Understanding wheat phenology: flowering response to sowing time

Dr Felicity Harris NSW DPI, Wagga Wagga; **Dr Peter Martin** Howqua Consulting; **Dr Howard Eagles** University of Adelaide

Key messages

» Flowering time is determined by responses to vernalisation, photoperiod and earliness per se.

» Match variety and sowing time to ensure flowering occurs during the optimal period for your growing environment.

Flowering time is critical!

It is critical to match variety and sowing time to ensure flowering occurs during the optimal flowering window to maximise grain yield potential. The optimum flowering window is determined by a balance in the water used during canopy development and water used during the grain formation and grain-filling phases (Fischer 1979), as well as the declining frequency and severity of frosts (Richards et al. 2014). Crops that flower too early have increased risk of frost damage, whilst crops that flower too late have an increased risk of high temperature impact and water deficit, which can restrict grain formation and grain-filling.

How is flowering time regulated?

Accumulated thermal time has a major influence on the developmental rate in wheat, with development occurring more rapidly as the temperature increases. The relative maturity of varieties is largely controlled by responses to vernalisation and photoperiod (Figure 1).

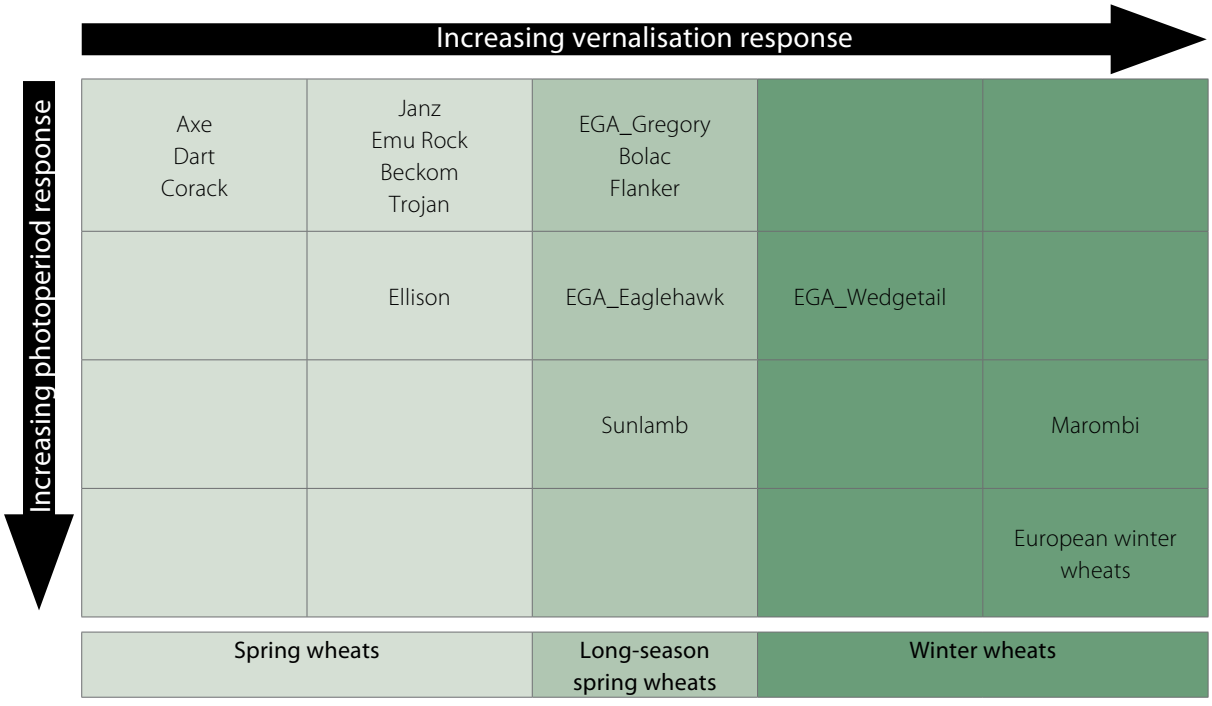

Figure 1. Estimated response of some wheat varieties to vernalisation and photoperiod.

Vernalisation

Varieties responsive to vernalisation require a period of cold temperatures to make the transition from vegetative to reproductive development. Following saturation of the vernalisation response, floral initiation occurs, marking the completion of the initiation of further leaves and the start of the floral organ initiation at the shoot apex. In wheat, vernalisation accumulates most rapidly between 3–10 °C, but can accumulate at a slower rate up to 17 °C. Vernalisation can occur at different stages of the individual plant's lifecycle: during germination, during vegetative plant growth, and for subsequent generations, during seed formation in the mother plant (Flood & Halloran 1986).

