Canola yield and heat stress in the Northern Agricultural Region

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Key messages

- Yield was highest from earlier sown plants; mid-May sown plants yielded only 18% of those sown in mid-April.
- This occurred despite warm autumn conditions which caused higher pod abortion on the main stems of mid-April sown plants.
- Irrigation in spring reduced pod abortion by 15%; this highlights the advantage in using agronomic methods such as stubble retention and canopy management to conserve moisture through to the podding stage.

Aims

To quantify the impact of high temperature and water stress at flowering on canola yield.

Background

Canola is most sensitive to heat stress from a week before flowers open until a week after. The critical temperatures range from 27 to 30°C (Kirkegaard et al 2017, Morrison and Stewart 2002). Many canola crops in the Northern Agricultural Region flower when temperatures are high enough to limit yield and there is concern that this will become more frequent and severe if spring temperatures increase, as predicted by climate change models.

Two ways to mitigate this risk include: 1) flower early before temperatures are too high by sowing early and using a short season variety; and 2) reduce the heat stress experienced by the crop by managing soil moisture so plants can transpire during flowering and podding to keep cool.

This trial was designed to look at both of these mechanisms by sowing at different dates and implementing +/- irrigation treatments to manipulate temperatures at flowering and plant water stress.

Methods

Canola (cv. Pioneer 43Y23 RR) was sown in 1.0 m rows at Geraldton on 4 dates (April 18, April 28, May 8 and May 18). At each TOS there were +/- irrigation treatments, hence there were 8 treatments; each replicated 5 times. 15 seed were sown per row and the plants were selectively thinned to ensure plants in each treatment were at similar plant development stages. Plant growth stage was monitored twice weekly with development stage on the main stem recorded using the APSIM canola phenology rating code. Volumetric soil moisture at 0-10 cm was monitored twice weekly using a Campbell scientific moisture probe. From early August to late September, when plants were maturing, moisture was measured to 1.0m using a Sentek 2000 Diviner. Temperature and humidity were recorded hourly.

The entire trial was irrigated several times in April and May to enable seed to germinate and ensure plants were not moisture stressed before flowering. At the commencement of flowering of the earliest sowing time a rainout shelter was placed above unirrigated plots and left in place through to harvest. Irrigated plots had 10mm irrigation treatments applied twice weekly from the end of August through to the third week in September. Stem sap flow was measured on the largest stems of two plants each in the irrigated and unirrigated plots of TOS4 from 12 September to 17 October using SF-3 sap flow sensors (Edaphic Scientific, Australia) logged with a Campbell Scientific CR10X datalogger at 30 minute intervals.

Plants were hand harvested as they reached maturity, from the September 22 to October 2. Measurements included biomass, number of pods and aborted pods on the main stem and whole plant, seed yield and seed size.

Results

Seasonal conditions

Rainfall was 315mm for the year to Nov (Table 1). This compares to a long term average for Geraldton of 445mm. Monthly rainfalls for March April and May were lower than long term average and irrigation was used to sow the trial. May and June were also warmer than average. Recording of temperature from the Bureau of Meteorology Geraldton town site ceased in 1953 and the Geraldton Airport site temperature is only available from 2011 to 2017. As such Mullewa temperature data is included in Table 1. This indicates 2017 April, May and June maximum temperatures were 2-3°C > long term.

Table 1. 2017 monthly rainfall (mm) from BOM Geraldton Airport station (8315). Monthly maximum temperature averages from BOM Mullewa station (8095).

Site	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Geraldton Rainfall	33	18	6	0	31	41	49	80	50	7	-	-	315
Mullewa max temp 2017	37.6	35.2	33.9	30.9	25.4	23.1	19.8	20.4	23.4	28.2	33.4	34.9	
Mullewa max temp 1925-2017	36.8	36.5	33.7	28.8	23.7	20.0	18.8	20.2	23.5	27.3	31.2	34.5	

Plant development

Flowering on the main stem commenced as early as June 6 and as late as July 31, depending on sowing date, and finished as early as June 26 and as late as August 21 (Figure 1). April 18 sown plants had the shortest main stem flowering period of 20 days, the rapid plant development corresponding to the higher temperatures. Main stem flowers were recorded on plants sown on April 28 for 31 days, May 5 32-38 days (-/+ irrigation) and 18 May 21 to 25 days (-/+ irrigation) (Figure 1). The very early flowering of April 18 sown plants meant they experienced higher temperatures during main stem flowering than other sowing times and in fact the latest sowing time had least exposure to high temperature during main stem flowering (Table 2). However, while temperatures were higher during main stem flowering in TOS1 than later times of sowing, a high proportion of yield was carried on branches which flowered later under cooler conditions. Similarly, branches on TOS4 plants flowered under warmer conditions than the main stem (Table 2).

