Phenology of canola cultivars in the northern region and implications for frost risk

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ABSTRACT

Risk of yield loss in canola due to spring frosts during the early reproductive period is a key constraint to canola production in the northern region. In this paper we show the rapid phenological development of canola in northern compared to southern locations (e.g. up to 40 days earlier flowering than at Wagga Wagga for a mid-May sowing), the strong locational variation in the northern region for canola phenology (eg 20-30 days variation across five locations in flowering date for a mid-May sowing), and interactions between location, cultivar maturity and sowing date. We couple the crop growth simulation model, APSIM-Canola, validated for simulation of flowering date, to long term climate data to define frost risks for two northern locations. The simulations show that it is possible to minimise frost risk to around 10% by appropriate choice of cultivar phenology for given sowing date. The impact of delayed sowing on lowering frost risk was particularly strong between mid-April and mid-May.

KEYWORDS

Canola, phenology, frost, sowing date, cultivar, simulation.

INTRODUCTION

Traditional practice in the northern grain belt is to sow winter grain crops in early-May to late June, a time which in some years predisposes crops to damage by spring frosts through flowering being too early. The recommended strategy to minimise frost risk is to sow a cultivar appropriate to the sowing date so that flowering occurs after the main frost risk period. The arrival at a optimum sowing time will depend on tradeoffs between lowered frost risk with delayed sowing and lowered yield potential. Frost risk has been well defined for wheat (Woodruff, 1992) but not for the current range of canola cultivars available. Hodgson (1978) attempted to define phenological development of older cultivars in relation to frost risk. This work is in need of updating with current cultivars and more contemporary methods of analysing crop phenological development. Frost will damage yield in canola if it occurs towards the end of the flowering period or during early grain-filling (Colton and Sykes, 1992) and Scott et al. (1973) noted yield loss due to frosts in early-sown winter rapeseed in the UK. The threat of frosts that cause major yield loss has been cited as a key reason why canola has not been grown widely in the northern region.

The quantification of frost risk involves the characterisation of cultivar phenology in relation to sowing date and location. As the experience with current Australian canola cultivars in the northern grains region is limited, the first aim of this paper is to document the range of flowering times that occur with the current range of cultivars across different sowing dates and locations. The ability to simulate the date of flowering in relation to sowing date, cultivar and location can be used in conjunction with long-term climatic data to define frost risks for sowing date x cultivar combinations at different locations. The second aim of this paper is to define frost risk for two northern locations using the simulation capability of the validated model APSIM-Canola.

MATERIALS AND METHODS

Phenology studies

A series of sowing date studies were conducted in the northern grains region in 1998 and 1999 at Tamworth, Moree, Lawes, Dalby and Roma, with details provided in Table 1. While a wide range of cultivars and breeding lines were sown in each study, results from only a subset are presented here. The Lawes study was irrigated, while the others were dryland. The dates were recorded of start of flowering (open flowers on 50% of plants) and end of flowering (no more open flowers on 95% plants).

Table 1. Details of canola sowing date studies at four locations in 1998 and 1999.

Location	Latitude, longitude	Sowing dates
Tamworth, NSW	31.09^{o}S 150.85^{o}E	14 April, 17 May, 18 June, 20 August 1999
Moree, NSW	29.50^{o}S 149.9^{o}E	26 May, 17 June 1998
Lawes, Qld	27.55^{o}S 152.34^{o}E	26 May, 16 June 1998; 24 March, 17 May, 17 June 1999
Roma, Qld	29.50^{o}S 149.9^{o}E	26 April, 28 May, 12 July 1999
Dalby, Qld	27.17 ^{o}S 149.9^{o}E	28 May, 19 June 1998

Validation of phenology model

APSIM-Canola accounts for the effects of vernalisation, non-vernalising temperatures and photoperiod on the rate of development from sowing to the start of flowering. Validation of the phenology sub-routines of APSIM-Canola (Robertson et al., 1999b) was conducted by comparing observed and simulated days to flowering. Validations were conducted for three cultivars, representative of early, mid and late maturing cultivars currently grown in Australia. Data used for validation was sourced from studies listed in Table 1 as well as other studies conducted throughout Australia. Performance of the model in simulating post-flowering development is not considered in this paper.

