Tools for Frost Protection

Dennis and Howell, 1974

Table 5. Critical temperatures during spring bud development in tart cherry

Bud Stage (a)	Temperature (°F) Possible injury	Severe injury
0 Dormant	-25 to +15 (b)	-30 to 0 (b)
1 First swelling	15	0
2 Side green	24	10
3 Green tip	26	20
4 Tight cluster	26	22
5 Open cluster	28	24
6 First white	28	24
7 First bloom	28	24
8 Full bloom	28	24

(a) See Fig. 4
(b) Wide range, depending on time of year.

- **How Useful Are Phenology Charts?**

Tools for Frost Protection

- Phenology scales were created to assess the development of floral buds, but they are inherently **Subjective**
- Reproductive **bud swelling** is widely recognized as the **first visible developmental stage to signify resumed development**
    - In other words, a visible sign that dormancy has been satisfied

Dennis and Howell, 1974

Tools for Frost Protection

- **Distinguishing** bud stages is **not so straighforward during early** development

- Yet, during these early stages of bud development, **~20°F of hardiness is lost**

- **It is during this period that greater precision predicting critical temperatures is required**

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(a) See Fig. 4
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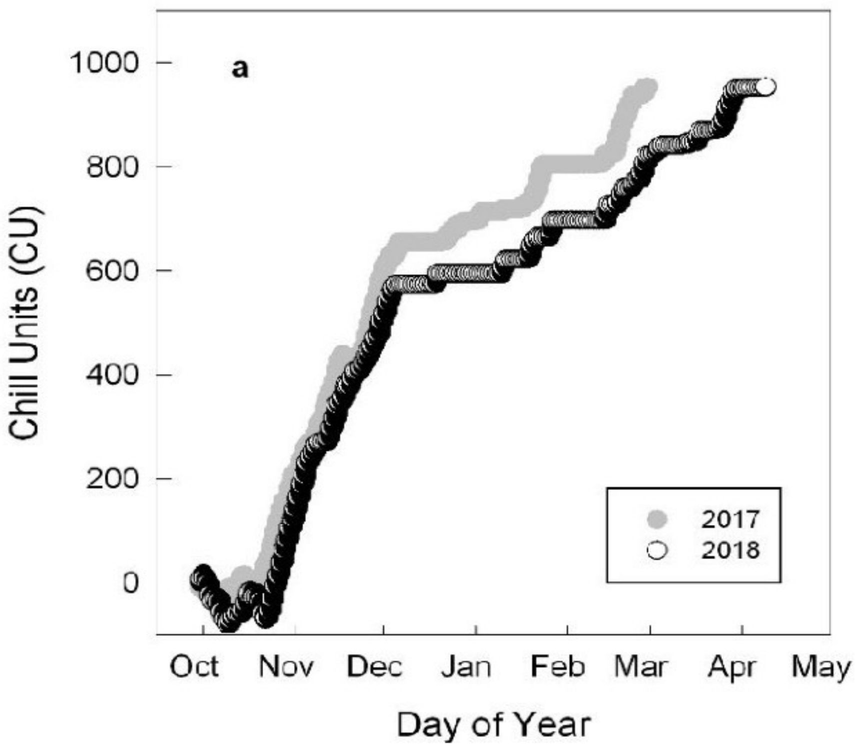
Chill and Heat Unit Accumulation

