TRIAL LOCATIONS: Cunderdin 2018, Cunderdin 2019, and Avondale 2020, Western Australia

TITLE:

TRIAL 1B: The interaction between seeding rate and row spacing of hybrid and open pollinated canola (*Brassica napus*) varieties on wild radish (*Raphanus raphanistrum*) growth and seed production.

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KEY MESSAGE

- The competitive ability of open pollinated and hybrid canola varieties against wild radish is enhanced by increasing canola seeding rates. Wild radish seed production was not reduced when canola was seeded at a narrow row spacing.

Introduction

Wild radish is a prevalent annual weed species infesting all cropping regions of southern Australia on neutral to acidic soils. The economic impact of wild radish is attributed to its ability to greatly reduce crop yield and quality. In addition, immature wild radish plants pose harvest and grain storage problems. Although herbicides are available to control wild radish, the protracted germination and long seed dormancy of wild radish make it difficult to control (Reeves et al., 1981). When growing in a crop, wild radish is a vigorous competitor capable of causing large reductions in crop yield. Wild radish densities of 7 and 200 plants m^2 have been found to reduce wheat (*Triticum aestivum* L.) yield by 10 and 50%, respectively (Code and Reeves, 1981; Pathan et al.), with wild radish that emerges with or shortly after the crop causing the largest reduction in yield (Cheam and Code, 1995). However, wild radish often emerges throughout the crops growing season with late-emerging plants capable of producing sufficient seed to replenish the soil seed bank (Cheam, 1986; Code and Donaldson, 1996; Reeves et al., 1981). Despite a diverse range of herbicide tolerance in F1 hybrid and open pollinated canola varieties, Australian weed surveys have found that wild radish is still present in 13% of the canola fields after all weed management practices are completed (Lemerle et al., 2001). Despite being recognized as a troublesome weed in canola; the effect that canola competitiveness has on wild radish, and the effect of wild radish on canola yield is not well documented. Therefore, this study was conducted to determine the effect of factorial combinations of seeding rate, row spacing and pollination type on canola yield and wild radish fecundity.

Methods

Trial design: Randomised complete block

Replicates: 3

Locations (3): Cunderdin 2018 and 2019 and Avondale 2020 in the Western Australian grainbelt.

Row Spacing (2): 25 and 50 cm

Seed rate / plant establishment target (3): 20 (0.4RR), 35 (0.7RR) and 50 (RR) plants/m^2

Variety (2): Trophy (Hybrid) and Bonito (Open pollinated).

Herbicide treatment (2): Without (Knockdown treatment only) and with herbicide (1 L/ha Propyzamide IBS, 1.1 kg/ha Atrazine IBS, 1.1 kg/ha Atrazine 2-4 leaf and 500 mL/ha Select 4-6 leaf).

Trial Management

Table 1 Trial management details.

Crop type	TT Canola	
Variety	HyTTec Trophy (Hybrid) and Bonito (OP)	
Seeding rate (kg/ha)	HyTTec Trophy 50 plants/m2 = 3.7 kg/ha HyTTec Trophy 35 plants/m2 = 2.6 kg/ha HyTTec Trophy 20 plants/m2 = 1.5 kg/ha Bonito 50 plants/m2 = 2.8 kg/ha Bonito 35 plants/m2 = 1.9 kg/ha Bonito 20 plants/m2 = 1.1 kg/ha	
Tillage type	Minimum tillage	
Seed bed	Standing stubble	
Clod size	None	
Stubble loading	20-30%	
Sowing equipment	Knife points and press wheels	
Sowing speed (km/hr)	5	
Sowing depth	1 cm	
Row spacing (cm)	25 and 50	
Fertiliser applied	Pre-emergent	70 kg/ha Gusto Gold 100 kg/ha Urea
Post-emergent	100 L/ha UAN	
Herbicides applied	Pre-emergent	2 L/ha Roundup Ultra Max 1 L/ha propyzamide 150 g/ha Lontrel (PSPE) Other pre-em herbicides as per treatment list

Post-emergent	As per treatment list 100 mL/ha Verdict (volunteer cereal management) 2 L/ha Reglone (23 Oct 2019)	
Fungicides applied	Seed treatment	400 mL/100 kg-seed Maxim XL
Fertiliser treatment	300 mL/ha Impact	
Post-emergent	500 mL/ha Aviator Xpro	
Insecticides applied	Seed treatment	1 L/100 kg-seed Cruiser Opti
Pre-emergent	1 L/ha chlorpyrifos 200 mL/ha bifenthrin	
Post-emergent	1 L/ha chlorpyrifos 50 g/ha Transform 300 mL/ha Affirm	

The data collected was statistically analysed by SAGI via linear mixed models with ASReml-R package (VSN International Ltd, Hemel Hempstead, UK).

LOCATIONS

The soil characterisation per site can be found in Table 2. A photo of the Avondale site can be seen in Figure 1. Each site had been under no-till production for 10 years before initiation of the study.

Table 2 Soil description at the trial sites.

		Cunderdin 2018	**Cunderdin 2019**	**Avondale 2020**
Location		-31.37S, 117.14E	-31.65S, 117.24E	-32.11S,116.86E
Growing season rainfall	mm	230	206	213
Colour		LTGR	LTGR	BRGR
Gravel	%	0	0	5
Texture		1.5	1.5	1
Conductivity	dS/m	0.142	0.161	0.108
pH Level (CaCl2)		5.4	6.1	4.8
pH Level (H2O)		6	6.6	5.7
Ammonium Nitrogen	meq/kg	3	2	11
Nitrate Nitrogen	meq/kg	45	50	33
Phosphorous	meq/kg	30	38	38
Colwell Potassium	meq/kg	49	55	94

Colwell Sulphur	meq/kg	16.7	18.1	15.7
Total Carbon	%	1.11	1.08	1.42

Figure 1 Aerial photo of the Avondale trial site in 2020 highlited in blue.

Results and Discussion.

WR establishment

Across the sites, there were significant interactions between the three factors studied (canola variety x row spacing x seeding rate) ($p<0.001$) (Table 4). Figure 2 shows that for the OP variety, wild radish establishment is reduced with increasing seeding rates at both row spacings, however wild radish establishment was the highest at the lowest canola seeding rate and widest row spacing. For the hybrid variety however, seeding rate appears to have no effect at both row spacings, although in the wider row spacing a lower wild radish establishment occurred compared to the narrow row spacing. As the wild radish seed was incorporated at seeding and located closer to the soil surface it is expected that the moist microclimate of the narrow row spacing crop may contribute to an improved wild radish germination.

