Optimal flowering periods for canola in eastern Australia

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Abstract
Recent trends in agronomic practice towards earlier sowing systems highlight the need to better define optimum flowering periods (OFPs) for canola. We define the OFP as the range of dates in which it is optimal to start flowering to maximise yield. Crops which flower too early may have insufficient biomass or frost damage, while late flowering increases heat and water stress. Despite its importance, OFPs for canola have not been comprehensively defined for canola across eastern Australia's cropping zone, especially for crops sown prior to the traditional sowing window (late April to early May). Identifying the OFP is a first step to establish appropriate variety by sowing date combinations to optimise yield in different environments. We used the APSIM-Canola model to simulate yield and flowering date of crops sown at weekly intervals from mid-February to late June using 50 years (1966-2015) of climate records at 25 locations in eastern Australia. Reductions in yield were applied for frost and heat damage based on air temperatures during sensitive periods. The OFP varied with location and season and was largely driven by seasonal water supply and demand, while effects of temperature extremes varied in importance across the region. The start of the OFP varied from 25 June (Minnipa, SA) to 8 August (Young, NSW) and the duration from 2 weeks in Condobolin, NSW to 7 weeks in Hamilton, Victoria.

Keywords
APSIM, Rapeseed, phenology, crop modelling, simulation, critical period.

Introduction
Canola (*Brassica napus* L.) is the third most important grain crop in Australia (annual production up to 3.4Mt in recent years, AOF 2016) and is also the most widely grown broadleaf break crop for cereal-based farming systems (Angus et al. 2015). The physiology that underpins the response to sowing time is relatively well understood. For a given environment, there will be an optimum flowering period that balances the risk of frost or limited biomass in crops flowering too early, with that of heat and water stress in crops that flower too late. Consequently, sowing date recommendations vary for cultivars with different phenology to optimise these physiological trade-offs under the climatic conditions in specific regions (Matthews et al. 2016). In recent years, changing seasonal conditions, improved agronomy and new varieties have prompted a re-evaluation of sowing date recommendations in canola. The traditional autumn "breaking rain" to establish crops has become less reliable since 1996 (Cai et al. 2012; Pook et al. 2009), and especially during the millennium drought from 2002 to 2010 (Verdon-Kidd et al. 2014), a trend thought likely to persist. Recent research has shown that earlier sowing of canola can improve productivity and reduce the risk associated with canola production if the crop flowers in the appropriate window (Kirkegaard et al. 2016, Brill et al. 2016). In addition, expansion of canola production into new environments in the high and low rainfall zones (Christy et al. 2013, Lilley et al. 2015), creates a greater need for the identification of the optimal flowering period for canola in those regions. While this has been studied in wheat (Flohr et al. 2017), there are no reports of the OFP in canola. We report a simulation analysis using APSIM-Canola (Holzworth et al. 2014) which identified the optimal flowering period for canola for 25 sites in eastern Australia.

Methods
We conducted this analysis using the Agricultural Production SIMulation (APSIM-Canola) model version 7.7 (Holzworth et al. 2014; http://www.apsim.info) to simulate canola yield and flowering date. APSIM-Canola has been widely validated across a broad range of environments (Robertson and Lilley 2016) and for a range of early sowing dates in Kirkegaard et al. (2016). The analysis was conducted at 25 sites across eastern Australia (Figure 1) and results from 8 diverse sites are reported here. For all sites, long-term daily climatic data were obtained from the SILO Patched Point Dataset (http://www.bom.gov.au/silo/) and the appropriate soil was chosen from the ApSoil database https://www.apsim.info/Products/APSoil.aspx). At each site, sowing was simulated at weekly intervals from 15 February to 28 June for 3 cultivars differing in

their rate of phenological development. The cultivars ranged from slow developing ("late") spring cultivars (e.g. Archer) to fast developing ("early")

