. They are either broken down or bound to soil particles, becoming less available to growing plants. They also may have little or no ability to be absorbed by roots.

Post-emergent and pre-emergent

These terms refer to the target and timing of herbicide application. Post-emergent refers to foliar application of the herbicide after the target weeds have emerged from the soil, while pre-emergent refers to application of the herbicide to the soil before the weeds have emerged. [11]

Herbicides have been classified into a number of 'groups'. The group refers to the way a chemical works – their different chemical make-up and mode of action. [12]

Getting the best results from herbicides

1. Control weeds as early as possible in the first six weeks after sowing.
2. Make sure that the crop and weeds are at the correct growth stage for the herbicide to be used.
3. Do not spray outside the recommended crop growth stages as damage may result.
4. Do not spray when the crop or weeds are under any form of stress such as drought, water logging, extreme cold, low soil fertility, disease or insect attack, or a previous herbicide.
5. Some herbicides should not be used when weeds are wet with rain or dew or if rain is likely to occur within three or four hours.
6. Do not spray in windy conditions (over 10 - 15 km/hour) as drift from herbicides can cause damage to non-target crops. Herbicide spray can also drift in very calm conditions, especially with air temperature inversions. For more information on conditions for spraying, see Section 6.3 Conditions for spraying, below.
7. Use sufficient water to ensure a thorough, uniform coverage regardless of the method of application.
8. Use good quality water. Hard, alkaline or dirty water can reduce the effectiveness of some herbicides.
9. Maintain clean, well-cared for equipment. A poorly maintained spray unit will cost you money in breakdowns, blocked jets, poor results and perhaps worse, crop damage through misapplication.
10. After products such as Atlantis®, chlorsulfuron, Hussar® metsulfuron or triasulfuron have been used in equipment, it is essential to clean that equipment thoroughly with chlorine before using other chemicals. After using Affinity®, Broadstrike® or Eclipse® decontaminate with liquid alkali detergent.
11. Seek advice before spraying recently released pulse varieties. They may differ in their tolerance to herbicides. [13]

6.3 Conditions for spraying

When applying herbicides, the aim is to maximise the amount reaching the target and to minimise the amount reaching off-target areas. This results in:

- improved herbicide effectiveness

VIDEOS

WATCH: Over the Fence North: Weed and nutrient research delivers at Silverton.

WATCH: GCTV17: Herbicide partnership.

11 GRDC Integrated weed management, Section 4: Tactics for managing weed populations, https://grdc.com.au/resources-and-publications/iwmhub

12 Agriculture Victoria. Monitoring Tools. http://agriculture.vic.gov.au/agriculture/farm-management/business-management/ems-in-victorian-agriculture/environmental-monitoring-tools/herbicide-resistance

13 Day, T., Day, H., Hawthorne, W., Mayfield, A., McMurray, L., Rethus, G., & Turner, C. (2008). Grain legume handbook. *GRDC: Canberra, ACT.*

- reduced damage and/or contamination of off-target crops and areas.

In areas where several agricultural enterprises coexist, conflicts can arise, particularly from the use of herbicides. All herbicides are capable of drift.

When spraying a herbicide, you have a moral and legal responsibility to prevent it from drifting and contaminating or damaging neighbours' crops and sensitive areas.

All grass herbicide labels emphasise the importance of spraying only when the weeds are actively growing under mild, favourable conditions (Photo 3). Any of the following stress conditions can significantly impair both uptake and translocation of the herbicide within the plant, likely resulting in incomplete kill or only suppression of weeds:

- moisture stress (and drought)
- waterlogging
- high temperature–low humidity conditions
- extreme cold or frosts
- nutrient deficiency, especially effects of low N
- use of pre-emergent herbicides that affect growth and root development; i.e. simazine, Balance®, trifluralin, and Stomp®
- excessively heavy dews resulting in poor spray retentions on grass leaves

Photo 3: *Boom spray on crop.*

Source: DAFWA

Ensure that grass weeds have fully recovered before applying grass herbicides.

6.3.1 Minimising spray drift

Before spraying

- Always check for susceptible crops in the area, for example broadleaf crops such as grape vines, cotton, vegetables and pulses, if you are using a broadleaf herbicide.
- Check sensitive areas such as houses, schools, waterways and riverbanks.
- Notify neighbours of your spraying intentions.

The Cotton Field Awareness Map is provided free of charge with the purpose of minimising off-target damage from downwind pesticide application, particularly during fallow spraying. Users can also access the map to check the location of the paddock(s) they may be planning to spray to assess the proximity of the nearest cotton crop.

During spraying

- Always monitor weather conditions carefully and understand their effect on 'drift hazard'.
- Do not spray if conditions are not suitable, and stop spraying if conditions change and become unsuitable.
- Record weather conditions (especially temperature and relative humidity), wind speed and direction, herbicide and water rates, and operating details for each paddock.
- Supervise all spraying, even when a contractor is employed. Provide a map marking the areas to be sprayed, buffers to be observed and sensitive crops and areas.
- Spray when the temperature is less than 28°C.
- Where surface temperature inversion conditions exist, it is unsafe for spraying due to the potential for spray drift.
- Maintain a downwind buffer. This may be in-crop, for example keeping a boom's width from the downwind edge of the field.
- Minimise spray release height.
- Use the largest droplets that will give adequate spray coverage.
- Always use the least-volatile formulation of herbicide available.
- If there are sensitive crops in the area, use the herbicide that is the least damaging.

6.3.2 Types of drift

Sprayed herbicides can drift as droplets, as vapours or as particles:

- *Droplet drift* is the easiest to control because, under good spraying conditions, droplets are carried down by air turbulence and gravity, to collect on plant or soil surfaces. Droplet drift is the most common cause of off-target damage caused by herbicide application. For example, spraying of fallows with glyphosate under the wrong conditions often leads to severe damage to establishing crops.
- *Particle drift* occurs when water and other herbicide carriers evaporate quickly from the droplet, leaving tiny particles of concentrated herbicide. This can occur with herbicide formulations other than esters. This form of drift has damaged susceptible crops up to 30 km from the source.
- *Vapour drift* is confined to volatile herbicides such as 2,4-D ester. Vapours may arise directly from the spray or evaporation of herbicide from sprayed surfaces. Use of 2,4-D ester in summer can lead to vapour drift damage of highly susceptible crops such as tomatoes, cotton, sunflowers, soybeans and grapes. This may occur hours after the herbicide has been applied.

In 2006, the Australian Pesticides and Veterinary Medicines Authority (APVMA) restricted the use of highly volatile forms of 2,4-D ester. The changes are now seen with the substitution of lower volatile forms of 2,4-D and MCPA. Products with lower 'risk' ester formulations are commonly labelled with LVE (low volatile ester). These formulations of esters have a much lower tendency to volatilise, but caution should remain as they are still prone to droplet drift.

Vapours and minute particles float in the airstream and are poorly collected on catching surfaces. They may be carried for many kilometres in thermal updraughts before being deposited.

Sensitive crops may be up to 10,000 times more sensitive than the crop being sprayed. Even small quantities of drifting herbicide can cause severe damage to highly sensitive plants.

6.3.3 Factors affecting the risk of spray drift

Any herbicide can drift. The drift hazard, or off-target potential, of a herbicide in a particular situation depends on the following factors:

- Volatility of the formulation applied. Volatility refers to the likelihood that the herbicide will evaporate and become a gas. Esters volatilise (evaporate), whereas amines do not.
- Proximity of crops susceptible to the particular herbicide being applied, and their growth stage. For example, cotton is most sensitive to Group I herbicides in the seedling stage.
- Method of application and equipment used. Aerial application releases spray at 3 m above the target and uses relatively low application volumes, while ground-rigs have lower release heights and generally higher application volumes, and a range of nozzle types. Misters produce large numbers of very fine droplets that use wind to carry them to their target.
- Size of the area treated. The greater the area treated the longer it takes to apply the herbicide. If local meteorological conditions change, particularly in the case of 2,4-D ester, then more herbicide is able to volatilise.
- Amount of active ingredient (herbicide) applied. The more herbicide applied per hectare, the greater the amount available to drift or volatilise.
- Efficiency of droplet capture. Bare soil does not have anything to catch drifting droplets, unlike crops, erect pasture species and standing stubbles.
- Weather conditions during and shortly after application. Changing weather conditions can increase the risk of spray drift.

