

Session B02 – Invited speaker

Integrating molecular insights into phenology modelling enhances flowering time predictions

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Abstract: Phenology determines the timing of key development stages in crops such as flowering and maturity, and the duration of the crop life cycle. It plays a critical role in crop adaptation to changing environments and is a major determinant of resilience and yield. However, most physiological crop models cannot fully capture the interactions between vernalization, photoperiod, and temperature in predicting phenology. This often leads to parameter equifinality, where multiple parameter sets produce similar performance, resulting in mischaracterized genotypes and inaccurate predictions.

The Cereal Anthesis Molecular Phenology (CAMP) model addresses this gap by incorporating the regulatory roles of three major genes—*Vrn1*, *Vrn2*, and *Vrn3*—in flowering physiology of wheat and barley. It models phenological development based on the expression of these genes in response to environmental cues (temperature, and photoperiod). This molecular–physiology linkage also enables a simplified phenotyping approach, using mainstem final leaf numbers of wheat and barley grown under controlled conditions, to characterize new genotypes. This reduces costs, improves cultivar characterization, and increases the accuracy of flowering time predictions from genotypic data (e.g., SNPs).

Implemented in the APSIM Next Generation (APSIM NG) framework, the CAMP model was tested against field data from multiple sites and sowing dates across diverse environments. It predicted wheat and barley flowering times within one week for a wide range of cultivars and enhanced the prediction of flowering times for new genotypes grown in novel environments. These results highlight the model's potential to predict cultivar flowering time at the time of release and to reduce the substantial costs of field experiments used to derive cultivar parameters. Moreover, it enables in-silico screening of genotypes prior to release, helping to avoid the expense of testing poorly adapted cultivars and the risks of planting them in unsuitable environments or at suboptimal sowing times.

The CAMP model in APSIM NG is now being used to develop a prototype Flowering Calculator (available at <https://www.cropflowering.com.au/>) to optimize sowing programs for wheat and barley across Australia. This tool identifies either the best sowing time for a given cultivar or the most suitable cultivar for a given sowing time at any location in Australia's grain-growing regions. Optimization is based on simulated flowering times aligned with the optimal flowering window, thereby minimizing frost, heat, and water stress while maximizing grain yield.

Keywords: Phenology. Flowering time, modelling, wheat, barley, APSIM NG, Flowering Calculator