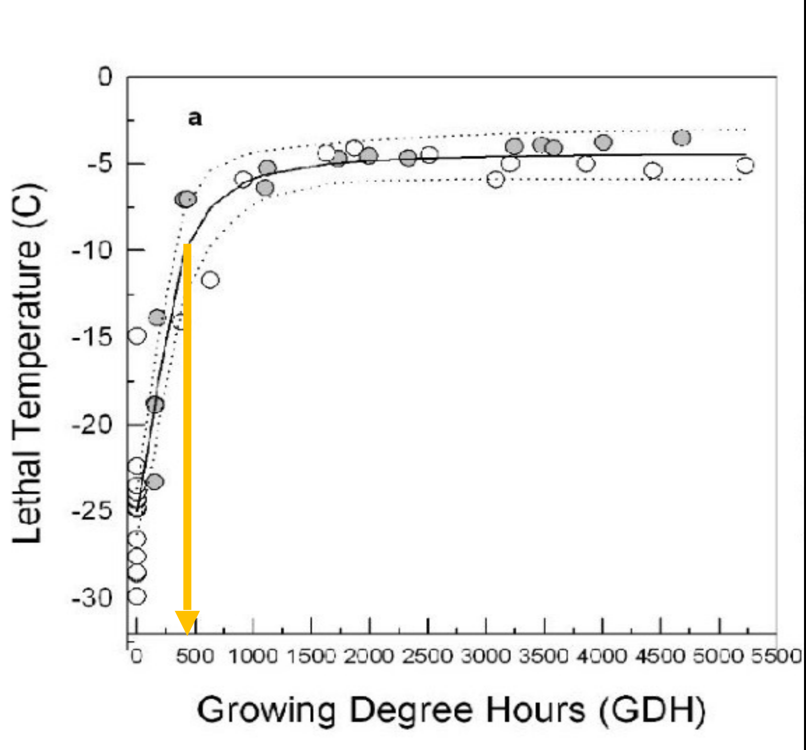
- Chill Unit accumulation began **Sep 30** and ceased when **chill units reached 954 CU**

- Early and seasonl rate of GDH accumulation was disparate between the years but Full Bloom occurred at similar GDH in both years [4700 to 5200 GDH]



Freeze Prediction Model

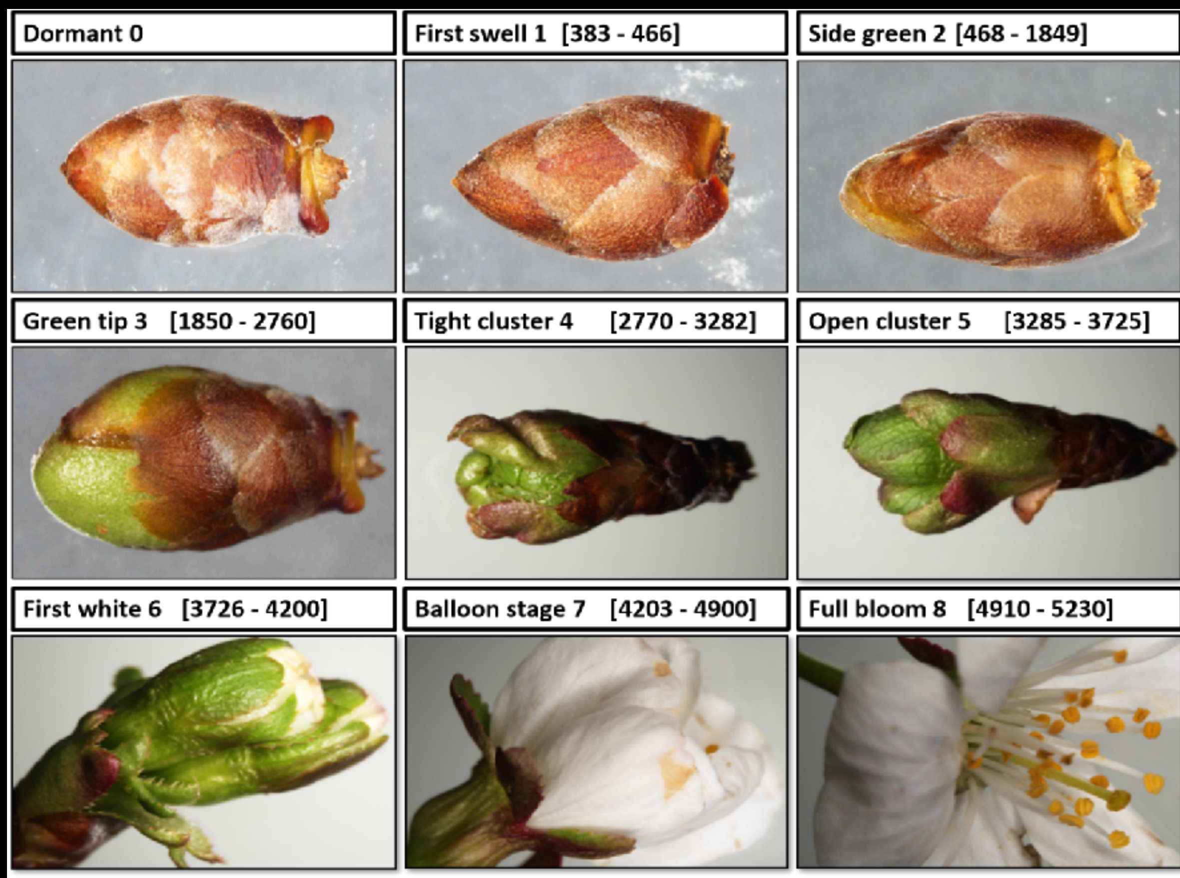
- GDH accumulation ushered a consistent loss of hardiness between dormancy and green tip that can be modeled
  - After green tip, no significant changes were observed for LT_{50}
- When buds were considered to be **at first swell (~400 GDH) ~15°C of hardiness was already lost**
- By 500 GDH, buds had lost 20°C hardiness