Volatility

Many ester formulations are highly volatile compared with the non-volatile amine, sodium salt and acid formulations. Table 1 is a guide to the more common herbicide active ingredients that are marketed with more than one formulation.

Table 1: *Relative herbicide volatility.*

Form of active ingredient	Full name	Product example
Non-volatile		
Amine salts		
MCPA DMA	dimethylamine salt	MCPA 500
2,4-D DMA	dimethylamine salt	2,4-D Amine 500
2,4-D DEA	diethanolamine salt	2,4-D Low Odour® 500
2,4-D IPA	isopropylamine salt	Surpass® 300
2,4-D TIPA	triisopropanolamine salt	Tordon® 75-D
2,4-DB DMA	dimethylamine salt	Buttress®
dicamba DMA	dimethylamine salt	Kamba 500
triclopyr TEA	triethylamine salt	Tordon® RegrowthMaster
picloram TIPA	triisopropanolamine salt	Tordon® 75-D
clopyralid DMA	Dimethylammonium salt	Lontrel® Advanced
clopyralid TIPA	triisopropanolamine salt	Archer®
aminopyralid TIPA	triisopropanolamine salt	Hotshot®
Other salts		
MCPA Na salt	sodium salt	MCPA 250
MCPA Na/K salt	sodium & potassium salt	MCPA 250
dicamba Na salt	sodium salt	Cadence®

Form of active ingredient	Full name	Product example
Non-volatile		
Some volatility		
Esters		
MCPA EHE	ethylhexyl ester	LVE MCPA
MCPA IOE	isooctyl ester	LVE MCPA
triclopyr butoxyl	butoxyethyl ester	Garlon® 600
Picloram IOE	isooctyl ester	Access®
2,4-D ehe	ethylhexyl ester	2,4-D LVE 680
fluroxypyr M ester	Methyl heptyl ester	Starane® Advanced

Source: NSW DPI

Minimising drift

A significant part of minimising spray drift is the selection of equipment to reduce the number of small droplets produced. However, this in turn may affect coverage of the target, and therefore the possible effectiveness of the pesticide application. This aspect of spraying needs to be carefully considered when planning to spray.

As the number of smaller droplets decreases, so does the coverage of the spray. A good example of this is the use of air-induction nozzles that produce large droplets that splatter. These nozzles produce a droplet pattern and number unsuitable for targets such as seedling grasses that present a small vertical target.

In 2010, APVMA announced new measures to minimise the number of spray drift incidents (Table 2). The changes are restrictions on the droplet-size spectrum an applicator can use, wind speed suitable for spraying and the downwind buffer zone between spraying and a sensitive target. These changes should be evident on current herbicide labels. Hand-held spraying application is exempt from these regulations.

Table 2: *Nozzle selection guide for ground application.*

Factor	Distance downwind to susceptible crop is <1 km	Distance downwind to susceptible crop is 1–30 km and more
Risk	High	Medium
Preferred droplet size (to minimise risk)	coarse to very coarse	medium to coarse
Volume median diameter (microns)	310	210
Pressure (bars)	2.5	2.5
Flat fan nozzle size #	11008	11004
Recommended nozzles (examples only)	Raindrop: Whirljet® Air induction: Yamaho Turbodrop® Hardi Injet® AI Teejet® LurmarkDrift-beta®	Drift reduction: DG TeeJet® Turbo TeeJet® Hardi® ISO LD 110 Lurmark® Lo-Drift
Caution	Can lead to poor coverage and control of grass weeds Requires higher spray volumes	Suitable for grass control at recommended pressures Some fine droplets

Volume median diameter (VMD): 50% of the droplets are less than the stated size and 50% greater.

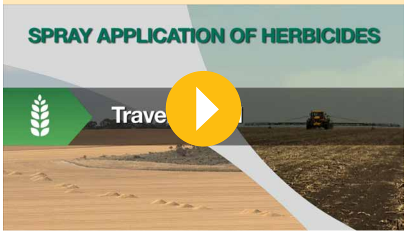
Refer to manufacturer's selection charts, as range of droplet sizes will vary with recommended pressure. Always use the lowest pressure stated to minimise the small droplets.

Source: DPI NSW

VIDEOS

WATCH: Nozzle Selection

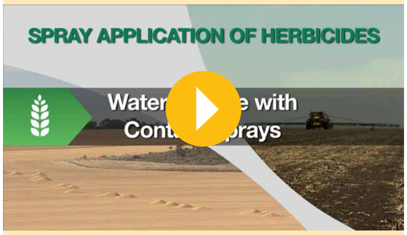
WATCH: Travel Speed



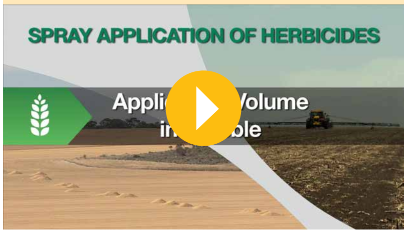
VIDEOS

WATCH: Spray deposition

WATCH: Water volume with contact sprays



WATCH: Application volume in stubble



Spray release height

- Operate the boom at the minimum practical height. Drift hazard doubles as nozzle height doubles. If possible, angle nozzles forward 30° to allow lower boom height with double overlap. Lower heights, however, can lead to more striping, as the boom sways and dips below the optimum height.
- 110° nozzles produce a higher percentage of fine droplets than 80° nozzles, but they allow a lower boom height while maintaining the required double overlap.
- Operate within the pressure range recommended by the nozzle manufacturer. Production of driftable fine droplets increases as the operating pressure is increased.

Size of area treated

When large areas are treated, greater amounts of active herbicide are applied and the risk of off-target effects increases due to the length of time taken to apply the herbicide. Conditions such as temperature, humidity and wind direction may change during spraying.

Application of volatile formulations to large areas increases the chances of vapour drift damage to susceptible crops and pastures.

Capture surface

Targets vary in their ability to collect or capture spray droplets. Well grown, leafy crops are efficient collectors of droplets. Turbulent airflow normally carries spray droplets down into the crop within a very short distance.

Fallow paddocks or seedling crops have poor catching surfaces. Drift hazard is far greater when applying herbicide in these situations or adjacent to these poor capture surfaces.

The type of catching surface between the sprayed area and susceptible crops should always be considered in conjunction with the characteristics of the target area when assessing drift hazard.

Weather conditions to avoid

Turbulence

- Updrafts during the heat of the day cause rapidly shifting wind directions. Spraying should be avoided during this time of day.

Temperature

- Avoid spraying when temperatures exceed 28°C.

Humidity

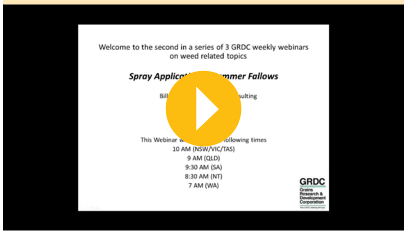
- Avoid spraying under low relative humidity conditions; i.e. when the difference between wet and dry bulbs exceeds 10°C.
- High humidity extends droplet life and can greatly increase the drift hazard under inversion conditions. This results from the increased life of droplets smaller than 100 microns.

Wind

- Avoid spraying under still conditions.
- Ideal safe wind speed is 3–10 km/h, a light breeze (when leaves and twigs are in constant motion).
- A moderate breeze of 11–14 km/h is suitable for spraying if using low-drift nozzles or higher volume application, say 80–120 L/ha. (Small branches move, dust is raised and loose paper is moving.)

