Modelling alfalfa (*Medicago sativa* L.) phenological development

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INTRODUCTION: Predicting alfalfa phenological development is important for optimising defoliation scheduling and other management events. Primary drivers of phenological development are temperature and photoperiod (Pp). This project quantified the response of alfalfa to these factors to create algorithms for the APSIMX model.

OBJECTIVE: To quantify and simulate alfalfa phenological development in seedling and regrowth crops.

MATERIALS AND METHODS:

Data source and experimental design. Data were assembled from two field experiments conducted from 2002 to 2018 at Lincoln University, Canterbury, New Zealand (43°38'S,172°28'E, 11 m a.s.l.). For both experiments, treatments were imposed as a complete randomized block design with four replications: 1) two cutting frequency and 2) fall dormancy and cutting frequency. Reported data are from fall dormancy class 5 and 42-day cutting frequency, with 7 growing years, each with 3-7 regrowth periods.

Thermal time calculation and base temperature determination. Phenological development parameterization involved calculating thermal time (Tt; ˚Cd) and selecting a base temperature (Tb; ˚C). For Tt calculations, "broken-stick", Fick framework, and the WE model were compared. For Tb determination, X-intercept, least variable, and regression coefficient methods were compared.

Phenological measurements and calculations. At the beginning of each regrowth cycle, five shoots were marked and node appearance, height, and flowering were measured every 7-10 days. Nodes were counted as primary leaf attachment and height (mm) was measured on fully extended stems. Time of 50% flowering was recorded. Phyllochron was calculated as the slope of Tt against node number. "Heightchron" was defined and calculated as the slope of Tt against height.

Statistical analyses. Regression analyses, analysis of variance (ANOVA), and Fisher's least significant difference (LSD) were determined with RStudio (R. 3.4.0). For model performance evaluation, coefficient of determination (R^2), Nash-Sutcliffe efficiency (NSE), and relative root mean square error (R_RMSE) were calculated. To quantify the causes of deviation, the error was further segmented into components, including standard bias (SB), non-unit (NU) slope, and lack of correlation (LC).

RESULTS:

- Statistical evaluation of methods for calculating Tt indicated that the "broken-stick" model to define cardinal temperature most accurately computed Tt. A Tb of 1 ˚C had the lowest CV% and highest *P* value.
- The relationship between Tt and primary node number was a positive linear response (R^2=0.84-0.99).
- Phyllochron was constant at 35 ˚Cd/primary leaf in increasing Pp condition. Phyllochron increased from 32 to 51 ˚Cd/primary leaf as Pp decreased from 16.7 to 10.5 h. R^2, R_RSME, and NSE values indicated strong agreement between predicted and observed values.
- The relationship between accumulated Tt and height was a positive linear response (R^2=0.79-0.99).
- "Heightchron" and mean Pp displayed a strong polynomial relationship (R^2=0.89) in which "heightchron" decreased as Pp increased from 2.2 to 0.6 ˚Cd/mm, with highly significant agreement between predicted and observed values.
- Tt to 50% flowering decreased as Pp increased; being 1000 ˚Cd at 12.3 h and about 500 ˚Cd at 16.7 h, with highly significant agreement between predicted and observed values.

CONCLUSIONS:

- The "broken-stick" model with a Tb of 1 ˚C was the most accurate approach for calculating Tt.
- Phyllochron was only responsive to Pp in decreasing Pp conditions (autumn). Greater Tt was required for leaf appearance in short Pp conditions.
- There was a strong polynomial relationship between "heightchron" and mean Pp.
- Tt to 50% flowering decreased as Pp increased.
- There was close agreement between predicted and observed values of node number, height, and time to 50% flowering.