$$y = \frac{a+b}{\left(1+exp\left(-\frac{\left(x-d*ln\left(2^{\frac{1}{e}}-1\right)-c\right)}{d}\right)\right)^{e}}$$

Phenology Staging

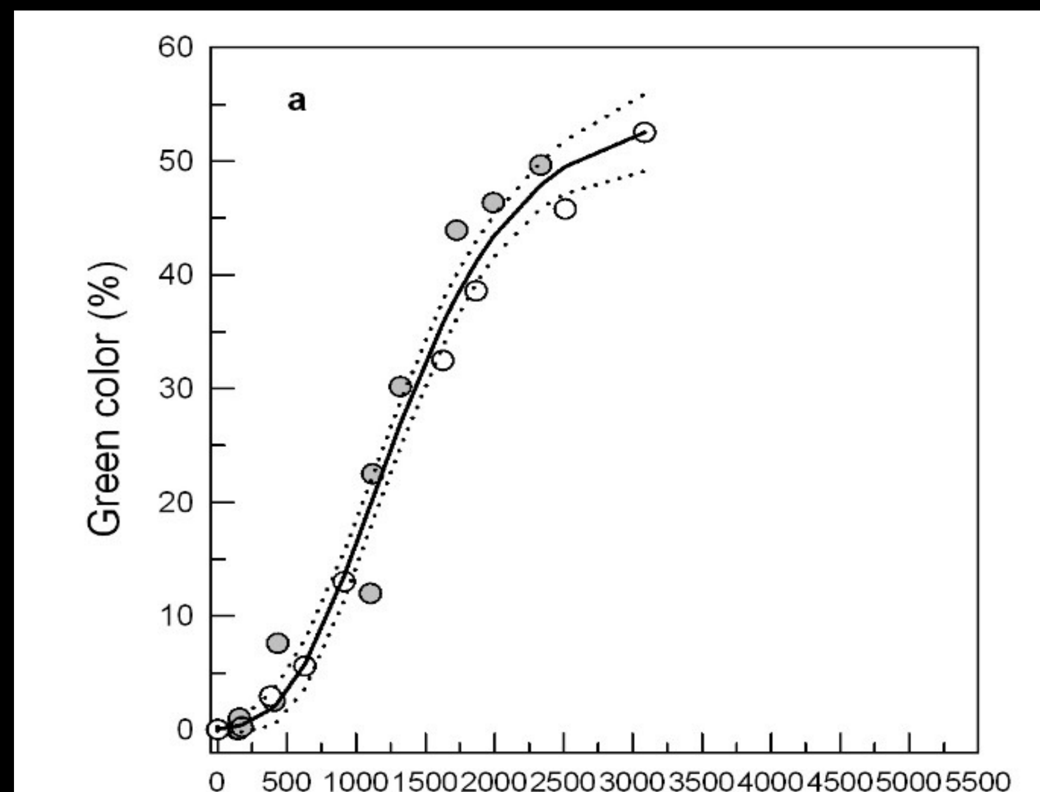
- SUBJECTIVE ANALYSIS of floral bud development produced data that assumed a double sigmoidal pattern
- Range of GDH for each stage varied considerably
- No visible changes to floral buds until ~ 400 GDH had accumulated



