FINAL REPORT 2015

PROJECT CODE :	S0713

PROJECT TITLE
Evaluating clethodim tolerance in canola

PROJECT DURATION

Project Start date	1 July 2013
Project End date	30 June 2015

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Project Code	
Project Type	

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PROJECT REPORT

Executive Summary

Increased application rates of clethodim have created concern due to crop damage in canola, which is the most sensitive crop of those registered for clethodim use. Field trials within this project have shown that late timings (bud initiation) of clethodim can result in severe yield losses; therefore care should be taken to apply at correct growth stages and application rates. Applications exceeding 0.5 L/ha are at high risk of causing yield reductions in most canola varieties. From the trial results it is evident that the early applications at 4-leaf growth stage of canola were the safest on the crop, although this may not be always the best time of application for targeting weed control. For example, a large proportion of the weed population may germinate later, requiring additional follow up sprays or delaying initial spray applications. Or higher use rates might be required to achieve acceptable control of weed populations developing resistance. This may require a compromise in rates and timings to best control weeds while minimising the risk of crop damage.

- Grain yield losses of up to 30% can be caused by clethodim at label recommended rates at late applications.
- Rates exceeding label recommendations used to target resistant ryegrass populations resulted in severe canola yield losses.
- Early application timings appear the best to avoid crop damage.
- Variation in tolerance was found between varieties across all herbicide tolerant crop types (Conventional, Clearfield and TT) in their level of sensitivity to clethodim.

Project Objectives

(a) To quantify the effects of increased application rates of clethodim on growth, development and yield of canola cultivars.

(b) To formulate recommendations to growers on cultivar tolerance, optimal economic use rate and timing of clethodim on canola based on crop safety.

The aim of this project is primarily to quantify the effects of increased application rates

of clethodim on growth, development and yield of canola cultivars. Clethodim is an important herbicide in the control of grass weeds, particularly annual ryegrass (*Lolium rigidum*) in canola and pulse crops. Increased application rates of clethodim have become widespread industry practice in efforts to achieve acceptable levels of control of FOP and DIM resistant annual ryegrass. In doing so, there are widespread observations suggesting that canola appears much more sensitive to these higher rates than pulse crops.

Outputs from this project would lead to a better understanding of clethodim tolerance in canola by determining the degree of grain yield losses occurring from its use. It would also identify any cultivars which may exhibit increased tolerance to assist in maximizing on-farm productivity and profitability.

Overall Performance

The project objectives were achieved in a timely manner without any difficulties. A number of SARDI personnel assisted in achieving objectives through help with field trials. SARDI – Port Lincoln group completed the sowing and harvesting at the Yeelanna field site during both years and SARDI – Clare group provided the same assistance at the Hart site. The Roseworthy field site was managed and maintained by SARDI New Variety Agronomy group from Waite, with some assistance from University of Adelaide staff located on site at Roseworthy. All field trials went to plan without any setbacks in either season to successfully fulfil the project objective.

Key Performance Indicators (KPI)

KPI	***Achieved (Y/N)***	***If not achieved, please state reason.***
Field trials planned and conducted at three sites during 2013	Y	
First year trial results compiled for Progress report to SAGIT and communicated via LEADA, Hart, CSSSA Newsletter, newsprint and other grower groups	Y	
Field trials planned and conducted at three sites during 2014	Y	
Trial results compiled for Progress report to SAGIT and communicated via LEADA, Hart, CSSSA Newsletter, newsprint and other grower groups	Y	
Final project report submitted to SAGIT with research outcomes completed	Y	

Technical Information

Over the course of this project, applications of clethodim were found to strongly influence the growth and development of canola, ultimately impacting on grain yields and quality. The rate and timing of applications had a large impact on the severity of damage and yield losses to canola. Field trials conducted at Hart and Yeelanna produced very similar results and it was evident that exceeding recommended label rates and later application times significantly increased the level of crop damage.

