HERBICIDE BEHAVIOUR FACT SHEET

GRDC™ GRAINS RESEARCH & DEVELOPMENT CORPORATION

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Optimising Group A herbicides in canola

Group A herbicides were first commercialised in Australia in the early to mid 1980s.

In the absence of herbicide resistance, these herbicides quickly and effectively shut down growth of small grass weeds. This removes competition within days of application, despite often taking a number of weeks for herbicide symptoms to become visible.

Several different Group A herbicides are used in Australia. Those that are registered for use in broadleaf crops such as canola are from the aryloxyphenoxypropionate (fop) or cyclohexanediones (dim) sub-classes. Other Group A herbicides used in certain cereal crops are not covered in this Fact Sheet.

After 30 years of commercial use, many populations of the main winter grass weeds such as annual ryegrass, brome grass or wild oats in cropping paddocks are resistant to one or more of these herbicides. Resistance varies significantly by paddock, and possibly even within the paddock. In some situations, herbicide performance is only marginally compromised, and a robust application rate may still provide acceptable control. More frequently, some Group A herbicides are now ineffective and others, while compromised, may still be able to provide some level of control.

As there is often a lack of alternative post-emergent herbicide options, many users continue to apply Group A herbicides to these compromised populations. This Fact Sheet addresses the key factors that should be considered in order to maximise performance.

PHOTO: CHRIS PRESTON

Group A herbicides are a key tool for post-emergent control of volunteer cereals and grass weeds in canola.

KEY POINTS

- Herbicide resistance in winter grass weeds is compromising performance in many paddocks.
- Conduct a resistance test to know which Group A herbicides are still effective.
- Correct application timing is critical for maximising efficacy while minimising potential for crop injury and residues in grain. Target small weeds, early in the crop.
- Environmental conditions can affect herbicide performance, especially frost prior to herbicide application.

Examples of Group A herbicides used in canola

Sub-group	Active ingredient	Example
Aryloxyphenoxypropionates (fops)	fluazifop	Fusilade®
	haloxyfop	Verdict®
	propaquizafop	Shogun®
	quizalofop	Targa®
Cyclohexanediones (dims)	butroxydim	Factor®
	clethodim	Select®
	sethoxydim	Sertin®

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Factors that influence Group A herbicide performance in canola

WEED SIZE, TIMING AND TRANSLOCATION

Group A herbicides work by inhibiting cell production of acetyl co-enzyme A carboxylase (ACCase) in susceptible weeds. This is a key enzyme required by the plant for production of fatty lipids used in the construction of new cell walls. As such, it is produced in high quantities in the crown of grass weeds where cell division is occurring. Small, actively growing grasses that are rapidly producing new cells have a high demand for ACCase and therefore are most susceptible to Group A herbicides.

To be effective, Group A herbicides need to translocate from the point of entry in the leaf, down to the crown of the plant, where ACCase is produced. Due to the chemical properties of these herbicides, the majority of applied herbicide remains trapped within leaf cells, with only a small amount reaching the crown of the plant (Congreve and Cameron (2018) provides more detail on the mechanisms involved).

Additionally, while translocating down to the crown of the plant, other metabolic enzymes within the plant can break down (detoxify) some of the herbicide before it reaches the crown.

For these reasons, small weeds will be better controlled by Group A herbicides. They have higher levels of ACCase production relative to the size of the plant and the physical distance between leaf entry and the crown of the plant is less, thus reducing the opportunity for the herbicide to be trapped in cells, or be metabolised, before reaching the crown of the plant.

ADJUVANTS AND APPLICATION

Leaf entry is assisted by oil-based adjuvants. Some Group A herbicide formulations may have adjuvants built into the formulation, although most recommend a crop oil concentrate or esterified vegetable oil adjuvant be tank mixed. Always follow label advice for the appropriate adjuvant recommendation for each herbicide.