VIDEOS

WATCH: Advances in weed management—Webinar 2—Spray application in summer fallows



MORE INFORMATION

Surface temperature inversions and spraying factsheet

Inversions

The most hazardous condition for herbicide spray drift is an atmospheric inversion, especially when combined with high humidity. An inversion exists when temperature increases with altitude instead of decreasing. An inversion is like a cold blanket of air above the ground, usually less than 50 m thick. Air will not rise above this blanket, and smoke or fine spray droplets and particles of spray deposited within an inversion will float until the inversion breaks down.

Do not spray under inversion conditions.

Inversions usually occur on clear, calm mornings and nights. Windy or turbulent conditions prevent inversion formation. Blankets of fog, dust or smoke and the tendency for sounds and smells to carry long distances indicate inversion conditions.

Smoke generators or smoky fires can be used to detect inversion conditions. Smoke will not continue to rise but will drift along at a constant height under the inversion 'blanket'. [14]

6.4 Pre-emergent herbicides

Pre-emergent herbicides control weeds between radicle (root shoot) emergence from the seed and seedling emergence through the soil. Some pre-emergent herbicides may also provide post-emergent control. This is the most effective way to control broadleaf weeds in vetch.

Good knowledge of possible weed burdens will help identify potential vetch paddocks and herbicides that may need to be applied prior to crop emergence. [15]

6.4.1 Incorporation by sowing

Incorporation by sowing (IBS) is when a herbicide is applied just before sowing (usually in conjunction with a knockdown herbicide such as glyphosate and soil throw from the sowing operation incorporates the herbicide into the seedbed.

Application of pre-emergent herbicides pre-sowing and then incorporating them into the seed bed during the sowing process will often increase safety to crops because the sowing operation removes a certain amount of herbicide away from the seed row. This can conversely reduce weed control for the very same reason, as chemical is moved out of the seed row. In this case, it is wise to include a water soluble herbicide into the mix aiming to have some herbicide wash into the seed furrow.

The preferred method of applying pre-emergent herbicides in conservation farming systems is by incorporation by sowing, as crop safety is maximised, stubble remains standing to protect the seedbed, and soil disturbance is minimised.

In vetch, Trifluralin should be incorporated by sowing and provides a range of broadleaf and grass control when used in combination with post-sowing, pre-emergent applications of Metribuzin. [16]

6.4.2 Benefits and issues for pre-emergent herbicides

- The residual activity of pre-emergent herbicides controls the first few flushes of germinating weeds while the crop or pasture is too small to compete.
- Good planning is needed to use pre-emergent herbicides as an effective tactic. It is necessary to consider weed species and density, crop or pasture type, soil condition and rotation of crop or pasture species.
- Soil activity and environmental conditions at the time of application play an important role in the availability, activity and persistence of pre-emergent herbicides.

14 A Storrie (2015) Reducing herbicide spray drift. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/content/agriculture/pests-weeds/weeds/images/wid-documents/herbicides/spray-drift

15 R Matic (2010) Vetch summary 2010. SARDI. Online Farm Trials. http://www.farmtrials.com.au/trial/14055

16 R Matic (2010) Vetch summary 2010. SARDI. Online Farm Trials. http://www.farmtrials.com.au/trial/14055

- Both the positive and negative aspects of using pre-emergent herbicides should be considered in the planning phase. [17]

The important factors in getting pre-emergent herbicide to work effectively while minimising crop damage are:

- to understand the position of the weed seeds in the soil; the soil type (particularly amount of organic matter and crop residue on the surface);
- the solubility of the herbicide; and
- its ability to be bound by the soil.

6.4.3 Understanding pre-emergent herbicides

With the increasing incidence of resistance to post-emergent herbicides across Australia, pre-emergent herbicides are becoming more important for weed control. Pre-emergent herbicides typically have more variables that can affect efficacy than post-emergent herbicides. Post-emergent herbicides are applied when weeds are present and usually the main considerations relate to application coverage, weed size and environmental conditions that impact on performance. Pre-emergent herbicides are applied before the weeds germinate and a number of other considerations come into play. The various pre-emergent herbicides behave differently in the soil and may behave differently in different soil types. Therefore, it is essential to understand the behaviour of the herbicide, the soil type and the farming system in order to use pre-emergent herbicides in the most effective way.

Pre-emergent herbicides have to be absorbed by the germinating seedling from the soil. To do so, these herbicides need to have some solubility in water and be in a position in the soil to be absorbed by the roots or emerging shoot. The dinitroaniline herbicides, such as trifluralin, are an exception in that they are absorbed by the seedlings as a gas. These herbicides still require water in order to be released from the soil as a gas. Therefore, weed control with pre-emergent herbicides will always be lower under dry conditions.

6.4.4 Behaviour of pre-emergent herbicides in the soil

Behaviour of pre-emergent herbicides in the soil is driven by three key factors:

- solubility of the herbicide,
- how tightly the herbicide is bound to soil components, and
- the rate of breakdown of the herbicide in the soil.

Characteristics of some common pre-emergent herbicides are given in Table 3.

The water solubility of herbicides ranges from very low values for trifluralin to very high values for chlorsulfuron. Water solubility influences how far the herbicide will move in the soil profile in response to rainfall events. Herbicides with high solubility are at greater risk of being moved into the crop seed row by rainfall and potentially causing crop damage. If the herbicides move too far through the soil profile they risk moving out of the weed root zone and failing to control the weed species at all. Herbicides with very low water solubility are unlikely to move far from where they are applied.

17 DAFWA. (2016) Herbicides. https://www.agric.wa.gov.au/herbicides/herbicides?page=0%2C2

Table 3: *Water solubility, binding characteristics to soil organic matter and degradation half-life for some common pre-emergent herbicides.*

Herbicide	Water solubility		Koc		Degradation half-life (days)
	mg L-1 (at 20 C and neutral pH)	Rating	mL g-1 (in typical neutral soils)	Rating	
Trifluralin	0.22	Very low	15,800	Very high	181
Pendimethalin	0.33	Very low	17,800	Very high	90
Pyroxasulfone	3.9	Low	223	Medium	22
Triallate	4.1	Low	3000	High	82
Prosulfocarb	13	Low	2000	High	12
Atrazine	35	Medium	100	Medium	75
Diuron	36	Medium	813	High	75.5
S-metolachlor	480	High	200	Medium	15
Triasulfuron	815	High	60	Low	23
Chlorsulfuron	12,500	Very High	40	Low	160

Source: University of Adelaide

The important factors in getting pre-emergent herbicides to work effectively while minimising crop damage are: to understand the position of the weed seeds in the soil; the soil type (particularly amount of organic matter and crop residue on the surface); the solubility of the herbicide; and its ability to be bound by the soil. Managing all these factors is complex, but some rules of thumb are:

1. Soils with low organic matter are particularly prone to crop damage from pre-emergent herbicides (especially sandy soils) and rates should be reduced where necessary to lower the risk of crop damage.
2. The more water-soluble herbicides will move more readily through the soil profile and are better suited to post sowing pre-emergent applications than the less water soluble herbicides. They are also more likely to produce crop damage after heavy rain.
3. Pre-emergent herbicides need to be at sufficient concentration at or below the weed seed (except for triallate which needs to be above the weed seed) to provide effective control. Keeping weed seeds on the soil surface will improve control by pre-emergent herbicides.
4. High crop residue loads on the soil surface are not conducive to pre-emergent herbicides working well as they keep the herbicide from contact with the seed. More water soluble herbicides cope better with crop residue, but the solution is to manage crop residue so that at least 50% of the soil surface is exposed at the time of application.
5. If the soil is dry on the surface, but moist underneath there may be sufficient moisture to germinate the weed seeds, but not enough to activate the herbicide. Poor weed control is likely under these circumstances. The more water soluble herbicides are less adversely affected under these conditions.
6. Many pre-emergent herbicides can cause crop damage. Separation of the product from the crop seed is essential. In particular care needs to be taken with disc seeding equipment in choice of product and maintaining an adequate seeding depth. [18]

