RUNNING TITLE:

Canola competitiveness against annual ryegrass

TITLE:

TRIAL 1A: The interaction between the seeding rate and row spacing of hybrid and open pollinated canola (*Brassica napus*) varieties on annual ryegrass (*Lolium rigidum*) growth and seed production.

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Key Words; Canola, *Brassica napus*, wild radish, *Raphanus raphanistrum*, crop competition, seed production, seeding rate, row spacing, hybrid, open pollinated.

INTRODUCTION

Canola (*Brassica napus*) is a major oilseed crop used to produce oil for frying and the development of margarine, shortenings, and other food products (de Oliveira et al., 2015). Rapid innovation of canola genetics incorporating herbicide-tolerant traits and F1 hybrid vigor has resulted in a rapid increase in canola plantings in Australia. Since the introduction of canola in Australia, canola production has grown from approximately 100,000 ha in the early 1990s to an estimated total area of 1.4 million ha in 2017 (ABARE 2018). Central to the increase in canola yields has been the rapid development of herbicide-tolerant canola varieties (HTC) (Harker, Blackshaw, Kirkland, Derksen, & Wall, 2000). However despite the use of herbicide tolerance in canola varieties, weeds still commonly occur (Lemerle et al., 2001). With the widespread resistance of weeds to many herbicide modes of action, non-chemical weed control tactics, such as crop competition is essential (Blackshaw, Anderson, & Lemerle, 2007). Canola competitiveness can be increased by reducing row spacing, increasing seeding rates and the use of crop cultivars that emerge quickly and exhibit early vigorous growth (Beckie, Johnson, Blackshaw, & Gan, 2008; Harker, Clayton, Blackshaw, O'Donovan, & Stevenson, 2003). The objective of this study is to determine the optimal combinations of canola cultivar, seeding rate and row spacing on annual ryegrass seed production and canola growth and yield.

MATERIALS AND METHODS

Locations

In 2018, experiments were conducted in Cunderdin (-31.37S, 117. 14E) and Mingenew (-29.19S, 115.44E) in the Western Australian grainbelt. Soil at both sites was a sandy loam over a medium calcareous clay subsoil with a pH of 5.4 and 6.2 respectively with the long-term average growing season (April to October) rainfall at Cunderdin and Mingenew being 333 mm and 293mm respectively (presented in Figure 1). Each site had been under no-till production for 10 years before initiation of the study.

Prior to seeding

In March 2018, before weed seed bank germinating rains, the baseline seed bank of both sites were estimated by taking 4 replicate intact soil core samples (8 cm in diameter by 10 cm deep) up the center of each plot location (total of 384 soil samples per site). Soil samples from each plot (n=4) were combined to estimate the annual ryegrass seed bank in each plot. Samples were placed in shallow seedling trays that had been partially filled with weed-free potting mix to ensure drainage. The soil samples from the field were then spread in a 2cm thick layer and watered using micro-jet irrigation. Samples were maintained outside from March to August each year. Germinated seedlings were recorded and removed at regular intervals. The census for annual ryegrass was ceased in August when no new seedlings emerged over a 4 week period. The number of seedlings to germinate in each tray represented the germinable weed seed bank and was converted to seeds per square meter for each plot.

