MANAGING BROME IN CANOLA ROTATIONS: COMPLEMENTING CHEMICAL CONTROL WITH CROP COMPETITION

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TAKE HOME MESSAGES

- Prioritise sowing canola on time to maximise yield potential, increase crop competition and decrease brome seed set. Delaying sowing to increase brome control with the knockdown herbicide reduced yield but brome seed set was the same as when the canola was sown on time.
- Even with good control from knockdowns and pre-emergent herbicides, it is important to apply a post-emergent herbicide to further reduce brome numbers and seed set.
- Growing canola as a part of the rotation provides growers the opportunity to control brome for one season as part of the three-season strategy to deplete the seed bank and provides an opportunity for growers to diversify the herbicide modes of action used to control brome.

BACKGROUND

Great brome grass (*Bromus diandrus*) is becoming a major problem across the Mallee, costing growers $6.7m in lost revenue each year (Llewellyn et al 2016).

Brome grass is one of the most competitive weeds, with an aggressive root system removing nitrogen, phosphorus and moisture from the soil that would otherwise be used by the crop. It is estimated that for every 1 brome plant per square metre in a wheat crop, 0.5% of yield potential is lost. By this calculation, 20 brome plants/m^2 could result in a yield loss of 10%.

Brome is a persistent weed issue due to the difficulties of reducing its seed bank. More than 20% of brome seed that sets will carry over into the next season and the seed can remain viable in the soil for more than three years. This means at least three years of complete control with no seed set is needed to fully deplete the seed bank.

When considering a rotation to control brome grass, it is important to consider different control options over at least three seasons (Kleemann and Gill 2009), including crop type, variety, herbicides, crop competition, harvest weed seed control and fallow management.

Controlling brome in the Mallee is complex due to variable rainfall patterns at sowing. Due to the shift to dry sowing of a larger proportion of the cropping program, often there isn't a chance to use a knockdown prior to sowing. Additionally, dry soil can reduce the efficacy of some pre-emergent herbicides. This variable efficacy of pre-emergent herbicides is further impacted upon by farming systems selecting for brome populations with increased seed dormancy, pushing it to germinate later and later, potentially outside the control window of knockdown and pre-emergent herbicides (Kleemann, Fleet, Preston and Gill 2018).

As a result of fewer opportunities to control brome prior to and immediately post-sowing, pressure is increasing put on in-season brome control which relies on in-crop selective herbicides. Unfortunately, the level of resistance to these in-crop herbicides in brome is steadily increasing. However, crop competition – where the crop can starve brome of resources – can be a useful tool to prevent or reduce seed set.

AIM

To investigate the effects of variety selection, time of sowing, plant density and herbicide strategies on brome seed set in canola.

PADDOCK DETAILS

Location:	Whirily
Crop year rainfall (Nov-Oct):	386mm
GSR (Apr-Oct):	240mm
Soil type:	Clay
Paddock history:	Wheat

TRIAL DETAILS

Crop type:	InVigor® T 4510 Hybrid TT Canola, ATR-Bonito Open Pollinated TT Canola
Treatments:	Refer to Table 1
Target crop density:	25 plants/m^2, 50 plants per/m^2
Seeding equipment:	Knife points, press wheels, 30cm row spacing
Sowing date:	TOS 1: 17 April, TOS 2: 15 May
Replicates:	Three
Harvest date:	Time of sowing (TOS) 1: 13 November, TOS 2: 16 November
Trial average yield:	1.5t/ha

TRIAL INPUTS

Fertiliser:	Granulock® Supreme Z + Flutriafol (200mL/100kg) @ 60kg/ha at sowing, and 160kg/ha of urea applied as a split application (12/6/2020, 28/7/2020)
Herbicide:	Refer to Table 1
	November 8 – Diquat @ 3L/ha (desiccation)
Insecticide:	Sowing – Chlorpyrifos @ 1.5L/ha (TOS 1: 17 April, TOS 2: 15 May)
	June 13 – Alpha-cypermethrin @ 100mL/ha
	October 10 – Alpha-cypermethrin @ 400mL/ha
Fungicide:	June 13 – Prosaro® @ 450mL/ha
	July 16 – Prosaro® @ 450mL/ha
	August 31 – Aviator® Xpro® @ 600mL/ha
Seed treatment:	Invigor® T 4510: Jockey® Stayer® @ 2L/100kg seed + Poncho® Plus @ 500mL/100kg seed
	ATR-Bonito: Cruiser® Opti @ 1L/100kg seed + Maxim XL @ 400mL/100kg seed

