Optimising grain yield of canola in Western Australia accounting for the risk of frost and heat stress

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Key messages

- To maximise canola yield in Western Australia, sow early.
- The Optimum Sowing Window that maximises canola yield is sowing in April in low and medium rainfall zones and up to mid-May in high rainfall zones, as a rule of thumb.
- Considering the steep yield decline with delay in sowing after the optimum window, over the long term, the maximum yield is achieved sowing early enough that the potential yield is high, even though there is still some frost risk, depending on location.

Aims

The aims of this research were:

1. To estimate the Optimum Sowing Window that maximises canola yield for different locations in Western Australia, accounting for frost and heat risk.
2. To study the influence of location, cultivar and soil type on the canola time of sowing yield response.

Background

In the last decade there has been a trend of earlier and earlier sowing of canola by farmers. Sowing canola in mid-April has become standard practice in most of the north of the WA cropping zone. Yield declines with sowing date ranging from 5% to 12% per week delay in sowing have been found in several Australian studies (Farre *et al*., 2002). However, there is a lack of experimental data on very early sowings before mid-April. This simulation study was designed to obtain yield relationships across a wide range of sowing dates (March to June) and to establish the optimum sowing window to maximise grain yield accounting for frost and heat stress for different locations in Western Australia

Method

The validated crop simulation model APSIM-Canola (v.7.9) (Farre *et al*., 2002; Keating *et al*., 2003) was used to run a series of crop simulation experiments to explore the effect of time of sowing and cultivar length on canola yields and the frost and heat risks around flowering.

Long-term simulations for the period 1976-2016 were run for 12 locations (Table 1) in the wheatbelt of Western Australia, with eight times of sowing from mid March to end of June at 15 day intervals, three canola cultivars and three soil types (sand, duplex, clay). The canola cultivars were generic long, medium and short season cultivars, equivalent to series 6 to 7, 5, and 3 to 4 of the current cultivars, respectively. The three generic soil types, differing mainly in the plant available water content (PAWC), were a sand (PAWC = 57 mm), duplex (PAWC = 90 mm) and clay soil (PAWC = 135 mm).

For each simulation, 10 mm irrigation was applied at sowing to ensure that the crop was successfully established for all sowing dates and fertiliser nitrogen was applied to prevent nitrogen limiting yield. Crop management was simulated to reproduce best management practices in each rainfall zone.

The default simulated yield in APSIM doesn't account for frost and heat damage. In this study, a yield reduction to account for frost and heat damage based on air temperature was applied according to the method published by Lilley *et al*., (2015). According to this method, yield reductions were calculated for minimum temperatures below 2 °C and maximum temperatures above 30 °C during a period of approximately 6 weeks around flowering and early grain filling.

Results

Year to year yield variability

The simulation experiments provided information on yield and time of sowing relationships, accounting for frost and heat stress for different locations, cultivars and soil types.

One of the main challenges in estimating an Optimum Sowing Window in canola is the great year-to-year yield variability for any given sowing date (Figure 1). Figure 1, shows the year to year yield variability for two sowing dates (end April and end May) in Wongan Hills for a mid maturity cultivar. The year to year yield variability is something to keep in mind when looking at average yields for a long term period.