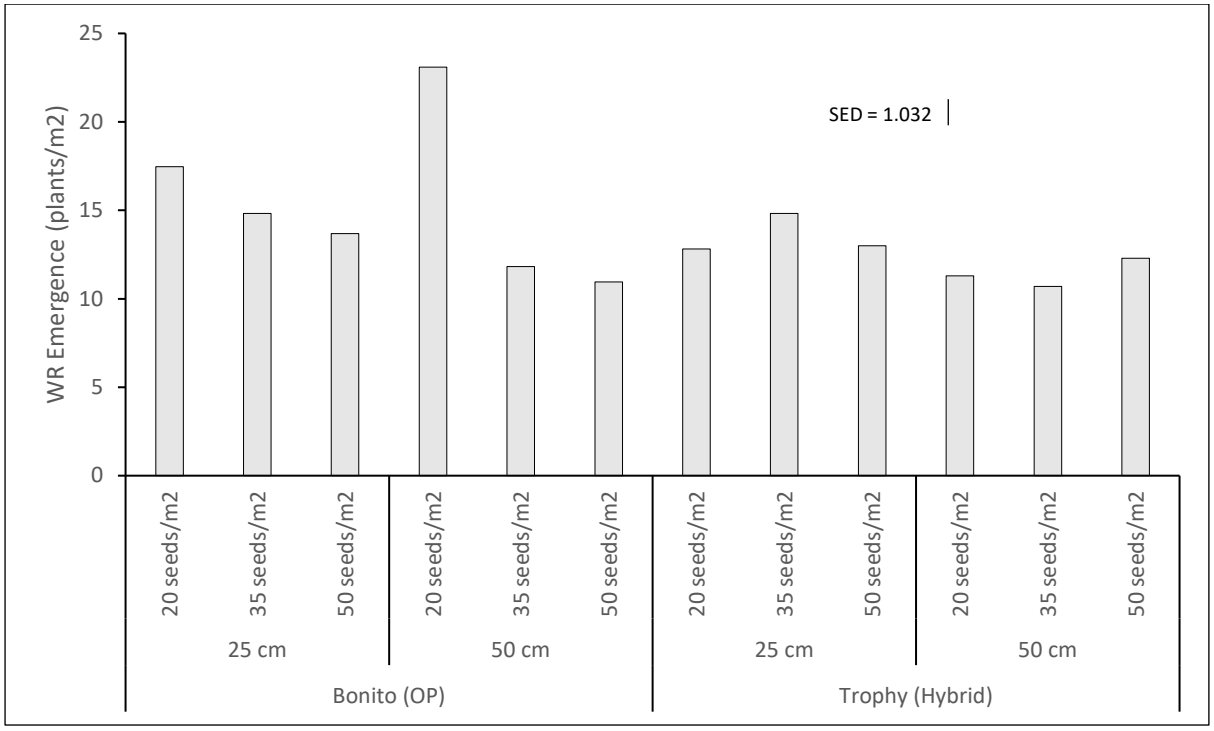

Figure 2 Wild radish emergence where no herbicide was applied across the three trial sites from 2018-2020. Results of the linear mixed model show significant third and second order interactions as well as main effects $p<0.001$.

Canopy cover

In the absence of WR competition, it was found that significant interactions between the three factors studied existed at 16 weeks after sowing ($p=0.044$) and variety ($p<0.01$) and seeding rate ($p<0.001$) were found to also contribute to canola canopy cover and early competitiveness significantly (Table 3). For the OP variety, as expected canopy cover increases with seeding rate at the 25 cm row spacing ($p<0.001$) (Figure 3); however, at the 50 cm row spacing, variable results were found with increased seeding rate. For the hybrid variety, a clearer trend can be observed with crop canopy cover increasing with increasing seeding rate in both the 25 and 50 cm row spacings. Although not significantly, the mean canopy cover was however greater when the hybrid variety was seeded at the 25 cm row spacing (Figure 3).

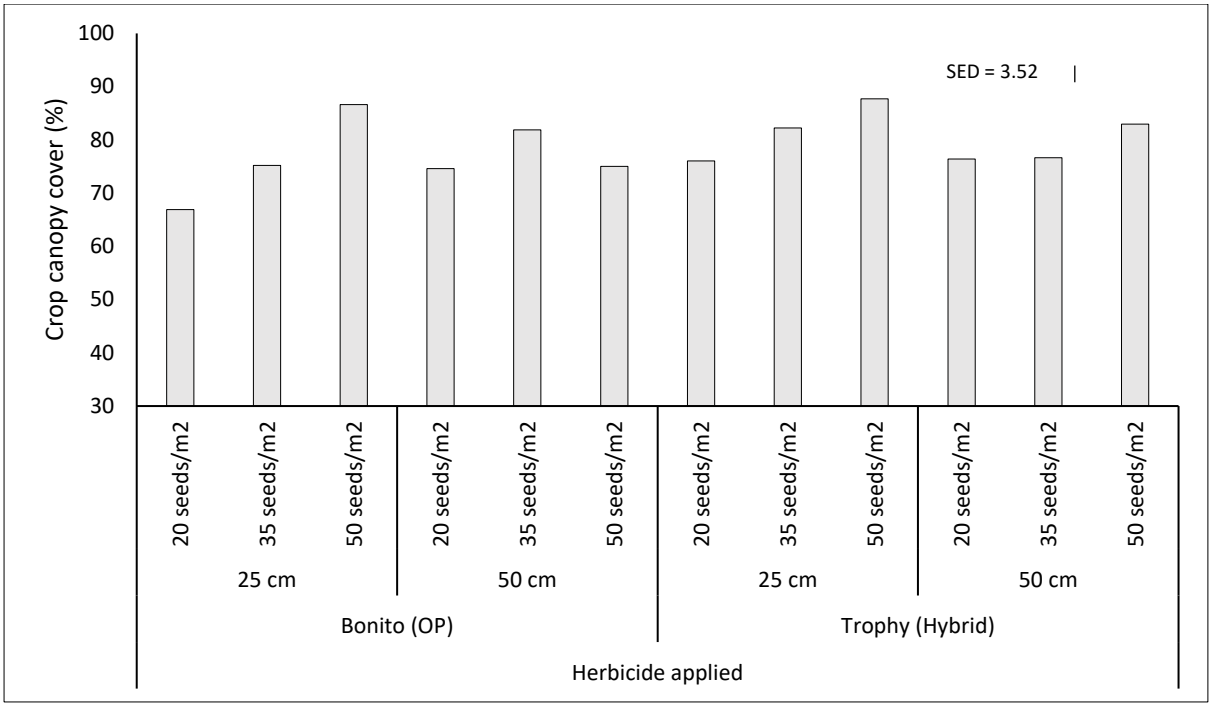

Figure 3: Percentage of Canola canopy cover measured at 16 weeks after establishment across the three trial sites from 2018-2020. Results of the linear mixed model show significant third and second order interactions as well as main effect for seeding rate ($p<0.05$).