Thermal time to the opening of first flowers ranged from 1008°Cd for TOS1 to 1280°Cd for TOS4. Irrigation increased the duration of the flowering period; irrigated plants flowered for 535°Cd while unirrigated plants for 434°Cd. Delayed sowing increased the thermal time to maturity; TOS1 2079°Cd and TOS4 2284°Cd.

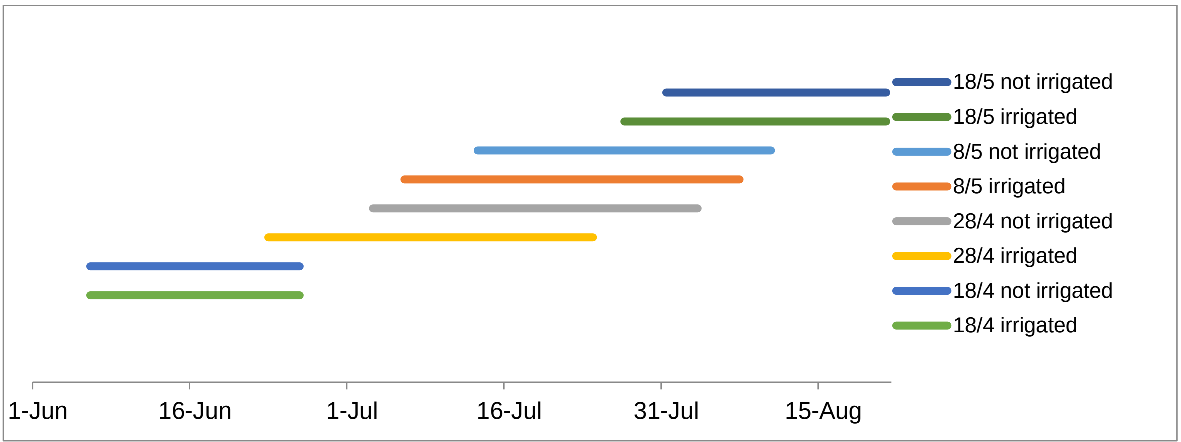


Figure 1. Main stem flowering period of canola sown at four times of sowing (+/- irrigation) at Geraldton in 2017.

Table 2. Average temperatures from data logger (hourly intervals) and total hours above specified temperatures during the main stem flowering period and total flowering period for plants sown on different dates at Geraldton in 2017.

	Main stem flowering period				**Total flowering period**			
	TOS1: 18/04/2017	**TOS2: 28/04**	**TOS3: 8/05**	**TOS4: 18/05**	**TOS1: 18/04**	**TOS2: 28/04**	**TOS3: 8/05**	**TOS4: 18/05**
Average temp°C	18.3	16.0	16.2	15.8	16.7	16.0	16.3	17.0
Hours > 27°C	45	3	3	0	48	3	17	64
Hours > 28°C	34	1	1	0	35	1	10	38
Hours > 29°C	17	0	1	0	17	1	6	28
Hours > 30°C	9	0	1	0	9	1	5	20

Soil moisture

There were clear differences in soil moisture between irrigated and unirrigated treatments during August and September (Figure 2). Irrigation treatments increased water down to a depth of 60 to 70 cm. Between 13 and 22 September the diurnal pattern of sap flow and sap velocity was almost identical in irrigated and unirrigated plants, suggesting soil water had not been sufficiently depleted to retard transpiration (Figure 3a). Between 7 and 16 October sap flow was significantly reduced in unirrigated plants (Figure 3b).