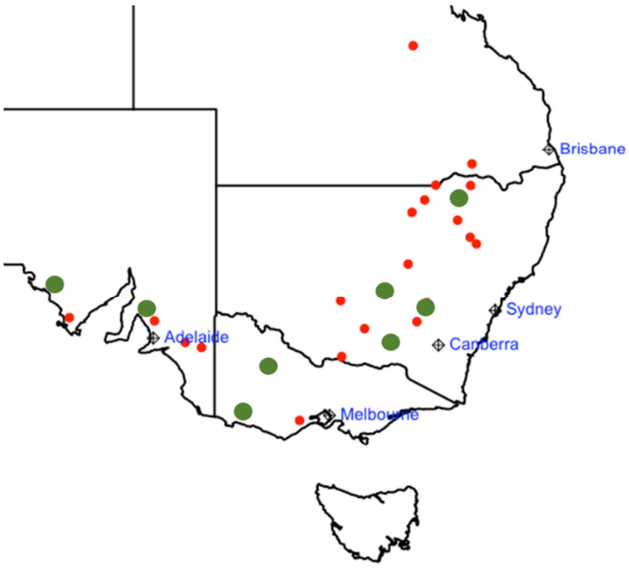

Figure 1. Locations in the eastern Australian cropping zone where Optimal Flowering Period (OFP) for canola was determined. Eight selected locations detailed in this paper are shown as larger green circles.

spring cultivars (e.g. Hyola50). For each site, 15 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 N limiting yield. A yield reduction to account for frost and heat damage based on air temperature was applied according to Lilley et al. (2015). Simulations were run from 1956 to 2015 without resetting of soil water content and output from the first 10 years was excluded to prevent effects of initial settings. Outputs from the simulation included yield, sowing date and the date flowering commenced (i.e. 50% of plants with one open flower). The combination of sowing dates and cultivar phenology generated a dataset with a large range of flowering dates in each environment. OFPs were calculated following the method of Flohr et al. (2017). In that method a 15-day running mean of yield associated with any given "start of flowering" date was calculated over the 50 years of simulation. The long-term average simulated yield associated with each flowering date, and the average frost, heat and water stress experienced by a crop flowering on that date is shown for Wagga Wagga, NSW (Figure 2). Flowering dates corresponding to a yield ≥ 95% of the peak mean yield were considered to be in the optimal flowering period (OFP) for each location. The OFP refers specifically to the date range in which it is optimal to start flowering to maximise the long-term average yield (i.e. the end of the range refers to the latest date by which flowering should commence). At each location, the simulation output was also used to estimate the range of sowing dates which achieved the OFP for each cultivar phenology type.

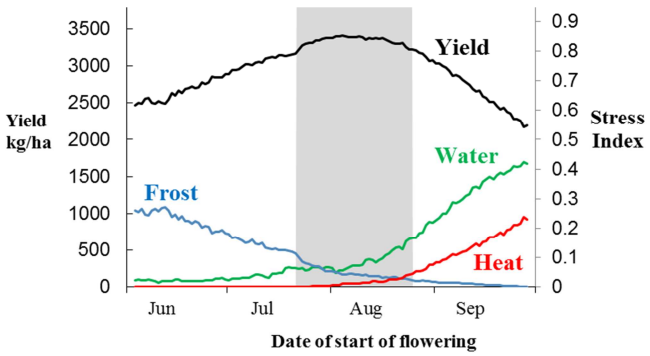

Figure 2. Optimum Flowering Period (period to target the start of canola flowering to achieve ≥ 95% of average peak yield) for Wagga Wagga, NSW (in grey). This period optimises all abiotic risk factors influencing yield including intercepted radiation, frost, heat and water stress. The long-term average simulated yield (black) and stress indices associated with a particular start of flowering date is shown. Frost (blue) and heat (red) stress index is the factor by which simulated potential yield is reduced due stress during the sensitive period. Water stress index (green) is the average simulated crop water deficit between flowering and maturity.

Table 1. Summary of the simulated Optimal Flowering Period (OFP; the range of dates in which it is optimal to start flowering to maximise yield) for canola for 8 locations in eastern Australia. The difference in OFP before and after 2000 is also shown for Wagga Wagga.