Clethodim application rates of 1L/ha significantly increased the risk of crop damage in field trials at Hart and Yeelanna. The current label recommended rate is 0.5L/ha, but with many growers commonly using higher rates to combat the development of herbicide resistant ryegrass. Therefore it is important to assess the impact of higher application rates. Early applications (4 leaf canola) up to 1L/ha were relatively safe as no significant yield reductions occurred in both seasons at either location (Table 1 and 2). When applied at the 8 leaf growth stage of canola the 0.5L/ha rate caused no significant yield loss at any site or season, but when applied at 1L/ha, yield reductions were recorded. Depending on the cultivar, grain yield was reduced by up to 13% at Hart (Table 1) and up to 25% at Yeelanna (Table 2). When applied later again, at bud initiation (green buds first become visible) grain yields were reduced at both application rates. Up to 20% yield losses at 0.5L/ha and 40% at 1L/ha were observed at Hart (Table 1). Very similar levels of damage occurred at Yeelanna, being up to 30% at 0.5L/ha and up 52% at 1L/ha (Table 2). From the results of these field trials it is clearly evident that later application timings of clethodim significantly increase the risk of yield reductions and these losses can be severe. When splitting the applied rates over two applications between 4 and 8 leaf crop growth stages, it improved the level of safety compared to applying the entire rate in a single application at the 8 leaf growth stage.

Table 1. Effect of clethodim applied at different timings and rates on the grain yield of canola at Hart during 2013 and 2014. Highlighted values indicate significantly less than untreated (p<0.05).

Application timing	Clethodim rate	ATR Gem		AV Garnet		Hyola 474 CL	
		2013	*2014*	*2013*	*2014*	*2013*	*2014*
Untreated		1.11 t/ha	1.65 t/ha	1.37 t/ha	2.11 t/ha	1.69 t/ha	2.06 t/ha
		----------grain yield % of control----------					
4 leaf	0.5L/ha	98	95	99	101	100	101
	1L/ha	94	99	106	100	96	98
8 leaf	0.5L/ha	99	102	104	95	96	97
	1L/ha	87	101	106	97	87	99
4 leaf and	0.25L/ha + 0.25L/ha	91	103	102	98	92	104
8 leaf split	0.5L/ha + 0.5L/ha	95	103	103	98	91	102
Bud initiation	0.5L/ha	80	95	97	96	87	93
	1L/ha	61	66	90	92	61	60

Table 2. Effect of clethodim applied at different timings and rates on the grain yield of canola at Yeelanna during 2013 and 2014. Highlighted values indicate

significantly less than untreated (p<0.05).

Application timing	Clethodim rate	ATR Gem		AV Garnet		Hyola 474 CL	
		2013	*2014*	*2013*	*2014*	*2013*	*2014*
Untreated		1.74 t/ha	1.94 t/ha	2.12 t/ha	2.01 t/ha	1.75 t/ha	2.34 t/ha
		grain yield % of control					
4 leaf	0.5L/ha	98	98	94	105	100	104
	1L/ha	94	107	94	117	100	95
8 leaf	0.5L/ha	95	103	95	99	95	101
	1L/ha	90	96	90	100	75	100
4 leaf and	0.25L/ha + 0.25L/ha	90	101	96	100	99	103
8 leaf split	0.5L/ha + 0.5L/ha	97	100	92	107	98	103
Bud initiation	0.5L/ha	76	91	86	91	70	91
	1L/ha	65	81	87	85	48	60

Of the three varieties used in the field trials at Yeelanna and Hart, AV Garnet was much more tolerant of clethodim. ATR Gem and Hyola 474CL had similar responses to clethodim treatments, but both had consistently greater yield reductions than AV Garnet (Table 1 and 2). This data was supported by the varietal tolerance trial conducted at Roseworthy in 2013 and 2014. In these trials AV Garnet was consistently one of the most tolerant varieties evaluated (Figure 1 and 2). There was a large range of variation between varieties in clethodim tolerance, with grain yield losses ranging between 0 % to almost 30% (Figure 1 and 2). A range of conventional, Clearfield and Triazine-tolerant varieties were tested, although some varieties were substituted during 2014 due to seed availability from breeders. Across each of the crop-herbicide groups no group indicated improved tolerance over another. Within each group there were good and poorer performing varieties in terms of clethodim tolerance. This has provided evidence that when the need arises for the use of clethodim at excessive rates or timings prone to damage that variety selection will have a large influence on the yield losses that can occur. Therefore understanding the susceptibility of canola varieties may be a useful tool in determining what rate and timing of clethodim can be used in specific situations. When comparing varieties, similarities in clethodim tolerance can be linked to varieties of closely related pedigrees. For example, Crusher TT has a very similar pedigree to AV Garnet, but with the addition of Triazine tolerance. Both these varieties displayed high levels of tolerance when tested together in 2013 (Figure 1).