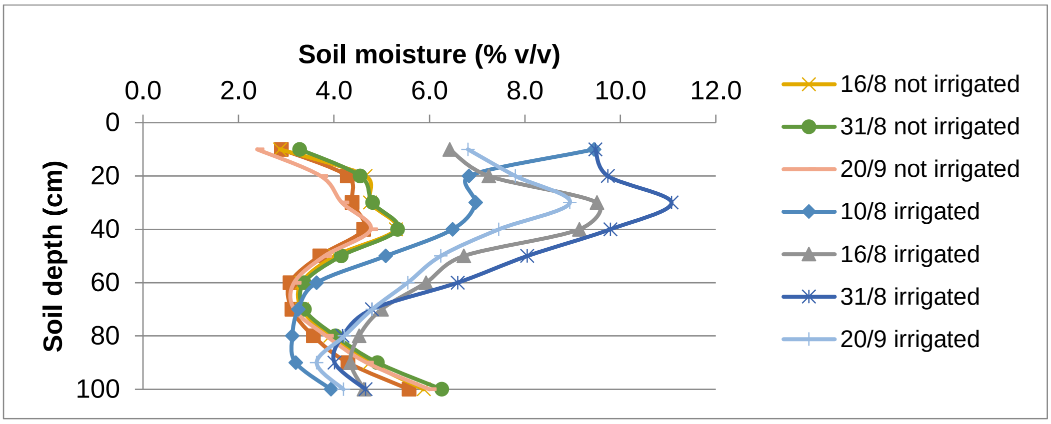
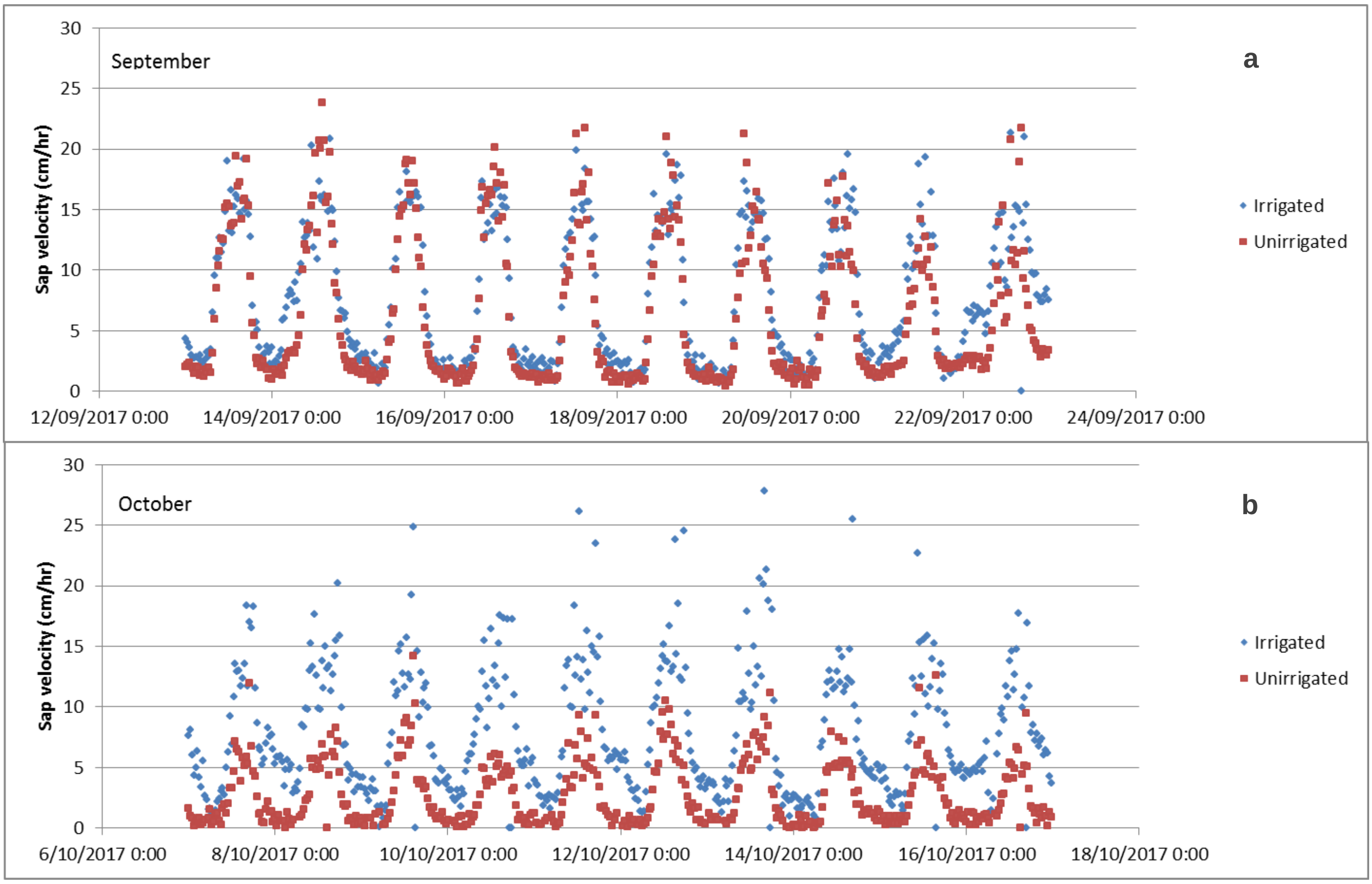


Figure 2. Soil moisture (% v/v) to 1.0 metre depth as measured in August and September.



