Effect of heat stress on canola yield and quality

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Key findings

- Heat stress during the reproductive development phase significantly reduced grain yield, harvest index and oil percentage.
- Varieties respond differently to heat stress: Nuseed Diamond had the highest reduction in grain yield and oil percentage under heat stress, whereas ATR Stingray[ⴲ] had the lowest reduction in grain yield.
- Under heat stress, seed formation is more severely affected than pod formation.
- Canola pods that appear healthy can produce less, or even no, seed, and therefore do not achieve yield potential under heat stress.

Introduction

Canola (*Brassica napus* L.) is an economically important oilseed globally and the third most valuable crop in Australia, contributing $2.67b to gross domestic product (GDP) annually.

Abiotic stresses such as elevated temperature and moisture shortage, especially during reproductive development, result in significant yield loss in canola. Recent climate change predictions emphasise that extreme climatic event frequency is expected to increase, which poses serious concerns for winter crop productivity. By the end of the 21st century, global mean surface temperature is predicted to increase by 0.3 °C to 4.8 °C, which could lead to significant economic loss for canola growers.

Canola is particularly susceptible to heat stress during reproductive development. In particular, supra-optimal temperatures above 30 °C result in reduced seed set, grain yield and oil content. This experiment developed a novel method for assessing heat tolerance under field conditions using portable heat chambers to allow assessments at the plot scale without confounding by other environmental factors. It is paramount to not only breed for heat tolerant germplasm, but also to test the crop's heat tolerance in reliable field-based experiments for commercial adoption of varieties. Therefore, the aim of this experiment was to understand canola variety heat stress responses and their capacity to adapt to warmer future climates.

Site details

Location	Wagga Wagga Agricultural Institute (35º7′2.1900″S latitude and 147º21′23.4792″E longitude)	
Soil type	Red–brown chromosol	
Soil nitrogen	75 kg/ha at the time of sowing	
Watering	To avoid any confounding effects from drought, the experiment was watered six times with a total 240 mm supplied using drip lines during the growing season.	

Treatments

Variety	Nuseed Diamond	Fast spring, hybrid conventional herbicide
	ATR Stingray[ⴲ]	Fast spring, open-pollinated triazine tolerant (OP TT)
	Pioneer® 43Y23 (RR)	Fast spring, hybrid roundup ready
	Hyola 350TT	Fast spring, hybrid triazine tolerant

This research paper is an extract from the publication *Southern NSW Research Results 2020*, available at https://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/publications/southern-nsw-research-results

Heat chambers	Eight chambers (2.5L × 1.8W × 1.2H m) were constructed with Suntuf Sunlite twin wall polycarbonate clear sheets fitted to a metal frame (Figure 1). Heating was provided by two standard 1200W fan heaters in each chamber, with the a 6KVA generator supplying power in the field. The heaters drew fresh air from outside the plots and a ceiling fan was used to distribute heat evenly throughout the chambers. A commercially available thermostat was used with extended thermocouples to control the heaters. Temperature and humidity inside the box were monitored at one-minute intervals using a TinyTag Plus2 temperature and humidity logger placed inside a small radiation screen.

Figure 1 Heat chambers for assessing heat stress in canola plots at Wagga Wagga Agricultural Institute.

Experiment design and heat treatments

A randomised complete block design with two heat treatments (control vs heat stress at 35 °C), three heat stress measurements (start of flowering, mid flowering and end of flowering), and four replications were used. Each chamber enclosed six 2.5 m long rows of canola plants covering an area of 4.5 square metres. Heat treatments were applied for eight days over two weeks to simulate the effect of a heat wave. The chambers were placed on the plots at 11.30 am and the heaters were switched on at 12.00 pm. The chambers were then heated to 35 °C. The time taken to achieve this temperature depended on ambient conditions on the day. The heaters were turned off at 4.30 pm and heat chambers removed at 5.00 pm.

Measurements

Plot yield, biomass, thousand seed weight and harvest index (HI) were assessed from 1.5 m^2 samples for each plot. The experiment was hand-harvested on 2 November 2019.

Results

Heat stress effect on grain yield

Heat stress had a significant effect on grain yield, biomass and HI, however, the interaction between heat and variety was not significant (Table 1). Nuseed Diamond was the highest yielding variety under non-stressed (control) conditions, followed by Hyola 350TT, Pioneer® 43Y23 (RR) and ATR Stingray$^{\Phi}$.

When heat stress was imposed at mid flowering, Nuseed Diamond had the maximum yield reduction (66%). ATR Stingray⁽ᵇ⁾ had a yield reduction of 44%, although HI was maintained under heat stress (17%). Nuseed Diamond HI, however, was reduced to 9% under heat stress.

Although Nuseed Diamond was the highest yielding variety, it also incurred the maximum yield penalty under heat stress due to reduced seed numbers per metre square: although pods were well developed, seeds did not form. Figure 2 shows developed Nuseed Diamond pods that failed to produce seed under heat stress. There were also varietal differences for reduced seed numbers under heat stress (Figure 3). For example, Nuseed Diamond seed numbers were significantly reduced as heat stress increased; however, ATR Stingray⁽ᵇ⁾ maintained seed numbers under the same heat stress conditions.

