Investigating glufosinate herbicide for annual ryegrass control

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Key findings

- Seasonal conditions at Hart and Hill River in 2023 were relatively dry from July through to Spring reducing emergence of annual ryegrass (ARG) populations. Trials conducted at these two sites targeted varying susceptibility: 100% susceptible to all chemistry (Hart) and moderate resistance to Group 1 – DIM herbicides and strong resistance to Group 2 – Imidazolinone herbicides (Hill River).
- Data from field trials undertaken at Hart and Hill River showed that Liberty® (200 g/L glufosinate) mixes applied as a two-spray approach, tank mixed with clethodim or registered glyphosate, applied with Liase® (ammonium sulphate) as the first application of the Liberty sequence, were the most effective options against ryegrass.
- At both sites, the low label rate of Liberty (2 L/ha + 2% Liase®) applied in sequence, ~14 days apart, was not adequate for the control of ARG.
- Liberty at higher label rates of 3 L/ha followed by a second 3 L/ha was effective in reducing ryegrass.

Introduction

A project supported by the South Australian Grains Industry Trust (SAGIT) was conducted in 2023 investigating best-use strategies for the control of annual ryegrass (ARG) with glufosinate herbicide. Active ingredient glufosinate-ammonium (200 g/L) registered as Liberty is a Group 10 (formerly N) herbicide which can now be applied in-crop to canola varieties with LibertyLink® technology (tolerance to Liberty herbicide). This registration provided a new herbicide mode of action (MOA) for use in broadacre cropping systems.

Glyphosate and glufosinate have two different MOA (Group 9 and 10, respectively), however structural elements are similar in that they are both charged herbicides (Preston, 2024). This means they are unable to pass through wax layers of plant cuticles and are alternatively required to enter via pectin strands (intercellular plant tissue) within cuticles. As pectin strands contain negative charges, these herbicides are slow moving into the leaf and the rate of this absorption is impacted by temperature and humidity (Preston, 2024). While the overall charge on glyphosate can be reduced by decreasing spray solution pH (5.73), the solution would need to be below pH 2.9 for this to be achieved (Preston, 2024).

Whilst glufosinate provides an alternative to glyphosate, its uptake, translocation and therefore activity can be strongly influenced by conditions upon application (e.g. temperature and humidity). Previous research suggests that temperature plays only a small part when it comes to glufosinate uptake, whereas humidity is the more important factor (Preston, 2024). Low humidity can reduce the ability of glufosinate to pass through the leaf via pectin strands within the cuticle, which need to remain hydrated for this to happen. It is suggested that humidity is not generally an issue in southern Australia during winter and that high humidity is only required for the first 24 hours after application for glufosinate uptake (Preston, 2024).

Atrazine, clethodim and glyphosate are the most common post-emergent herbicides used to control ryegrass in canola. Previous studies have shown that the combination of clethodim with glyphosate can improve control of ryegrass resistant to either, or in some cases both herbicides. This treatment is only relevant for glyphosate tolerant canola varieties. Although rare, ryegrass resistant to tank mix glyphosate + clethodim is being detected (Peter Boutsalis pers. comm.). To lower the risk of further increases in resistance to glyphosate and clethodim, the inclusion of another mode of action herbicide such as glufosinate (Liberty) would be useful.

A series of agronomic field and pot experiments exploring the effects of temperature and humidity on herbicide efficacy experiments with Liberty were implemented in 2023. In this article, data from field experiments at two locations across the Mid North region of SA is discussed.

Methodology

Site selection and rainfall

Two trials were implemented in the medium rainfall zone of the Mid North to evaluate the efficacy of glufosinate herbicide under field conditions (Table 1).

The core trial was located at Hill River with a known background population of ARG, susceptible to glyphosate and glufosinate herbicides. The site had moderate resistance to Group 1 – DIM herbicides (45% survival) and strong resistance to Group 2 – Imidazolinone herbicides (60% survival). Total annual rainfall received was 450 mm with 312 mm of growing season rainfall (GSR). Early rainfall from April–June promoted ARG germination, however seasonal conditions from July through to spring were below average (Figure 1), suppressing conditions for further ryegrass to emerge.