Figures 3 a & b. Stem sap flow (cm/hr) over two 10 days periods in September and October of irrigated and unirrigated canola plants at Geraldton in 2017.

Plant growth

Earlier sown plants had greater stem diameter (*P* <0.001) and total plant weight (*P* <0.001, Table 3). Irrigation did not affect stem diameter but appeared to increase total biomass, especially in early sowing times, even though this was not statistically significant.

Yield and yield components

Irrigated early sown plants produced highest yield. Yield declined with each delay in sowing date and TOS4 produced only 18% as much yield as TOS1 (mean of irrigation treatments), consistent with previous sowing time trials in the region. The proportion of total yield carried on the main stem was very low, especially in the earliest sowing times where it was 1.5% in irrigated and 2.3% in unirrigated plants (Table 4). Hence whilst temperatures during main stem flowering of mid-April sown plants were higher and pod abortion rates were higher (Table 4) compensating seed production from later flowering branches resulted in higher yield potential and harvest index (*P* <0.001) (Table 3).

There was a clear trend for irrigation to increase yield, particularly on earlier sown plants, but the variability in single plant yield meant this was not statistically significant (Figure 4, Table 3). Because irrigation main effect was not significant the TOS irrigation interaction was also considered not significant despite a low P value.

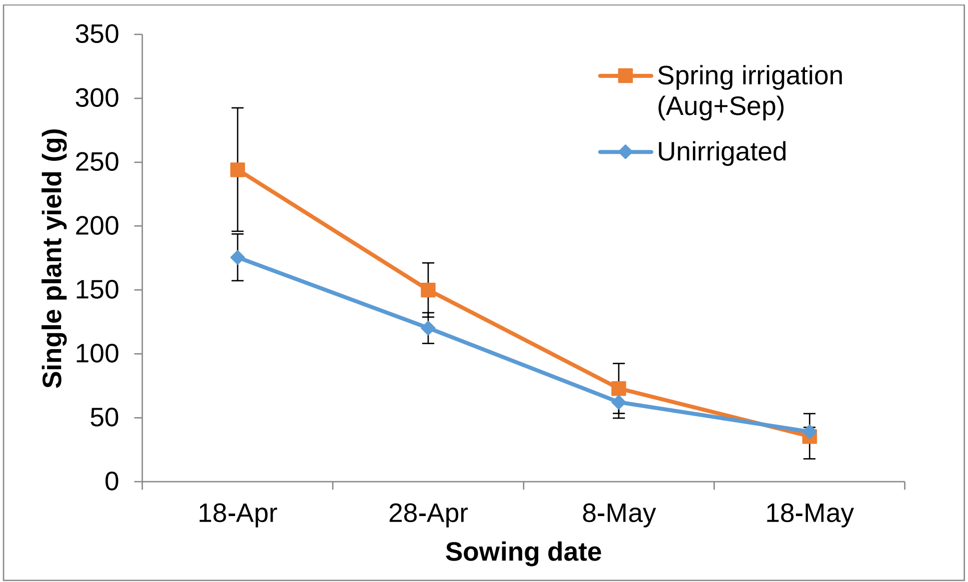


Figure 4. Plant yield (g/plant) as affected by sowing date and irrigation at Geraldton in 2017.

Plant podding

Averaged across irrigation treatments TOS1 plants initiated almost twice as many pods (fertile plus aborted) as TOS4 plants (Table 3). Irrigation increased pod initiation by 6% compared to unirrigated but this was not significant. The proportion of total initiated pods that aborted (aborted %) was not affected by sowing date but was reduced by irrigation (*P* <0.001). Averaged across all sowing times irrigation reduced pod abortion by around 15%.

There were more fertile pods per plant at earlier sowing dates (*P* <0.001) and when irrigated (*P* <0.05). Averaged across irrigation treatments TOS1 plants produced twice as many fertile pods as TOS4 plants. Irrigation increased fertile pods by 40% compared to control plants (Table 3).

There was less main stem pod abortion in later sown plants (Table 4). Although we expected early sown plants to have less main stem pod abortion this observation is consistent with higher temperatures during the main stem flowering period of early sown plants. It is interesting that there was little difference between sowing times in total initiated main stem pods (90-103 averaged across irrigation treatments) (Table 4).

Seed size

Earlier sowing times produced larger seed (*P* <0.001). Irrigation had no effect on seed size, perhaps due to the increased yield of irrigated plots from earlier sowing times.