METHOD

A replicated split-plot trial was sown with the main plot as time of sowing and the subplot being randomised for variety, plant density and herbicide strategy treatments. Assessments in crop included canola and brome establishment counts, brome counts six weeks after in crop sprays and brome panicle counts at brome maturity. At canola maturity, pod and branch counts were conducted as a measure of crop competition. Plots were harvested for grain yield and the subsequent canola grain was tested for grain quality parameters of protein, oil, moisture, and test weight.

Table 1. Treatment outline.

Variety	Time of sowing (TOS)	Plant density	Herbicide strategy
InVigor® T 4510	TOS 1: 17 April	25 plants/m^2	**Knockdown only:**
ATR-Bonito	TOS 2: 15 May	50 plants/m^2	Sowing – Glyphosate 540g/L @ 2L/ha (TOS 1: 17 April, TOS 2: 15 May)
			Pre-emergent only:
			Sowing – Atrazine @ 1.8kg/ha + Glyphosate 540g/L @ 2L/ha (TOS 1: 17 April, TOS 2: 15 May)
			Pre- and post-emergent:
			Sowing – Atrazine @ 1.8kg/ha + Glyphosate 540g/L @ 2L/ha (TOS 1: 17 April, TOS 2: 15 May)
			4 leaf – Haloxyfop @ 75mL/ha (TOS 1: 12 June, TOS 2: 16 July)
			Premium pre- and post-emergent:
			Sowing – Atrazine @ 1.8kg/ha + Glyphosate 540g/L @ 2L/ha (TOS 1: 17 April, TOS 2: 15 May)
			4 leaf – Atrazine @ 400mL/ha + Haloxyfop @ 75mL/ha (TOS 1: 12 June, TOS 2: 16 July)

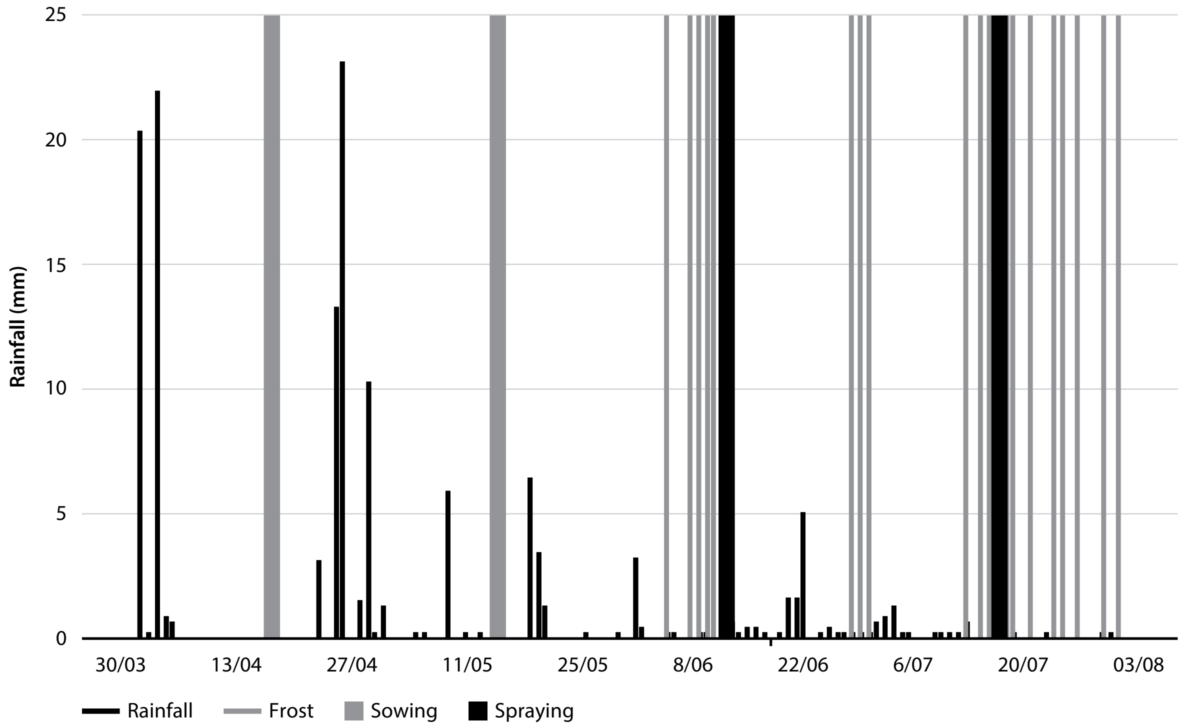

Figure 1. Timing of sowing and spraying compared to rain and frost events. Frost event defined as any day in which a weather station at 2m in height had a minimum temperature of less than 2°C (0 at canopy height).