Similar conditions were observed at the Hart field site, SA, where a secondary trial was located, however both GSR and annual rainfall were lower, receiving 236 and 354 mm, respectively. This trial was sown to Liberty tolerant InVigor LR 4540P canola. Prior to seeding, ARG (wild type) with a known susceptibility to all herbicide groups was spread across the site ensuring adequate weed emergence (250 plants/m^2). Both Hart and Hill River trials were sown by a knife point press wheel trial plot seeder with 23 cm row spacings on April 2 and June 16, respectively.

Table 1. Site details for glufosinate trials at Hart and Hill River, SA in 2023.

Hart	**Plot size**	2.0 m x 10.0 m	**Water rate**	100 L/ha
	Seeding date	April 2, 2023	**Nozzle type**	Coarse
	Seed rate	45 plants/m^2		
	Previous crop	Kingbale oaten hay		
Hill River	**Plot size**	2.0 m x 10.0 m	**Water rate**	70–100 L/ha
	Seeding date	June 16, 2023	**Nozzle type**	Coarse
	Seed rate	45 plants/m^2		
	Previous crop	Kingbale oaten hay		
	Harvest date	November 22, 2023		

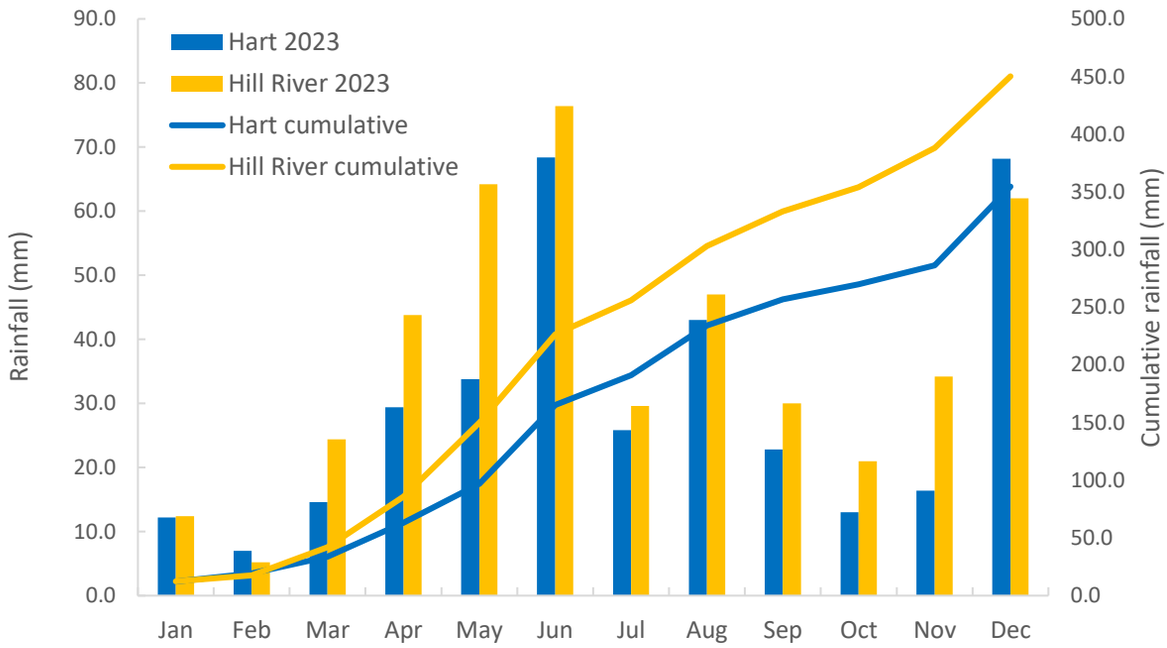

Figure 1. Monthly and cumulative rainfall for Hart and Clare (nearest Mesonet station to Hill River) in 2023 (Source: Mid North Mesonet).