WR seed production

In the absence of herbicides, wild radish seed production was affected by Variety ($p=0.006$), row spacing ($p<0.001$) and seeding rate ($p<0.001$) (Table 4). For the OP variety, wild radish seed production decreased with increasing seeding rates at both row spacings ($p<0.001$) (Figure 4), especially when going from 20 to 35 plants per m^2 within the narrow row spacing. However, at this narrow 25 cm row spacing no further significant reduction in wild radish seed production was found when increasing the seeding rate from 35 to 50 plants/m^2. At the wider row spacing of 50 cm there was a trend towards reduced wild radish seed production when seeding rates were increased, however this was not statistically significant ($p>0.05$). The combined results of three trials indicate that if wider row spacing are used with the OP variety Bonito, maximising the establishment density is important in reducing wild radish seed production; however, if narrow row spacing are used then wild radish seed production can be similarly reduced at the 35 plant/m^2 density (70% of the full establishment density). For the hybrid variety, a similar significant reduction in seed production is observed at both row spacings when increasing the seeding rates from 20 to 35 plants/m^2. However, when increasing

the seeding rate from 35 to 50 plants/m2 no significant further reduction in seed production can be seen at both row spacings (p>0.05), however a reduction in WR seed production was still evident.

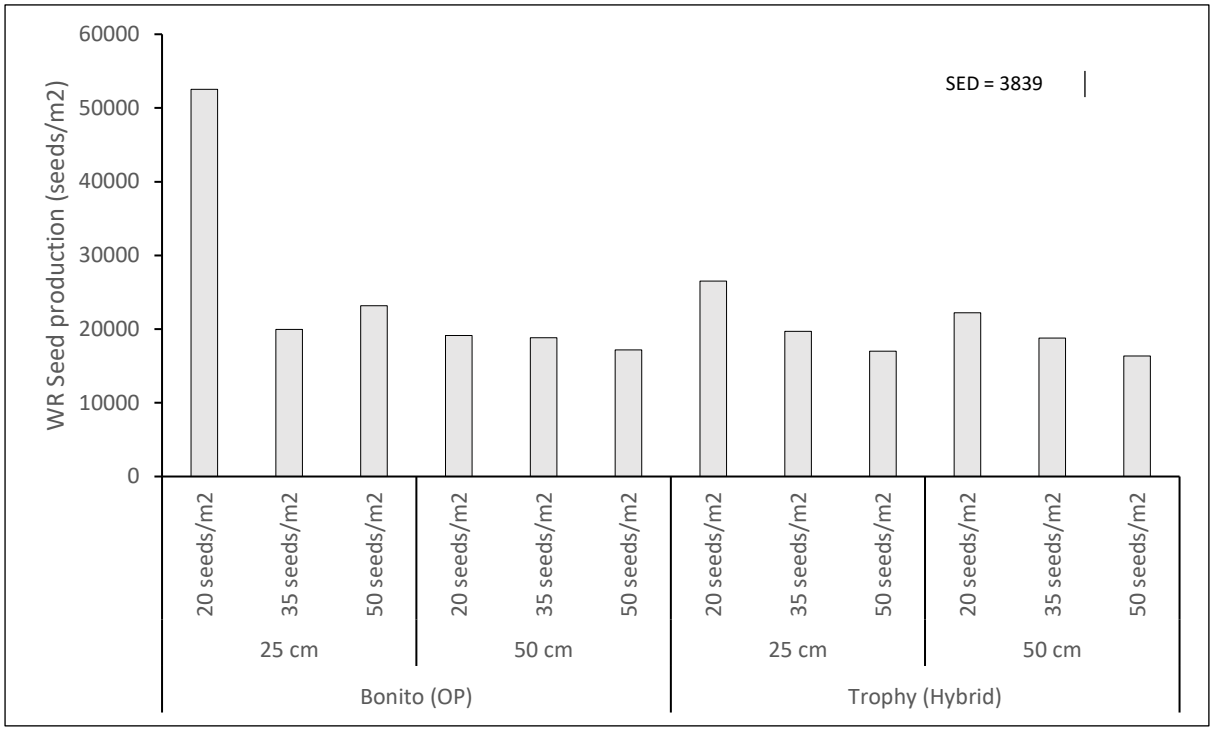

Figure 4: Wild radish seed production across the three trial sites from 2018-2020. Results of the linear mixed model show significant third and second order interactions as well as main effects for all factors (p<0.05).

Canola yield

With herbicide application, the assessment of canola yield found no significant interactions (p>0.05); however, significant effects were found for variety (p<0.001), seeding rate (p=0.003) and row spacing (p<0.001) (Table 3). The hybrid variety out yielded the OP variety within all seeding rate and row spacing treatments (Figure 5). When herbicide was applied, the hybrid variety produced 12% more grain than the OP; in the absence of herbicides the hybrid yielded 28% greater than the OP. Interestingly, when herbicides were applied seeding rate had no significant effect on yield for both varieties and row spacing (p>0.05), supporting previous research by French et al (2016). In competition with wild radish, increasing the canola seeding rate consistently increased the yield for both OP and hybrid varieties. When increasing the seeding rate from 20 to 50 seeds/m^2, yields were incremented by 25% for the OP variety and 18% for the hybrid variety.

Interestingly the results show that across the three sites in the absence of wild radish competition, the wider row spacing treatment (50 cm) consistently out yielded the narrow 25 cm row spacing

(p<0.001), with the OP and hybrid variety yielding 13% and 8% more at the 50cm row spacing compared to the 25cm row spacing, respectively. When wild radish was not controlled by herbicides, a similar trend and effect of row spacing on yield was found however it was not significant (p>0.05).