Seeds per pod

Earlier sowing times produced more seeds per pod (*P* <0.001) (Table 3). Irrigation had no effect on the number of seeds per pod.

Table 3. Stem diameter (mm), final plant dry weight (g/plant), number of pods per plant, seed weight (g/1000 seed), seed number per fertile pod, seed yield (g) and harvest index (HI) of canola sown at four times of sowing x +/- irrigation at Geraldton in 2017.

Sow date	Irrigate	Stem diameter (mm)	Dry matter (g/plant)	Fertile pods /plant	Aborted pods/ plant	Total pods initiated/ plant	Aborted pods (% of total)	Seed wt. (g/1000)	Seeds/ pod	Yield (g)	HI
18-Apr	Yes	40.3	781	4210	2029	6239	33	3.58	15.9	241	0.31
28-Apr	Yes	33.6	505	3742	2001	5743	35	3.72	11.3	147	0.30
8-May	Yes	26.2	281	2255	1163	3418	34	3.24	10.3	69	0.26
18-May	Yes	25.1	168	1697	981	2678	37	2.62	8.5	33	0.20
	Yes Av.	31.3	434	2976	1544	4520	35	3.29	11.5	123	0.27
18-Apr	No	42.2	573	2633	2492	5125	49	3.70	14.3	172	0.30
28-Apr	No	34.2	401	2679	2554	5233	49	3.36	13.4	117	0.30
8-May	No	29.0	253	1531	1892	3423	55	3.55	12.0	58	0.26
18-May	No	22.1	265	1622	1705	3327	51	2.84	10.2	37	0.18
	No Av.	31.9	373	2116	2161	4277	51	3.36	12.5	96	0.26
Overall Av.		31.6	403	2546	1852	4398	43	3.33	12.0	109	0.27
P value sow date		<0.001	<0.001	<0.001	<0.05	0.002	NS	<0.001	<0.001	<0.001	<0.001
Lsd sow date		4.2	143	957	769	1584		0.45	2.4	43.4	0.06
P value irrigation		NS	NS	<0.05	<0.05	NS	<.001	NS	NS	NS	NS
Lsd irrigation				676	544		6			30.7	
P value interaction		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 4. Number of main stem fertile pods and aborted pods, yield (g/stem) and yield as a % of total plant yield of canola sown at four times of sowing x +/- irrigation at Geraldton in 2017.

Sow date	Irrigation	Total pods initiated on main stem	Fertile pods on main stem	Aborted pods on main stem	Aborted pods per MS (% of total)	Yield (g/stem)	% of plant yield
18-Apr	Yes	91	56	35	38	3.0	1.5
28-Apr	Yes	111	75	36	32	3.5	2.4
8-May	Yes	99	75	24	24	3.9	6.8
18-May	Yes	86	78	8	9	2.8	8.8
	Yes Av.	97	71	26	26	3.3	4.9
18-Apr	No	89	55	34	38	3.7	2.3
28-Apr	No	98	64	34	35	3.1	2.7
8-May	No	108	68	40	37	4.2	6.8
18-May	No	110	64	46	42	2.6	7.0
	No Av.	101	63	38	38	3.4	4.7
Overall Av.		67	99	32	32	3.4	4.4
P value sow date		<0.05	<0.001	NS	0.085	NS	<0.001
Lsd sow date		11	9		9.4		
P value irrigation		<0.05	NS	<0.001	<0.001	NS	NS
Lsd irrigation		8		7	6.6		
P value interaction		NS	NS	NS	<0.05	NS	NS
Lsd interaction					13		

Conclusions

Yield was highest from early sowing despite heat stress reducing main stem pod set of mid-April sown plants due to pod set occurring on branches at a later date. Hence, it was best to sow early even though autumn conditions were unusually warm.

It is challenging to separate the effects of heat stress (the effect of short term temperature spikes) and terminal drought on yield as in practice the two usually occur together. However, we showed that maintaining high soil moisture levels with irrigation reduced pod abortion by an average of 15%. This suggests that any practice that can conserve soil water until the reproductive stage, such as conservation tillage, stubble retention and altering row spacing and plant density combinations may reduce pod abortion.

The results from this trial reinforce the idea that in the Northern Agricultural Region heat stress across the total flowering period is most likely to be avoided by sowing in April and by using short season varieties. Conserving soil moisture using agronomy to manage the crop canopy such as wide row spacing and low plant density is also likely to improve the plants ability to tolerate high temperatures.

Key words

Canola, heat stress, irrigation, sowing time

Acknowledgments

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