A More Sophisticated Phenology Staging

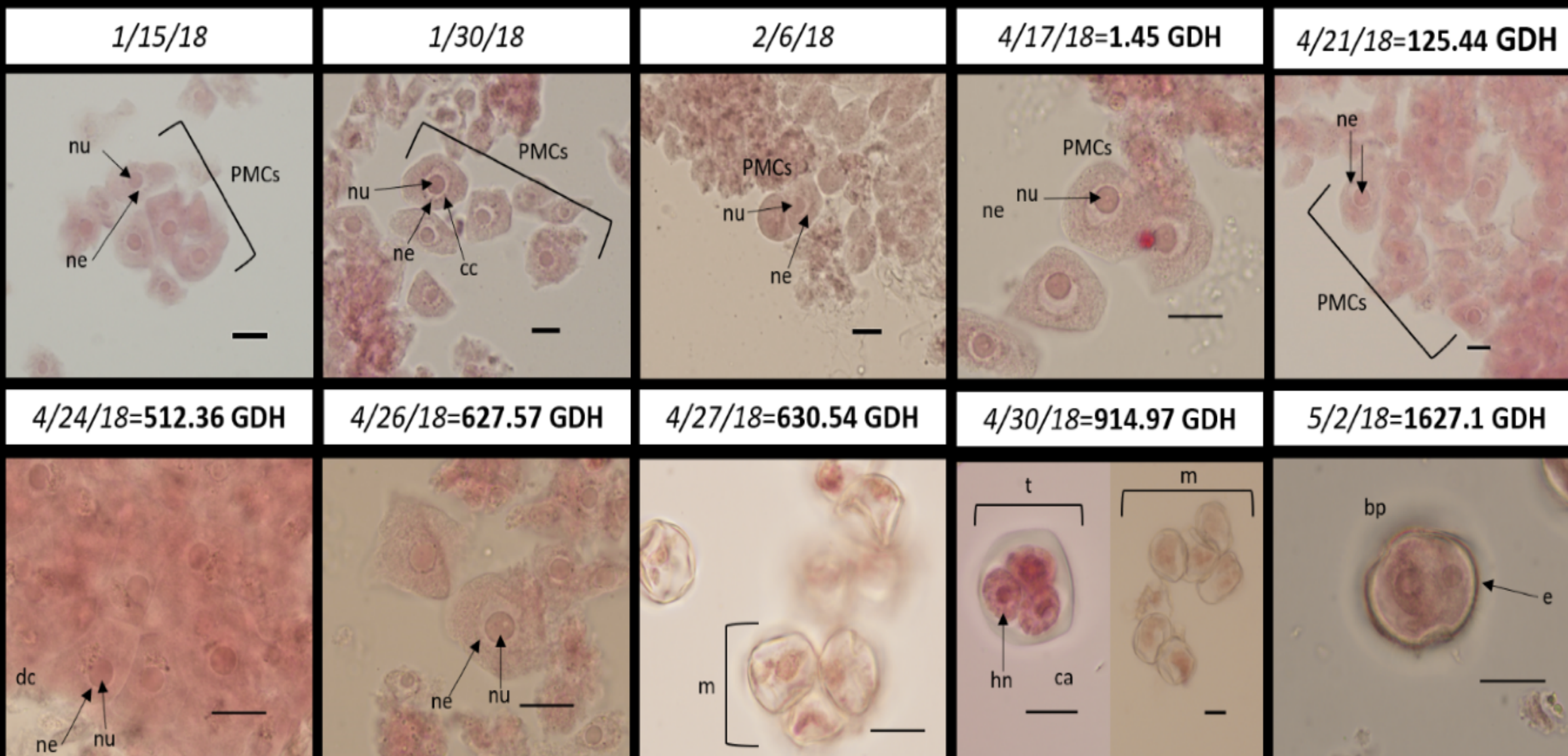
- **Image analysis** first detected green color on bud scales at **~300 GDH** *(BEFORE BUD SWELLING)*
  - **Recall that our subjective assessment** of green color showed first green at **468 GDH**

$$y = a * exp(-exp(-\frac{x - c * ln(ln(2)) - b}{c}))$$



Can Microscopy Detect Dormancy Transitions?