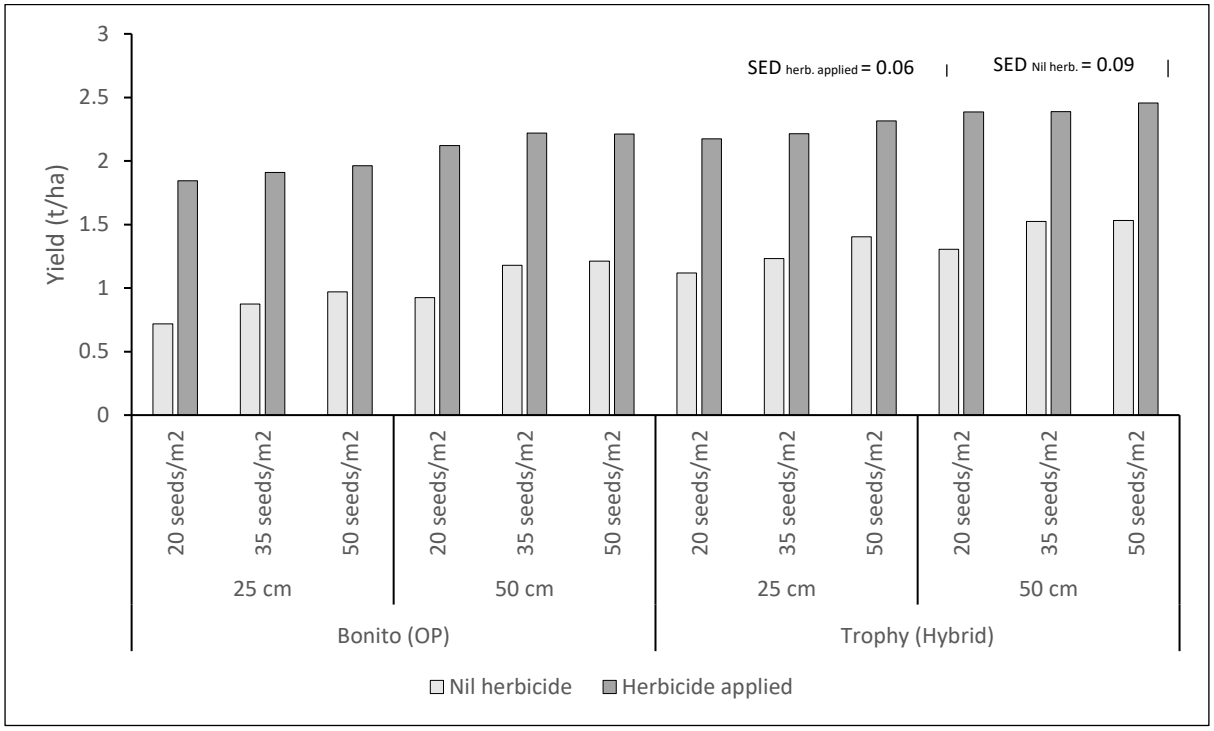

Figure 5 Canola yield across the three trial sites from 2018-2020. Results of the linear mixed model suggest no significant third or second order interactions for both herbicide applied and nil herbicide treatments (p>0.05); however, all the individual treatments (variety, row spacing, and seeding rate) were significant as main effects (p<0.05).

Maximising yield and reducing wild radish seed production

In order to identify the optimum combination of canola pollination type, seeding rate and row spacing on wild radish seed production, canola yield was modelled as per equation 1.

$$Yield = y \sim \log(x) \quad [1]$$

Where y is the mean predicted yield per treatment and x is wild radish seed production seeds/m^2.

Results indicate that if sowing the OP variety, a wide row spacing of 50 cm and the highest seeding rate treatment (50 plants/m^2) optimised both canola yield while reducing WR seed production (Figure 6). For the hybrid variety, a similar optimum combination was found with a 50 cm row spacing and a high seeding rate of 50 plants/m^2 being the optimal combination (Figure 6).

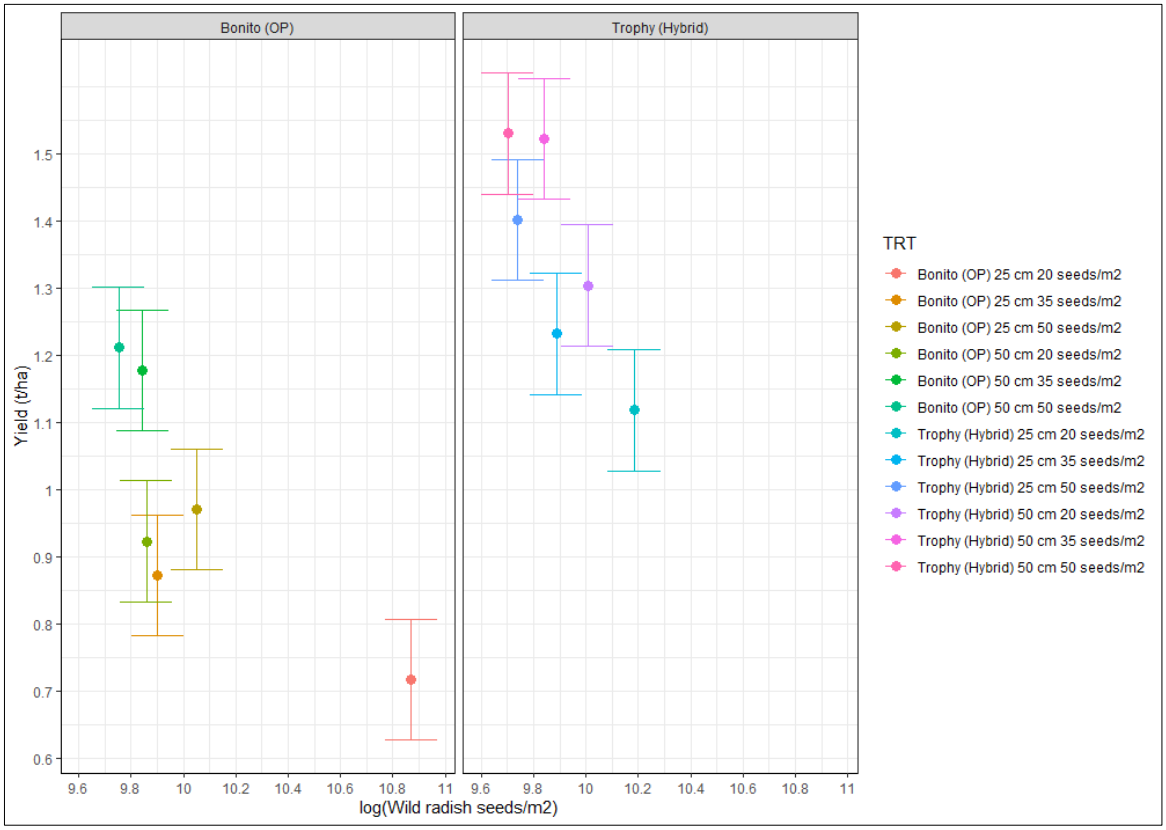

Figure 6 Canola yield as a function of wild radish seed production in response to canola varieties (OP vs Hybrid), row spacing (25 and 50 cm), and seeding rate (20,35, and 50 seeds/m2).

Herbicide applied.

Table 3 The P value and averaged standard error of differences (SED) results using the linear mixed model (LMM) for the effect of canola pollination type (variety), row spacing (spacing), seeding rate (rate) and the relevant interactions for canola in the absence of WR competition for combined analysis and individual environments with herbicide applied.

