OPTIMAL PREDICTION OF WALNUT HARVEST DATES USING THERMAL TIME MODEL

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Introduction

In highly complicated systems, like the biochemical system of fruit ripening, our knowledge of the system is insufficient to develop useful mechanistic models. Instead we rely on statistical models that are informed by our understanding of the biology (Črepinšek et al., 2006). Generally speaking, there are three steps in specifying these statistical models: (1) selection of thermal time model functional form, (2) selection of cardinal temperatures for calculating thermal time, and (3) selection of thermal time accumulation length. These methods have been extensively applied to flowering and harvest prediction for a variety of fruit and nut crops over the past 15 years (Mimoun and DeJong, 1998; Marra et al., 2001; DeBuse et al., 2008; Ruml et al., 2011). However, no attempts have been made to systematically optimize this process.

Models of thermal time accumulation can be classified by the number of parameters they have. Models with more parameters generally more flexible, and may more closely reflect reality. However, they are computationally more intensive to fit and there is a higher risk of overfitting. Models with one or two parameters do not mimic our understanding of the biology as closely, but they are much less prone to overfitting. It is important to remember that the model with the best fit is not necessarily the model that most closely reflects reality.

The simplest model of thermal time accumulation includes just one parameter Yang et al. (1995).

$$GDH = T - T_b$$

where GDH is the growing degree hours accumulated, T is the current temperature and T_b is the base temperature. A slightly more complicated model includes two parameters. This allows it to flatten off as temperature increases.

$$GDH = \begin{cases} 0 & T \leq T_b \\ T - T_b & T_b \leq T \leq T_o \\ T_o & T_o \leq T \end{cases}$$

where T_o is the optimal temperature. This model still neglects the deleterious effects of very high temperatures. The simplest model that includes these effects is the three parameter triangle model from (citation?), where T_b, T_o, and T_c are the base, optimal and critical temperatures respectively.

$$GDH = \begin{cases} 0 & T \leq T_b \\ T - T_b & T_b \leq T \leq T_o \\ \frac{(T_c - T)(T_o - T_b)}{T_c - T_o} & T_o \leq T \leq T_c \\ 0 & T_c \leq T \end{cases}$$

The most widely used model of thermal time accumulation is another three parameter model from Anderson et al. (1985).

$$GDH = \begin{cases} 0 & T \leq T_b \\ \frac{T_o - T_a}{2}\left[1 + \cos\left(\pi + \pi \cdot \frac{T - T_b}{T_o - T_b}\right)\right] & T_b \leq T \leq T_o \\ (T_o - T_a)\left[1 + \cos\left(\frac{\pi}{2} + \frac{\pi}{2} \cdot \frac{T - T_o}{T_c - T_o}\right)\right] & T_o \leq T \leq T_c \\ 0 & T_c \leq T \end{cases}$$

The most complicated model used in the literature is beta model from Marra et al. (2001).

$$GDH = T_o \cdot$$

Normally in statistical analysis

Biology tells us that trees will stop fruit development if temperatures get too low or too high. So many potential functional forms include a critical

Materials and Methods

References

Anderson, J. L., Richardson, E. A., and Kesner, C. D. (1985). Validation of chill unit and flower bud phenology models for'Montmorency'sour cherry. In *I International Symposium on Computer Modelling in Fruit Research and Orchard Management 184*, pages 71–78.

Črepinšek, Z., Kajfež-Bogataj, L., and Bergant, K. (2006). Modelling of weather variability effect on fitophenology. *Ecological Modelling*, 194(1):256–265.

DeBuse, C., Lopez, G., and DeJong, T. (2008). Using Spring Weather Data to Predict Harvest Date for'Improved French'Prune. In *IX International Symposium on Plum and Prune Genetics, Breeding and Pomology 874*, pages 107–112.

Marra, F. P., Inglese, P., DeJong, T. M., and Johnson, R. S. (2001). Thermal time requirement and harvest time forecast for peach cultivars with different fruit development periods. In *V International Peach Symposium 592*, pages 523–529.

Mimoun, B. and DeJong, T. M. (1998). Using the relation between growing degree hours and harvest date to estimate run-times for peach: a tree growth and yield simulation model. In *V International Symposium on Computer Modelling in Fruit Research and Orchard Management 499*, pages 107–114.

Ruml, M., Milatovi, D., Vuli, T., and Vukovi, A. (2011). Predicting apricot phenology using meteorological data. *International journal of biometeorology*, 55(5):723–732.

Yang, S., Logan, J., and Coffey, D. L. (1995). Mathematical formulae for calculating the base temperature for growing degree days. *Agricultural and Forest Meteorology*, 74(1):61–74.