18 Preston C. (2014). Understanding pre emergent cereal herbicides. https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2014/03/understanding-pre-emergent-cereal-herbicides

MORE INFORMATION

[Using pre-emergent herbicides in conservation farming systems.](#)

[Gearing up to use pre-emergent herbicides.](#)

[GRDC Pre-emergent herbicides Factsheet.](#)

[How pre-emergent herbicides work.](#)

[Seeding systems and pre emergence herbicides](#)

Top tips for using pre-emergent herbicides:

- Only use pre-emergent herbicides as part of an integrated weed control plan including both chemical and non chemical weed control practices.
- Preparation starts at harvest. Minimise compaction and maximise trash spreading from the header
- Minimise soil disturbance allowing weed seeds to remain on the soil surface.
- Leave stubble standing rather than laying it over.
- Knife points and press wheels allow greatest crop safety. Avoid harrows.
- If using a disc seeder understand the mechanics of your machine and the limitations it may carry compared to a knife point and press wheel.
- Pay attention to detail in your sowing operation and ensure soil throw on the inter row whilst maintaining a seed furrow free from herbicide.
- Ensure the seed furrow is closed to prevent herbicide washing onto the seed.
- IBS rather than PSPE for crop safety.
- Understand herbicide chemistry. Choose the right herbicide in the right paddock at the right rate. [19]

6.5 Post-plant pre-emergent herbicides

Post-sowing, pre-emergent herbicides use is when a pre-emergent herbicide is applied after sowing (but before crop emergence) to the seedbed.

Post-plant pre-emergent herbicides are primarily absorbed through the roots, but there may also be some foliar absorption.

When applied to soil, best control is achieved when the soil is flat and relatively free of clods and trash. Sufficient rainfall (20–30 mm) to wet the soil through the weed root-zone is necessary within 2–3 weeks of application. Best weed control is achieved from Pre-sowing, Pre-emergence application because rainfall gives the best incorporation. Mechanical incorporation pre-sowing is less uniform, and so weed control may be less effective. If applied pre-sowing and sown with minimal disturbance, incorporation will essentially be by rainfall after application. Weed control in the sowing row may be less effective because a certain amount of herbicide will be removed from the crop row.

6.6 In-crop herbicides: knock downs and residuals

It is important to consider growth stage in making herbicide management decisions (Table 4).

A number of herbicides are registered for controlling grass weeds in vetch. These herbicides include Shogun, Fusilade Forte, Targa and Verdict.

Many weed populations have some tolerance to post-emergent herbicides.

19 Haskins B. DPI NSW. Using pre-emergent herbicides in conservation farming systems. http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0003/431247/Using-pre-emergent-herbicides-in-conservation-farming-systems.pdf

Table 4: *Herbicides registered for weed control in vetch in the Northern region. Group A*

Active ingredient	Notes
butroxydim	Do not graze or cut for stock food for 14 days after application
fluazifop	Do not graze or cut for stock food for 21 days after application or remove stock from treated area 7 days before slaughter
haloxyfop	Broadleaf herbicides should not be added to products containing haloxyfop. Apply products containing haloxyfop and broadleaf herbicides at least a week apart. Do not graze or cut for stock food for 28 days after application
propaquizafop	Do not graze or cut for stock food for 3 days after application
quizalofop	Do not harvest for 12 weeks after application Do not graze or cut for stock food for 28 days after application

Source: NSW DPI

*Note: For pulses, the window for application for selective grass control herbicides (Group As) is generally dictated by regulatory requirements to avoid residues in produce that exceed levels acceptable to various markets. Check the labels for individual herbicides but pulse crop safety for most Group As is not influenced by growth stage up to at least flowering.

For up to date registrations, chemical Witholding Periods and other label information, see the APVMA search facility.

6.6.1 Application

Key points:

- Knowledge of a product's translocation and formulation type is important for selecting nozzles and application volumes.
- Evenness of deposit is important for poorly or slowly translocated products.
- Crop growth stage, canopy size and stubble load should influence decisions about nozzle selection, application volume and sprayer operating parameters.
- Robust rates of products and appropriate water rates are often more important for achieving control than the nozzle type, but, correct nozzle type can widen the spray window, improve deposition and reduce drift risk.
- Travel speed and boom height can affect control and drift potential.
- Appropriate conditions for spraying are always important. [20]

In-crop herbicides will normally require a different set of nozzles compared to those used in summer fallow spraying and application of pre-emergent herbicides.

In-crop post-emergent herbicides should be applied as an upper-end medium to lower-end coarse droplet spectrum depending on the particular herbicide being used.

Remember that this must be combined with the relevant application volume to get enough droplets per square centimetre on the target to achieve good coverage. You must also match the nozzles to your spray rig, pump and controller and desired travel speed.

Operate within the recommended ground speed range and apply the product in a higher application volume. The actual recommended application volume will vary with the product and situation, so read the label and follow the directions.

20 GRDC Factsheets: In-crop herbicide use. (2014). https://grdc.com.au/GRDC-FS-InCropHerbicideUse

MORE INFORMATION

Weed control in Winter crops

GRDC In-crop herbicide use Factsheet.

Pre-harvest herbicide use factsheet

GRDC-funded trials http://www.farmtrials.com.au/trial/13574

How to get the most out of post-emergent herbicides:

Consider application timing—the younger the weeds the better. Frequent crop monitoring is critical.

Consider the growth stage of the crop.

- Consider the crop variety being grown and applicable herbicide tolerances.
- Know which species were historically in the paddock and the resistance status of the paddock (if unsure, send plants away for a 'Quick-Test').
- Do not spray a crop stressed by waterlogging, frost, high or low temperatures, drought or, for some chemicals, cloudy/sunny days. This is especially pertinent
- for frosts with grass-weed chemicals.
- Use the correct spray application:
- Consider droplet size with grass-weed herbicides, water volumes with contact chemicals and time of day.
- Observe the plant-back periods and withholding periods.
- Consider compatibility if using a mixing partner.
- Add correct adjuvant. [21]

6.7 Herbicide tolerance ratings, NVT

Vetch is tolerant to most grass-selective herbicides and intolerant of herbicides residues from cropping phase, particularly sulfonylurea herbicides.

Vetch is susceptible to spray topping herbicides (Glyphosate, Paraquat & Diquat) as well as to most broad leaf herbicides that are used in cereal crops. [22]

Vetch is advantageous to cropping sequence as it can open up weed control options. They have useful tolerance to the triazine group of herbicides (e.g. atrazine). This enables vetch to be double-cropped after sorghum or maize provided that excessively high rates of atrazine have not been used in the preceding summer cereal. Any likelihood of crop damage to the vetch will be further minimised by only planting in situations where there is a reasonable profile of sub-soil moisture at planting (60 cm wet soil). [23]

6.8 Potential herbicide damage effect

Pulse crops can be severely damaged by some herbicides whether as residues in soil, contaminants in spray equipment, spray drift onto the crop or by incorrect use of the herbicide.

Some soil active herbicides used for weed control in pulses can damage crops where conditions favour greater activity and leaching.

6.8.1 Residues in Soil

Herbicides move more readily in soils with low organic matter and/or soils with more sand, silt or gravel. Herbicide movement is much less in soils with higher organic matter and higher clay contents. Damage from leaching is also greater where herbicides are applied to dry, cloddy soils than to soils which have been rolled and which are moist on top from recent rainfall.

Picloram (e.g. Tordon® 75-D) residues from spot-spraying can stunt any pulse crop grown in that area (Photo 4). In more severe cases bare areas are left in the crop where this herbicide has been used - in some cases more than five years previous. Although this damage is usually over a small area, correct identification

21 WeedSmart. Post-emergents. http://www.weedsmart.org.au/post-emergents/

22 R Matic, S Nagel, G Kirby (2008) Common Vetch. Pastures Australia. http://keys.lucidcentral.org/keys/v3/pastures/Html/Common_vetch.htm

23 DAF (2011) Vetches in southern Queensland. DAF QLD. https://www.daf.qld.gov.au/plants/field-crops-and-pastures/pastures/vetches

of the problem avoids confusion and concern that it may be some other problem such as disease.