Dependent variable	Source	Combined analysis	Cunderdin 2018	Cunderdin 2019	Avondale 2020
Crop Emergence (plants/m2) 10WAS	Variety	0.003	0.001	0.017	0.008
	Spacing	0.036	<0.001	NS	0.001
	Rate	<0.001	<0.001	<0.001	<0.001
	Variety x Spacing	NS	NS	NS	NS
	Variety x Rate	NS	NS	NS	NS
	Spacing x Rate	0.049	NS	NS	NS
	Variety x Spacing x Rate	NS	NS	NS	NS
Crop canopy cover % 16WAS	Variety	0.010	NS	0.029	0.008
	Spacing	NS	NS	NS	NS
	Rate	0.001	0.001	NS	NS
	Variety x Spacing	NS	NS	NS	NS
	Variety x Rate	NS	NS	NS	NS
	Spacing x Rate	0.030	NS	0.037	NS
	Variety x Spacing x Rate	0.044	NS	NS	NS
NDVI 16WAS	Variety	<0.001	NS	0.055	<0.001
	Spacing	<0.001	NS	<0.001	0.005
	Rate	<0.001	0.011	NS	<0.001
	Variety x Spacing	NS	NS	NS	NS
	Variety x Rate	<0.001	NS	NS	0.031
	Spacing x Rate	NS	NS	0.054	NS
	Variety x Spacing x Rate	NS	NS	NS	NS
Crop Radiation Interception (µmol m-2 s-1)	Variety	NS	NS	NS	NS
	Spacing	0.024	NS	NS	NS
	Rate	NS	NS	NS	0.030
	Variety x Spacing	NS	NS	NS	0.028
	Variety x Rate	0.053	0.039	NS	NS
	Spacing x Rate	NS	NS	NS	NS
	Variety x Spacing x Rate	NS	NS	0.027	NS
Crop Radiation Interception (%)	Variety	NS	NS	NS	NS
	Spacing	NS	0.024	NS	NS
	Rate	0.030	NS	NS	0.016
	Variety x Spacing	NS	NS	NS	0.013
	Variety x Rate	NS	NS	NS	NS
	Spacing x Rate	NS	NS	NS	NS
	Variety x Spacing x Rate	NS	NS	NS	NS
Canola Yield (t/ha)	Variety	<0.001	NS	<0.001	<0.001
	Spacing	<0.001	<0.001	<0.001	NS
	Rate	0.003	NS	0.003	NS
	Variety x Spacing	NS	NS	0.043	NS
	Variety x Rate	NS	NS	NS	0.007
	Spacing x Rate	NS	NS	NS	0.027
	Variety x Spacing x Rate	NS	NS	NS	NS
Canola 1000 seed weight (g)	Variety		NS	<0.001	
	Spacing		NS	0.024	
	Rate		NS	NS	
	Variety x Spacing		NS	0.005	
	Variety x Rate		NS	NS	
	Spacing x Rate		NS	NS	
	Variety x Spacing x Rate		NS	NS	
Canola Oil (%)	Variety		0.010	<0.001	
	Spacing		NS	0.006	
	Rate		0.021	NS	
	Variety x Spacing		NS	0.004	
	Variety x Rate		NS	NS	
	Spacing x Rate		NS	NS	
	Variety x Spacing x Rate		NS	NS	

Herbicide nil.

Table 4 The P value and averaged standard error of differences (SED) results using the linear mixed model (LMM) for the effect of canola pollination type (variety), row spacing (spacing), seeding rate (rate) and the relevant interactions for canola in the absence of WR competition for combined analysis and individual environments with herbicide free.

Dependent variable	Source	Combined analysis	Cunderdin 2018	Cunderdin 2019	Avondale 2020
Canola Emergence (plants/m2) 10WAS	Variety	0.006	0.003	0.013	0.008
	Spacing	0.006	<0.001	NS	<0.001
	Rate	<0.001	<0.001	<0.001	<0.001
	Variety x Spacing	NS	NS	NS	NS
	Variety x Rate	NS	NS	NS	NS
	Spacing x Rate	0.038	NS	NS	NS
	Variety x Spacing x Rate	NS	NS	NS	0.052
WR Emergence (plants/m2) 10WAS	Variety	<0.001	NS	<0.001	NS
	Spacing	0.018	NS	0.002	<0.001
	Rate	<0.001	NS	<0.001	<0.001
	Variety x Spacing	0.021	NS	0.022	NS
	Variety x Rate	<0.001	NS	<0.001	NS
	Spacing x Rate	<0.001	NS	<0.001	NS
	Variety x Spacing x Rate	0.001	NS	<0.001	NS
WR Biomass (g/plant)	Variety	0.002	NS	0.001	NS
	Spacing	NS	NS	NS	NS
	Rate	0.005	0.048	NS	0.024
	Variety x Spacing	NS	NS	NS	NS
	Variety x Rate	NS	NS	NS	NS
	Spacing x Rate	NS	NS	NS	NS
	Variety x Spacing x Rate	NS	NS	NS	NS
Total WR seed production (seeds/m2)	Variety	0.006	NS	0.009	0.005
	Spacing	<0.001	NS	<0.001	<0.001
	Rate	<0.001	0.008	<0.001	<0.001
	Variety x Spacing	0.003	NS	<0.001	0.004
	Variety x Rate	0.024	NS	0.029	0.010
	Spacing x Rate	0.001	NS	0.001	<0.001
	Variety x Spacing x Rate	0.003	NS	0.001	<0.001
Canola Yield (t/ha)	Variety	<0.001	NS	<0.001	<0.001
	Spacing	<0.001	0.006	<0.001	0.002
	Rate	<0.001	<0.001	0.007	0.007
	Variety x Spacing	NS	NS	NS	NS
	Variety x Rate	NS	NS	NS	NS
	Spacing x Rate	NS	NS	NS	NS
	Variety x Spacing x Rate	NS	NS	NS	NS
Canola 1000 seed weight g	Variety		0.029	0.004	
	Spacing		NS	NS	
	Rate		NS	NS	
	Variety x Spacing		NS	NS	
	Variety x Rate		NS	NS	
	Spacing x Rate		NS	NS	
	Variety x Spacing x Rate		NS	NS	
Canola Oil %	Variety		NS	0.014	
	Spacing		NS	NS	
	Rate		NS	NS	
	Variety x Spacing		NS	NS	
	Variety x Rate		NS	NS	
	Spacing x Rate		NS	NS	
	Variety x Spacing x Rate		0.058	NS	

Table 5 Means and standard errors of predicted values using the linear mixed model (LMM) for the effect of canola pollination type (variety), row spacing (spacing), seeding rate (rate) and the relevant interactions for canola in the absence of WR competition for combined analysis and individual environments with herbicide applied --- Part A.