Trial establishment

In May 2018, all the Cunderdin and Mingenew experiments were direct-seeded into cereal stubble. A factorial combination of canola cultivar, seeding rate, and row spacing was randomized in complete blocks with four replicates. Canola cultivars, Hyola 559 (Hybrid mid-maturity) and Bonito (Open-pollinated mid-maturity Triazine Tolerant (TT) were seeded at 25cm and 50cm row spacing. All canola treatments were planted at only one sowing depth (approx. 20mm) in an effort to minimise the confounding effects of emergence rate and seeding depth differences on biomass and grain yield. Within the variety and row spacing treatments, canola was seeded at a target densities of 20, 35 and 50 viable seeds m^{-2} (on a weight basis these seeding rates equated to 3.0, 2.1 and 1.2 kg ha^{-1} and 2.8, 1.9 and 1.1 kg ha^{-1} for Hyola 559 and Bonito varieties, respectively). Both cultivars received the same fungicide/insecticide seed treatment comprising of 1L of Cruiser Opti [210 g/L Thiamethoxam 37.5 g/L Lambda-Cyhalothrin, Syngenta Australia] and 400 mL/100 kg Maxim XL [25 g/L Fludioxonil 10 g/L Metalaxyl-M Syngenta Australia] applied per 100 kg of seed. Immediately prior to seeding, all experimental areas were treated with 1.5L ha^{-1} Roundup Ultramax (Glyphosate 540 g/L, Sinochem Australia) and 150ml ha^{-1} Lontrel (Clopyralid 750g/L, DowAgrosciences Australia) to control all germinated weeds. Each plot was sub plotted with no additional weed control for competition assessments on weed growth and weed-free treatment to assess the effect of factorial combinations on the canola growth and light interception. The weed-free treatment was maintained using 1 L/ha Kerb (500 g/L Propyzamide, Dow AgroSciences Australia) incorporated by sowing (IBS), 1.1 kg/ha Atradex (900g/kg Atrazine, Nufarm Australia Limited) IBS followed by 1.1 kg/ha of Atradex and 500 mL/ha Select (240g/L Clethodim, Sumitomo Chemical Australia) applied at the 4-6 leaf stage of the canola. Herbicides were applied using a motorized sprayer calibrated to deliver a carrier volume of 120 L water ha^{-1} at 275 kPa pressure. Each subplot size was 4m wide by 10m long. To ensure optimal canola growth, 70 kg/ha Gusto Gold (Summit Fertilisers Australia, N – 10.2%, P- 13.1%, K- 12%, S- 7.6%, Cu- 0.07%, Zn- 0.14% and Mn- 0.01%) treated with 300ml ha^{-1} Impact (250 g/L Flutriafol, Cheminova Australia) was drilled 3cm below the seed to minimise contact with the germinating canola seed with 100kg/ha of Urea (Summit Fertilisers Australia, N – 46%) broadcast evenly on the soil surface immediately after seeding. At the 4-6 leaf stage of the canola, 100L/ha of urea and ammonium nitrate liquid fertiliser (UAN) (Summit fertilisers Australia) (N- 32%) was evenly sprayed across the site to maintain growth.

At ten weeks after sowing (WAS), canola establishment was assessed by counting two adjacent 50cm rows over 4 replicate locations per plot. Annual ryegrass density was assessed at 10 and 14 WAS by counting the number of plants present in four replicate a 33 x 33cm quadrants (0.11 m^{-2}) per plot. To compare the growth of the canola in the weed-free split plots, Normalized Difference Vegetation Index (NDVI) was measured at 7, 10, 13 and 16 WAS using a Crop Circle™ Handheld Optical Sensor Unit (Holland Scientific, Lincoln, NE, USA) oriented 0.8m off the ground, perpendicular to the center row of the plot. NDVI quantifies vegetation by measuring the difference between near-infrared in which vegetation strongly reflects and red light which vegetation absorbs. In each plot three replicate NDVI measurements were made and reported as a plot average.

Measurements of the fractional green canopy cover (FGCC) were done using the Canopeo™ android application (www.canopeoapp.com) to estimate canopy development and light interception (Patrignani & Ochsner, 2015). Canopeo™ is an image analysis tool (Mathworks, Inc., Natick, MA) that uses color values in the red–green–blue (RGB) system to measure the green canopy cover percentage. Canopeo™ images were assessed for all weed free crop treatments at 13 WAE using a 14-megapixel camera that was oriented 0.8m above the top of the crop canopy, perpendicular to the center row of the plot.

Both incoming and outgoing photosynthetically active radiation (PAR) values were measured 14WAS at the top and bottom of the canola canopy throughout the season using line quantum sensor LI-191SA (LICOR Inc., Lincoln, NE, USA). The fraction intercepted PAR (PAR) was calculated as per Monteith (1981)

$$PAR = \frac{(Io - I)}{I} \qquad [1]$$

: where Io is incident PAR at the top of the canopy and I is the transmitted PAR at the bottom of the canopy.