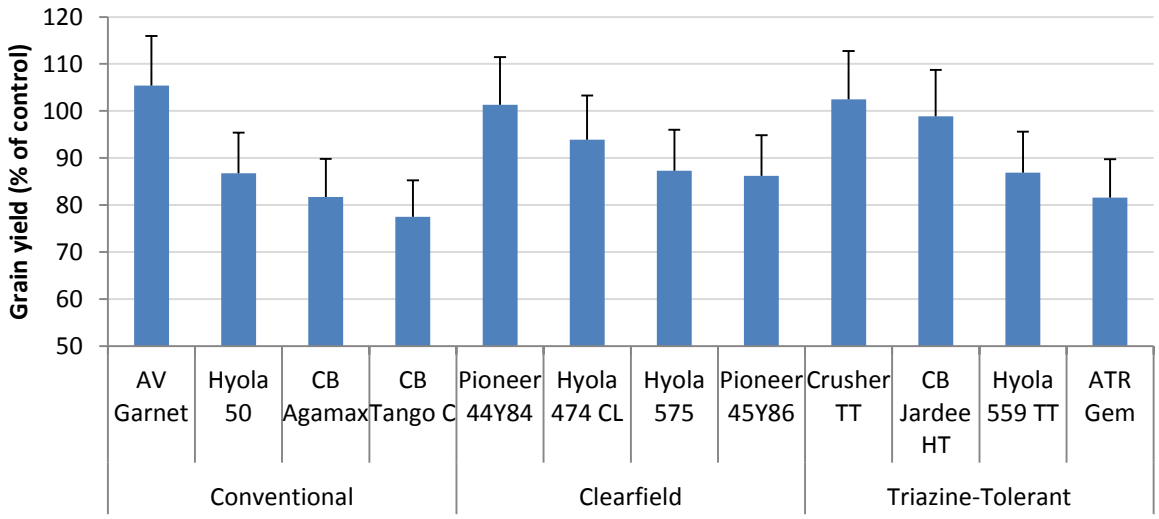

Figure 1. Average grain yields of canola sprayed with 2L/ha (480gai/ha) of clethodim at Roseworthy, SA during 2013. Yields expressed as a percentage of untreated controls.

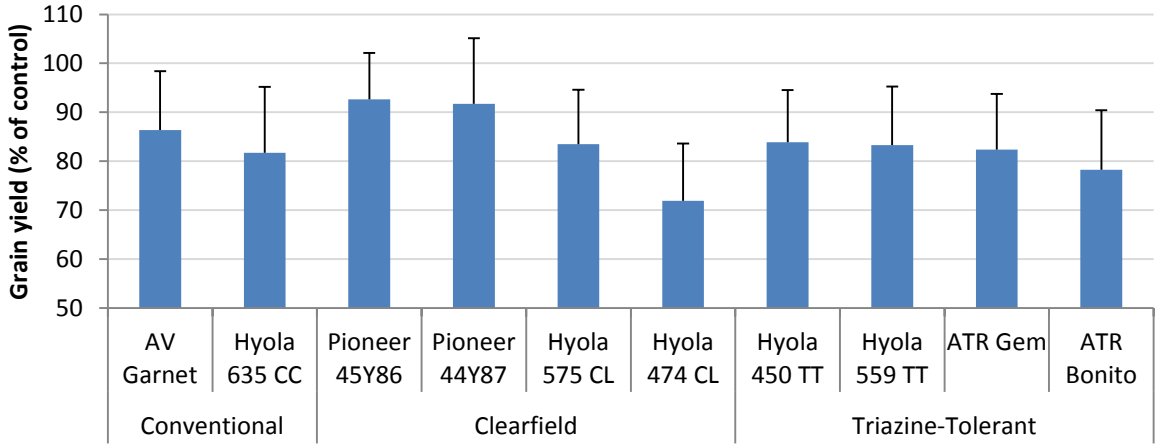

Figure 2. Average grain yields of canola sprayed with 2L/ha (480gai/ha) of clethodim at Roseworthy, SA during 2014. Yields expressed as a percentage of untreated controls.