Photoperiod

Wheat is a long-day plant, in which the rate of development is increased with longer day-lengths. However, individual genotypes of current commercial varieties have varying levels of responsiveness to photoperiod, including insensitivity. A large number of Australian varieties are insensitive to photoperiod (Cane et al. 2013). In photoperiod sensitive genotypes, short-day (SD) conditions (10 hours or less light) prolong the vegetative phase and delay the transition to reproductive development, whilst long-day (LD) conditions (14 hours or more light) decrease time to floral initiation (Beales et al. 2007).

In vernalisation responsive varieties, following saturation of the vernalisation response, long days hasten progressive inflorescence development and stem elongation. Vernalisation is essentially the prerequisite for long days to reduce the time to flowering (Trevaskis 2010).

Table 1. The vernalisation and photoperiod genes present in some commercial varieties grown in New South Wales, their relative maturities and habit classification (Cane et al. 2013).

Cultivar	Gene*					Maturity**	Type
	Ppd-B1	*Ppd-D1*	*Vrn-A1*	*Vrn-B1*	*Vrn-D1*		
Axe$^{\Phi}$	*a*	*a*	*a*	*a*	*v*	Fast	Spring
Bolac$^{\Phi}$	*b*	*a*	*a*	*v*	*v*	Mid–slow	Spring
Corack$^{\Phi}$	*b*	*a*	*v*	*a*	*a*	Mid–fast	Spring
Dart$^{\Phi}$	*b*	*a*	*a*	*a*	*v*	Fast	Spring
EGA_Eaglehawk$^{\Phi}$	*b*	*b*	*b*	*v*	*a*	Mid–slow	Spring
EGA_Gregory$^{\Phi}$	*b*	*a*	*v*	*v*	*a*	Mid	Spring
EGA_Wedgetail$^{\Phi}$	*b*	*a*	*v*	*v*	*v*	Slow	Winter
Ellison$^{\Phi}$	*a*	*b*	*v*	*a*	*a*	Mid–fast	Spring
Emu Rock$^{\Phi}$	*b*	*a*	*a*	*a*	*v*	Mid–fast	Spring
Gauntlet$^{\Phi}$	*a*	*a*	*a*	*v*	*v*	Mid–fast	Spring
H45$^{\Phi}$	*d*	*a*	*a*	*v*	*a*	Fast	Spring
Harper$^{\Phi}$	*b*	*d*	*a*	*a*	*v*	Mid	Spring
Janz$^{\Phi}$	*c*	*a*	*a*	*v*	*v*	Mid	Spring
Lancer$^{\Phi}$	*a*	*a*	*a*	*v*	*v*	Mid–slow	Spring
Livingston$^{\Phi}$	*b*	*a*	*a*	*a*	*v*	Mid	Spring
Mace$^{\Phi}$	*a*	*a*	*v*	*a*	*v*	Mid–fast	Spring
Marombi$^{\Phi}$	*a*	*b*	*w*	*v*	*v*	Slow	Winter
Merlin$^{\Phi}$	*b*	*a*	*v*	*a*	*a*	Mid–fast	Spring
Mitch$^{\Phi}$	*b*	*a*	*w*	*a*	*a*	Mid–slow	Spring
Spitfire$^{\Phi}$	*a*	*a*	*v*	*a*	*a_v*	Mid–fast	Spring
Sunguard$^{\Phi}$	*a*	*a*	*a*	*v*	*v*	Mid	Spring
Suntop$^{\Phi}$	*d*	*a*	*v*	*a_v*	*a*	Mid	Spring
Sunvale$^{\Phi}$	*a*	*a*	*a*	*v*	*v*	Mid	Spring
Trojan$^{\Phi}$	*a*	*c*	*v*	*a*	*a*	Mid	Spring

*Ppd-B1b is responsive to photoperiod, while Ppd-B1a, Ppd-B1c and PpdB1d are less responsive; Ppd-D1b is a functional gene that is responsive to photoperiod, Ppd-D1a is generally non-responsive to photoperiod and promotes early flowering, while Ppd-D1c and Ppd-D1d are corrupted genes that are largely non-responsive to photoperiod and associated with later flowering; Vrn-A1a and Vrn-A1b are the spring alleles and generally unresponsive to vernalisation, Vrn-A1v is a winter allele and responsive to vernalisation, Vrn-A1w is a winter allele and has a strong vernalisation response; Vrn-B1a and Vrn-D1a are the spring alleles and generally unresponsive to vernalisation, Vrn-B1v and Vrn-D1v are the winter alleles and respond to vernalisation.