Above ground biomass samples of annual ryegrass were removed 27WAS in three 0.25m^2 quadrants per plot. Biomass samples were dried at 60^{o}C and weighed. From these samples, the number of ryegrass panicles was counted. In order to estimate annual ryegrass seed production, a representative sample of 50 panicles was collected from each plot and thrashed to extract seed. The number of seeds extracted was counted using an S-25 optical seed counter (Data Technologies, Kibbutz Tzora, Israel) to calculate the mean number of seeds produced per panicle. Total seed produced was estimated by multiplying the average seed yield per panicle by the number of panicles produced.

At 29WAS, the whole plot (10 m length with 6 by 22-cm rows) was machine harvested to determine grain yield. Grain samples (400 g) were analysed for moisture and oil using an

Infratec™ Sofia Near Infrared Spectroscope (NIR) (FOSS analytics, VIC, Australia). To calculate the mean canola seed weight, approximately 7000 seeds were counted S-25 optical seed counter (Data Technologies, Kibbutz Tzora, Israel) and weighed to calculate the mean canola seed weight.

<u>Statistical analysis</u>

Experimental Design

A split plot design accommodating a 3 factorial (2 levels of row-spacing, 2 canola varieties, and 3 levels of seeding rate) experiment with herbicide applied (weed free) and herbicide not applied (weedy) free blocks (Figure 1). Each block is divided into 2 main plots to which the levels of the row-spacing were randomly assigned. The main plot is further divided into 6 subplots to which 6 combinations of the canola variety and seeding rate were randomly assigned. In split-plot design, each block represents a complete replication of all 12 treatment combinations. The treatments were replicated 3 times for both (nil and applied herbicide) types of blocks in a single experiment. Two separate experiments were conducted on two sites: Cunderdin and Mingenew.

Statistical Models

The data were analysed using the analysis of variance technique for the split-plot design where the main-plot factor was row-spacing, and the subplot factor was created with 6 levels of variety and seeding-rate combinations. The objective of the experiment was to assess the effects of row-space, variety, seeding rate, and their interactions on a set of traits, listed below. The treatment means and their statistical significance were obtained using the appropriate blocking and treatment structures in the analysis. The analysis for the herbicide applied and free treatments were conducted separately.

The traits analysed for herbicide applied blocks are as follows: four recorded NDVI values on different dates, Canopeo, two Radiation interception values, Canola yield, crop emergence, two types of weed densities, and before treatment soil seed bank.

Under herbicide free treatment, the analysed responses were: weed-biomass, canola yield, before treatment soil seed bank, after treatment soil seed bank, total seed production, and two types of weed densities.

The analyses were conducted using R package msanova 1.0 (VSN International Ltd, Hemel Hempstead, UK).

A.

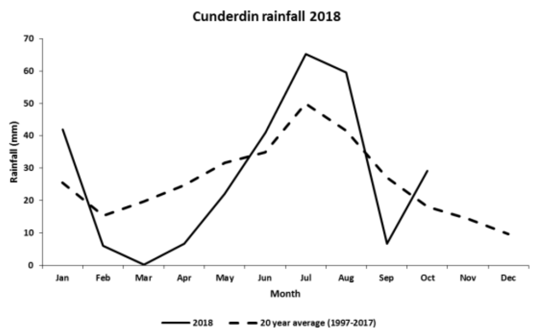
B.

Figure 1. Aerial trial photos of the (A.) Cunderdin and (B.) Mingenew field sites in 2018.

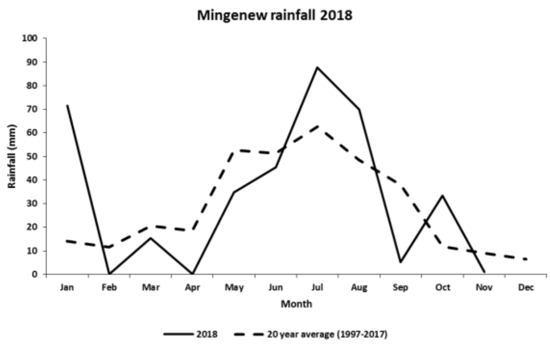
Results.

Rainfall data

In 2018, the Cunderdin site recorded 230mm of growing season rainfall (April – October) which is less than the 333mm long term average. This rainfall was characterized by a lack of season breaking rains in April and May. The June and July rainfall totals exceeded long term average and the crop was able to mature with good soil moisture. The Mingenew site in 2018 had 276mm of growing season rainfall (April – October) which is similar to the sites long term average of 293mm. The Mingenew site also had a dry season start with minimum rains in April, however good rainfall in June, July allowed the crop to mature with good soil moisture.



