Optimal prediction of walnut harvest dates using thermal time model

Introduction

* Spring accumulation of growing degree days/hours (GDD/H) have been used for a number of years to predict harvest dates of a number of tree crops
* And as one might expect there are a number of potential models for relating spring temperatures to harvest dates
* However because of a lack of computing power/quantitative methods widespread comparisons of these methods have been missing
* In general we can break up the model into three pieces
  1. Selection of thermal time model functional form
  2. Optimization of cardinal temperatures for calculation of thermal time
  3. Selection of thermal time accumulation length
* In this paper we present what we consider an optimal model for calculating effective thermal time accumulation for 13 walnut cultivars

Part 1: Selection of Model Functional Form

* Model Options
  + Constant season length
  + Constant harvest date
  + Growing Degree Days Zalom 1983/Snyder 1999
  + Growing Degree Hours
    - Trig curve – Anderson 1986
    - No Critical value
    - Trapezoid
    - Composite Models
* Because there were only four that seemed to be worth investigating we carried out the next step for all four and then made our decision
* plots of error and R2
* They are not really that different
* Anderson and GDD are the best probably and are the most widely used
* This part seems to not have a big affect on the outcomes

Part 2: Parameter Optimization

* Once we have our functional form we need to optimize the cardinal temperatures (base temp etc)
* The biggest choice here is what do we use to measure how 'good' a set of parameters is
* Potential Candidates (Yang 1995)
  + min error in days
  + min SD in thermal time
  + min SD in days
  + min Coefficient of Variation of thermal time
* Min CV is best according to Arnold 1959 and Marra 2002 among others
* Some analytical solutions are available for calculating the base temperature for the GDD model, but I am not aware of any analytical equations for multi-parameter models
* So we use optim in R
* need to bound parameters at 0 and 100
* plot optimization 'landscape'

Part 3: Selection of Thermal Time Accumulation Length

* Boonprakob 1992 suggested that the 30 – 45 days after bloom have the most impact on peaches
* So people started using GDH30 especially in stone fruits
* However research has started to branch out and GDH30 is probably not optimal for other tree crops
  + Tombesi 2010 tried 30, 50 and 90GDH and found 90 performed the best
  + Ruml 2011 compared 30, 45 and 60 and found 60 did the best
* We calculated GDH for every possible length of thermal time accumulation (from 1-150 days)
* Optimal GDH by cultivar
* Plot/table of how they line up in Julian days
* Why is there a dip in R2 later on?
  + Is the second half less sensitive
  + have less predictive power
  + Too much variation in x parameter for not enough variation in y parameter
  + Split into two models in optim?
* What do the optimal regressions look like?
* How much better than GDH30 are they?
* What about other predictors
  + water stress
  + “hot spells”

Notes on thermal time papers

Mimoun and DeJong 1998

* Anderson
* Peach
* GDH30

Marra 2002

* Beta (not implemented yet)
* Peach
  + Maycrest – GDH32
  + Mayglo – GDH25
  + Elegant Lady – GDH34
  + Fantasia – GDH52
  + O'Henry – GDH25

Day 2007

* Anderson
* Peach and Nectarine
* GDH30

DeBuse 2010

* Anderson
* French Prune
* GDH30

Tombesi 2010

* Anderson
* Almond (many cultivars)
* Tested GDH30,50,90
* GDH90 did the best, but was dependent on cultivar

Ruml

* Degree Days
* Apricot
* Daily Max Temp from the first 30, 45 and 60 days
* Worked really well for some reason
* 60 days was the best

Arnold, C.Y. 1959. Determination and significance of base temperature in a linear heat unit system. Proc. Amer. Soc. Hort. Sci. 74:430-445.

Boonprakob, U., Byrne, D.H. and Rouse, R. E. 1992. Response of fruit development period to temperature during specific periods after full bloom in peach. Fruit Varieties Journal 46:137-140.