**adapted from Cane et al. (2013) and Matthews, McCaffery and Jenkins (2015). Varieties suited for sowing in NSW range in maturity from slow winter (suited to early sowing) to fast spring types (suited to later sowing).

Genetic controls of flowering time

The genetic control of flowering time is complex. There are three primary gene sets with each set controlling vernalisation response, photoperiod response and earliness per se. The genes interact to determine the time of flowering in a specific environment (Slafer & Whitechurch 2001; Trevaskis et al. 2007).

Diagnostic markers for the vernalisation (*Vrn-A1*, *Vrn-B1* and *Vrn-D1*) and photoperiod (*Ppd-B1* and *Ppd-D1*) genes have enabled characterisation of current commercial varieties (Cane et al. 2013) (Table 1). The traditional classification of winter versus spring wheat has been oversimplified. Identifying the form of gene (allele) present enabled genotypes to be grouped as either a spring or winter type, or as being photoperiod-sensitive or insensitive. A spring genotype is characterised by the presence of at least one dominant *VRN1* allele (*a*). A winter genotype required recessive *VRN1* alleles (*v*) at the three *VRN1* loci in wheat, for example *Vrn-A1v* + *Vrn-B1v* + *Vrn-D1v* (Eagles et al. 2009). Photoperiod response is determined by the presence of either the insensitive allele (*a*), or the sensitive allele (*b*) at the *Ppd-D1* locus (Eagles et al. 2009). A more complex analysis of the effect of these genes on development is made possible by identifying the effect of key alleles and allelic combinations of the known major vernalisation and photoperiod genes. Cane et al. (2013) studied the influence of allelic variation and the interactions between the *VRN1* and *PPD1* genes, and reported significant differences in heading date attributed to the allelic combinations of *Vrn-A1*, *Vrn-B1*, *Vrn-D1*, *Ppd-B1* and *Ppd-D1*. The identified alleles accounted for 53% of the genetic variance for heading date.

It is likely that other major *VRN1* and *PPD1* genes affect phasic development in wheat (e.g. *Vrn-D4*) and that there are other unknown major genes and alleles affecting phasic development. Whilst the general adaptation in flowering time is affected by the major *VRN1* and *PPD1* genes, flowering time in both winter and spring wheat genotypes is also controlled by a third level of genes, the earliness *per se* (*Eps*) genes. The effects of *Eps* genes are not as defined as vernalisation and photoperiod, and only a few *Eps* loci have been properly identified in wheat. These have been identified as having more of a fine-tuning effect on flowering time relative to regional adaptations. The interactive nature of the vernalisation and photoperiod genes means the effect of certain genes on flowering time is much greater in specific combinations of alleles.

Flowering response to sowing time

To achieve maximum grain yield potential, it is important to ensure wheat varieties are sown according to their relative maturities (dictated by their response to vernalisation and photoperiod) so flowering occurs in the optimal window.

Wheat varieties responsive to vernalisation (winter types) can be sown early, and will remain vegetative until their vernalisation requirement has been satisfied. This acts to delay reproductive development so that flowering coincides with favourable seasonal conditions. Should a spring variety be sown early (when temperatures are warmer and days longer), development will progress quickly and flowering will occur earlier than optimum, reducing grain yield potential. For example, cv. Dart sown 16 April 2015 at Wagga Wagga flowered on 16 September, while EGA_Wedgetail sown on the same day flowered on 11 October and within the optimum flowering window for Wagga Wagga. However, when sown 6 weeks later (25 May), they flowered more closely together: Dart flowered 14 October and EGA_Wedgetail flowered 17 October.

In sowing time trials at Wagga Wagga and Canowindra in 2015 the highest grain yields were achieved when flowering occurred at the optimum time. Wheat varieties with varied responses to vernalisation and photoperiod can provide greater flexibility to the sowing schedule. Winter wheats can be sown from late February through to April, long-season spring wheats from mid-April to early May and mid-short season spring wheats from late April onwards. Getting wheat phenology right by matching sowing time and variety is critical to optimising yield potential, and is low-cost in comparison with other agronomic management tactics.

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Acknowledgements

This experiment was part of the the project 'Management of barley and barley cultivars for the southern region', DAN00173, 2013–18, jointly funded by GRDC and NSW DPI.

Thank you to Neroli Graham for biometrical support and advice. Thanks to the technical assistance of Linda Brangwin, Fraser Campbell, Nick Hill and Holly Menz.