RESULTS AND INTERPRETATION

Impact of time of sowing

Time of sowing had a significant effect on brome density at establishment and following in crop sprays ($p<0.001$, LSD=1.116, CV=83.4%) with earlier sowing resulting in higher brome densities (Table 2). This difference is due to a germination event within six weeks of TOS 1, which meant that brome that germinated was controlled by the knockdown prior to sowing in TOS 2, however the brome plants that germinated in TOS 1 were able to establish (Table 2).

This difference in early brome numbers however did not lead to a significant difference in brome panicles at maturity or brome seed set (Table 2). This highlights the importance of crop competition, as one third of the number of brome plants in TOS 2 were able to produce a similar amount of brome seeds and panicles as TOS 1.

Table 2. Brome (plants/m²⁻) averaged for variety and canola plant density at the two sowing times. Please note high CV% and interpret with caution.

	Brome establishment (plants/m²)	Brome in season (plants/m²)	Brome panicles at maturity (panicles/m²)	Weed seed set (seeds/m²)
TOS 1 – Knockdown only	9.41[a]	11.92[a]	8.83	149
TOS 2 – Knockdown only	3.33[b]	5.5[b]	8.33	180
Sig. diff.				
Variety	**0.768**	**0.006**	**0.265**	**0.508**
TOS	**<0.001**	**<0.001**	**0.065**	**0.465**
Seed Rate	**0.812**	**0.231**	**0.315**	**0.152**
Herbicide strategy	**<0.001**	**<0.001**	**<0.001**	**<0.001**
LSD				
Variety	**1.093**	**1.116**	**NS**	**NS**
TOS	**1.093**	**1.116**	**NS**	**NS**
Plant density	**1.093**	**NS**	**NS**	**NS**
Herbicide strategy	**1.545**	**1.578**	**2.107**	**141.7**
CV%	**89.5**	**83.4%**	**127.5%**	**31.3**

The earlier sown canola was able to establish and start growing in the warmer late autumn and early winter, which is likely to have increased its early growth, rooting depth and competitiveness as compared to the later sown crop.

TOS 1 yielded significantly better than TOS 2 ($p<0.001$, LSD=0.0626, CV=10.4%), with sowing one month earlier increasing yields by an average of 14% (0.22t/ha). By sowing earlier, the canola started flowering in the optimal flowering window and had finished flowering before the weather warmed up (Figure 2). The canola sown later experienced three days of over 30°C at the end of its flowering period. It has been shown previously that heat stress at the end of flowering causes the largest reduction in yield compared periods of heat stress from stem elongation to late podding (Uppal, Brill and Bromfield 2019).