Trial design and treatments

Hill River

The trial located at Hill River, SA, was established as a randomised complete block design with three replicates, each containing 16 treatments. The aim of this trial was to investigate and test best-use spray strategies required to optimise ARG control with the use of glufosinate herbicide (Table 2). The trial compared effects of:

- Liberty herbicide at two rates (2 and 3 L/ha)
- Rate of Liase (2% and 4%)
- Liberty herbicide +/- Liase
- Application timing (7, 14 and 21 days after initial application)
- Water rate (70 or 100 L/ha)
- Tank mixes as either glyphosate or clethodim (at various rates)
- Extended application window (first flower)
- Spray conditions (low temperature)

Three varieties with herbicide tolerances, including the LibertyLink trait were included:

- InVigor LT 4530P: LibertyLink + Triazine Tolerant + PodGuard® (TT) (early-mid maturity)
- InVigor LR 4540P: LibertyLink + TruFlex® + PodGuard (early-mid maturity)
- InVigor R 4520P: TruFlex + PodGuard (early-mid maturity)

The glufosinate herbicide product used was Liberty (200 g/L glufosinate) and Liase was selected as the ammonium sulphate (417 g/L) inclusion. Roundup Ready® PL herbicide with Plantshield® (Roundup Ready PL) was selected as the glyphosate option, however Crucial® is also registered for use on Roundup Ready, TruFlex or Optimum GLY® canola options. Herbicide applications were applied from August 11 to September 13, 2023 (Table 2 and Figure 2).

Hart field site

A secondary trial was undertaken at the Hart field site and was established as a split-plot design with five treatments and three application timings to target ryegrass at different growth stages. The trial investigated standalone Liberty herbicide at two rates (2 or 3 L/ha) with Liase (ammonium sulphate) and tank mixture of either glyphosate or clethodim (Table 3). Application dates and climate data can be found in Appendix 1.

Herbicide treatments were applied at three ARG growth stages from early emergence through to tillering (2-4 leaf, 1-2 tiller and 3-4 tiller) using a 100 L/ha water rate and coarse nozzles. No residual herbicides were applied pre-seeding.

Field assessments for both trials at Hart and Hill River included weed counts (plants/m^2) and ARG head counts (heads/m^2) as a measure of seed set. Data was analysed using a REML spatial model (Regular Grid) in Genstat 23rd edition. Ryegrass head counts for Hill River were analysed as log-transformed data for multiple comparisons using statistical program R.