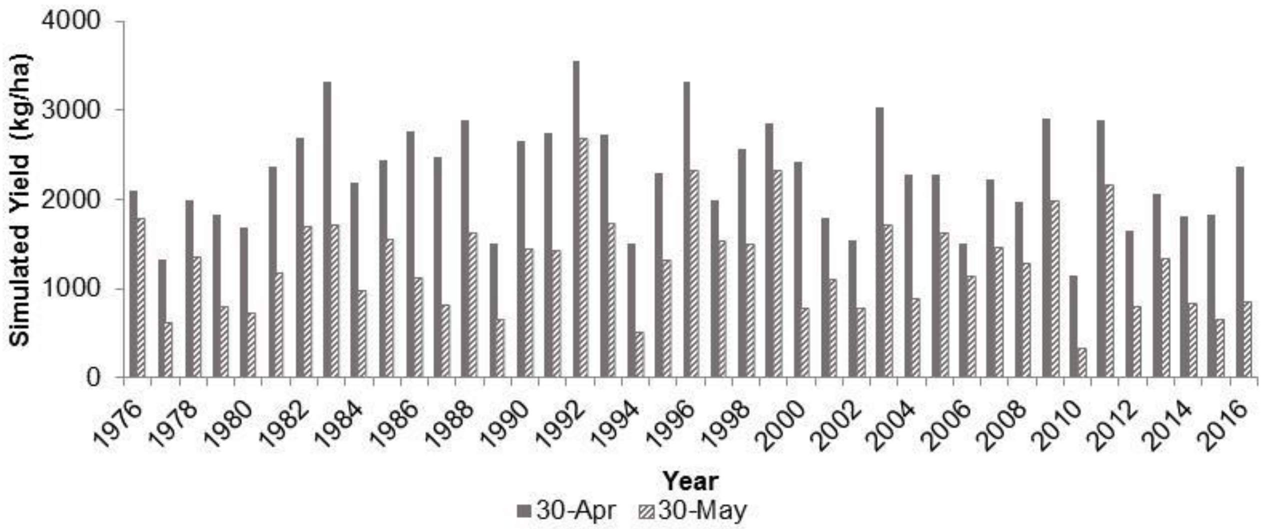

Figure. 1. Simulated yields with APSIM-Canola for every year from 1976 to 2015 for two sowing dates, 30 April (solid fill) and 30 May (pattern fill), for Wongan Hills on a sandy soil and for a mid maturity canola cultivar.

Peak yield relationships

The long-term average simulated yield associated with each sowing date for two selected locations, Wongan Hills and Kojonup (Figure 2), shows a peak yield relationship. In the two locations, there is a bell shaped yield vs time of sowing relationship. There is a yield penalty for very early sowings, when temperatures are high and the crop grows fast and reaches flowering quickly and the total above ground-biomass is low and thus the potential yield is also low. It is well documented that the potential grain yield is related to the biomass at flowering (McCormick *et al*., 2012). Additionally, very early sowings have an increased frost risk and greater potential yield penalty due to frost stress during early grain-filling. So, very early sowings, such as mid-March, have a lower yield than sowings at the optimum time due to both low yield potential and greater yield penalty due to frost. We don't have experimental data for mid-March sowing, but this study suggests that sowing as early as mid-March would incur a yield penalty in the 12 locations studied. More field trials with March sowings are necessary to validate the simulation results.

Similarly, late sowing shortens the period from sowing to flowering, and thus reduces the biomass at flowering and decreases the yield potential (McCormick *et al*., 2012). Additionally, there is also greater yield penalty due to heat stress.

The frost risk, expressed as the total number of days with minimum temperatures below certain thresholds during the early grain-filling period (see Table 3 in Lilley *et al*., 2015), was higher in Kojonup than in Wongan Hills, especially for early sowings (Figure 2).

Heat risk, expressed as the number of days with maximum temperature above certain thresholds during the flowering period (see Table 3 in Lilley *et al*., 2015), was greater at Wongan Hills than at Kojonup, for late sowings (Figure 2).