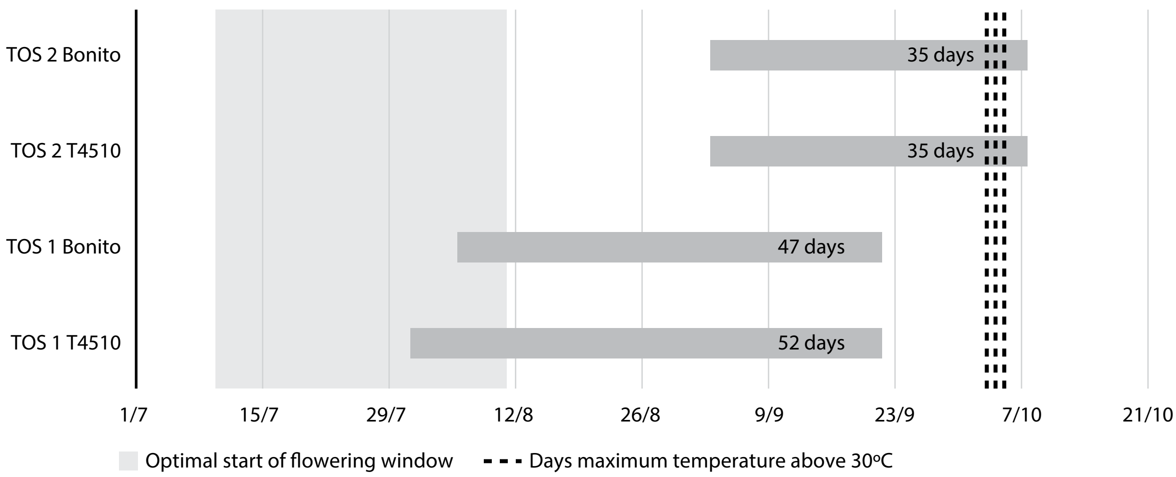

Figure 2. Flowering period and length of the canola varieties sown on 17 April (TOS1) and 15 May (TOS2). Days over 30°C in the flowering period indicated by dotted line.

Impact of variety selection

Growing a hybrid variety (InVigor® T 4510) compared to an open pollinated variety (ATR Bonito) did not have a significant effect on brome control, despite hybrid varieties generally having more early vigour and being considered more competitive. However this early vigour – potentially due to bigger seed size – did see InVigor® T 4510 (36.22 plants/m²) establish significantly better than ATR Bonito (30.88 plants/m²) (p<0.001, LSD=2.73 plants/2, CV=19.3%).

InVigor® T 4510 yielded significantly better than ATR Bonito at both times of sowing (Figure 3). This could be due to the hybrid variety having good early vigour and higher genetic potential.

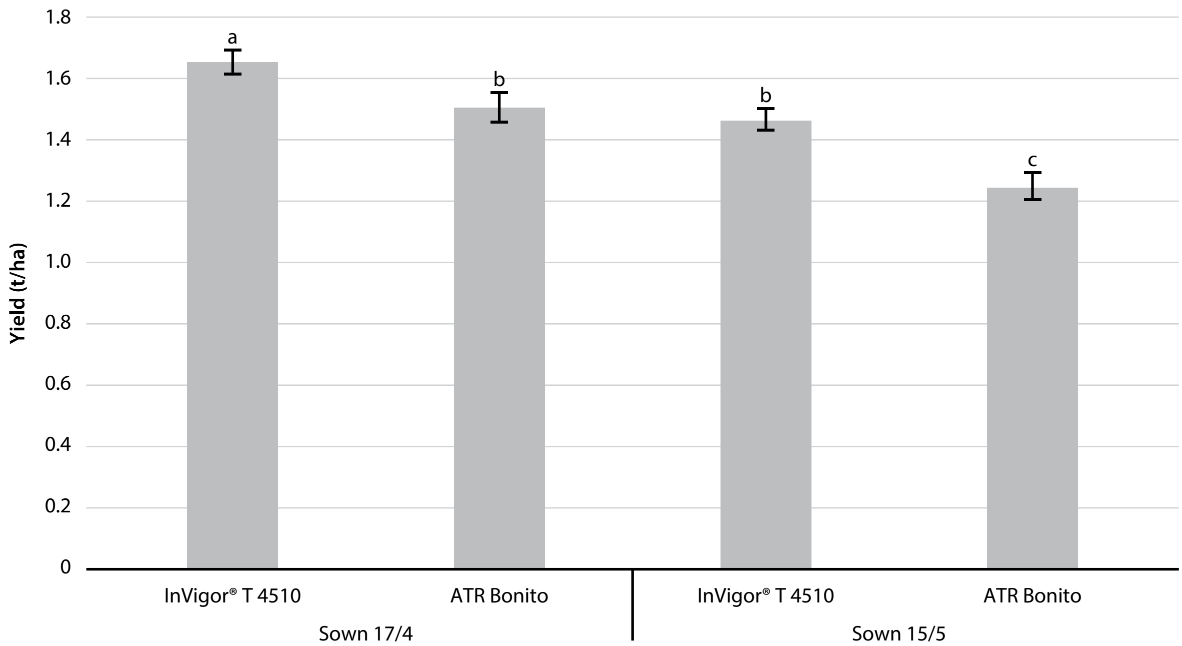

Figure 3. Yield (t/ha) by variety and time of sowing. Variety: p<0.001, LSD=0.0626t/ha, CV (95%)=10.4%. TOS: p<0.001, LSD=0.0626t/ha, CV (95%)=10.4%. Bars with different letters are significantly different at P=0.05.