Herbicide Applied			**Crop Emergence (plants/m^2) 10WAS**				**Canopy cover % 16WAS**				**NDVI 16WAS**				**Radiation Interception (µmol m-2 s-1)**			
	Variety		**Bonito**		**Hybrid**		**Bonito**		**Hybrid**		**Bonito**		**Hybrid**		**Bonito**		**Hybrid**	
	Spacing	***Rate***	***predicted value***	***SE***	***predicted value***	***SE***	***predicted value***	***SE***	***predicted value***	***SE***	***predicted value***	***SE***	***predicted value***	***SE***	***predicted value***	***SE***	***predicted value***	***SE***
Combined analysis	25cm	0.4RR	19.337	4.335	23.172	4.076	69.775	6.831	78.939	6.863	0.588	0.133	0.683	0.133	658.247	97.622	634.096	98.104
		0.7RR	27.936	4.076	32.589	4.085	78.933	6.939	84.229	6.863	0.649	0.133	0.696	0.133	663.772	97.478	668.653	97.478
		RR	39.149	4.161	42.808	4.076	86.644	6.863	87.509	6.795	0.665	0.133	0.713	0.133	710.695	98.104	631.767	97.478
	50cm	0.4RR	22.081	4.076	23.027	4.076	74.709	6.863	78.184	6.863	0.519	0.133	0.653	0.133	692.110	97.478	690.030	97.478
		0.7RR	27.866	4.076	28.829	4.076	81.700	6.795	77.844	6.863	0.633	0.133	0.682	0.133	675.676	97.478	691.341	97.478
		RR	34.701	4.076	38.095	4.076	75.233	6.863	83.899	6.863	0.623	0.133	0.690	0.133	713.199	97.478	670.220	97.478
	averaged SED		2.222				3.521				0.015				28.696			
Cunderdin 2018	25cm	0.4RR	19.978	3.584	20.305	3.584	76.102	5.328	70.360	4.372	0.717	0.032	0.720	0.032	633.087	22.135	616.230	27.110
		0.7RR	30.785	3.584	21.074	4.388	86.303	4.372	80.130	4.372	0.787	0.032	0.800	0.039	630.833	22.135	624.073	22.135
		RR	39.300	3.584	37.008	3.584	94.850	4.372	92.267	4.372	0.823	0.032	0.830	0.032	684.825	27.110	584.907	22.135
	50cm	0.4RR	37.990	3.584	23.908	3.584	81.850	4.372	74.813	4.372	0.780	0.032	0.753	0.032	667.163	22.135	655.583	22.135
		0.7RR	54.365	3.584	39.955	3.584	86.403	4.372	79.723	4.372	0.793	0.032	0.790	0.032	626.683	22.135	683.110	22.135
		RR	56.330	3.584	49.125	3.584	83.660	4.372	87.497	4.372	0.803	0.032	0.807	0.032	672.943	22.135	643.430	22.135
	averaged SED		5.126				6.098				0.046				32.062			
Cunderdin 2019	25cm	0.4RR	12.773	2.985	17.030	1.724	54.970	4.387	68.433	4.387	0.419	0.021	0.400	0.026	575.850	75.472	384.617	66.812
		0.7RR	20.650	1.724	24.580	1.724	67.684	5.287	75.463	4.387	0.454	0.026	0.356	0.021	509.470	66.812	546.137	66.812
		RR	32.458	2.111	36.060	1.724	74.183	4.387	74.127	4.387	0.433	0.021	0.431	0.021	513.363	66.812	502.177	66.812
	50cm	0.4RR	15.500	1.724	17.667	1.724	63.457	4.387	70.563	4.387	0.364	0.021	0.348	0.021	522.910	66.812	562.200	66.812
		0.7RR	20.500	1.724	21.833	1.724	68.707	4.387	64.073	4.387	0.391	0.021	0.369	0.021	611.970	66.812	505.953	66.812
		RR	28.333	1.724	30.500	1.724	58.760	4.387	69.033	4.387	0.336	0.021	0.335	0.021	580.933	66.812	470.400	66.812
	averaged SED		2.679				5.859				0.029				67.243			
Avondale 2020	25cm	0.4RR	21.288	3.122	23.580	3.122	80.027	3.834	96.090	4.696	0.711	0.010	0.821	0.010	670.023	61.640	917.530	61.640
		0.7RR	31.768	3.122	41.593	3.122	84.895	4.696	95.620	4.696	0.775	0.010	0.832	0.010	854.043	61.640	913.837	61.640
		RR	41.265	3.122	46.505	3.122	92.975	4.696	96.717	3.834	0.790	0.010	0.845	0.010	939.340	61.640	916.010	61.640
	50cm	0.4RR	19.700	3.122	19.208	3.122	80.350	4.696	87.545	4.696	0.624	0.012	0.788	0.010	829.953	61.640	839.857	61.640
		0.7RR	26.185	3.122	29.386	3.122	90.607	3.834	90.850	4.696	0.760	0.010	0.817	0.010	842.183	61.640	687.673	61.640
		RR	30.002	3.122	41.206	3.122	86.480	4.696	96.935	4.696	0.751	0.010	0.827	0.010	933.610	61.640	892.620	61.640
	averaged SED		4.415				6.358				0.022				81.677			

Table 6 Means and standard errors of predicted values using the linear mixed model (LMM) for the effect of canola pollination type (variety), row spacing (spacing), seeding rate (rate) and the relevant interactions for canola in the absence of WR competition for combined analysis and individual environments with herbicide applied --- Part B.