While Group A herbicides are systemic, performance is usually

PHOTO: TOM BICKNELL

7 to 10 days following an effective Group A herbicide application, the primary tiller of grass weeds such as annual ryegrass detaches and can be easily removed.

enhanced where high levels of leaf coverage are achieved. Oil-based adjuvants that contain higher concentrations of non-ionic surfactant in the adjuvant blend frequently perform better with Group A herbicides.

As good coverage is important, a medium to coarse spray quality, with water volumes above 70 litres/hectare, will provide the best results. With small grass weeds, some droplets landing on the leaf may also run down closer to the crown (meristematic region) and hence have shorter distance to translocate.

Performance of dim herbicides can be adversely affected when using water with elevated levels of bicarbonate. Pre-conditioning high bicarbonate water with ammonium sulphate may help to reduce these detrimental effects.

ENVIRONMENTAL CONDITIONS

Translocation to the crown of the grass weed is critical for control. Environmental conditions that slow or stop translocation in the plant are detrimental to performance. Poor soil moisture or too much soil water (temporary waterlogging) will reduce herbicide translocation.

As these herbicides are often applied in mid winter, frost can also place environmental stress on the plant and thereby reduce translocation. A worst-case scenario occurs where translocation has stopped, and no herbicide is moving to the crown of the plant, but metabolism continues to occur and the herbicide continues to be broken down in the plant. Thus, when conditions improve and translocation recommences, there is less active herbicide available for weed control.

Research conducted by the University of Adelaide (see table below) tested one susceptible and three clethodim-resistant populations of annual ryegrass when exposed to frost for three nights before or three nights after a clethodim application, and compared results to where no frost occurred.

For all populations, frost occurring either before or after application required slight to significantly higher application rates to achieve the same level of control of the population not affected by frost. Frost occurring before application was more detrimental to herbicide performance. The impact of frost, especially frost occurring before application, became increasingly significant as resistance levels increased.

Increase in dose rate required to achieve 50% control of the population, compared to the susceptible population without frost.
Adapted from Saini et al. (2016).

	No frost	Frost for 3 nights before spraying	Frost for 3 nights after spraying
Population VLR1 (susceptible[1])		1.3x[#]	1.1x
Population 48-12 (moderate resistance[2])	1.6x	1.7x	1.7x
Population 571-12 (strong resistance[3])	8.6x	23.7x	10.6x

[#] 1.3x indicates that 1.3 times the dose rate is required to achieve the same level of control as the susceptible population without frost i.e. an increase of 30%.

Resistance status was determined by separately testing populations for resistance by applying 350 mL/ha Select® (84 gai/ha) + Hasten® in the absence of frost: [1] All plants were controlled [2] 20% resistance [3] 90% resistance

HERBICIDE RESISTANCE

Reduced performance due to Group A herbicide resistance is common in many winter grass weeds. There are many different genetic mechanisms involved, which makes results often unpredictable and potentially confusing. The mechanism(s) that confer resistance in one paddock are often different to that on a neighbour's farm, or even between paddocks on the same farm. For self-pollinating species (e.g. wild oats) it is possible that resistance patterns can be quite different between patches within the same paddock.

The only way to truly understand which Group A herbicides may still be effective against an individual population is to conduct a resistance test. Commercial testing services are provided by:

Plant Science Consulting http://www.plantscienceconsulting.com.au/ or

Charles Sturt University https://www.csu.edu.au/plantinteractionsgroup/herbicide-resistance

For Group A herbicides, target-site mutations are a very common resistance mechanism. There are currently several known locations within the target site where an amino acid substitution results in Group A resistance.

A substitution occurring at one of these locations may affect individual Group A herbicides differently. A substitution may completely block binding of a particular Group A herbicide, or it may only reduce the strength of binding and hence provide weaker resistance. The specific substitution may only affect an individual herbicide, it may affect a whole sub-class or may affect all the Group A herbicides.

In annual ryegrass, selection for target-site resistance to the fop sub-class often results in high levels of resistance and tends to be selected quicker than resistance for the dims. However, this generalisation does not always hold true, as exceptions can occur in individual populations. To try to extract more years of effective weed management from the Group A herbicides, it has been common to use fop herbicides until they fail, and then switch to dim herbicides. For some of the more common target site resistance mechanisms this may result in additional years of control from the dim herbicides, until further resistance mechanisms are selected.