Impact of plant density

Brome seed set was decreased by 40% when the canola plant density increased from 25 plants/m² to 50 plants/m². Due to highly variable weed population at the site however this was not statistically significant (P=0.079).

The higher crop sowing density (50 plants/m²) yielded significantly higher than 25 plants/m² across both varieties (P=0.003, LSD=0.0626t/ha, CV=10.4%) (Table 3). This highlights the importance of establishing an optimal canola plant population (30-50 plants/m²) (GRDC 2015) for both yield potential and weed suppression through crop competition. Previous BCG research has shown that canola yields do not increase above 45 plants/m² however this does depend on the season (Browne and McDonald 2019).

Table 3. Plant establishment (plants/m²), yield (t/ha) and weed seed set (seeds/m²) of sowing densities and varieties.

Target plant density	Variety	Plant establishment (plants/m²)	Yield (t/ha)	Weed seed set (seeds/ m²)
50 plants/m²	InVigor® T 4510	46.3	1.60	50
50 plants/m²	ATR Bonito	37.5	1.39	172
25 plants/m²	InVigor® T 4510	26.2	1.51	218
25 plants/m²	Bonito	24.2	1.36	194
	Sig. diff.			
	Variety	**<0.001**	**<0.001**	**0.508**
	TOS	**0.536**	**<0.001**	**0.465**
	Seed rate	**<0.001**	**0.003**	**0.152**
	Herbicide strategy	**0.85**	**<0.001**	**<0.001**
	LSD			
	Variety	**2.73**	**0.0626**	**NS**
	TOS	**NS**	**0.0626**	**NS**
	Plant density	**2.73**	**0.0626**	**NS**
	Herbicide strategy	**NS**	**0.0885**	**141.7**
	CV%	**19.3**	**10.4**	**31.3**

Impact of herbicide strategy

Applying atrazine significantly reduced brome density six weeks after sowing as compared to the knockdown treatment only (Table 4). The pre-emergent chemistries were effective in the 2020 season. This was due to good soil moisture present at sowing followed by rainfall to wash herbicides into the soil profile and provide good soil moisture to allow for uptake by weed seedlings. Applying haloxyfop post-emergence significantly reduced brome density six weeks after spraying compared to both the pre-emergent only and knockdown only treatments (Table 4). The addition of atrazine to the post-emergent haloxfop application did not reduce brome densities compared to haloxyfop only. The same pattern was observed in the density of brome panicles at maturity (Table 4). The haloxyfop applications were effective in TOS 2, despite being applied in the middle of a frosty period.

Table 4. Average brome density (plants/m2), panicle production (panicles/m²) and weed seed set (seeds/m²) for herbicide strategies across the two sowing times and varieties. Please note high CV and interpret with caution.

	Brome in season (plants/m²)	Brome panicles at maturity (panicles/m²)	Weed seed set (seeds/m²)
Knockdown only	8.708^{c}	8.583^{c}	508^{c*}
Atrazine @ 1.8kg/ha IBS	2.75^{b}	2.333^{b}	112^{b*}
Atrazine @ 1.8kg/ha IBS + Haloxyfop 75mL/ha	0.333^{a}	0.583^{a}	18^{a*}
Atrazine @ 1.8kg/ha + Propyzamide @ 1L/ha IBS + Haloxyfop 75mL/ha + Atrazine @400g/ha	0.5^{a}	0.625^{a}	19^{a*}
Sig. diff.			
Variety	**0.006**	**0.265**	**0.612**
TOS	**<0.001**	**0.065**	**0.595**
Seed Rate	**0.231**	**0.315**	**0.079**
Herbicide strategy	**<0.001**	**<0.001**	**<0.001**
LSD			
Variety	**1.116**	**NS**	**NS**
TOS	**1.116**	**NS**	**NS**
Plant density	**NS**	**NS**	**NS**
Herbicide strategy	**1.578**	**2.107**	***4.239**
CV%	**83.4%**	**127.5%**	***30.8%**

*Significance calculated from analysis of square root transformed data, means are the untransformed data.