A.



B.

Figure 1: The rainfall totals for 2018 compared to the historical 20 years mean rainfall for A. Cunderdin and B. Mingenew in the Western Australian grainbelt.

Table 1: Mean, P-values and LSD for Pollination Type, Row Spacing (cm) and Seeding Rate on crop competitiveness in the absence of ARG at Cunderdin in 2018.

Herbicide	**Pollination Type**	**Row spacing (cm)**	**Seeding Rate**	**Crop Emergence 10WAS**	**Canopeo 14WAS**	**Radiation Interception (µmol m^{-2} s^{-1})**	**Radiation Interception (%)**	**Canola Yield 29WAS (t/ha)**	**Canola seed size (mg/seed)**	**Canola moisture (%)**	**Canola oil (%)**
Herbicide applied	Hyola 559	25	0.4RR	39.3	84.1	690.6	0.877	1.787	3.405	6.10	42.9
			0.7RR	30.4	88.7	663.8	0.853	1.992	3.638	6.17	43.0
			RR	35.7	90.5	626.3	0.870	2.196	3.392	6.40	42.7
		50	0.4RR	25.0	77.4	687.8	0.877	2.123	3.491	6.17	43.0
			0.7RR	28.6	76.4	657.6	0.877	2.320	3.286	6.13	42.9
			RR	31.1	81.4	683.8	0.863	1.923	3.565	6.17	42.8
	Bonito	25	0.4RR	31.2	60.3	653.0	0.827	2.267	3.539	6.03	42.9
			0.7RR	26.9	85.5	604.0	0.843	2.338	3.554	6.07	43.4
			RR	31.8	92.3	639.3	0.827	2.303	3.593	6.13	42.9
		50	0.4RR	28.3	78.1	626.7	0.850	2.164	3.461	6.23	42.8
			0.7RR	23.7	76.5	617.4	0.840	1.807	3.738	6.03	42.7
			RR	21.5	79.5	665.1	0.853	2.335	3.668	5.93	43.5
Source of variation				***p-values (5% LSD)***							
Pollination Type				NS	NS	NS	0.016 (0.023)	NS	0.028 (0.114)	0.025 (0.101)	NS
Row spacing				NS	NS	NS	NS	NS	NS	0.020 (0.024)	NS
Seeding Rate				NS	NS	NS	NS	NS	NS	NS	NS
Pollination Type x Row spacing				NS	NS	NS	NS	NS	NS	NS	NS
Pollination Type x Seeding Rate				NS	NS	NS	NS	NS	NS	NS	NS
Row spacing x Seeding Rate				NS	NS	NS	NS	NS	NS	0.026 (0.143)	NS
Pollination Type x Row spacing x Seeding Rate				NS	NS	NS	NS	NS	0.031 (0.260)	NS	NS

WAS – Week after sowing, NS – Not significant

0.4 RR – 20 seeds m2, 0.7 RR – 35 seeds m2, RR – 50 seeds m2

Table 2: Mean, P-values and LSD for Pollination Type, Row Spacing (cm) and Seeding Rate on crop competitiveness in the absence of ARG at Cunderdin in 2018.

Herbicide	**Pollination Type**	**Row spacing (cm)**	**Seeding Rate**	**NDVI 7WAS**	**NDVI 10WAS**	**NDVI 13WAS**	**NDVI 16WAS**
Herbicide applied	Hyola 559	25	0.4RR	0.160	0.430	0.777	0.753
			0.7RR	0.163	0.407	0.827	0.757
			RR	0.143	0.390	0.810	0.730
		50	0.4RR	0.143	0.340	0.827	0.743
			0.7RR	0.153	0.330	0.793	0.730
			RR	0.170	0.377	0.767	0.720
	Bonito	25	0.4RR	0.170	0.350	0.580	0.720
			0.7RR	0.147	0.377	0.823	0.737
			RR	0.153	0.460	0.840	0.757
		50	0.4RR	0.140	0.367	0.747	0.750
			0.7RR	0.140	0.370	0.823	0.747
			RR	0.153	0.357	0.790	0.763
Source of variation				***p-values (5% LSD)***			
Pollination Type				NS	NS	NS	NS
Row spacing				NS	NS	NS	NS
Seeding Rate				NS	NS	0.011 (0.056)	NS
Pollination Type x Row spacing				NS	NS	NS	0.036 (0.036)
Pollination Type x Seeding Rate				NS	NS	0.009 (0.079)	0.026 (0.025)
Row spacing x Seeding Rate				0.028 (0.026)	NS	0.020 (0.105)	NS
Pollination Type x Row spacing x Seeding Rate				NS	NS	NS	NS