Photo 4: *Chemical residues from previous years can cause problems. Tordon® was used here with plants in the affected area showing stunting.*

Source: Grain Legume Handbook

Residues of sulfonylurea herbicides can persist in some soils. These residues can last for several years, especially in more alkaline soils and where there is little summer rainfall. The pulses emerge and grow normally for a few weeks and then start to show signs of stress. Leaves become off-colour, roots may be clubbed, plants stop growing and eventually die.

Refer to the labels for recommendations on plant-back periods for pulses following use of any herbicides. [24]

6.8.2 Contamination of Spray Equipment

Traces of sulfonylurea herbicides (such as chlorsulfuron, metsulfuron or triasulfuron) in spray equipment can cause severe damage to legumes when activated by some of the grass control herbicides (Photo 5).

Always clean spray tanks and lines with chlorine, according to recommendations, after using sulfonylurea herbicides and before using these grass control herbicides. Traces of Affinity® can also damage pulse crops. Decontaminate with alkali detergent. [25]

24 Day, T., Day, H., Hawthorne, W., Mayfield, A., McMurray, L., Rethus, G., & Turner, C. (2008). Grain legume handbook. *GRDC: Canberra, ACT.*

25 Day, T., Day, H., Hawthorne, W., Mayfield, A., McMurray, L., Rethus, G., & Turner, C. (2008). Grain legume handbook. *GRDC: Canberra, ACT.*

Photo 5: *Hygiene between spraying operations is essential. After using Glean® or Ally® make sure the boom spray is cleaned out with chlorine before starting on grass control in legumes. The effect as shown is dramatic.*

Source: Grain Legume Handbook

6.8.3 Spray Drift

Pulse crops can be severely damaged by some hormone herbicide sprays, such as 2,4-D ester, drifting into the crop. This can happen when these sprays are applied nearby in very windy or still conditions, especially where there is an inversion layer of air on a cool morning. When using these herbicides spray when there is some wind - to mix the spray with the crop. Do not use excessively high spray pressure as this will produce too fine a spray, which is more likely to drift onto a neighboring pulse crop. [26]

6.8.4 Residual herbicides

Pulse growers need to be aware of:

- Possible herbicide residues impacting on crop rotation choices where rainfall has been minimal.
- Herbicide residues could possibly influence crop rotations more than disease considerations.
- Weed burden in the new crop will depend on the seed set from last year.
- Herbicide efficacy and crop safety of the new crop can suffer if the soil is dry at application time.

Herbicide breakdown

Herbicides applied to paddocks in previous years may not have broken down adequately because of insufficient rainfall. Summer rainfall is not necessarily as effective as growing season rainfall in breaking down herbicide residues, so needs to be substantial and to keep the soil wet for a specified time. Read the herbicide label. It will be extremely important to know the chemical type used, as well as the plant-back periods, and the soil pH, rainfall and other requirements for breakdown. Herbicides applied two years ago could still have an impact too, as could the presence of cereal stubble with herbicides like Lontrel®.

26 Day, T., Day, H., Hawthorne, W., Mayfield, A., McMurray, L., Rethus, G., & Turner, C. (2008). Grain legume handbook. *GRDC: Canberra, ACT.*

MORE INFORMATION

Residual herbicides and weed control.

Withholding periods for dicamba or similar 'spikes' to knockdown sprays used pre-sowing may need to be longer if there is no rainfall to activate chemical breakdown, otherwise poor establishment can occur. Note that dicamba plant-backs only commence after 15 mm of rain. Alternative products with lesser or no residual may be more appropriate (e.g. carfentrazone-ethyl, oxyfluorfen). In areas that receive minimal summer-autumn rains and delayed opening rains, then the herbicide residual effect becomes far more pressing on rotation choices. Pulse following cereal could then become a higher risk situation than pulse following a pulse. [27]

6.8.5 Avoiding herbicide damage

Select a herbicide which is necessary for the weed population you have. Make sure you consider what the recropping limitations may do to future rotation options. Read the herbicide label including the fine print.

Chemical users are required to keep good records, including weather conditions, but in the case of unexpected damage good records can be invaluable, particularly spray dates, rates, batch numbers, rainfall, soil type and pH (including different soil types in the paddock).

If residues could be present, choose the least susceptible crops (refer to product labels). Optimise growing conditions to reduce the risk of compounding the problem with other stresses such as herbicide spray damage, disease and nutrient deficiency. These stresses make a crop more susceptible to herbicide residues.

Be wary of compounding a residue problem by planting a herbicide resistant crop and spraying with more of the same herbicide group. You may get around the problem with residues in the short term, only to be faced with herbicide resistant weeds in the longer term.

Group B: The sulfonylureas (SU's).

The sulfonylureas persist longer in alkaline soils (pH > 7) where they rely on microbial degradation. Residual life within the sulfonylurea family varies widely with chlorsulfuron persisting for 2 or more years and not suitable for highly alkaline soils. Triasulfuron persists for 1–2 years and metsulfuron generally persists for less than 1 year. Legumes and oilseeds are most vulnerable to SU's.

Group B: The triazolopyrimidines (sulfonamides).

There is still some debate about the ideal conditions for degradation of these herbicides. However, research in southern Australia has shown that the sulfonamides are less likely to persist than the SU's in alkaline soils. Plant back periods should be increased in shallow soils.

Group B: The imidazolinones (IMI's).

The imidazolinones are very different from the SU's as the main driver of persistence is soil type, not soil pH. They tend to be more of a problem on acid soils, but carryover does occur on alkaline soils. Research has shown that in sandy soils, they can break down very rapidly (within 15 months in alkaline soils), but in heavy clay soils they can persist for several years. Breakdown is by soil microbes. Oilseeds are most at risk. Widespread use of imi-tolerant canola and wheat in recent years has increased the incidence of imidazolinone residues.

Group C: The triazines.

Usage of triazines has increased to counter Group A resistance in ryegrass and because of high rates used on Triazine Tolerant canola. Atrazine persists longer in soil than simazine. Both generally persist longer on high pH soils. Recent research in the US indicates that breakdown rates tend to increase when triazines are used regularly as the number of microbes able to degrade the herbicide can increase. This may

27 Pulse Australia. (2015). Australia Pulse Bulletin: Residual herbicides and weed control. http://www.pulseaus.com.au/growing-pulses/publications/residual-herbicides

MORE INFORMATION

Avoiding crop damage from residual herbicides

mean that breakdown can take an unexpectedly long time in soils that have not been exposed to triazines for some years.

Group I: The phenoxys.

2,4-D used for fallow weed control in late summer may cause a problem with autumn sown crops. There have been changes to the 2,4-D label recently and not all products can be used for fallow weed control – ensure to check the label.

The label recommends to avoid sowing sensitive crops, until after a significant rainfall event. Oilseeds and legumes are very susceptible to injury from 2,4-D. [28]

Group I: The pyridines.

Clopyralid and aminopyralid can be more risky on heavy soils and in conservation cropping as it can accumulate on stubble. Even low rates can cause crop damage up to two years after application. They cause twisting and cupping, particularly for crops suffering from moisture stress.

6.9 Herbicide resistance

Vetch hay as a crop in the farm rotation is one of the best methods to reduce herbicide resistance weeds and to avoid chemical contamination of paddocks.

Vetch provides non-selective weed control options for reducing the risk of herbicide resistant weeds in cropping phases (e.g. grazing, green/brown manuring, and hay production, spray-topping). [29]

Resistance characteristics:

- Resistance remains for many years, until all resistant weed seeds are gone from the soil seed bank
- Resistance evolves more rapidly in paddocks with frequent use of the same herbicide group, especially if no other control options are used.