Table 1 Effect of heat stress on biomass yield, grain yield and harvest index in canola at reproductive development.

Variety	Biomass yield (t/ha)		Seed yield (t/ha)		Harvest index	
	Control	Heat stress	Control	Heat stress	Control	Heat stress
Pioneer® 43Y23 (RR)	10.60	8.90	2.30	0.88	0.22	0.09
ATR Stingray	8.50	6.50	2.12	1.18	0.25	0.17
Nuseed Diamond	12.20	11.30	3.15	1.07	0.26	0.09
Hyola 350TT	11.50	9.80	2.73	1.25	0.24	0.12
P (variety)	<.001		0.007		0.156	
P (heat)	<.001		<.001		<.001	
P (interaction)	0.178		0.382		0.859	
l.s.d.	0.68		0.38		0.038	

l.s.d., least significant difference.

Figure 2 Effect of heat stress on Nuseed Diamond seed pods at mid flowering stage.

Heat stress effect on oil percentage

Heat stress and variety individually had a significant effect on oil and protein percentage, however, the interaction between heat and variety was not significant (Table 2). Oil percentage was significantly reduced under heat stress in all varieties, with the maximum reduction of 6% in Nuseed Diamond. There is a trade-off between oil percentage and protein percentage, with protein percentage increasing under heat stress.

Table 2 Heat stress effect on oil percentage and protein in canola at reproductive development.

	Oil %		Protein %	
Variety	**Control**	**Heat stress**	**Control**	**Heat stress**
Pioneer® 43Y23 (RR)	41.95	39.98	22.43	23.57
ATR Stingray	43.88	41.67	22.28	24.55
Nuseed Diamond	44.32	41.38	20.00	23.33
Hyola 350TT	42.97	40.79	22.23	24.49
P (variety)	0.077		0.004	
P (heat)	<.001		<.001	
P (interaction)	0.767		0.664	
l.s.d.	1.666		1.230	

l.s.d., least significant difference.

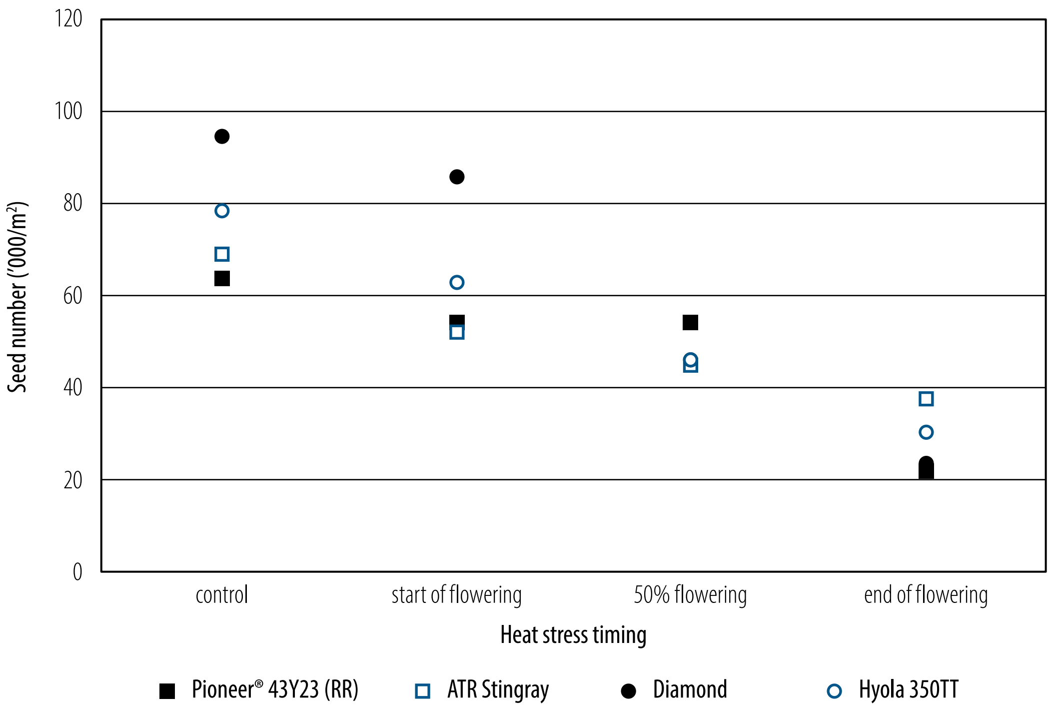

Figure 3 Effect from heat stress timing and variety on seed number/m^2 in canola.

Conclusions

The implications of this research are that heat stress has a significant effect on canola crops. Healthy canola pods heat stressed during the reproductive phase can have reduced seed and oil and therefore do not achieve yield and quality potential. Our field-based portable heat chamber system has increased the reliability of heat tolerance research and will allow the effect of heat stress on canola cultivars to be assessed for breeding programs.

Acknowledgements

This experiment was part of the 'Effect of heat stress on canola – protocol and hypothesis development' pilot project, BLG108, 2017–19, a joint investment between GRDC and NSW DPI under the Grains Agronomy and Pathology Partnership (GAPP)

Thanks to technical support from Warren Bartlett, Danielle Malcolm and Sophie Brill.