- Anthers initiated microsporogenesis near April 24th 2018 at 512 GDH
  - **Other physiological changes had already occurred**



PMCs = pollen mother cells
ne = nuclear envelope
nu = nucleolus
cc = condensed chromatin

dc = decondensed chromatin
m = microspore
t = tetrad

hn = haploid nuclei
bp = binucleate pollen grain
e = exine

*Image and analysis by C. Goeckeritz

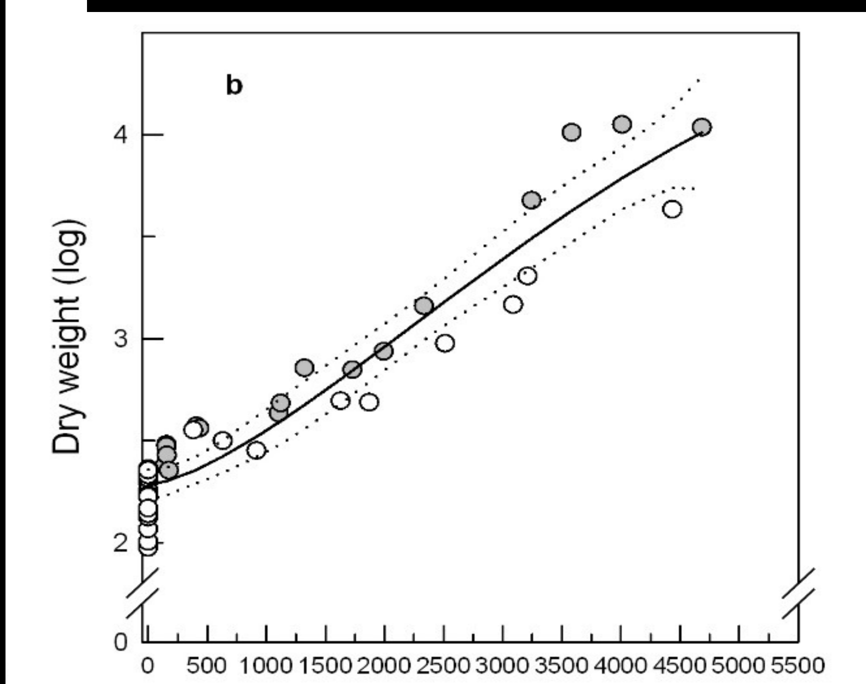
Scale bars are 10 µm

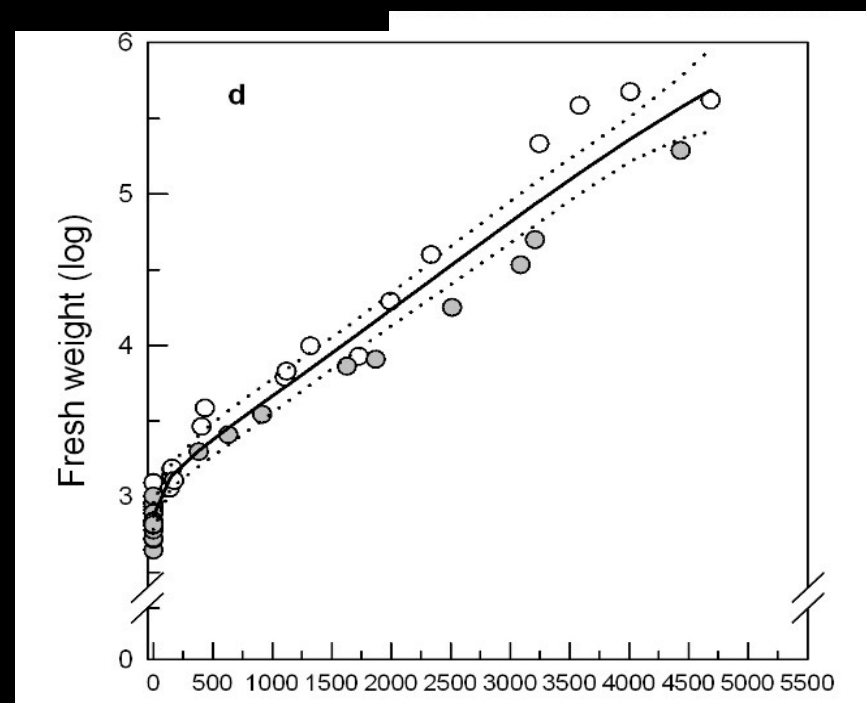
What About MACRO Measures?