Herbicide Applied			**Radiation Interception (%)**				**Canola Yield (t/ha)**				**Canola 1000 seed weight (g)**				**Canola Oil (%)**			
	Variety		**Bonito**		**Hybrid**		**Bonito**		**Hybrid**		**Bonito**		**Hybrid**		**Bonito**		**Hybrid**	
	Spacing	***Rate***	***predicted value***	***SE***	***predicted value***	***SE***	***predicted value***	***SE***	***predicted value***	***SE***	***predicted value***	***SE***	***predicted value***	***SE***	***predicted value***	***SE***	***predicted value***	***SE***
Combined analysis	25cm	0.4RR	84.221	3.426	83.402	3.426	1.843	0.552	2.173	0.553	NA	NA	NA	NA	NA	NA	NA	NA
		0.7RR	85.136	3.341	83.666	3.341	1.910	0.552	2.214	0.552	NA	NA	NA	NA	NA	NA	NA	NA
		RR	90.978	3.434	85.988	3.341	1.963	0.552	2.316	0.552	NA	NA	NA	NA	NA	NA	NA	NA
	50cm	0.4RR	84.711	3.341	85.756	3.341	2.122	0.553	2.386	0.552	NA	NA	NA	NA	NA	NA	NA	NA
		0.7RR	86.953	3.341	85.587	3.341	2.219	0.553	2.387	0.552	NA	NA	NA	NA	NA	NA	NA	NA
		RR	89.869	3.341	85.767	3.341	2.211	0.552	2.456	0.553	NA	NA	NA	NA	NA	NA	NA	NA
	averaged SED		2.713				0.064											
Cunderdin 2018	25cm	0.4RR	89.392	2.630	86.476	2.630	1.950	0.195	1.835	0.195	4.141	0.087	4.177	0.087	44.100	0.315	44.233	0.315
		0.7RR	91.058	2.630	87.437	2.630	2.040	0.195	1.793	0.195	4.070	0.087	4.145	0.087	43.867	0.315	43.967	0.315
		RR	95.455	3.221	87.080	2.630	1.979	0.195	2.084	0.195	4.084	0.087	4.101	0.087	43.567	0.315	43.933	0.315
	50cm	0.4RR	92.863	2.630	94.257	2.630	2.355	0.195	2.253	0.195	4.155	0.087	4.135	0.087	43.767	0.315	44.533	0.315
		0.7RR	89.953	2.630	93.709	2.630	2.188	0.195	2.167	0.195	4.188	0.087	4.057	0.087	43.733	0.315	43.667	0.315
		RR	95.517	2.630	92.302	2.630	2.379	0.195	2.204	0.195	4.068	0.087	4.096	0.087	43.600	0.315	44.133	0.315
	averaged SED		3.796				0.144				0.115				0.266			
Cunderdin 2019	25cm	0.4RR	87.836	3.933	81.116	3.933	0.917	0.072	1.254	0.075	3.433	0.058	2.900	0.058	46.533	0.298	43.733	0.298
		0.7RR	81.959	3.305	81.130	3.305	0.995	0.071	1.359	0.076	3.500	0.058	2.933	0.058	46.133	0.298	43.433	0.298
		RR	88.295	3.305	85.566	3.305	1.062	0.072	1.443	0.071	3.400	0.058	2.933	0.058	45.933	0.298	43.667	0.298
	50cm	0.4RR	79.150	3.305	80.084	3.305	1.238	0.078	1.475	0.073	3.233	0.058	2.900	0.058	45.233	0.298	43.800	0.298
		0.7RR	86.840	3.305	83.114	3.305	1.299	0.075	1.488	0.072	3.167	0.058	3.000	0.058	45.200	0.298	43.533	0.298
		RR	86.198	3.305	81.284	3.305	1.329	0.072	1.545	0.078	3.400	0.058	2.933	0.058	45.767	0.298	43.567	0.298
	averaged SED		4.303				0.073				0.079				0.307			
Avondale 2020	25cm	0.4RR	68.260	4.524	87.440	4.524	2.844	0.141	3.553	0.147	NA	NA	NA	NA	NA	NA	NA	NA
		0.7RR	81.479	4.524	85.913	4.524	2.856	0.147	3.230	0.142	NA	NA	NA	NA	NA	NA	NA	NA
		RR	90.229	4.524	91.279	4.524	2.683	0.140	3.400	0.141	NA	NA	NA	NA	NA	NA	NA	NA
	50cm	0.4RR	80.547	4.524	80.662	4.524	2.815	0.138	3.581	0.138	NA	NA	NA	NA	NA	NA	NA	NA
		0.7RR	84.139	4.524	71.445	4.524	3.317	0.137	3.543	0.136	NA	NA	NA	NA	NA	NA	NA	NA
		RR	88.838	4.524	84.094	4.524	2.876	0.138	3.527	0.138	NA	NA	NA	NA	NA	NA	NA	NA
	averaged SED		6.399				0.146											

Table 7 Means and standard errors of predicted values using the linear mixed model (LMM) for the effect of canola pollination type (variety), row spacing (spacing), seeding rate (rate) and the relevant interactions for canola in the absence of WR competition for combined analysis and individual environments with herbicide free --- Part A.

Herbicide Nil			**Canola Emergence (plants/m2) 10WAS**				**WR Emergence (plants/m2) 10WAS**				**WR Biomass (g/plant)**				**Total WR seed production (seeds/m2)**			
	Variety		**Bonito**		**Hybrid**		**Bonito**		**Hybrid**		**Bonito**		**Hybrid**		**Bonito**		**Hybrid**	
	Spacing	***Rate***	***predicted value***	***SE***	***predicted value***	***SE***	***predicted value***	***SE***	***predicted value***	***SE***	***predicted value***	***SE***	***predicted value***	***SE***	***predicted value***	***SE***	***predicted value***	***SE***
Combined analysis	25cm	0.4RR	20.267	2.663	21.374	2.721	17.473	3.363	12.809	3.363	87.157	13.286	94.445	13.207	52536.990	6823.785	26501.890	6618.728
		0.7RR	28.863	2.663	32.303	2.663	14.819	3.363	14.825	3.363	84.460	12.973	62.553	12.973	19943.050	6618.728	19691.830	6618.728
		RR	38.940	2.663	43.372	2.663	13.681	3.363	12.992	3.363	79.937	12.973	68.274	12.973	23172.270	6618.728	16981.910	6618.728
	50cm	0.4RR	20.124	2.663	22.205	2.663	23.092	3.363	11.289	3.363	90.088	12.973	76.220	13.207	19119.730	6823.785	22193.930	6618.728
		0.7RR	25.725	2.663	30.219	2.663	11.821	3.363	10.693	3.363	78.127	12.973	64.562	12.973	18831.670	6618.728	18781.520	6618.728
		RR	35.169	2.663	35.661	2.663	10.955	3.363	12.288	3.363	83.510	13.034	66.983	12.973	17183.430	6618.728	16331.400	6618.728
	averaged SED		2.290				1.032				9.083				3839.268			
Cunderdin 2018	25cm	0.4RR	20.960	3.959	15.065	3.959	20.267	3.890	23.067	3.890	76.871	9.195	68.178	11.261	50309.067	9273.775	47092.933	9273.775
		0.7RR	26.855	3.959	19.978	3.959	17.467	3.890	14.533	3.890	51.181	9.195	42.134	9.195	8950.133	9273.775	18255.333	9273.775
		RR	37.008	3.959	26.855	3.959	15.200	3.890	16.467	3.890	51.942	9.195	53.614	9.195	15195.733	9273.775	19474.667	9273.775
	50cm	0.4RR	30.130	3.959	21.288	3.959	26.000	3.890	22.200	3.890	67.071	9.195	63.053	11.261	36827.867	9273.775	28410.267	9273.775
		0.7RR	39.628	3.959	32.750	3.959	27.000	3.890	15.400	3.890	54.181	9.195	63.869	9.195	37990.667	9273.775	20125.333	9273.775
		RR	47.815	3.959	41.265	3.959	21.933	3.890	14.733	3.890	55.737	9.195	54.416	9.195	23912.133	9273.775	25112.000	9273.775
	averaged SED		5.600				5.501				13.534				13115.100			
Cunderdin 2019	25cm	0.4RR	15.720	2.064	18.340	2.064	12.000	0.743	7.067	0.743	80.262	10.700	96.339	8.778	43782.224	3273.694	15232.765	2673.765
		0.7RR	22.943	2.064	28.427	2.064	9.467	0.743	9.600	0.743	93.333	8.778	63.389	8.778	11383.836	2673.765	10505.475	2673.765
		RR	36.388	2.064	38.680	2.064	8.267	0.743	7.600	0.743	91.867	8.778	69.356	8.778	14486.384	2673.765	7485.063	2673.765
	50cm	0.4RR	17.500	2.064	20.000	2.064	17.533	0.743	5.067	0.743	87.778	8.778	72.683	8.778	6121.045	3273.694	11989.014	2673.765
		0.7RR	21.667	2.064	27.000	2.064	5.867	0.743	4.933	0.743	79.739	8.778	55.750	8.778	7993.725	2673.765	9333.478	2673.765
		RR	32.000	2.064	33.000	2.064	5.133	0.743	6.800	0.743	93.728	8.778	63.489	8.778	7223.143	2673.765	6218.007	2673.765
	averaged SED		2.920				1.034				12.262				3909.202			
Avondale 2020	25cm	0.4RR	25.873	2.606	25.520	3.105	15.300	3.024	12.240	3.024	95.583	22.441	134.833	22.441	34698.264	12791.130	52116.111	12791.130
		0.7RR	37.905	2.606	39.376	2.606	7.650	3.024	6.120	3.024	127.000	22.441	91.500	22.441	22342.867	12791.130	7880.727	12791.130
		RR	40.990	2.606	53.055	2.606	10.710	3.024	6.426	3.024	71.500	22.441	63.667	22.441	13235.391	12791.130	5124.319	12791.130
	50cm	0.4RR	19.700	2.606	23.312	2.606	24.480	3.024	30.600	3.024	155.833	22.441	107.167	22.441	207806.914	15492.970	55871.488	12791.130
		0.7RR	27.416	2.606	32.669	2.606	13.770	3.024	18.360	3.024	121.000	22.441	53.500	22.441	13232.541	15492.970	11562.162	12791.130
		RR	35.296	2.606	36.281	2.606	12.852	3.024	11.246	3.024	76.968	27.451	83.500	22.441	19452.583	12791.130	17581.123	12791.130
	averaged SED		3.339				4.217				31.922				17737.180			