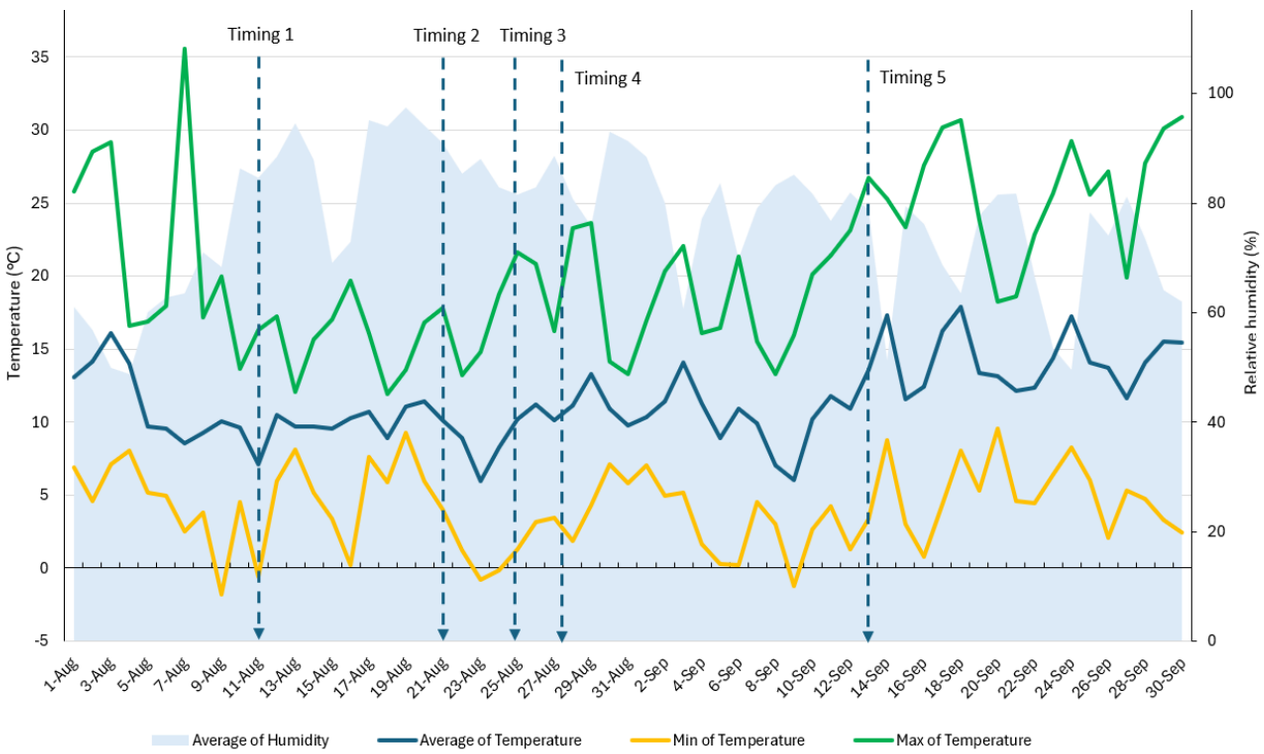

Figure 2. Average temperature (°C) and relative humidity (RH%) for Hill River, SA. Blue dotted lines indicate each application timing.

Table 2. Treatment list and application dates for glufosinate trial located at Hill River, SA in 2023.

Trt	PSPE		2-4 Leaf		6-8 Leaf (7 days later)		10-Leaf (14 days later)		Stem elongation (21- 28 days later)		First flower (≤10%)	
	June 16		August 11		August 21		August 25		August 28		September 13	
	Product	Rate	Product	Rate	Product	Rate	Product	Rate	Product	Rate	Product	Rate
1	Nil											
2	Atrazine	1 kg	Liberty + clethodim + Uptake + Liase	2 L + 330 mL + 0.5% + 2%			Liberty + Liase	2 L + 2%				
3			Liberty + Roundup PL + Liase	2 L + 1.67 L + 2%			Liberty + Liase	2 L + 2%				
4			Roundup PL + clethodim + Uptake + Liase	1.67 L + 330 mL + 0.5% + 2%			Roundup PL + Liase	1.67 L + 2%				
5			Liberty + Roundup PL	2 L + 1.67 L			Liberty	2 L				
6			Liberty + Roundup PL + Liase	2 L + 1.67 L + 4%			Liberty + Liase	2 L + 4%				
7			Clethodim + Liberty + Uptake + Liase	330 mL + 2 L + 0.5% +2%			Liberty + Liase	2 L + 2%				
8			Liberty + Roundup PL + Liase	2 L + 1.15 L + 0.5% + 2%			Liberty + Liase	2 L + 2%				
9			Liberty + Liase	2 L + 2%			Liberty + Liase	2 L + 2%				
10			Clethodim + Liberty + Uptake + Liase	330 mL + 2 L + 0.5% + 2%					Liberty + Liase	2 L + 2%		
11			Clethodim + Liberty + Uptake + Liase	330 mL + 2 L + 0.5% +2%	Liberty + Liase	2 L + 2%						
12			Liberty	2 L			Liberty	2 L				
13			Liberty + Liase	3 L + 2%			Liberty + Liase	3 L + 2%				
14			Clethodim + Liberty + Uptake + Liase	330 mL + 2 L + 0.5% + 2%			Liberty + Liase	2 L + 2%				
15			Liberty + Liase	2 L + 2%			Liberty + Liase	2 L + 2%			Roundup PL + Liase	1.67 L + 2%
16*			Clethodim + Liberty + Uptake + Liase	330 mL + 2 L + 0.5% +2%			Liberty + Liase	2 L + 2%				