Action points:

- Assess your level of risk with the online glyphosate resistance toolkit.
- Aim for maximum effectiveness in control tactics, because resistance is unlikely to develop in paddocks with low weed numbers.
- Do not rely on the same MoA group.
- Monitor your weed control regularly.
- Stop the seedset of survivors. [30]

Overuse of particular groups of herbicides can lead to herbicide resistance, especially in grass weeds. Broad-scale herbicide resistance is continuing to spread through the GRDC Northern Region (Photo 6). Effective grass control in the vetch crop has the benefit of reducing the need for selective grass herbicides in the following cereal year. [31]

28 Agriculture Victoria (2013) Avoiding crop damage from residual herbicides. http://agriculture.vic.gov.au/agriculture/farm-management/chemical-use/agricultural-chemical-use/chemical-residues/managing-chemical-residues-in-crops-and-produce/avoiding-crop-damage-from-residual-herbicides

29 R Matic, S Nagel, G Kirby (2008) Common Vetch. Pastures Australia. http://keys.lucidcentral.org/keys/v3/pastures/Html/Common_vetch.htm

30 QDAF (2015) Stopping herbicide resistance in Queensland. Queensland Department of Agriculture and Fisheries, https://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/weed-management-in-field-crops/herbicide-resistance

31 W Hawthorne (2007) Lupins in South Australia and Victoria. Pulse Australia. http://www.pulseaus.com.au/storage/app/media/crops/2007_Lupins-SA-Vic.pdf

Photo 6: *2,4-D resistant radish, Wongan Hills.*

Photo A Storrie, Source: GRDC

Survey work in the region has identified over 70 different weed species that impact on grain production and over 10% of these weed species have confirmed populations within Australia that are resistant to glyphosate and several other chemical modes of action (MOA) (Table 5).

Table 5: *Confirmed herbicide resistance in weed populations found in NSW and Queensland.*

Mode of Action	Resistant weeds
A (fops, dims, dens)	wild oats, paradoxa grass, annual ryegrass
B (SUs, imis etc)	annual ryegrass, wild oats, paradoxa grass, Indian hedge mustard, charlock, wild radish, turnip weed, African turnip weed, common sowthistle, black bindweed
C (triazines, ureas, amides etc)	awnless barnyard grass, liverseed grass
D (DNAs, benzamides etc)	annual ryegrass
I (phenoxys, pyridines etc)	wild radish
L (bipyridyls i.e. diquat, paraquat)	flaxleaf fleabane
M (glycines i.e. glyphosate)	annual ryegrass, awnless barnyard grass, liverseed grass, windmill grass, feathertop Rhodes grass, sweet summer grass, flaxleaf fleabane, common sowthistle
Z (dicarboxylic acids etc)	wild oats

Source: adapted from a table prepared by M Widderick, DAF, in WeedSmart

6.9.1 Why do weeds develop resistance?

Resistant weeds are naturally present in most paddocks in low numbers, even if herbicides have not been applied. Weeds not controlled by a herbicide application are either spray escapes or are naturally resistant survivors. If the resistant weeds set seed, the proportion of resistant weeds in the paddock increases. Resistant weeds will eventually dominate the population if high selection pressure is continued by repeatedly using the same herbicide group (Figure 1). Once a weed population is resistant to a herbicide it is also resistant to other herbicides with the same mode of action. Changing brand names will not control these weeds. Be aware of the mode of action group of the product, and use different chemical modes of action. Multiple resistance (to more than one mode of action) has developed in some weed populations of annual ryegrass and wild radish.

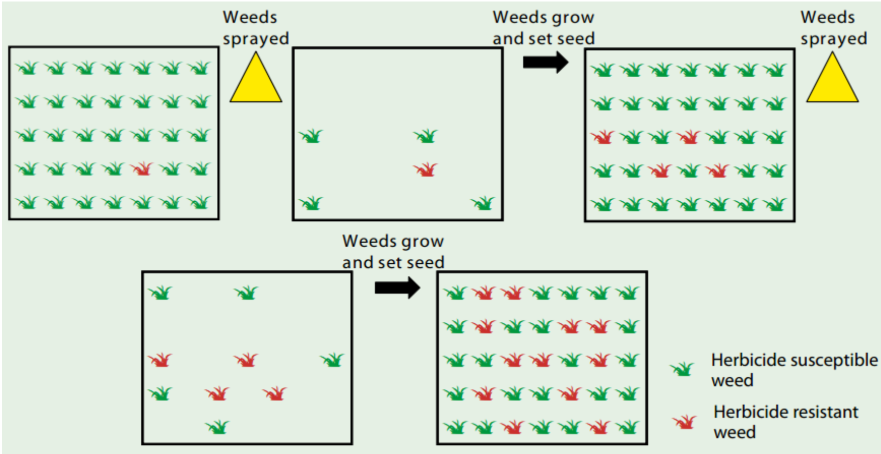


Figure 1: *Resistant weeds are naturally present in most paddocks and can dominate the population if a different herbicide mode of action or another form of weed control is not used to control them.*

Source: NSW DPI

Once resistance has developed in a paddock it will be impossible to totally eradicate all the resistant individuals. It will be necessary to adopt an IWM plan that keeps the numbers of resistant individuals at very low levels in future crops. The rate at which herbicide resistance appears in a population is affected by the selection pressure placed on the population, the initial frequency of the resistance gene and the total number of weeds treated. Resistance may develop in one location under certain conditions but may not develop in another location under similar conditions. [32]

Although growers are making good use of chemical strategies such as double knock, residual herbicides, spot spraying and weed sensing technology to preserve herbicide efficacy, there is an urgent need to investigate non-chemical options that can be added to a weed management program to target resistant weeds in the Northern region.

To avoid herbicide resistance, weed management through the rotation should minimise the need for herbicides. Avoid overuse of any one chemical group, use the least selective herbicide, and avoid the need to spray high weed populations.

6.9.2 Non-herbicide weed control in the Northern region

Diversity in cropping systems and diversity in weeds in the GRDC Northern Region calls for diversity in weed management solutions, which includes the utilisation of non-herbicide tactics.

Weeds researchers recognise that although growers are making good use of chemical strategies such as double-knock, residual herbicides, spot spraying and weed-sensing technology to preserve the efficacy of herbicides for as long as possible, there remains an urgent need to investigate non-chemical options that can be added to a weed management program to target resistant weeds, as outlined in the WeedSmart 10 Point Plan.

MORE INFORMATION

Weed control in central-west NSW – Herbicide resistance.

32 A Johnson, N Border, B Thompson, A Storrie (2007) Weed control in central west NSW – Chapter 7: Herbicide resistance. NSW DPI. http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0007/154726/Weed-control-for-cropping-and-pastures-in-central-west-NSW-Part-8.pdf

Strategic tillage

Most growers are keen to preserve their zero- or minimum-till farming systems because they have delivered significant benefits, and are understandably reluctant to re-introduce cultivation to control weeds. Research is under way to investigate ways to use cultivation that will have maximum effect on driving down weed numbers while having least impact on minimum-till farming. The aim of this research is to investigate the impact of different types of tilling where the weed population has blown out and intensive patch or paddock management is required.

For the research team, the key was to understand weed ecology, particularly how seed in the soil seedbank responds to different types of cultivation. The team used small plots to determine the effect of burying weed seeds on their persistence (long-term viability after burial in soil) and emergence. They also experimented to determine the displacement of seed throughout the cultivated zone using four different types of machine compared to a zero-till control.

Sowthistle emergence occurs primarily from seeds close to the soil surface, with up to 30% of viable seeds emerging over five months. Seed can emerge from a depth of up to 2 cm, with approximately 4% emergence after six months. Seed buried below 5 cm is unable to emerge, but still remains viable.

Seed persistence in fleabane was most reduced when seed was buried to 2 cm and let undisturbed for at least two years. Seed buried to a depth of 10 cm remained viable for over three years.

Feathertop Rhodes grass seed persisted for only 12 months regardless of being left on the surface or buried to 10 cm.