Table 8 Means and standard errors of predicted values using the linear mixed model (LMM) for the effect of canola pollination type (variety), row spacing (spacing), seeding rate (rate) and the relevant interactions for canola in the absence of WR competition for combined analysis and individual environments with herbicide free --- Part B.

Herbicide Nil			**Canola Yield (t/ha)**				**Canola 1000 seed weight g**				**Canola Oil %**			
	Variety		**Bonito**		**Hybrid**		**Bonito**		**Hybrid**		**Bonito**		**Hybrid**	
	Spacing	***Rate***	***predicted value***	***SE***	***predicted value***	***SE***	***predicted value***	***SE***	***predicted value***	***SE***	***predicted value***	***SE***	***predicted value***	***SE***
Combined analysis	25cm	0.4RR	0.718	0.304	1.119	0.304	NA	NA	NA	NA	NA	NA	NA	NA
		0.7RR	0.873	0.305	1.233	0.304	NA	NA	NA	NA	NA	NA	NA	NA
		RR	0.971	0.304	1.402	0.304	NA	NA	NA	NA	NA	NA	NA	NA
	50cm	0.4RR	0.924	0.303	1.305	0.303	NA	NA	NA	NA	NA	NA	NA	NA
		0.7RR	1.178	0.303	1.523	0.303	NA	NA	NA	NA	NA	NA	NA	NA
		RR	1.212	0.303	1.531	0.303	NA	NA	NA	NA	NA	NA	NA	NA
	averaged SED		0.090											
Cunderdin 2018	25cm	0.4RR	0.658	0.123	0.614	0.123	3.905	0.117	4.021	0.117	43.400	0.427	43.000	0.427
		0.7RR	1.059	0.123	0.942	0.123	4.135	0.134	3.950	0.117	44.200	0.427	43.700	0.427
		RR	1.047	0.123	1.235	0.123	3.713	0.117	3.881	0.117	42.900	0.427	44.100	0.427
	50cm	0.4RR	0.976	0.123	0.867	0.123	3.859	0.117	3.972	0.117	43.667	0.427	44.400	0.427
		0.7RR	0.994	0.123	1.153	0.123	3.760	0.117	3.983	0.117	43.300	0.427	43.633	0.427
		RR	1.322	0.123	1.428	0.123	3.792	0.117	4.032	0.117	43.733	0.427	43.467	0.427
	averaged SED		0.160				0.129				0.557			
Cunderdin 2019	25cm	0.4RR	0.283	0.103	0.753	0.098	2.967	0.067	2.867	0.067	43.733	0.474	42.700	0.474
		0.7RR	0.415	0.103	0.795	0.099	3.067	0.067	2.800	0.067	43.533	0.474	42.400	0.474
		RR	0.519	0.101	0.946	0.097	3.067	0.067	2.900	0.067	43.733	0.474	43.300	0.474
	50cm	0.4RR	0.524	0.095	0.938	0.098	2.987	0.082	2.937	0.082	43.333	0.474	43.200	0.474
		0.7RR	0.776	0.094	1.146	0.096	2.933	0.067	2.887	0.082	43.433	0.474	43.233	0.474
		RR	0.798	0.094	1.113	0.098	3.037	0.082	2.902	0.114	43.300	0.474	42.867	0.474
	averaged SED		0.105				0.104				0.509			
Avondale 2020	25cm	0.4RR	1.148	0.237	2.062	0.237	NA	NA	NA	NA	NA	NA	NA	NA
		0.7RR	1.481	0.237	2.545	0.237	NA	NA	NA	NA	NA	NA	NA	NA
		RR	1.795	0.237	2.757	0.237	NA	NA	NA	NA	NA	NA	NA	NA
	50cm	0.4RR	1.072	0.237	1.688	0.237	NA	NA	NA	NA	NA	NA	NA	NA
		0.7RR	1.484	0.237	1.923	0.237	NA	NA	NA	NA	NA	NA	NA	NA
		RR	1.130	0.237	2.088	0.237	NA	NA	NA	NA	NA	NA	NA	NA
	averaged SED		0.271											

CONCLUSION

This study aimed to determine the competitive ability of open pollinated and hybrid canola varieties (Bonito and Trophy respectively) on wild radish seed production when three competition variables (variety, row spacing, and seeding rate) were optimised. Trials were in Cunderdin 2018, Cunderdin 2019 and Avondale 2020. This study found that wild radish density negatively correlates with canola yield (R^2=0.42), supporting previous research by Blackshaw et al. (2002) who studied the effects of wild radish time of emergence on yield. In order to reduce wild radish seed production and optimise canola yield, canola row spacing and seeding rate can be adjusted. This study found that increasing canola seeding rate resulted in lower wild radish seed production, however the wider row spacing of 50 cm also resulted in lower wild radish seed production requiring further investigation. The most effective combination of treatments which will achieve the highest yields and the lowest wild radish seed production for both OP and hybrid varieties were a wide row spacing of 50 cm and the recommended seeding rate of 50 seeds/m^2.

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