**Second application applied early morning in cold temperatures of 9 degrees Celsius (°C).*

Table 3. Treatment list for glufosinate trial located at the Hart field site, SA in 2023. Treatments were applied targeting annual ryegrass at 3 different growth stages (2-4 leaf, 1-2 tiller and 3-4 tiller).

Trt	Timing 1		Timing 2 (10–14 days later)	
1	Nil			
2	Liberty + Liase	2 L + 2%	Liberty + Liase	2 L + 2%
3	Liberty + Liase	3 L + 2%	Liberty + Liase	3 L + 2%
4	Liberty + Roundup PL + Liase	2 L + 1.67 L + 2%	Liberty + Liase	2 L + 2%
5	Liberty + clethodim + Uptake + Liase	2 L + 330 mL + 0.5% + 2%	Liberty + Liase	2 L + 2%

Results and discussion

Hill River

Weed control

Low ARG numbers were initially observed across the site at Hill River in 2023 (61 plants/m^2), despite the paddock having a known high weed pressure. The low ARG numbers were likely due to an effective knockdown and pre-emergent herbicide treatment (Overwatch at 1.25 L/ha) coupled with below average winter rainfall from July onwards. Ryegrass numbers were highest in the untreated control (Nil treatment = 120 plants/m^2) where significant seed set resulted (160 heads/m^2; Figure 3 and Table 4).

Reduced weed control was observed for all standalone Liberty treatments at 2 L/ha +/- Liase (Treatments 9 and 12), applied as a two-spray approach.

Liberty herbicide applied at 3 L/ha + Liase at 2% as a two-spray approach (Treatment 13) could improve weed control and performed similarly to most Liberty treatments applied as a two-spray approach with either clethodim or glyphosate tank-mixed in initial applications. Similar trends were observed for ARG head counts (measured as seed set) for standalone Liberty treatments at 2 L/ha +/- Liase, with a greater number of heads measured (16–34 heads/m^2). When rates of Liberty were increased to 3 L/ha + Liase, the overall number of annual ryegrass heads was reduced, performing similarly most other treatments, with an average of 1 head/m^2 (Table 4).

There was no evidence to suggest that reducing the water application rate from 100 to 70 L/ha compromised the activity of Liberty mixtures with clethodim, uptake and Liase. In addition, similar control was observed irrespective of whether the follow-up application was undertaken at 7 or 21 days. However, it is important to note that the ARG weed pressure across the site was low. Cold conditions (<10 degrees Celsius) experienced when the second application of Liberty was undertaken (Treatment 16) also had no negative impact on weed control.

Despite the population being DIM resistant (Group 1), TruFlex spray regimes of Roundup Ready PL + clethodim (followed by (fb) Roundup Ready PL) provided similar control to Liberty + glyphosate and Liberty + clethodim as the first of two spray timings (fb Liberty approximately 14 days later: Figure 3).