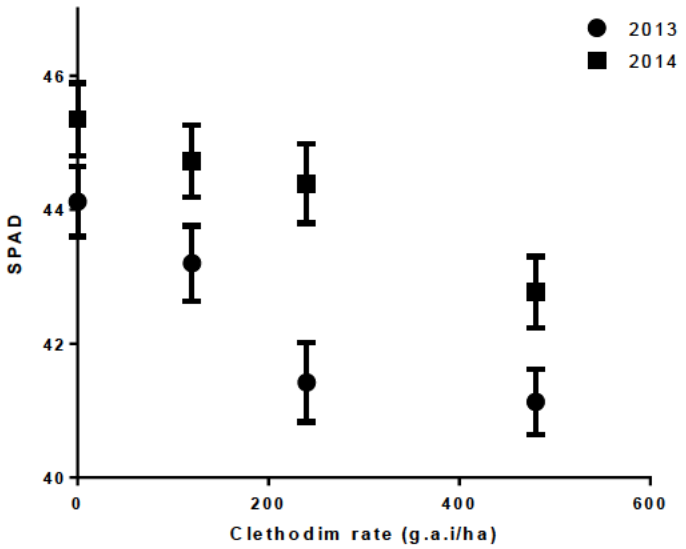

Figure 3. Chlorophyll content (SPAD) of youngest open leaf during stem elongation, following applications of clethodim at the 6-8 leaf growth stage at Roseworthy, SA during 2013 and 2014.

From a visual damage perspective, a number of symptoms were consistently observed throughout development following application. They included leaf colour changes, flower and pod distortion, with flower distortion being the most distinguishable. The flower distortion symptom common with clethodim damage was clearly evident in damaged plots and visual degree of damage scores positively correlated with yield losses. SPAD (Chlorophyll/greenness) readings were recorded at Roseworthy in both seasons and were strongly affected by clethodim applications. The higher application rates of clethodim lowered the SPAD readings (Figure 3), effectively reducing the degree of greenness in the crop canopy. Despite this, clethodim treatments had no impact on biomass production, plant height or maturity. Although in severely damaged plots, ripening was commonly delayed from pod distortion. Pods would often be much smaller and thicker, maintaining their greenness for a longer period of time.

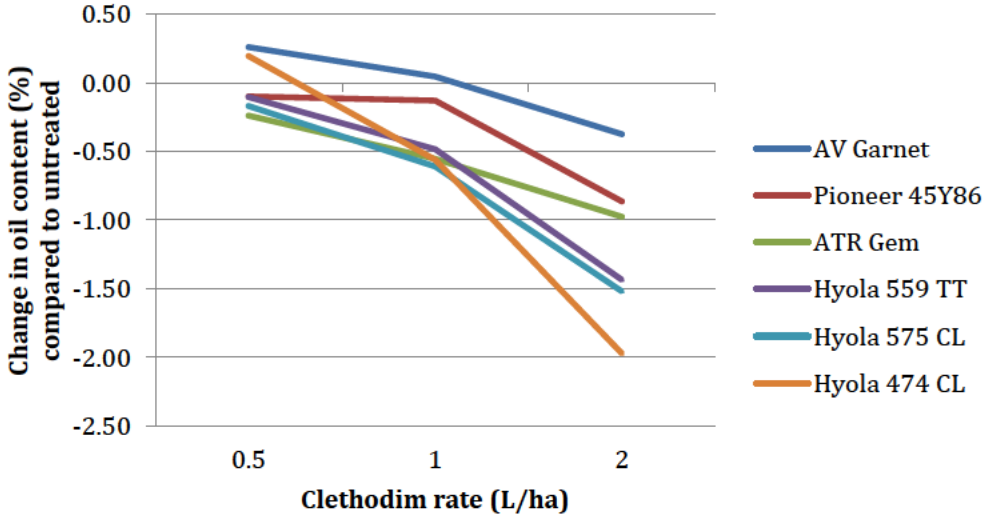

Figure 4. Change in oil content (%) of various canola varieties in response to the application of clethodim (Data combined from 2013 and 2014).