Some target-site substitutions only provide low-level resistance to the Group A herbicides, particularly with dim herbicides. Where this low-level resistance occurs, it may be possible to achieve a level of control by increasing application rates, within constraints of the label. For example, original clethodim labels supported use rates as low as 150 mL/ha of a 240 g/L formulation (36 gai/ha) for control of annual ryegrass. Over time, typical use rates increased to 250 mL/ha (60 gai/ha) as low-level resistance emerged and many labels were further increased to 500 mL/ha (120 gai/ha).

Non target-site resistance is also present in many weed populations, with several mechanisms potentially involved. For Group A herbicides, weeds with enhanced ability to metabolise the herbicide before it reaches the target-site is common, especially with the fop sub-class.

Weed populations that have enhanced metabolism in conjunction with a target-site substitution, or multiple target-site substitutions, are likely to be very difficult to control, regardless of application rate. These populations are becoming increasingly common.

PHOTO: GRDC

Targeting high weed burdens with Group A herbicides will rapidly select for resistance. Incorporate additional tactics, such as harvest weed seed control, to manage any survivors.

What is target-site herbicide resistance?

When a herbicide reaches its site of activity in a susceptible plant (the target-site), it binds at that location. This disrupts the critical enzyme process that normally occurs at that location, resulting in plant death.

Binding at the target-site occurs in association with specific amino acids that are located at the binding site. Typically, several amino acids are involved.

Through random genetic mutation it is possible that a plant may have a different amino acid substituted at one of these specific locations. If that change in amino acid prevents the herbicide from being able to bind to the target-site, then the weed may survive. Over time, if the same herbicide is continually used and the progeny that contain this genetic change are allowed to survive and are not removed by other weed management tactics they will come to dominate the population, and the population will be considered to have been selected for target-site resistance.

TANK MIX PARTNERS

Users often want to mix other pesticides in the spray tank. This may be to broaden the spectrum of weed control or to increase efficiency of farm operations, e.g. the desire for one sprayer pass applying many pesticides simultaneously.

It is generally possible to obtain advice regarding the physical compatibility of mixtures, i.e. will the products react and cause separation or coagulation resulting in nozzle blockages? Where information is not available, a simple jar test at proposed concentrations can often give useful understanding of potential for physical compatibility problems.

Biological interactions between different products are often more complex and is unlikely to be visually evident at application. Positive interactions between products is often desired, a good example being the benefit obtained from adding adjuvants. For Group A herbicides, an oil-based adjuvant with a high loading of surfactant assists leaf coverage and penetration.

Of concern are negative interactions whereby the products react with each other in the spray tank, reduce leaf penetration, reduce translocation or increase speed of metabolism within the plant. Any of these interactions can result in reduced performance.

Group A herbicide labels generally indicate known negative interactions, while also listing pesticide partners that are compatible. Exercise caution when tank mixing. The research on compatible mixtures is often historic and was conducted on weeds that were 'susceptible' to the herbicide. At that time, Group A herbicides were very robust, and any negative interaction may not have been detected or deemed to be 'acceptable', as the applied rate was able to mask any antagonism and weed control was not compromised. When targeting resistant populations, and robust control is unlikely, negative interactions with other products are more likely to be magnified. When targeting suspected resistant populations with Group A herbicides, it is advisable to apply the Group A herbicide alone, with the recommended adjuvant. This avoids any possible negative interactions, while also ensuring correct application timing, i.e. broadleaf herbicides or fungicide tank mixes are usually applied later in the crop, so waiting for this timing results in larger grass weeds which will be more difficult to control.

Tank mixing two different Group A herbicides has been common practice in some locations. Individual Group A herbicides have different strengths and weaknesses across the grass weed spectrum. This often resulted in a tailored mix of a fop and a dim, especially where there was a broad range of grass weeds in the paddock.