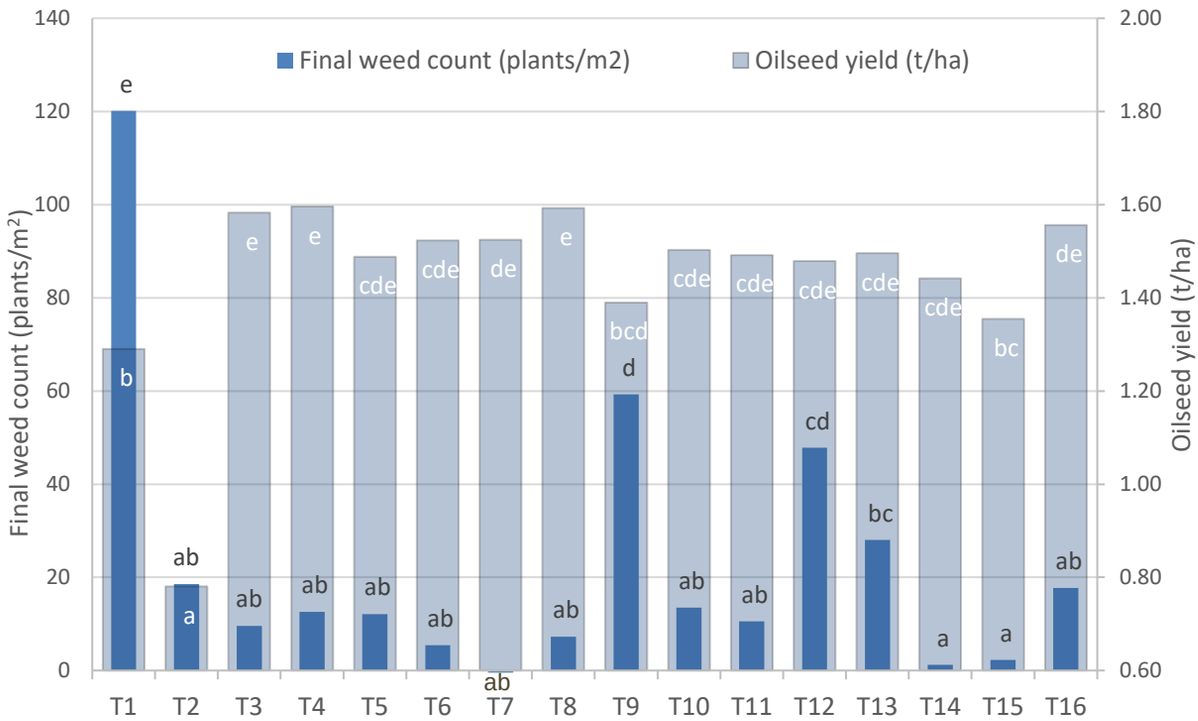

Figure 3. Final weed count (plants/m²) and oilseed yield (t/ha) for all treatments at Hill River, SA in 2023. Columns for final weed count (■) or oilseed yield (■) with the same letter are not significantly different.

Table 4. Annual ryegrass final weed counts (plants/m²) and head counts for all herbicide treatments at Hill River. Shaded values show best performing treatments

Treatment	Annual ryegrass head count (heads/m²)
1	160^{d}
2	2^{a}
3	0^{a}
4	0^{a}
5	1^{a}
6	0^{a}
7	0^{a}
8	2^{ab}
9	34^{cd}
10	2^{ab}
11	1^{a}
12	16^{bc}
13	1^{a}
14	0^{a}
15	0^{a}
16	1^{a}
P-value	**<0.001**

Oilseed yield

The lowest grain yield observed at Hill River was stacked tolerance variety InVigor LT 4530P (LibertyLink + Triazine Tolerant + PodGuard). This result was not entirely unexpected and may be associated with the TT tolerance trait which can influence yield. Yields were lowest for Liberty 2 L (+/- Liase) as a two-spray regime (1.3–1.39 t/ha) and the untreated control (1.29 t/ha). These results can be attributed to higher ARG numbers, competing with canola for soil moisture and nutrition (Figure 3).

A yield penalty was observed for Treatment 15 which had an extended application timing (glyphosate <10% flower). This is likely due to poor control with Liberty at 2 L/ha +/- Liase applied as a two-spray approach, with the third application of glyphosate too late to prevent ARG competition.

Hart

Weed control

Results at the Hart field site in 2023, on a susceptible ARG population show that herbicide regime was most significant in determining weed control (plants/m^2). It is important to note that while applications were made to ARG at varying growth stages from 2-4 leaf to 2-4 tiller, tillering ARG plants were small and sprayed early (not at stem elongation). Similar humidity (RH%) and temperature (°C) conditions were observed at each application (see Appendix 1).