Grain quality was also severely affected by applications of clethodim. A key component of quality, oil content was significantly reduced as rates of clethodim increased. In some varieties, oil content decreased by up to 3-4% when 2L/ha of clethodim was applied (Figure 4). Despite all varieties incurring decreased oil content with increased rates of clethodim, the degree of oil content loss varied between varieties. The variety, AV Garnet suffered minimal changes losing approximately 0.5% oil content from untreated to 2L/ha application (Figure 4). Meanwhile other varieties such as Hyola 474 CL incurred a 2% oil decrease when compared across the same treatments (Figure 4). This observed difference in oil content responses between varieties was very similar to the rankings in yield loss responses. Such that a sensitive variety suffering a large yield loss using increased rates of clethodim will also incur a large decrease in oil content. For example, AV Garnet was a variety consistently showing increased tolerance to clethodim, with minimal yield reductions (Figure 1 and 2). It also then resulted in very low changes in oil content compared to other varieties (Figure 4).

Conclusions Reached &/or Discoveries Made

After completing extensive field trials in evaluating the effects of clethodim on crop tolerance of canola, there were consistent results observed over two growing seasons. It was confirmed that canola is sensitive to increased application rates of clethodim and sensitivity is also influenced by variety and growth stage at application.

Increasing application rates from 0.5L/ha (current maximum label recommendation) to 1L/ha significantly increased the risk of crop damage and consequently leading to yield reductions. When applied at the 8 leaf growth stage of canola the maximum observed yield loss was 5% compared to at 1L/ha where yield losses ranged up to 25%. This effect on canola yields was also influenced by application timings. Earlier clethodim applications from the 4 leaf growth stage were safer and caused less damage to the crop compared to the most damaging treatment at bud initiation. Applying 1L/ha caused no significant damage when applied early in development, but at bud initiation, yield reductions of over 50% were observed. Therefore when requiring high rates of clethodim, applications at early growth stages of canola are best to avoid crop damage and minimize potential yield losses.

Varietal selection also influenced the level of crop damage observed from applications of clethodim. Some varieties were more tolerant than others, with significant differences in yield reductions. The variety, AV Garnet was the most tolerant, incurring minimal yield reductions, compared to other varieties tested. AV Garnet would maintain relatively consistent high grain yields after all clethodim treatments, compared to other varieties suffering up to 25% further yield reductions from the same herbicide treatments. Among the varieties tested there was no evidence to suggest any difference in clethodim tolerance between conventional, Clearfield and Triazine-tolerant varieties. There was a range in tolerance between varieties in each of these herbicide tolerance crop types.

The impact of clethodim on the grain yield of canola was the end result following various damage symptoms throughout development after application. Firstly, clethodim caused leaf discoloration and distortion, where leaves would become paler in colour. Later in development flowering and pod formation would also show signs of distortion, which consequently led to reduced seed set and lower yields. No changes in biomass, plant height or flowering time were recorded. When clethodim damage was observed grain quality was also affected by reductions in oil content by up to 2% in severe cases. The effect of oil content changes were closely related the degree of damage observed in grain yield.

On completion of this project is has been confirmed that clethodim can severely impact the growth, development and grain yield of canola. These effects are amplified with increasing herbicide rates and applications at later canola growth stages. Not all canola varieties are affected to the same degree, which may lead to further studies to identify possible explanations.

Intellectual Property

No intellectual property generated.

Application / Communication of Results

On completion of this project a number of key outcomes have been identified;

- Clethodim rates exceeding 500mL/ha significantly increase the risk of losses to grain yield in canola.
- Applications at early growth stages of canola appear the best to avoid crop damage.
- Variation does exist between varieties across all crop types in their level of sensitivity to clethodim.
- Visual damage symptoms were observed throughout development following application, with flower distortion being the most distinguishable.

These findings have a significant potential impact to industry given the widespread use and importance of clethodim to control grass weeds in break crops such as canola. Given the increasing incidence of clethodim resistance in weeds such as annual ryegrass, application rates have also increased, causing widespread damage in canola crops. This research provides valuable information to growers such as what type of crop damage to expect and what crop losses can be expected at various application rates and timings. This is important in assessing the trade-offs between weed control and crop damage.

Throughout the duration of the project, findings have been published and extended to a

very wide audience. Various crop walks and field days have been utilized to present research findings at the Hart field day and crop walks, LEADA spring field day and GRDC panel tours. Articles were published in Hart field day result books 2013-14, LEADA result newsletters, EP farming systems 2013 publication and Crop Science Society of SA newsletter.