- **Dry weight of buds** increased 1.5-fold between dormancy and anthesis but **lagged behind fresh weight** which increased three-fold over the same period
- Fresh weight increase detected earlier than DW
- DW: $y = a + b * x^{1.5} + c * x^{2.5} + d * x^3$
- FW: $v = a + b * x^2 + c * x^{2.5} + d * x^{0.5}$

DW: $y=a+b*x$^1.5+$c*x$^2.5+$d*x$^3

FW: $y=a+b*x$^2+$c*x$^2.5+$d*x$^0.5



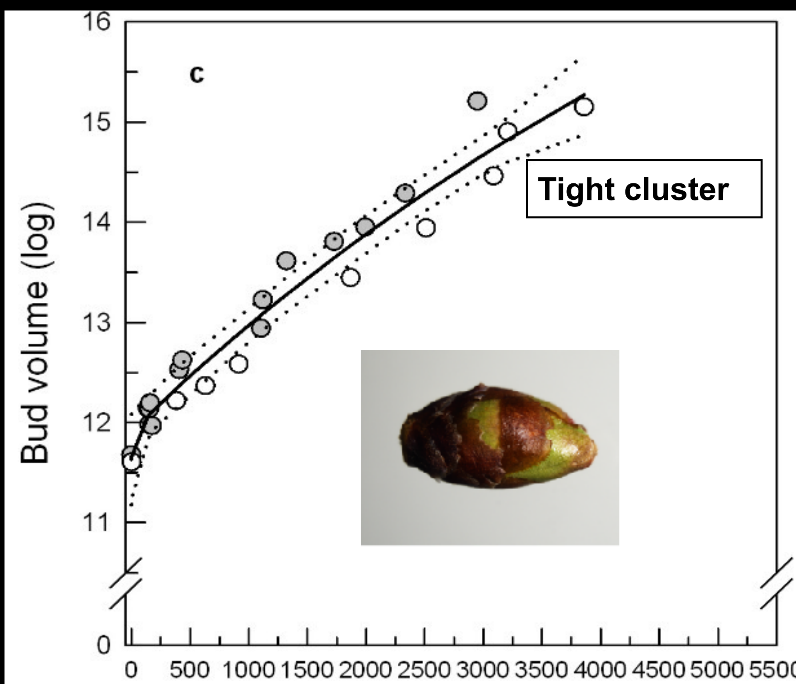


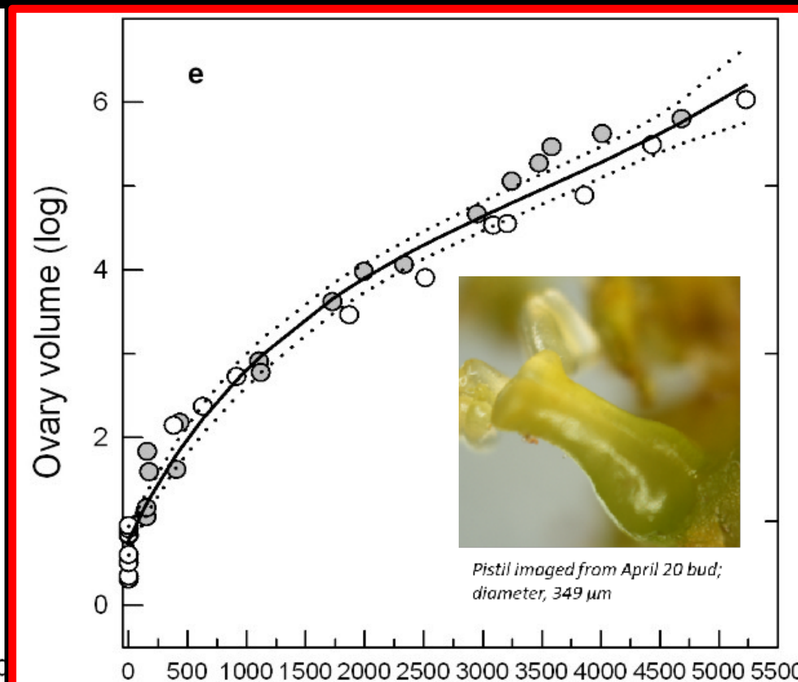
Digging a Little Deeper into the Buds…

- **Ovary volume preceeded visible changes** in bud phenology stage, increasing steadliy from the onset of GDH

Bud: $y = a + b(1 - \exp(-c * x)) + d(1 - 1)/(1 + d * e * x)$

Ovary: $y = \mathrm{a} + \mathrm{b} * \mathrm{x} + \mathrm{c} * x^{1.5} + d * x^{2.5}$