Similarly to Hill River results, applications of Liberty standalone, sprayed as a sequential two-spray regime had reduced ARG control (62 plants/m^2), when compared to Liberty tank mixed with clethodim or Roundup Ready PL (23 plants/m^2) in initial spray timings. Liberty at 3 L/ha performed similarly, reducing overall weed number. Liberty at 2 L/ha + Liase at Hart also significantly reduced overall ARG head number (Table 5), similar to all other treatments, this result was not observed at Hill River. The untreated control had the highest level of ARG present, with an average of 219 plants/m^2 (Figure 4).

Figure 4. Photos showing post-emergent activity for treatments applied at 2-4 leaf stage: 2 L/ha Liberty + 330 mL clethodim + 2% Liase (left), untreated control (middle) and 2 L/ha Liberty + 2% Liase (right). All treatments received 2 L/ha Liberty + 2% Liase 12 days later.

Table 5. Average annual ryegrass weed count and head density following final herbicide treatment at Hart in 2023. There was no significant effect of growth stage on ryegrass weed count (p-value=0.735) or head density (p-value=0.964). Shaded values show best performing treatments.

Treatment	Annual ryegrass weed count (plants/m^2)	Annual ryegrass head count (heads/m2)
1	219^{c}	240^{b}
2	62^{b}	19^{a}
3	28^{ab}	5^{a}
4	20^{a}	8^{a}
5	19^{a}	4^{a}
P-value	**<0.001**	**<0.001**

Summary

Data from field trials undertaken at Hill River and Hart in the Mid North of SA showed that Liberty at low label rate of 2 L/ha + ammonium sulphate was not adequate for the control of ARG.

The higher rate of 3 L/ha + 3 L/ha Liberty provided more consistent results reducing both weed numbers and ARG head numbers. Liberty herbicide tank mixed with clethodim or registered glyphosate options in early spray applications with ammonium sulphate, were generally the most effective treatments indicating that these mixes are more likely to provide better ryegrass control than Liberty only treatments, particularly at lower label rates of Liberty. The use of the 3 L/ha Liberty followed by a further 3 L/ha should be considered in a rotation to slow down resistance developing to clethodim and glyphosate. Liase or similar products should be included to improve activity.

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References

Preston C., (2024). Strategies for optimising glufosinate and tackling efficacy challenges. Available online : https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2024/02/strategies-for-optimising-glufosinate-and-tackling-efficacy-challenges

Appendix 1. Application timing details for glufosinate trial at Hart, 2023.

ARG Growth stage timing at application 1: 2-leaf	**Application 1**	
	Canola growth stage:	2-4 leaf
	Date:	June 29
	Time:	12:30pm
	Cloud cover:	10%
	RH%	66%
	Temperature:	12°C
	Application 2	
	Canola growth stage:	2-4 leaf
	Days since application:	**12**
	Date:	July 11
	Time:	12:30pm
	Cloud cover:	10%
	RH%	59%
	Temperature:	17°C
ARG Growth stage timing at application 1: 1-2 tiller	**Application 1**	
	Canola growth stage:	6 Leaf
	Date:	July 21
	Time:	1:00pm
	Cloud cover:	15%
	RH%	69%
	Temperature:	13°C
	Application 2	
	Canola growth stage:	10 leaf
	Days since application:	**17**
	Date:	August 7
	Time:	12:00pm
	Cloud cover:	90% but conditions still bright
	RH%	62%
	Temperature:	17°C
ARG Growth stage timing at application 1: 2-4 tiller	**Application 1**	
	Canola growth stage:	10 leaf
	Date:	August 7
	Time:	12:00pm
	Cloud cover:	90% but conditions still bright
	RH%	62%
	Temperature:	17°C
	Application 2	
	Canola growth stage:	Stem elongation-budding
	Days since application:	**14**
	Date:	August 21
	Time:	1:00pm
	Cloud cover:	10% - cloud cover from 3pm + small amount of rain
	RH%	67%
	Temperature:	18°C