WAS – Week after sowing, NS – Not significant
0.4 RR – 20 seeds m2, 0.7 RR – 35 seeds m2, RR – 50 seeds m2

Table 3: Mean, P-values and LSD for Pollination Type, Row spacing (cm) and Seeding Rate on weed biomass and seed production affected by ARG at Cunderdin in 2018.

Herbicide	**Pollination Type**	**Row spacing (cm)**	**Seeding Rate**	**ARG density 10WAS (plants m²)**	**ARG density 14WAS (plants m²)**	**Biomass ARG 27WAS (g m²)**	**Total ARG seed production (seeds/m²)**	**Before treatment ARG soil seed bank (seeds/m²)**	**After treatment ARG soil seed bank (seeds/m²)**
No herbicide applied	Hyola 559	25	0.4RR	263.9	104.0	348	103625	3801	114255
			0.7RR	268.4	94.1	309	156369	3435	159275
			RR	209.7	112.6	432	233556	2704	235584
		50	0.4RR	270.8	113.3	438	205055	6359	209825
			0.7RR	277.7	110.9	443	202270	5263	206217
			RR	303.0	98.0	381	150553	4020	153569
	Bonito	25	0.4RR	294.7	110.9	547	239746	7236	245173
			0.7RR	272.5	92.5	418	205687	4824	209305
			RR	261.5	120.2	415	172104	3655	174845
		50	0.4RR	269.3	113.2	300	119338	5117	123176
			0.7RR	267.0	110.2	309	156155	4897	159828
			RR	196.7	84.1	253	116023	4239	119203
Source of variation				***p-values (5% LSD)***					
Pollination Type				NS	NS	NS	NS	NS	NS
Row spacing				NS	NS	NS	NS	NS	NS
Seeding Rate				NS	NS	NS	NS	NS	NS
Pollination Type x Row spacing				NS	NS	< 0.001 (110.7)	0.0136 (41799)	NS	0.0156 (40907)
Pollination Type x Seeding Rate				NS	NS	NS	NS	NS	NS
Row spacing x Seeding Rate				NS	0.019 (19.3)	NS	NS	NS	NS
Pollination Type x Row spacing x Seeding Rate				NS	NS	NS	0.0337 (85060)	NS	0.0407 (85745)

WAS – Week after sowing, NS – Not significant
0.4 RR – 20 seeds m2, 0.7 RR – 35 seeds m2, RR – 50 seeds m2

Table 4: Mean, P-values and LSD for Pollination Type, Row spacing (cm) and Seeding Rate on weed biomass and seed production affected by ARG at Cunderdin in 2018.

Herbicide	**Pollination Type**	**Row spacing (cm)**	**Seeding Rate**	**Canola Yield 29WAS (t/ha)**	**Canola seed size (mg/seed)**	**Canola moisture (%)**	**Canola oil (%)**
No herbicide applied	Hyola 559	25	0.4RR	1.327	3.534	6.30	42.8
			0.7RR	1.126	3.620	6.17	42.6
			RR	1.249	3.826	6.27	43.5
		50	0.4RR	1.474	3.741	6.37	42.6
			0.7RR	0.958	3.647	6.30	42.7
			RR	0.891	3.850	6.37	41.8
	Bonito	25	0.4RR	0.690	3.649	6.23	42.7
			0.7RR	1.444	3.809	6.40	42.9
			RR	1.052	3.926	6.17	42.9
		50	0.4RR	1.545	3.706	6.33	42.8
			0.7RR	1.023	3.745	6.33	42.2
			RR	1.138	3.545	6.53	42.3
Source of variation				***p-values (5% LSD)***			
Pollination Type				NS	NS	NS	NS
Row spacing				NS	NS	NS	NS
Seeding Rate				NS	NS	NS	NS
Pollination Type x Row spacing				NS	NS	NS	NS
Pollination Type x Seeding Rate				NS	NS	NS	NS
Row spacing x Seeding Rate				NS	NS	NS	NS
Pollination Type x Row spacing x Seeding Rate				NS	NS	NS	NS