Barnyard grass however, persisted on the soil surface for up to two years, and when buried to 10 cm depth remained viable for over three years.

The Gyral machine placed the majority of weed seed in the 0–2 cm and 2–5 cm zones while the offset discs and one-way discs achieving burial of about half the seed below 5 cm depth.

All species responded to increased tilling intensity with reduced germinations. The message from this research is that infrequent but intense cultivation can be a useful weed-management tool within an otherwise zero-till system. Generally, once a paddock has been deeply cultivated there should be no cultivation of that area or paddock for at least four years so as to avoid the risk of bringing seed back to the soil surface.

Strategic burning

Feathertop Rhodes grass is known to colonise around mature plants, and may spread from here to form distinct weedy patches. Once it gets this big, killing the large plant at the centre of the colony is usually not possible using chemical treatments.

In this situation, the strategic burning of early infestations can effectively reduce the biomass of the part of the colony that survives and reduce the amount of viable seed present on the soil surface from 7,500 seeds/m^2 to less than 500 seeds/m^2. Growers have made effective use of a flame-thrower to burn large feathertop Rhodes grass plants during the fallow (Photo 7).

MORE INFORMATION

Non-herbicide weed control in the Northern region

Managing herbicide resistance in northern NSW

Photo 7: *Strategic burning of feathertop Rhodes grass in a fallow can be an effective way of reducing the biomass of the survivor plant and of reducing the amount of viable seed on the soil surface.*

Source: WeedSmart

Crop competition

Using crop competition by planting with a narrower row spacing and or greater planting density provides an effective offensive against common weeds. However, the effect of crop competition on its own, in commercial situations, would have to be used in conjunction with herbicide. [33]

Managing brown manure pulse crops in southern NSW

Key points:

- Brown manuring can form part of a strategy to manage herbicide resistance.
- It boosts soil nitrogen while conserving moisture for the next crop.
- Cereal diseases, such as take-all and crown rot, can be reduced through use of break crops.
- The timing of spray application is determined by the target weeds.
- The value of a pulse needs to be considered in the context of the whole rotation.

Brown manuring of pulse crops is becoming an increasingly popular tool for weed management, particularly where there is herbicide resistance, and for boosting reserves of soil nitrogen for use by the following crop.

Brown manure cropping involves growing a pulse crop to spray out using a knockdown herbicide to prevent weed seed set and maximise nitrogen fixation. This is different to green manuring, where the crop and weeds are killed by cultivation.

There are three key reasons for brown manuring pulses: to help manage weeds, particularly if there is herbicide resistance present, to boost soil nitrogen and to conserve soil moisture for subsequent crops. Some growers in southern NSW have had difficulty in marketing pulses in recent years or have experienced damage to legume hay. These factors have influenced growers to consider including brown manured crops in a rotation, rather than leaving pulses out altogether.

Anecdotal evidence suggests 20,000 or more hectares of vetch has been sown within the southern NSW system for brown manuring, hay or seed. Morava(D and Blanchefleur are the most common vetch varieties but growers are now moving to the earlier, higher yielding variety Volga(D. Brown manuring also brings further benefits of addition of soil nitrogen from N_2 -fixation, extra soil moisture storage as a result of the earlier "fallow" and a more protective mulch cover over the summer period.

33 WeedSmart (2017) Non-herbicide weed control in the Northern Region. WeedSmart, http://www.weedsmart.org.au/bulletin-board/non-herbicide-weed-control-in-the-northern-region/

MORE INFORMATION

[Brown manuring pulses on acidic soils in southern NSW- is it worth it?]

[Strategic risk management]

[Farm business management: making effective business decisions]

VIDEOS

WATCH: [Act now: Plan your weed management program]

To use brown manuring for weed control, pulse crops must be desiccated at or before the milky dough stage of the target weeds. This is usually at or before the flat pod stage of the pulse, well before the crop's peak dry matter production. At this stage, the crop is growing at its maximum rate – about 80 to 100 kilograms of DM per hectare per day – and so the amount of nitrogen fixed will be reduced in proportion to its growth stage at desiccation. [34]

6.9.3 Ten-point plan to weed out herbicide resistance

WeedSmart has developed a 10-point plan that farmers can use to protect the longevity of chemicals and slow down the development of resistance. [35]

1. Act now to stop weed seedset

Creating a plan of action is an important first step in integrated weed management.

- Destroy or capture weed seeds.
- Understand the biology of the weeds present.
- Remember that every successful weed-smart practice can reduce the weed seedbank over time.
- Be strategic and committed: herbicide resistance management is cannot just happen over one year, but over many years.
- Research and plan a weed-smart strategy.
- Growers may have to sacrifice yield in the short term to manage resistance.

2. Capture weed seeds at harvest

Destroying or capturing weed seeds at harvest is the number one strategy for combating herbicide resistance and driving down the weed seedbank. There are several ways to do this:

- Tow a chaff cart behind the header.
- Use an Integrated Harrington Seed Destructor (Photo 8). [36]
- Create and burn narrow windrows.
- Produce hay where suitable.
- Funnel seed onto tramlines in controlled-traffic farming (CTF) systems.
- Use a green or brown manure crop to achieve 100% weed control and build soil nitrogen levels.

Controlling weed seeds at harvest is emerging as the key to managing the increasing levels of herbicide resistance, which is putting Australia's no-till farming system at risk.

Photo 8: *Integrated Harrington weed-seed destructor at work in the paddock.*

Source: Michael Walsh

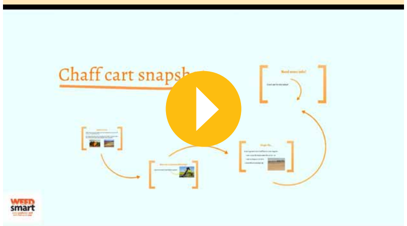
34 GRDC. (2013). Managing brown manure crops in southern NSW – Factsheet.

35 WeedSmart. Ten-point plan. WeedSmart, http://weedsmart.org.au/10-point-plan/

36 A Roginski (2012) Seed destructor shows its national potential. Ground Cover. No. 100. GRDC, https://grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-issue-100/Seed-destructor-shows-its-national-potential

VIDEOS

WATCH: Chaff carts 101

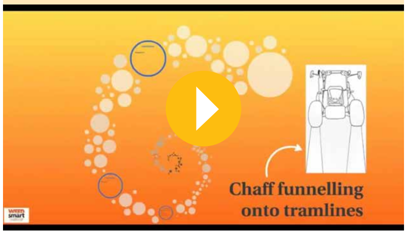


WATCH: Capture weed seeds at harvest: Harrington seed destructor

WATCH: Strategic narrow windrow burning

WATCH: The art of narrow windrow burning

WATCH: Chaff funneling onto tramlines



For information on harvest weed-seed control and its application, see Section 12: Harvest.

3. Rotate crops and herbicide modes of action

Crop rotation is beneficial to farming systems. Make sure weed management is part of the decision when planning crop rotation. Crop rotation offers many opportunities to use different weed control tactics, both herbicide and non-herbicide, against different weeds at different times. Rotating crops also gives farmers a range of intervention opportunities. For example, growers can; crop-top vetch and other pulses, windrow canola, and delay sowing some crops.

Rotations that include both broadleaf crops (e.g. pulses and oilseeds) and cereals allow the use of a wider range of tactics and chemistry.

Growers also have the option of rotating to non-crop options, e.g. pastures and fallows.

Within the rotation it is also important to not repeatedly use herbicides from the same MOA group. Some crops have fewer registered-herbicide options than others, so this needs to be considered too, along with the opportunities to use other tactics, such as the control of harvest weed seed, in place of one or more herbicide applications.

4. Test for resistance to establish a clear picture of paddock-by-paddock status

- Before harvest, sample weed seeds and resistance test to determine effective herbicide options. One such service is provided by Plant Science Consulting.
- Use the 'quick test' option to test emerged ryegrass plants after sowing to determine effective herbicide options before applying in-crop selective herbicides.
- Collaborate with researchers by collecting weeds for surveys
- Visit WeedSmart for more information on herbicide-resistance survey results.