As resistance to Group A herbicides became more common, mixing has been used to improve performance. For example, as fop herbicides started to be compromised from resistance, adding clethodim often masked the developing fop resistance issue, by providing control of fop resistant individuals.

More recently, some users have been able to improve performance on certain populations of annual ryegrass with low-level clethodim resistance by applying mixtures of clethodim and butroxydim. Research has shown this strategy to be effective on many, but not all, populations. Results will depend on the specific resistance profile of the individual population, so resistance testing should be undertaken before implementing this strategy.

It is also important to note that the maximum registered rate for clethodim in canola is 60 or 120 gai/ha (depending on individual labels) and 20 gai/ha for butroxydim, due to canola safety considerations. The clethodim plus butroxydim mixing strategy may be more effective in winter pulses, where higher rates of butroxydim can be used.

CROP GROWTH STAGE

Where pre-emergent herbicides are not used, winter grass weeds typically germinate with crop emergence or soon after. In these situations, best results will be achieved by targeting Group A herbicides at small seedling or early tillering weeds, with the canola crop typically at the early rosette growth stage.

Where grass weed pressure is high, or Group A resistance is known to be present and Group A herbicides alone cannot be relied on, it is now very common for growers to use a pre-emergent herbicide to reduce early weed pressure at crop establishment. Pre-emergent herbicide strategies, while usually very effective at protecting crop yield, rarely achieve 100% weed control, leaving enough weeds for weed seedbank replenishment. Some weeds may escape the pre-emergent herbicide treatment, or the pre-emergent herbicide may 'run-out' before canopy closure, resulting in late germinations. Often one or both scenarios may see users want to apply a Group A herbicide later in the crop.

Response of 17 field collected annual ryegrass populations from Western Australia treated in 2018 with clethodim, butroxydim and a mixture of clethodim plus butroxydim. *(Roberto Busi pers. com. 2019).*

	Susceptible (<5% resistant individuals)	Developing resistance (6-20% resistant individuals)	Resistant (>20% resistant individuals)	Average % survival across 17 populations	Most resistant population (% survival)
	Number of populations				
Butroxydim @ 25 gai/ha	13	3	1	4%	38%
Clethodim @ 60 gai/ha	8	3	6	19%	78%
Butroxydim 25 gai/ha + clethodim 60 gai/ha	17	0	0	0.7%	5%

Butroxydim applied as Factor® WG (250 g/kg butroxydim) @ 100 g/ha. **Note: these results are from pot tests without crop. The maximum registered rate for Factor WG in canola is 80 g/ha (20 gai/ha).** Clethodim applied as Sequence® (240 g/L clethodim) @ 250 mL/ha.

These 17 populations were collected from focus paddocks which had been implementing harvest weed seed control and other best management practices for annual ryegrass control. As such, the resistance status may have been less significant than average farms.

Clethodim damage in canola.

Clethodim damage to canola flowers resulting in petal retention.

PHOTOS: MAURIE STREET.

Later applications of Group A herbicides can be problematic:

- Mixed weed sizes, and/or larger weeds will be more difficult to control, especially if herbicide resistance is present.
- Later applications may result in detectable herbicide residues at harvest, with the potential to violate maximum residue levels (MRLs).
- Later applications have the potential to cause flower damage/abortion and negatively impact yield.

Residues in grain – Later applications increase the possibility of herbicide residues remaining in the crop at harvest, potentially exceeding MRLs for export destinations. In particular, problems have occurred with late applications of haloxyfop in canola. As a result, the application timing for canola on the haloxyfop label was changed in 2016, with applications required to be made before the canola passes the eight-leaf growth stage, or the start of stem elongation should this occur before the eight-leaf stage. Under no circumstances should any Group A herbicide be applied under or on top of windrows at swathing.

Flower damage/abortion/petal retention – At higher application rates, clethodim and butroxydim can damage canola, especially when applied after stem elongation commences. This is particularly significant as application rates are increased. Refer to individual product labels for correct application timing.