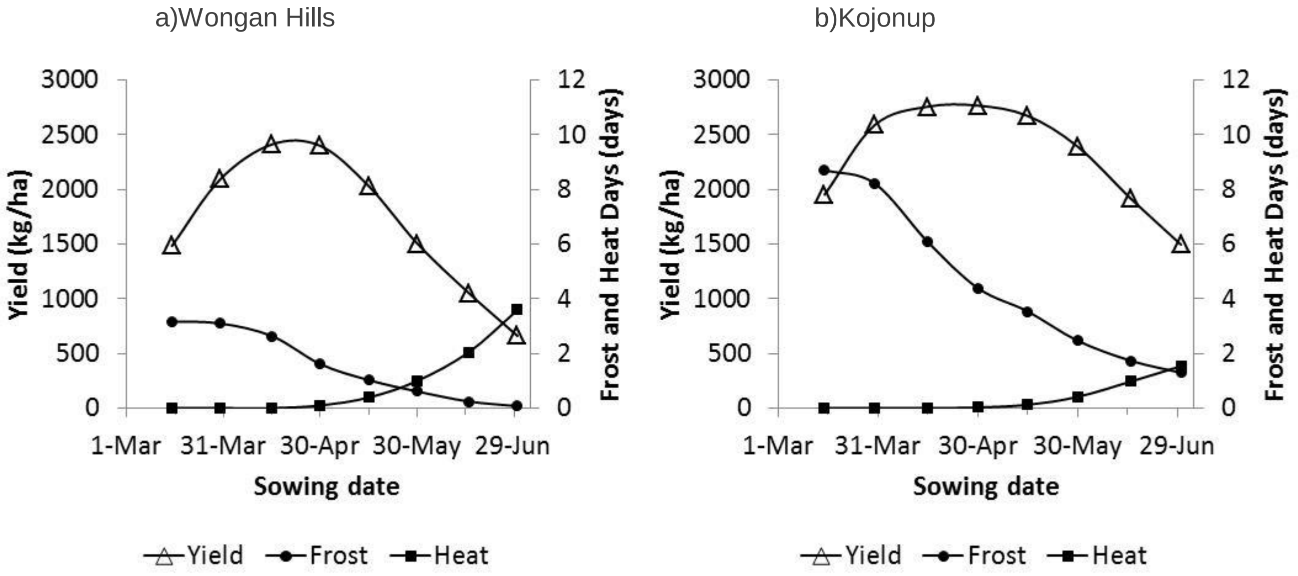

Figure 2. Simulated average yields (open triangle) for the period 1976-2016 for (a) Wongan Hills and (b) Kojonup on a duplex soil, for a medium season canola cultivar for different sowing dates. Long-term average number of frost days around early grain-filling (closed circle) and heat days around flowering (closed square).

Optimum sowing window

The optimum sowing window, or period when average yield is within 95% of the maximum yields (Table 1), varies with location and cultivar type. As a rule of thumb, the optimum sowing window for a medium maturity cultivar in low and medium rainfall areas is from the beginning to end of April, and for high rainfall areas is from the beginning of April to mid-May.

There is an optimal sowing window that maximises grain yield for a given location and maturity type for an average year, keeping in mind there exists a great year-to-year variability in yield. The optimum sowing window shows the sowing period which results in maximum average yield, even though there is still significant frost risk. Frost risk/damage decreases with later sowing, but yield potential decreases more markedly with later sowing, so choosing a sowing date that completely eliminates frost risk would give a much lower potential yield. Given the penalty due to frost and the penalty due to late sowing, the compromise is to choose the sowing window that on average maximises grain yield, even though some frost risk still exists.

A mild environment such as Kojonup has a longer optimum sowing window than a more water limited environment such as Wongan Hills. The duration of the optimum sowing window for a medium maturity cultivar is 38 and 28 days for Kojonup and Wongan Hills, respectively.

Maturity type cultivar

This analysis showed that, with the combined effect of sowing date and frost risk on yield, long season cultivars would, on average, out yield short and medium season cultivars for early sowings at all 12 locations studied. Within the optimum sowing period, yield differences among cultivars diminished with later sowings (Figure 3). For late and very late sowings, long season cultivars yielded less than short and medium season cultivars in most of the 12 locations studied (Figure 3a). In some locations with mild growing conditions, such as Esperance and Kojonup, there was no difference in yield between the different cultivars for late sowings (Figure 3b).

So, if an early opportunity occurred APSIM predicts a long season cultivar would be preferred in most locations. However, if an early sowing opportunity did not occur, a medium or short season cultivar would be preferred in most locations.

Table 1. Optimum sowing window (expressed as the sowing period that achieves on average more than 95% of the peak yield) for 12 locations and 3 cultivars. Duration of the optimum sowing window in days for 3 cultivars**.**

	Optimum Sowing Window			Duration (days)		
Location	**Long cultivar**	**Medium cultivar**	**Short cultivar**	**Long**	**Medium**	**Short**
Mullewa	22 Mar - 17 Apr	5 Apr - 1 May	2 Apr - 7 May	26	26	35
Geraldton	30 Mar - 4 May	12 Apr - 15 May	19 Apr - 21 May	35	33	32
Mingenew	29 Mar - 24 Apr	9 Apr - 9 May	14 Apr - 14 May	26	30	30
Badgingarra	30 Mar - 4 May	11 Apr - 14 May	14 Apr - 21 May	35	33	37
Wongan Hills	25 Mar - 24 Apr	6 Apr - 4 May	13 Apr - 7 May	30	28	24
Merredin	21 Mar - 12 Apr	1 Apr - 25 Apr	7 Apr - 4 May	22	24	27
Cunderdin	23 Mar - 19 Apr	4 Apr - 29 Apr	9 Apr - 7 May	27	25	28
Wandering	29 Mar - 3 May	5 Apr - 11 May	15 Apr - 11 May	35	36	26
Lake Grace	22 Mar - 17 Apr	2 Apr - 25 Apr	7 Apr - 1 May	26	23	24
Kojonup	23 Mar - 5 May	30 Mar - 7 May	2 Apr - 17 May	43	38	45
Salmon Gums	15 Mar - 14 Apr	25 Mar - 24 Apr	4 Apr - 29 Apr	30	30	25
Esperance	20 Mar - 1 May	30 Mar - 9 May	5 Apr - 17 May	42	40	42