It is clearly too late to prevent the evolution of resistance to many common herbicides. However, a resistance test when something new is observed on the farm can be very useful in developing a plan to contain the problem, and in developing new strategies to prevent this resistance evolving further.

Perhaps the best use for herbicide-resistance tests is to use them to determine if a patch of surviving weeds are worse than what the grower may have observed before. Take a GPS recording of the site location of potentially resistant weeds. These weeds may give insight into the future resistance profile of the farm if it is not contained and resistance testing in these situations can be very useful in building preventative strategies.

5. Never cut the rate

The Australian Herbicide Resistance Initiative (AHRI) has found that ryegrass being sprayed at below the advised rate of Sakura® evolved resistance not only to Sakura® but to Boxer Gold® and Avadex® too. To avoid this problem occurring:

- Use best management practice in spray application: apply according to the directions on the label.
- Consider selective weed sprayers.

VIDEOS

WATCH: Capture weed seeds at harvest: Bale Direct System

WATCH: IWM: Weed seed vdestruction—Beer can height

WATCH: Crop rotation with Colin McAlpine

WATCH: Test for resistance to establish a clear picture of paddock-by-paddock farm status

6. Don't automatically reach for glyphosate

Glyphosate has long been regarded as the world's most important herbicide, so it's common for growers to reach for it at the first sign of weeds. Resistance to this herbicide is increasing rapidly, and in some areas it may fail completely. This can be due to too much reliance on one herbicide group, giving the weed opportunity to evolve resistance.

Instead, introduce paraquat products when dealing with smaller weeds, and for a long-term solution farm with a very low seedbank. Also:

- Use a diversified approach to weed management.
- Consider post-emergent herbicides where suitable.
- Consider strategic tillage.

7. Carefully manage spray events

It's important to set up spray gear to maximise the amount of herbicide that directly hits the target. This makes the spray application more cost-effective by killing the maximum number of weeds possible, and it also protects other crops and pastures from potential damage and/or contamination.

Spray technology has improved enormously in the last 10 years, making it far easier for growers to get herbicides precisely where they need to be. Also, many herbicide labels specify the droplet spectrum to be used when applying the herbicide.

As a general rule, medium to coarse droplet size combined with higher application volumes provides better coverage of the target. Using a pre-orifice nozzle slows droplet speed so that droplets are less prone to bouncing off the target.

Using oil-based adjuvants with air-induction nozzles can reduce herbicide deposition by reducing the amount of air in the droplets. These droplets then fail to shatter when they hit the target, which increases droplet bounce.

- Stop resistant weeds from returning into the farming system.
- Focus on management of survivors in fallows.
- Where herbicide failures occur, do not let the weeds seed. Consider cutting for hay or silage, fallowing or brown manuring the paddock.
- Patch-spray areas of resistant weeds only if appropriate.

8. Plant clean seed into clean paddocks with clean borders

With herbicide resistance increasing, planting clean seed into clean paddocks with clean borders has become a top priority. Controlling weeds is easiest before the crop is planted. Once weeds have been controlled in a paddock plant weed-free crop seed to prevent the introduction of new weeds and the spread of resistant ones.

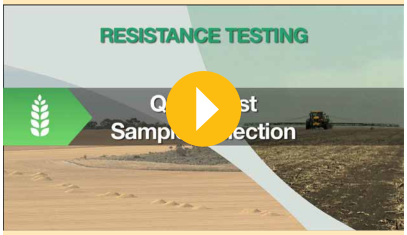
Introducing systems that increase farm hygiene will also prevent new weed species and resistant weeds. These systems could include crop rotations, reducing weed burdens in paddocks or a harvest weed-seed control such as the Harrington Seed Destructor or windrow burning.

Lastly, roadsides and fence lines are often a source of weed infestations. Weeds here set enormous amounts of seed because they have little competition, so it's important to control these initial populations by keeping clean borders.

- It is easier to control weeds before the crop is planted.
- Plant weed-free crop seed to prevent the introduction of new weeds and the spread of resistant weeds.
- An AHRI survey showed that 73% of grower-saved crop seed was contaminated with weed seed.
- The density, diversity and fecundity of weeds are generally greatest along paddock borders and areas such as roadsides, channel banks and fence lines.

VIDEOS

WATCH: IWM: Resistance Testing—'Quick-Test' sample collection



WATCH: IWM: Seed test—What's involved

WATCH: Don't cut the rate

WATCH: Don't automatically reach for glyphosate

WATCH: Manage spray drift

9. Use the double-knock technique

The benefits of the double-knock technique is in combining two weed-control tactics with different modes of action, on a single flush of weeds. These two 'knocks' happen sequentially, with the second application being designed to control any survivors from the first.

One such strategy is the glyphosate–paraquat double-knock. These two herbicides use different MOAs to eliminate weeds and so make an effective team when paired. When using this combination ensure the paraquat rate is high. The best time to initiate this double-knock is after rainfall. New weeds will quickly begin to germinate and should be tackled at this small stage.

10. Employ crop competitiveness to combat weeds

There are numerous ways that growers can increase the competitive ability of crops against weeds:

- Consider narrow row spacing and increasing seeding rates.
- Consider twin-row seeding points.
- Consider east-west crop orientation.
- Use triticale and varieties that tiller well.
- Use high-density pastures as a rotation option.
- Consider brown-manure crops.
- Rethink bare fallows.

6.9.4 Suspected resistant weeds

As soon as resistance is suspected, growers should contact their local agronomist. The following steps are then recommended.

First, consider the possibility of other common causes of herbicide failure by asking:

- Was the herbicide applied in conditions and at a rate that should kill the target weed?
- Did the suspect plants miss herbicide contact or emerge after the herbicide was applied?
- Does the pattern of surviving plants suggest a spray miss or other application problem?
- Has the same herbicide or herbicides with the same MOA been used in the same field or in the general area for several years?
- Has the uncontrolled species been successfully controlled in the past by the herbicide in question or by the current treatment?
- Has a decline in the control been noticed in recent years?
- Is the level of weed control generally good on the other susceptible species?

If resistance is still suspected:

- Contact crop and food-science researchers in your state agricultural department for advice on sampling suspect plants for testing of resistance status..
- Ensure all suspect plants do not set seed.
- If resistance is confirmed, develop a management plan for future years to reduce the impact of resistance and likelihood of further spread. [37]

37 DAF Qld (2015) Stopping herbicide resistance in Queensland. DAF Queensland, https://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/weed-management-in-field-crops/herbicide-resistance

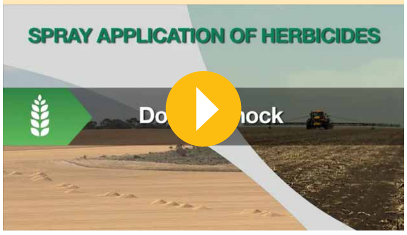
VIDEOS

WATCH: Plant clean seed into clean paddocks with clean borders

WATCH: Best results with double-knock tactic

WATCH: Double-knock application—a grower's experience

WATCH: Spray application of herbicides—Double-knock



Testing services

For testing of suspected resistant samples, contact:

- Charles Sturt University Herbicide Resistance Testing
  School of Agricultural and Wine Sciences Charles Sturt University
  Locked Bag 588
  Wagga Wagga, NSW 2678
  Phone (02) 6933 4001
- Charles Sturt University's Graham Centre weed research group
- Plant Science Consulting
  22 Linley Avenue, Prospect
  SA 5082
  email: info@plantscienceconsulting.com.au
  Phone: 0400 664 460

MORE INFORMATION

CropLife Australia

Australian Glyphosate Sustainability Working Group

Australian Herbicide Resistance Initiative

Cotton Info, Weed pack

Managing herbicide resistance in Northern NSW