An issue that has risen in publishing findings of this research has involved how to communicate "off-label" chemical treatments used in the study. The use of clethodim at rates above 500mL/ha is not recommended on current label specifications, but research on higher rates is warranted as increasing rates are being widely used to combat herbicide resistant weeds. These "off-label" related findings have been difficult to publish in some situations due to the associated legalities.

POSSIBLE FUTURE WORK

This research provided an initial investigation into the effects of using increased clethodim rates and influence of timing and variety on crop damage caused to canola. In addition to this work, further research could possibly continue in investigating the underlying causes of differing tolerance in varieties. This work could be directed at identifying what is happening within the canola plant that makes it more susceptible to damage from clethodim compared to other broad-leaf crops.

This research also could be on-going in some form, as significant differences have been identified between varieties. To maintain relevance and stay up-to-date with current varieties, varietal tolerance testing could continue in some form. This could be to continue to test canola varieties and clethodim interactions in similar manner to what occurs in the larger GRDC funded cereal and pulse herbicide tolerance programs.

Having determined yield reductions caused by clethodim at various rates and application times, cost analysis could be used to investigate to financial impact of crop damage. This could potentially include comparisons of weighing up the impacts of crop losses via herbicide damage or weed infestation, especially in later crop salvage situations.

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Clethodim tolerance in canola

Michael Zerner and Rob Wheeler, SARDI

- **Grain yield losses of up to 50% can be caused by clethodim at particular rates and timings.**
- **Early application timings appear the best to avoid crop damage.**
- **Variation does exist between varieties across all herbicide tolerant crop types (Conventional, Clearfield and TT) in their level of sensitivity to clethodim.**
- **Flower distortion was the major clethodim damage symptom observed, which led to poor pod development resulting in yield reductions.**

Why do the trial?

Clethodim has become a very important herbicide in the control of annual ryegrass in southern Australia. In recent times, label rate changes have occurred to enable higher rates of up to 500 mL/ha to be used for increased levels of weed control. This rate increase applies to canola, pulse crops and pasture legumes. Since the use of this higher rate of clethodim, a number of crop effects have been reported, particularly in canola. Observed symptoms include, delayed flowering, distorted flower buds and possible grain yield suppression. Symptoms appear to be more severe from later application timings. Other factors that may influence crop effects include herbicide rate, crop stress at herbicide application and possible varietal differences in tolerance.
Given the widespread importance of the use of clethodim in the farming rotation and increased application rates to combat herbicide resistant annual ryegrass, a field trial at Yeelanna was established to identify the level of crop tolerance to these rates in canola. The level of actual yield losses that may occur from the use of high clethodim rates is relatively unknown.

How it was done?

The trial was established as a split-plot design with three replicates. Three canola varieties were used; AV Garnet (conventional), ATR Gem (triazine tolerant) and Hyola 474 CL (Clearfield) to investigate the influence of clethodim rate and timing. Nine clethodim treatments were applied to each variety as listed below in Table 1. This trial was solely aimed at investigating the impact of clethodim on crop safety rather than weed control. The trial was sown on the 13 May with 2.5 L/ha trifluralin, 250 mL/ha Dual Gold and 1 L/ha Lorsban. At seeding 150 kg/ha of 19:13:0:9 blend fertilizer was applied with 400 mL/ha of Impact, followed by an additional 100 kg/ha of urea on the 13 June and 15 July.

Spray treatments for each growth stage were applied on the same day for each variety. As a result the exact growth stage at the time of application for each variety may have differed slightly, despite all varieties used in this trial being of very similar maturity. Following each spray application NDVI readings using a Greenseeker and visual damage scores were recorded.

Table 1. Clethodim treatments applied at Yeelanna during 2013.

CLETHODIM TREATMENTS
1. Untreated control
2. 0.5L/ha applied at 4-leaf growth stage
3. 1L/ha applied at 4-leaf growth stage
4. 0.5L/ha applied at 8-leaf growth stage
5. 1L/ha applied at 8-leaf growth stage
6. 0.25L/ha applied at 4-leaf and 8-leaf growth stages (0.5 L/ha in total)

7. 0.5L/ha applied at 4-leaf and 8-leaf growth stages (1 L/ha in total)
8. 0.5L/ha applied at bud initiation
9. 1L/ha applied at bud initiation

Application of clethodim at 1L/ha is not a registered rate and was undertaken for experimental purposes.

What happened?