Simulation studies of long term frost risk

Long-term simulations, using APSIM-Canola (Robertson et al., 1999b) were conducted for Roma in SW Qld (1893-1997) and Moree in NW NSW (1879-1997). Sowings of early-, mid- and late-maturing cultivars were simulated for 15th of April, May, June and July. The risk of a damaging frost during early grain-filling was quantified by the occurrence of at least one day when the minimum temperature reached a threshold temperature during simulated early grain-fill. It is currently unknown what screen or crop temperatures will actually cause loss of yield in canola. Also, the relationship between screen temperature and crop temperature will be a function of paddock aspect, topography, and the extent of crop canopy development and height, so that the air temperature causing yield loss will vary from situation to situation. Hence, we simulated frost thresholds of -1^{0}C and –2^{o}C measured in screen, because of lack of a well-defined threshold for canola.

RESULTS AND DISCUSSION

Phenological development of canola in the northern region

Within the northern grain region there are large location effects on time to flowering. For instance, Oscar (a late-maturing cultivar) sown around mid-May started flowering between 90 and 115 days depending on whether it was sown at Lawes, Roma, Dalby, Moree or Tamworth. A similar spread exists for the mid-season cultivar, Mystic (75-100 days) and the early-season cultivar, PacN145 (60-90 days). For the early-and mid-season cultivars, development was slowest for mid-May sowings; while for cv. Oscar at some locations (e.g. Tamworth) sowing before mid-May did not result in a shorter time to flowering, perhaps indicative of a vernalisation requirement. The locations at which development was slowest also showed the greatest response to sowing date. Time to flowering for cv. Oscar at Tamworth, which is at the southern extremity of the northern grains region, is similar to that at Wagga Wagga in southern NSW, while for the mid-season cultivar Mystic, development is 10-15 days earlier at Tamworth than at Wagga Wagga. At Roma and Lawes, further north than Tamworth, and hence warmer, development was ca. 20 and 40 days faster, respectively, than at Wagga for cvs. Oscar and Mystic. These results emphasise (1) the rapid development of canola in northern compared to southern locations, (2) strong locational variation in the northern region for canola phenology, and (3) interactions between location, cultivar maturity and sowing date. These findings suggest that sowing date recommendations for the northern region for minimising frost risk have to be location- and cultivar- specific.

Simulation of flowering date

The phenology sub-routines of APSIM-Canola were able to account for 68, 93 and 93 % of the observed variation in days to flowering for the early- (PacN145), mid- (Mystic) and late-maturing (Oscar) cultivars used for testing (Fig. 1). Root mean-squared deviation values for observed and simulated were 6.9, 3.7 and 4.1 days, respectively, which was 9.6, 4.5 and 4.4% of the mean observed days to flowering.

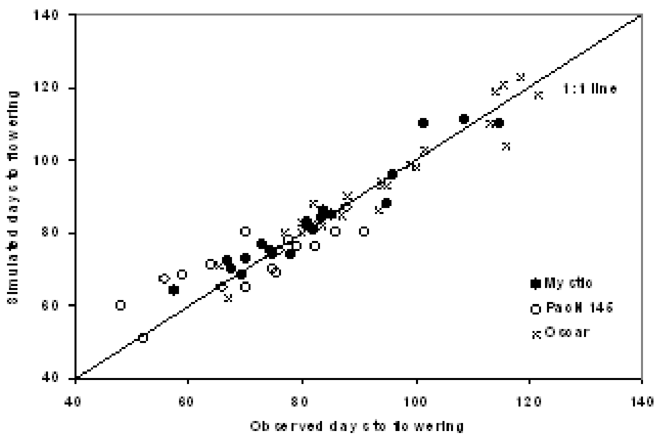

Figure 1. Observed and simulated days to flowering for an early (PacN145), mid (Mystic) and late-flowering (Oscar) cultivar. The 1:1 line is shown.

Frost risk in relation to cultivar maturity and sowing date

The results of the long-term simulations using the validated model for the early, mid and late flowering cultivar types demonstrate the steep response of frost risk to delay in sowing date at two northern locations, Moree and Roma (Fig. 2). For instance, delaying sowing date between mid-April and mid-May will lower the risk of a –1 ^{o}C frost by ca. 12 % points per week's delay in sowing at Moree and 15% points per week at Roma. The effect of later cultivar maturity appears to be to decrease risk by 10% points for sowings before mid-May. After mid-May the differences between cultivar groups diminishes, so that by late-May there is little difference between cultivar groups in frost risk at either location or frost threshold.