Location	OFP	Duration (days)
Minnipa, SA	25-Jun to 26-Jul	31
Hart, SA	3-Jul to 4-Aug	33
Birchip, VIC	6-Jul to 2-Aug	27
Moree, NSW	11-Jul to 31-Jul	20
Condobolin, NSW	18-Jul to 4-Aug	17
Wagga Wagga, NSW	21-Jul to 25-Aug	35
Hamilton, VIC	22-Jul to 13-Sep	53
Young, NSW	8-Aug to 14-Sep	36
Wagga Wagga, NSW	22-Jul to 31 Aug (1966-2000),	40
	23-Jul to 14 Aug (2001-2015)	22

To demonstrate how the OFP changes from season to season, the OFP was calculated separately for deciles 1-2, 3-4, 5-6, 7-8 and 9-10 of April-October rainfall for one location (Wagga Wagga, NSW, Table 1). In addition the OFP was determined separately for the periods 1966-2000 and 2001-2015, the latter period reflecting more variable climatic conditions which are likely to persist into the future. A further simulation analysis was conducted to compare the effect of cultivar group type (hybrid, open-pollinated or triazine tolerant) on the OFP.

Results and Discussion

The predicted OFP for canola varied across regions, occurring earlier in the year in warmer and drier environments such as those in South Australia (Table 1) where sharp rises in summer temperatures and strongly Mediterranean rainfall patterns bring earlier onset of water and heat stress. Colder, and more frost-prone inland environments such as Young, NSW had the latest opening of the OFP where avoidance of frost is key to maximising yield. Wetter and milder environments such as those in southern Victoria (Hamilton) had the longest duration of the OFP (53 days), whilst drier inland environments such as Condobolin, NSW were much shorter (17 days). The analysis showed that OFP was largely a function of the environment, with only small differences in OFP for different cultivar maturity types (Figure 3). Generally, slower developing cultivars tended to have a later opening and close of the OFP, although at Hamilton, the late developing type had the longest OFP. The analysis of more vigorous hybrid cultivars and triazine tolerant cultivars with a lower yield potential showed that these cultivar characteristics had little impact on the OFP, confirming that it is related to rate of phenological development and environmental characteristics of particular location. Once the OFP was identified for any particular location, the phenology type which achieved that OFP could be matched with the sowing opportunity (Figure 3). Our analysis showed that an understanding of the drivers of phenology which determine flowering date in response to climate was essential to ensure appropriate cultivar choice for any particular sowing opportunity. In all environments, cultivar choice will effect both flowering date and yield potential.

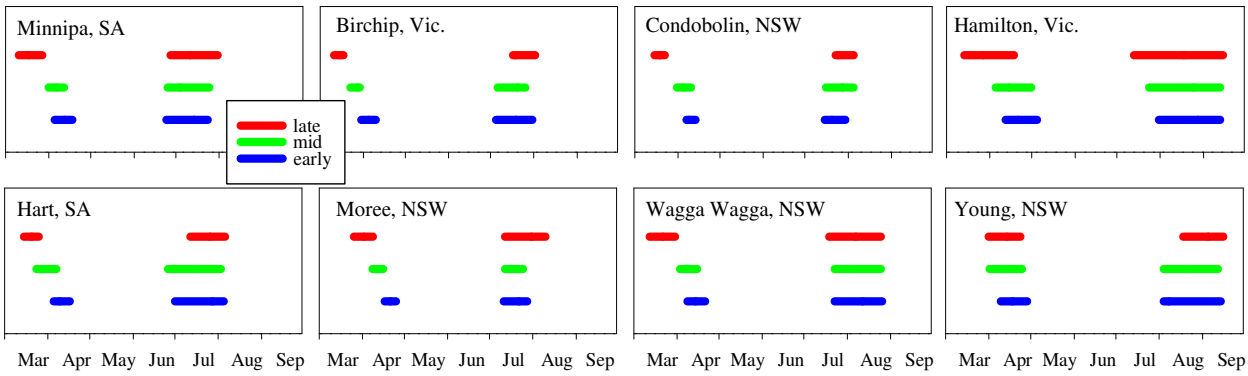

Figure 3. Optimum Flowering Period and optimal sowing period to achieve that OFP for 3 different cultivar maturity types (early, mid and late) at 8 locations in the study.