WAS – Week after sowing, NS – Not significant
0.4 RR – 20 seeds m2, 0.7 RR – 35 seeds m2, RR – 50 seeds m2

Table 5: Mean, P-values and LSD for Pollination Type, Row Spacing (cm) and Seeding Rate on crop competitiveness in the absence of ARG at Mingenew in 2018.

Herbicide	**Pollination Type**	**Row spacing (cm)**	**Seeding Rate**	**Crop Emergence 10WAS**	**Canopeo 14WAS**	**Radiation Interception ($\mu mol\ m^{-2}\ s^{-1}$)**	**Radiation Interception (%)**	**Canola Yield 29WAS (t/ha)**	**Canola seed size (mg/seed)**	**Canola moisture (%)**	**Canola oil (%)**
Herbicide applied	Hyola 559	25	0.4RR	28.3	72.22	633.0	0.703	1.937	3.275	7.50	40.7
			0.7RR	30.4	84.36	547.3	0.690	2.111	3.286	7.60	41.1
			RR	33.2	90.85	709.0	0.670	2.076	3.297	7.53	41.4
		50	0.4RR	25.0	52.92	542.0	0.520	1.489	2.406	7.60	40.7
			0.7RR	28.6	71.43	718.7	0.757	2.014	3.342	7.50	41.7
			RR	34.2	66.09	445.7	0.330	1.539	3.304	7.70	40.0
	Bonito	25	0.4RR	32.2	54.91	869.7	0.707	2.280	3.440	7.47	42.3
			0.7RR	26.4	81.38	791.7	0.717	2.470	3.474	7.43	41.5
			RR	32.4	82.70	807.7	0.663	2.391	3.600	7.40	43.1
		50	0.4RR	24.4	76.80	588.7	0.710	2.409	3.358	7.50	41.6
			0.7RR	23.9	79.06	633.7	0.737	2.254	3.341	7.60	41.7
			RR	26.5	68.07	921.0	0.727	2.493	3.518	7.33	41.7
Source of variation				***p-values (5% LSD)***							
Pollination Type				NS	NS	NS	NS	<0.001 (0.26)	NS	NS	0.001 (0.570)
Row spacing				NS	NS	NS	NS	NS	NS	NS	NS
Seeding Rate				NS	NS	NS	NS	NS	NS	NS	NS
Pollination Type x Row spacing				NS	NS	NS	NS	NS	NS	NS	NS
Pollination Type x Seeding Rate				NS	NS	NS	NS	NS	NS	NS	NS
Row spacing x Seeding Rate				NS	NS	NS	NS	NS	NS	NS	0.047 (0.956)
Pollination Type x Row spacing x Seeding Rate				NS	NS	NS	NS	NS	NS	NS	NS

WAS – Week after sowing, NS – Not significant
0.4 RR – 20 seeds m2, 0.7 RR – 35 seeds m2, RR – 50 seeds m2

Table 6: Mean, P-values and LSD for Pollination Type, Row Spacing (cm) and Seeding Rate on crop competitiveness in the absence of ARG at Mingenew in 2018.