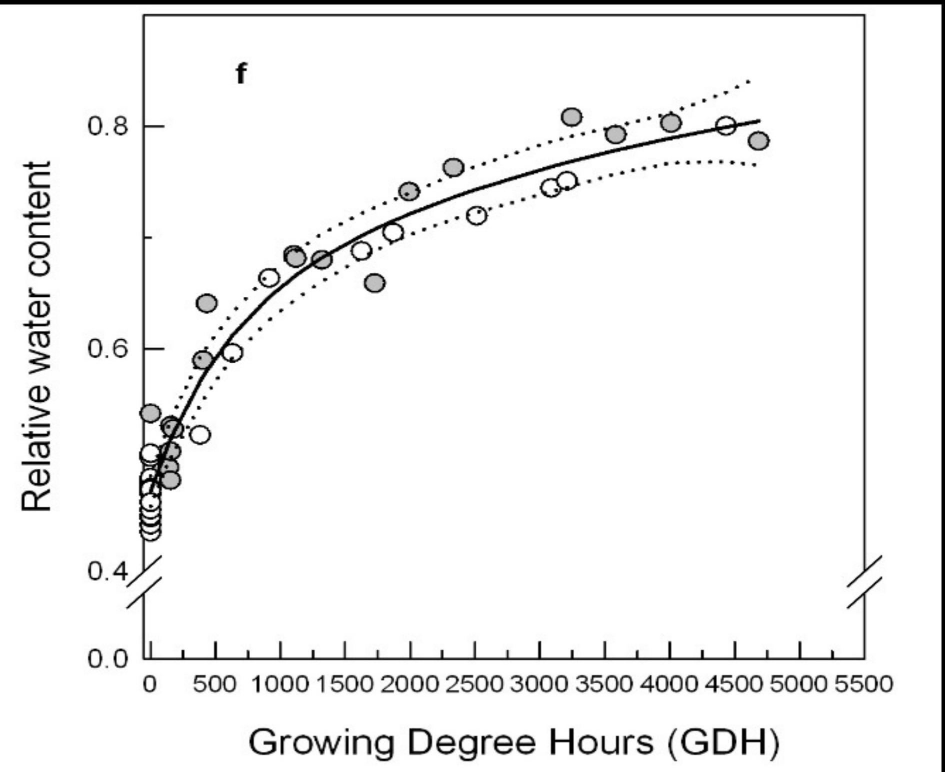


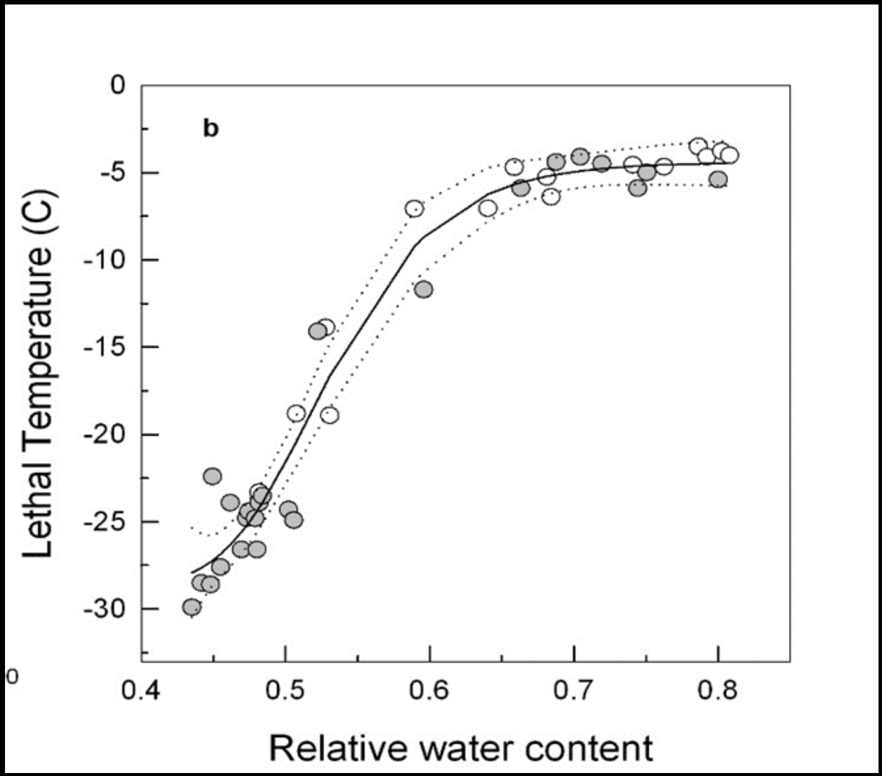
Pistil imaged from April 20 bud; diameter, 349 µm

REGARDING THE WATER CONTENT OF BUDS

- **Relative water content was the earliest and most robust predictor** of dormancy release, increasing steadily with the onset of GDH between 45% to 80%