Recommended application timing and associated maximum application rates differ for different clethodim labels. Read and adhere to label directions for the product you are using. Carefully monitor canola growth stage. Under certain environmental conditions, flower buds may initiate any time from about the 4-leaf growth stage onwards.

DO NOT apply any clethodim products after flower buds become visible (green bud stage).

The risk of crop injury is reduced where lower rates are applied (up to 60 gai/ha) and applications are made to rosette growth stages prior to commencement of stem elongation.

Effect of clethodim @ 120 gai/ha (500 mL/ha of 240 g/L clethodim) applied at different timings and rates on canola flower damage. *Hart, SA trials: Zerner and Wheeler (2013), Central NSW trials: Grain Orana Alliance (2017).*

Growth stage		Location	Variety	% flower damage
Early rosette	2-4 leaf	Parkes, NSW	44Y84 (CL)	+
	3-4 leaf	Coolah, NSW	44Y84 (CL)	3
	4 leaf	Hart, SA	ATR Gem	+
	4 leaf	Hart, SA	AV Garnet	+
	4 leaf	Hart, SA	474CL	+
	4-5 leaf	Wellington, NSW	44Y84 (CL)	+
	4-6 leaf	Peak Hill, NSW	44Y84 (CL)	3
Late rosette	8 leaf	Parkes, NSW	44Y84 (CL)	+
		Hart, SA	ATR Gem	+
		Hart, SA	AV Garnet	+
		Hart, SA	474CL	+
		Wellington, NSW	44Y84 (CL)	+
		Peak Hill, NSW	44Y84 (CL)	6
Elongation		Parkes, NSW	44Y84 (CL)	+
		Peak Hill, NSW	44Y84 (CL)	30
Bud initiation		Hart, SA	ATR Gem	10
		Hart, SA	AV Garnet	+
		Hart, SA	474CL	15
		Wellington, NSW	44Y84 (CL)	+
Early flowering		Parkes, NSW	44Y84 (CL)	+
		Coolah, NSW	44Y84 (CL)	5
		Peak Hill, NSW	44Y84 (CL)	7

\+ no visual difference to the untreated control
Shaded boxes signify >5% flower injury

FREQUENTLY ASKED QUESTIONS

What is the best choice of adjuvant for Group A herbicides?

Most of the commonly used Group A herbicides require tank mixing of a quality crop oil concentrate adjuvant or similar. For example, adjuvants such as Hasten® or Uptake® are often recommended. These adjuvants contain a robust level of surfactant to enhance spreading on the leaf surface plus an oil to assist leaf penetration. Always follow specific directions on the label of the Group A herbicide being used.

Additionally, when using dim herbicides and in particular clethodim, there may be benefit in pre-treating spray water with ammonium sulphate, especially where the water is high in bicarbonates.

The grass weeds in my canola crop are small and at the right size for clethodim application, although frosts are predicted for the next few nights. Should I apply now, or wait until the frost event passes when the weeds are likely to be larger?

This is a common scenario, with no simple answer. While clethodim is one of the most active Group A herbicides against ryegrass, its chemical properties dictate that it does not translocate well to the target site within the crown of the grass weed. Translocation of clethodim will be significantly better under warmer application conditions and against smaller weeds, where the physical distance required to translocate is less. Under frosty conditions at application, minimal clethodim reaches the target site and control can be reduced. This effect is magnified where clethodim resistance is present and especially where frosty conditions occur in the days leading up to application. There is little that can be done to address the lack of translocation under these conditions.

Always ensure application rates are robust and the optimal adjuvant and spray set up is chosen. Avoid tank mixing with other products. Addressing these factors with give the clethodim the best chance of translocating, but may still not be adequate to ensure reliable control under cold or frosty application conditions. Delaying application for a few days may be a viable option should forecasts indicate a substantially warmer period will occur in the near future. Although typically during mid-winter it is unlikely that there will be a substantial improvement in application conditions by delaying application for a few days.

RESOURCES

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MORE INFORMATION

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