Herbicide	**Pollination Type**	**Row spacing (cm)**	**Seeding Rate**	**NDVI 7WAS**	**NDVI 10WAS**	**NDVI 13WAS**	**NDVI 16WAS**
Herbicide applied	Hyola 559	25	0.4RR	0.163	0.287	0.573	0.673
			0.7RR	0.180	0.317	0.670	0.720
			RR	0.183	0.40	0.650	0.747
		50	0.4RR	0.157	0.287	0.540	0.547
			0.7RR	0.160	0.367	0.650	0.687
			RR	0.170	0.373	0.640	0.693
	Bonito	25	0.4RR	0.167	0.317	0.613	0.650
			0.7RR	0.183	0.383	0.720	0.790
			RR	0.210	0.413	0.737	0.773
		50	0.4RR	0.170	0.350	0.687	0.70
			0.7RR	0.173	0.373	0.707	0.740
			RR	0.173	0.390	0.717	0.743
Source of variation				***p-values (5% LSD)***			
Pollination Type				0.008 (0.007)	NS	< 0.001 (0.039)	NS
Row spacing				NS	NS	NS	NS
Seeding Rate				< 0.001 (0.009)	0.002 (0.0429)	0.002 (0.048)	0.032 (0.079)
Pollination Type x Row spacing				NS	NS	NS	NS
Pollination Type x Seeding Rate				NS	NS	NS	NS
Row spacing x Seeding Rate				0.049 (0.014)	NS	NS	NS
Pollination Type x Row spacing x Seeding Rate				NS	NS	NS	NS

WAS – Week after sowing, NS – Not significant
0.4 RR – 20 seeds m2, 0.7 RR – 35 seeds m2, RR – 50 seeds m2

Table 7: Mean, P-values and LSD for Pollination Type, Row Spacing (cm) and Seeding Rate on weed biomass and seed production affected by ARG at Mingenew in 2018.

Herbicide	**Pollination Type**	**Row spacing (cm)**	**Seeding Rate**	**Weed Density 10WAS**	**Weed Density 14WAS**	**Biomass ARG 27WAS (g m^2)**	**Total ARG seed production (seeds/m^2)**	**Before treatment ARG soil seed bank (seeds/m^2)**	**After treatment ARG soil seed bank (seeds/m^2)**
No herbicide applied	Hyola 559	25	0.4RR	201.96	252.45	255.05	116885	3582	120466
			0.7RR	315.94	235.62	284.74	161437	2558	163996
			RR	250.15	257.80	207.41	138635	585	139220
		50	0.4RR	339.66	289.93	429.07	232859	1169	234028
			0.7RR	186.66	231.79	377.57	172006	1389	173395
			RR	317.47	247.86	279.90	155736	2704	158441
	Bonito	25	0.4RR	388.62	302.17	413.51	235203	2339	237542
			0.7RR	328.18	197.37	266.51	185865	1838	187703
			RR	303.70	198.90	291.04	163412	3582	166993
		50	0.4RR	281.52	250.92	303.60	225450	2193	227643
			0.7RR	240.97	234.85	282.01	122878	1389	124266
			RR	272.34	295.29	387.64	238708	1608	240316
Source of variation				***p-values (5% LSD)***					
Pollination Type				NS	NS	NS	NS	NS	NS
Row spacing				NS	NS	NS	NS	NS	NS
Seeding Rate				NS	NS	NS	NS	NS	NS
Pollination Type x Row spacing				NS	NS	NS	NS	NS	NS
Pollination Type x Seeding Rate				NS	NS	NS	NS	NS	NS
Row spacing x Seeding Rate				NS	NS	NS	NS	NS	NS
Pollination Type x Row spacing x Seeding Rate				NS	NS	NS	NS	NS	NS

WAS – Week after sowing, NS – Not significant
0.4 RR – 20 seeds m2, 0.7 RR – 35 seeds m2, RR – 50 seeds m2

Table 8: Mean, P-values and LSD for Pollination Type, Row spacing (cm) and Seeding Rate on weed biomass and seed production affected by ARG at Mingenew in 2018.

Herbicide	**Pollination Type**	**Row spacing (cm)**	**Seeding Rate**	**Canola Yield 29WAS (t/ha)**	**Canola seed size (mg/seed)**	**Canola moisture (%)**	**Canola oil (%)**
No herbicide applied	Hyola 559	25	0.4RR	0.990	3.526	7.43	42.7
			0.7RR	0.828	3.524	7.43	43.1
			RR	1.229	3.455	7.43	42.7
		50	0.4RR	0.936	3.479	7.50	42.9
			0.7RR	1.312	3.438	7.43	42.3
			RR	0.856	3.384	7.50	42.1
	Bonito	25	0.4RR	1.004	3.679	7.20	43.9
			0.7RR	1.385	3.430	7.10	43.9
			RR	1.798	3.385	7.27	43.2
		50	0.4RR	1.107	3.402	7.47	42.0
			0.7RR	1.275	3.706	7.10	43.7
			RR	1.553	3.595	7.30	43.7
Source of variation				***p-values (5% LSD)***			
Pollination Type				0.002 (0.19)	NS	0.004 (0.14)	0.037 (0.70)
Row spacing				NS	NS	NS	NS
Seeding Rate				0.018 (0.23)	NS	NS	NS
Pollination Type x Row spacing				NS	NS	NS	NS
Pollination Type x Seeding Rate				NS	NS	NS	NS
Row spacing x Seeding Rate				NS	0.03 (0.17)	NS	NS
Pollination Type x Row spacing x Seeding Rate				NS	0.01 (0.21)	NS	NS