Determination of the OFP at Wagga Wagga based on climate data since 2000 (rather than over 50 years) showed that the end date of the OFP was up to 2 weeks earlier (Table 1). This may have implications for understanding OFP in future climate scenarios. The effects of pests and disease on yield were not accounted for in these simulations, so the relationship between disease risk and the optimal flowering period may also require consideration given that the two major diseases of canola (Blackleg and Sclerotinia) are both able to infect upper canopies and cause significant yield loss in crops flowering during winter (Sprague et al. 2017). Current evidence suggests that disease risk is highest just prior to the opening of the OFP predicted using abiotic stresses, but this is an area of ongoing work. Although optimum sowing dates can be identified based on OFP, other aspects of the farming system including the capacity to establish crops reliably and the risk of pests, diseases and effective weed control may all influence sowing date decisions at the farm level.

Conclusion

This study has identified the optimal flowering period for the start of flowering for canola across eastern Australia's cropping zone, a first step to establish appropriate variety by sowing date combinations to optimise yields in different environments.

Acknowledgements

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References

AOF (2016). Australian Oilseeds Federation Crop Reports. (http://www.australianoilseeds.com/oilseeds_industry/crop_report_assets).

Angus JF, Kirkegaard JA, Hunt JR, Ryan MH, Ohlander L and Peoples MB (2015). Break crops and rotations for wheat. Crop and Pasture Science 66, 523-552.

Brill RD, Jenkins LM, Gardner MJ, Lilley JM and Orchard BA (2016). Optimising canola establishment and yield in south-eastern Australia with hybrids and large seed. Crop and Pasture Science 67, 409-418.

Cai W, Cowan T and Thatcher M (2012). Rainfall reductions over Southern Hemisphere semi-arid regions: the role of subtropical dry zone expansion. Scientific Reports 2, Art No. 702.

Christy B, O'Leary G, Riffkin P, Acuna T, Potter T and Clough A (2013). Long-season canola (Brassica napus L.) cultivars offer potential to substantially increase grain yield production in south-eastern Australia compared with current spring cultivars. Crop and Pasture Science 64, 901–913.

Flohr, BM, Hunt JR, Kirkegaard JA and Evans JR (2017). Water and temperature stress define the optimal flowering period for wheat in southern-eastern Australia. Field Crops Research (submitted).

Holzworth DP, et al. (2014). APSIM - Evolution towards a new generation of agricultural systems simulation. Environmental Modelling and Software 62, 327-350.

Kirkegaard JA, Lilley JM, Brill RD, Sprague SJ, Fettell NA and Pengilley GC (2016). Re-evaluating sowing time of spring canola (Brassica napus L.) in south-eastern Australia – how early is too early? Crop and Pasture Science 67, 381-397.

Lilley JA, Bell LW and Kirkegaard JA (2015). Optimising grain yield and grazing potential of crops across Australia's high-rainfall zone: a simulation analysis. 2. Canola. Crop and Pasture Science 66, 349-363.

Matthews P, McCaffery D and Jenkins L (2016). Winter crop variety sowing guide 2016. NSW Department of Primary Industries. (http://www.dpi.nsw.gov.au).

Pook M, Lisson S, Risbey J, Ummenhofer CC, McIntosh P and Rebbeck M (2009). The autumn break for cropping in southeast Australia: trends, synoptic influences and impacts on wheat yield. International Journal of Climatology 29, 2012-2026.

Robertson MJ and Lilley JM (2016). Simulation of growth, development and yield of canola (Brassica napus) in APSIM. Crop and Pasture Research 67, 332-344.

Sprague S, Graham J, Brill R and McMaster C (2017). Early-flowering canola – what is the blackleg risk? Australian Society of Agronomy (These proceedings).

Verdon-Kidd DC, Kiem AS and Moran R (2014). Links between the Big Dry in Australia and hemispheric multi-decadal climate variability - implications for water resource management. Hydrology and Earth System Sciences 18, 2235-2256.