There is no published knowledge of what screen temperatures cause frost damage and yield loss in canola. In a commercial crop monitored in the Roma district in 1999, we recorded a –1.4 ^{o}C minimum temperature at the end of flowering, which resulted in 70% loss in yield (Anonymous, 2000). These simulations show a substantial difference in risk of frost between –1 and –2 ^{o}C thresholds, for sowing dates before mid-May, and estimation of safe sowing dates should account for this difference.

These simulations suggest that there are strong reasons to delay the sowing of canola beyond the end of April, if the avoidance of significant frost risk is an important priority of the grower. However, this delay will come at the cost of a lowered yield potential (Robertson et al., 1999a), oil content, higher temperatures during grain-filling, and possible conflict with the sowing time of other winter crops on the farm. Clearly, the arrival at an optimum sowing time will depend on tradeoffs between all of these considerations and the risk attitude of the grower. Seasonal climate forecasts are known to provide some skill in frost risk assessment in this region (Stone et al., 1996) and this has been shown to be valuable in tactical management of frost risk in wheat (Hammer et al., 1996) and could be adapted to canola.

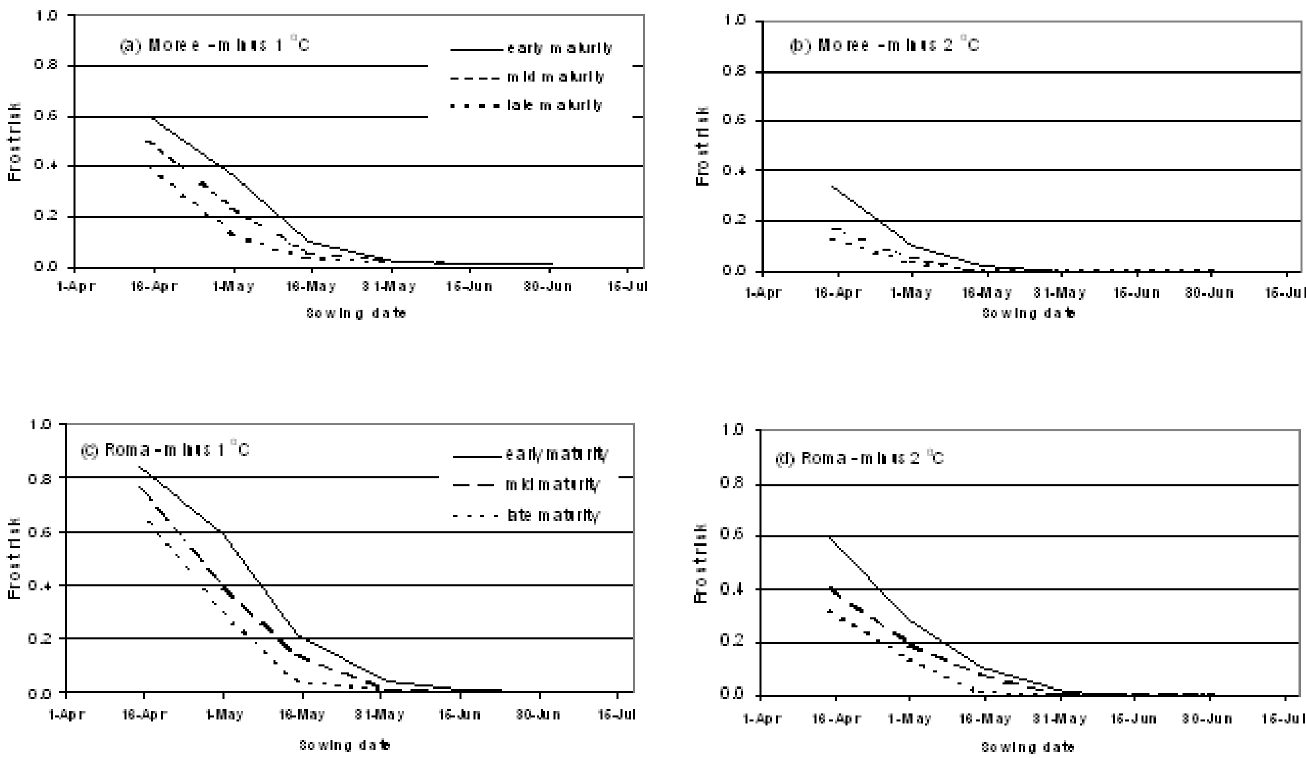

Figure 2. Simulated long-term risk of sustaining a minus 1 °C or minus 2°C screen temperature during early grain filling for early, mid and late flowering cultivars at (a) and (b) Moree, NSW and (c) and (d) Roma, Qld.

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