WAS – Week after sowing, NS – Not significant
0.4 RR – 20 seeds m2, 0.7 RR – 35 seeds m2, RR – 50 seeds m2

Results

In this study, the main effect of canola cultivar (F1 Hybrid vs Open pollinated), canola seeding rate and seeding row spacing was assessed in a field trials at Cunderdin and Mingenew in the Western Australian grainbelt in 2018. The results from the analyses of the traits at the Cunderdin trail are presented in Tables 1 to 4 with the results from the Mingenew trial are presented in Tables 5 to 8.

Main effects at Cunderdin

At Cunderdin, the main effects of pollination type, row spacing, and seeding rate were significant when herbicides were applied (weed free) for NDVI (13WAS) and % radiation interception. When herbicides were not applied (in a weedy situation), no main effects were identified. In a weed-free situation, the NDVI analysis conducted at 13WAS was increased by increasing seeding rate. The percent radiation interception was found to be affected by pollination type with the F1 hybrid (Hyola 559) intercepting a greater proportion of the available light compared to the open pollinated canola variety (Bonito).

Main effects at Mingenew

Conversely, at the Mingenew site in the weed-free situation (herbicide applied), the main effects were significant for crop emergence, canola biomass measured by NDVI (7WAS), NDVI (10WAS), NDVI (12WAS), NDVI (13WAS) and canola yield (weed free). When herbicides were not applied at the Mingenew site, canola yield (with weeds) was only the only trait that was affected by the main factor (variety and seeding rate). When post emergent ryegrass control was not applied (weedy situation), canola yield was greatest in open pollinated treatments and where seeding rates were at their greatest (50 plants/m^2).

Main effect interactions at Cunderdin

Whilst there were not many main effects identified at the Cunderdin site, there were multiple main effect interactions of interest. In the absence of weeds (herbicide applied), analyses revealed significant interactions between row spacing and seeding rate for NDVI results taken 7WAS and 13WAS. The Final NDVI result taken 16WAS demonstrated interactions between pollination type and row spacing with Hybrid varieties having a greater increase in NDVI when row spacings were reduced from 50 to 25cm. With weeds present (nil herbicide applied), reduction in the ARG density at 14WAS was affected by the interaction between canola seeding rate and row spacing, with wider row spacing (50cm) decreasing ARG density when seeding rates were increased. In the Cunderdin trial, the ARG numbers in the 25cm remained unresponsive to canola seeding rate.

Main effect interactions at Mingenew

In the absence of weeds (herbicide applied) the interaction Canola row spacing and seeding rate was identified in early canola biomass (NDVI 7WAS), however, this difference was not apparent in the following NDVI assessments (10WAS, 13WAS, 16WAS).

Summary and Implications

The results of this study suggest:

1. Increasing the canola seeding rate of both OP and Hybrid varieties increased the crops potential competitiveness by increasing early biomass (NDVI) and % radiation interception.
2. Increasing canola row spacing increased the crops light interception.
3. At Cunderdin, the greatest decrease in ARG establishment in response to canola seeding rate occurred where both OP and Hybrid canola varieties were sown at wider (50cm) row spacing's.
4. The Mingenew site had a significantly higher weed density, reducing the trials competitive effect on ARG density, biomass, and seed production. Sites with lower weed seed banks will be identified in 2019.
5. At the Mingenew site, canola yield was higher in open pollinated variety (Bonito). At Cunderdin, no effects were identified.

Acknowledgments

This research was funded by the Grains Research Development Corporation of Australia (GRDC).

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