Yield was inversely correlated with weed density, with both pre- and post-emergent herbicide treatments yielding significantly higher than the pre-emergent only and knockdown only treatment yielding the lowest (Figure 4). This highlights the competitiveness of brome and the importance of controlling weeds to ensure crops can have full access to all available moisture and nutrients.

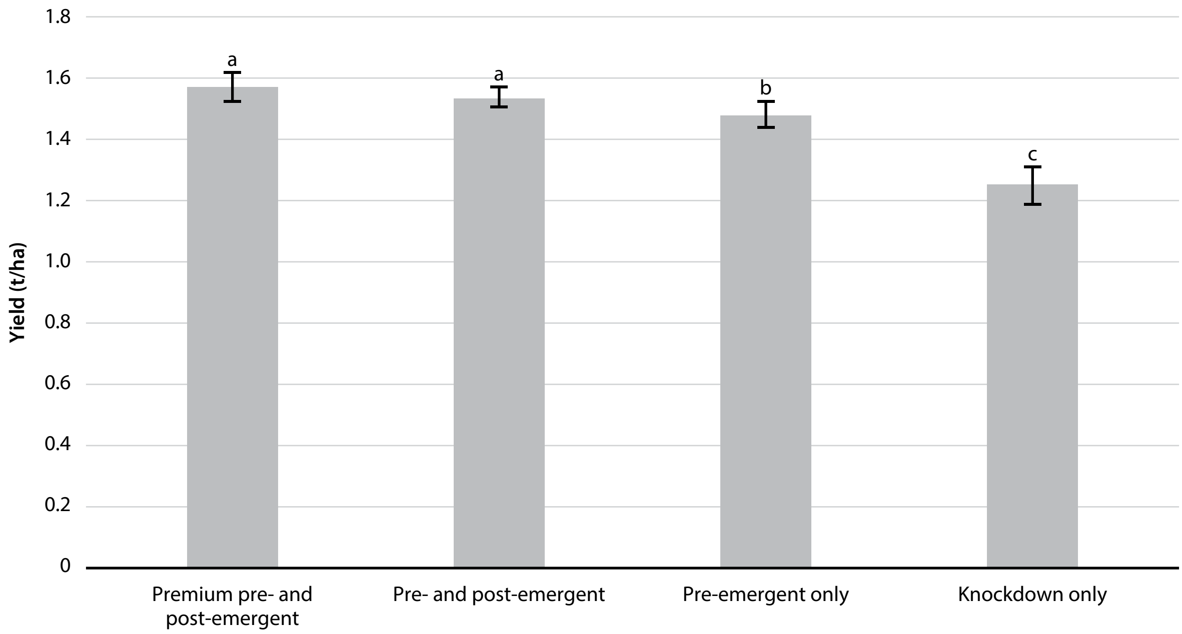

Figure 4. Effect of herbicide strategy on yield (t/ha) across sowing times and varieties. Herbicide: p<0.001, LSD=0.0885t/ha, CV=10.4%.

COMMERCIAL PRACTICE AND ON-FARM PROFITABILITY

In the 2020 season, it was simple to match sowing date to flowering date as canola sown into moist soil germinated immediately. However, this is more difficult to do in a dry sowing scenario. It is also important to note that in 2020, sowing later to control more brome with the knockdown did reduce in-crop brome plant density but did not result in significant differences in brome panicles and weed seed set and came with a major yield and economic penalty. This highlights the importance of growing the most competitive crop possible to not only reduce brome seed set but to maximise yields and income.

Matching canola maturity to sowing and/or germination date to ensure it flowers during the optimal period is vital to maximise both yield potential and economic returns. Sowing on time rather than too late in this trial increased income by $125/ha or 15% when averaged across the trial (Table 5). Time of sowing is something that farmers can control and is a way to increase yields without increasing expenditure.

Table 5. Effect of TOS on grower income. ANOVA results across whole trial displayed.