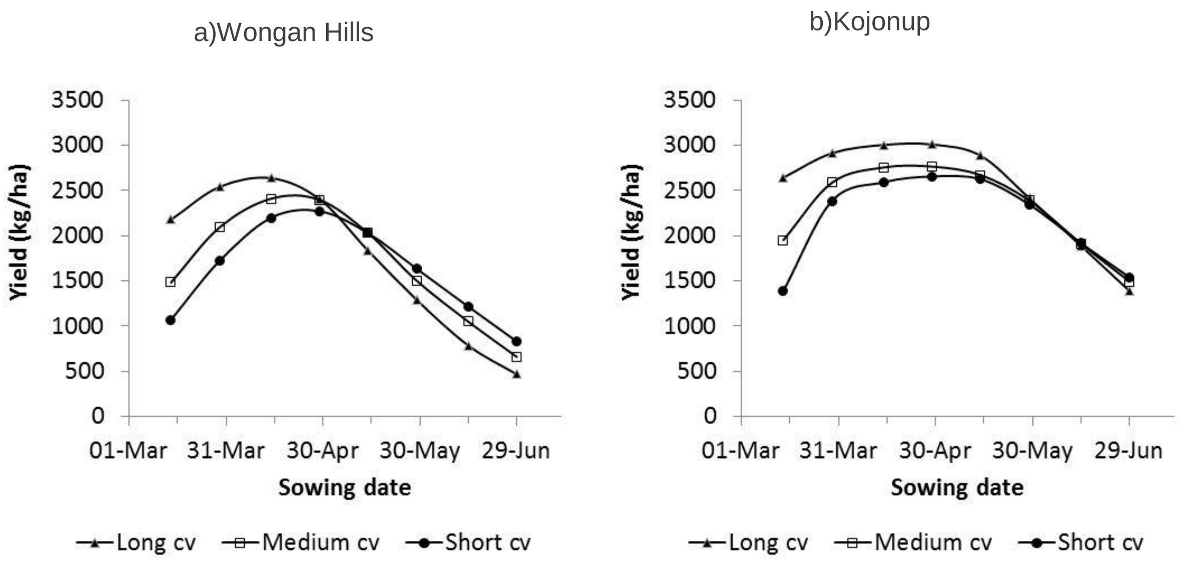

Figure 3. Average simulated yield for the period 1976-2016 for (a) Wongan Hills and (b) Kojonup on a duplex soil, for a long (triangle), medium (square) and short (circle) canola cultivars for different sowing dates.

Weighing up the risk of not taking an early sowing opportunity

There may be good reasons for sowing earlier than the optimum sowing period. The early autumn rains have a high probability of being followed by long dry periods (Table 2), so if a late March or early April sowing opportunity is not taken there is a risk a second opportunity will not occur until after the optimal sowing window has passed. This happened in some locations in 2017. This is especially the case in low rainfall short-growing season environments such as Mullewa and Merredin where it may be better to sow earlier than the optimum and risk some frost damage rather than risk missing an opportunity and having to sow after the optimal sowing window or not at all. This will only be advisable when there is sufficient stored soil moisture from summer rain to ensure an early emerging crop will survive until reliable winter rains begin.

Table 2. Percentage of years with rains of either 0-9mm or >=10mm in April (n=42).

		Week in April			
		1	2	3	4
Mullewa	0-9 mm	88	79	83	81
	>10mm	12	22	17	19
Esperance	0-9 mm	81	74	79	62
	>10mm	19	26	22	38

Conclusion

This study has estimated the optimal sowing period to achieve maximum canola yields for a number of locations in the wheatbelt of Western Australia, accounting for frost and heat stress. As a rule of thumb sowing in April will achieve the maximum canola yield in most locations in the WA cropping region. For long season environments and/or mild conditions this period extends to mid-May.

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Key words

APSIM, crop modelling, simulation, optimal sowing period

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