The trial results reflected the sensitivity of canola to high rates of clethodim. Of the varieties tested the conventional type variety Garnet appeared to show a greater level of tolerance to clethodim than the other varieties. Both Gem (TT) and Hyola 474 CL were more intolerant of clethodim, with Hyola 474 being the most sensitive, incurring up to 50% yield losses in the most damaging clethodim treatment.

Of the various clethodim timings, the later the application, the more damage to grain yields that occurred. Applications within current label recommendations of up to the 8-leaf growth stage appear relatively safe in this trial. As all treatments sprayed with a single label rate application of 500 mL/ha up to and including this growth stage were not significantly different from the unsprayed control for any variety.

Early sprays (4 leaf growth stage) at rates up to 1 L/ha had no significant implications on grain yield for any variety. The next timing at 8-leaf was safe when applied at 0.5 L/ha, but when rates exceeded this, significant yield losses occurred of up to 25% in Hyola 474 and 10% yield losses in Garnet and Gem. The split application appeared to improve the safety of the 1 L/ha treatment when it is applied over two applications rather than in one application at the later, 8-leaf timing. Yield losses at this rate became insignificant for all varieties, when split over two applications. Later timing treatments at bud initiation which are outside current label recommendations were found to be highly damaging causing significant yield reductions. All varieties were significantly affected at both rates with yield losses ranging from 14-30% at 0.5 L/ha and 13-52% at 1 L/ha depending on the variety. Garnet showed improved tolerance levels at this timing where it was least affected at both rates, incurring 14% (0.5 L/ha) 13% (1 L/ha) yield reductions.

These findings in grain yields closely matched visual scoring of damage symptoms during the season. A range of symptoms were observed the first of which was a slight change in the colour of the crop canopy. The more damaged or sensitive plots become paler green in colour as compared to the untreated control plots. There were no visual changes in overall crop biomass or any significant change in NDVI between treatments in this particular trial. As the crop further develops to reach flowering the damage symptoms become more pronounced. The flower buds become distorted and fail to open up fully leading to poor pod development, which in turn resulted in reduced grain yields. The grain yield losses were strongly correlated to the severity of the observed visual symptoms.

Table 2. Effect of clethodim applied at different timings and rates on the grain yield of canola at Yeelanna during 2013. Highlighted values indicate significantly less than untreated (p<0.05).

Application Timing	**Clethodim Rate**	**ATR Gem**	**AV Garnet**	**Hyola 474 CL**
Untreated		1.74 t/ha	2.12 t/ha	1.75 t/ha
		————grain yield % of control————		
4 leaf	0.5L/ha	98	94	100
	1L/ha	94	94	100
8 leaf	0.5L/ha	95	95	95
	1L/ha	90	90	75

4 leaf and 8 leaf split	0.25L/ha + 0.25L/ha	90	96	99
	0.5L/ha + 0.5L/ha	97	92	98
Bud initiation	0.5L/ha	76	86	70
	1L/ha	65	87	48

What does this mean?

As clethodim application rates have increased to manage ryegrass and other grass weeds developing resistance, it has created concern for crop damage to canola, the most sensitive crop of those registered for clethodim use. This trial at Yeelanna has shown that particularly late timings of clethodim can result in severe yield losses, therefore care should be taken to apply at correct growth stages and application rates. Applications exceeding 0.5 L/ha are at high risk of causing yield reductions in most canola varieties. From the trial results it is evident that the early application at 4-leaf growth stage of canola was the safest on the crop but this may not be always the best time of application for targeting weed control. For example, a large proportion of the weed population may germinate later requiring additional follow up sprays or delaying initial spray applications. This may lead to requiring a compromise in rates and timings to best control weeds while minimizing the risk of crop damage. There also appears to be differences in clethodim tolerance between varieties. Such that varietal selection may be a contributing factor in minimizing clethodim damage in canola. Further research is still required to establish ratings for varieties based on their level of clethodim tolerance.

Acknowledgements

The funding support from SAGIT for this research and SARDI Port Lincoln staff for trial management is gratefully acknowledged.

Trial Information

Location: Yeelanna
Mark Modra
LEADA

Rainfall:
Av. Annual: 422 mm
Av. GSR: 342 mm
2013 Total: 490 mm
2013 GSR: 403 mm

Yield
Potential: 4.6 t/ha
Actual: 1.9 t/ha (Control treatment average)

Plot size 10 m × 1.8m with 3 reps