	Yield (t/ha)	Oil (%)	$/t	Income ($/ha)
TOS1	1.58^{a}	38.6%^{a}	$528	$841^{a}
TOS2	1.36^{b}	41.5%^{b}	$543	$716^{b}
Sig. diff.				
Variety	**<0.001**	**<0.001**		**0.017**
TOS	**<0.001**	**<0.001**		**<0.001**
Plant density	**0.003**	**0.15**		**0.40**
Herbicide strategy	**<0.001**	**<0.001**		**<0.001**
LSD				
Variety	**0.0626**	**0.616**		**62.4**
TOS	**0.0626**	**0.616**		**62.4**
Seed Rate	**0.0626**	**NS**		**NS**
Herbicide strategy	**0.0885**	**0.871**		**88.3**
CV%	**10.4**	**3.8**		**18.9**

Controlling brome also made economic sense in the 2020 season. By controlling brome, the income increased by $169/ha or 21% after including the cost of the herbicides and applying the herbicides when averaged across the trial (Table 6). Controlling brome and reducing weed seed set may also reduce herbicide costs in 2021 and will help to deplete the weed seed bank over time. While controlling a grass weed such as brome in canola might be considered simple, it is important to ensure that both a pre-emergent and post-emergent are applied so that canola can become one of the three years in the rotation with no seed set to fully deplete the brome seed bank. It is interesting to note that even with the use of best herbicide options, this brome population managed to produce 18 seeds/m^2. These results highlight the practical difficulties growers face in eliminating brome from their cropping paddocks.

Table 6. Effect of herbicide strategy on grower income. ANOVA results across whole trial displayed. Herbicide cost calculated using atrazine @ $8/kg, haloxyfop @$44/L, propzyamide @ $21.8/L glyphosate 540 @ $5.4/L. Application costs were $11 per hectare (SARDI Gross Margin Guide).

	Yield (t/ha)	Oil (%)	$/t	Herbicide Cost ($/ha)	Income after herbicide costs ($/ha)
Atrazine FB Verdict	1.54^{a}	41.6%	$545	$51	$791^{a}
Propyzamide Atrazine FB Verdict Atrazine	1.57^{a}	41.5%	$544	$76	$784^{a}
Atrazine	1.48^{b}	39.8%	$535	$36	$755^{a}
Untreated	1.25^{c}	37.4%	$516	$22	$622^{b}
Sig. diff.					
Variety	**<0.001**	**<0.001**			**<0.001**
TOS	**<0.001**	**<0.001**			**<0.001**
Plant density	**0.003**	**0.15**			**<0.001**
Herbicide strategy	**<0.001**	**<0.001**			**<0.001**
LSD					
Variety	**0.0626**	**0.616**			**32.79**
TOS	**0.0626**	**0.616**			**32.79**
Seed Rate	**0.0626**	**NS**			**32.79**
Herbicide strategy	**0.0885**	**0.871**			**46.37**
CV%	**10.4**	**3.8**			**10.8**

While plant density and variety had a significant effect on yield, it did not have a significant effect on income when treatment costs were included. Choosing to grow a hybrid over an OP did not significantly increase or decrease income for the grower in 2020.

It is also important when choosing canola varieties to carefully consider herbicide tolerances. The top triazine-tolerant varieties have yielded similarly to the top Clearfield® varieties in the Birchip NVT. Choosing to grow a triazine tolerant variety provides a break away from the Clearfield® system which will help to slow the rate of development of Clearfield® resistant brome. The option to include multiple herbicide modes of action in a spray program, such as in the premium herbicide strategy, is also a useful tool to reduce the rate of resistance.

REFERENCES

Browne C. McDonald G. (2019) Narrowing the gap between seeding rate and emergence. *2019 BCG Season Research Results*. pp 65-75

Grains Research & Development Corporation (2015) Canola Southern Region. GRDC GrowNotes™. <https://grdc.com.au/GN-Canola-South>

Kleemann S. Fleet B. Preston C. Gill G. (2018) Latest research on brome grass and susceptibility of emerging weed species to harvest weed seed capture and control. GRDC Update Papers. <https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2018/02/latest-research-on-brome-grass-and-susceptibility-of-emerging-weed-species>

Kleemann S. Gill G. (2017) Population Ecology and Management of Rigid Brome (Bromus rigidus) in Australian Cropping Systems. Weed Science 57(2), pp 202-207.

Llewellyn RS, Ronning D, Ouzman J, Walker S, Mayfield A and Clarke M (2016) Impact of Weeds on Australian Grain Production: the cost of weeds to Australian grain growers and the adoption of weed management and tillage practices. CSIRO, Australia. <www.grdc.com.au/ImpactOfWeeds>

Uppal RK. Brill R. Bromfield J. (2019) Effect of heat stress on canola grain yield and quality. GRDC Update Papers. <https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2019/02/effect-of-heat-stress-on-canola-grain-yield-and-quality>

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