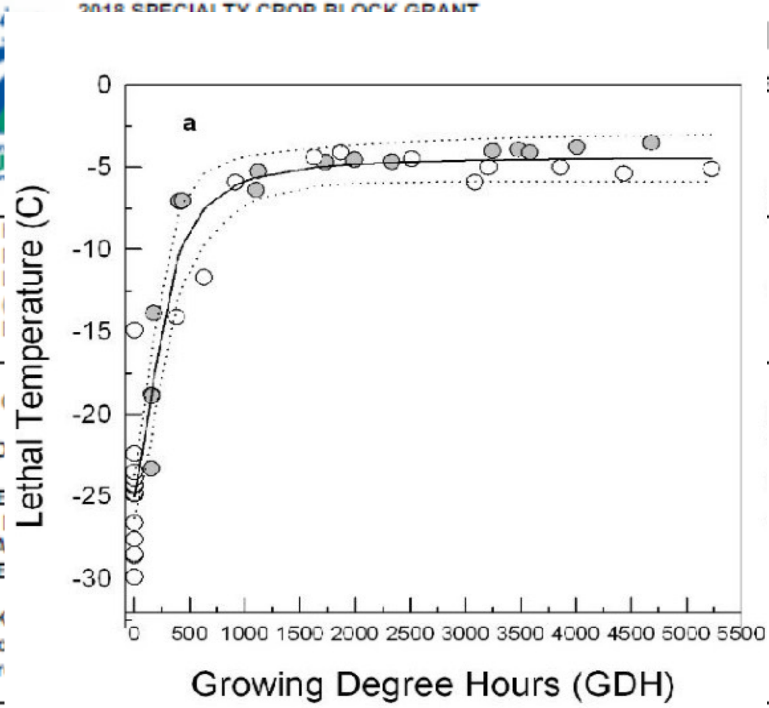
$$y = a + b(1 - \exp(-c * x)) + d(1 - \exp(-e * x))$$





So, can we develop a model on two years of data?

2018 SPECIALTY CROP BLOCK GRANT



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PROJECT TITLE

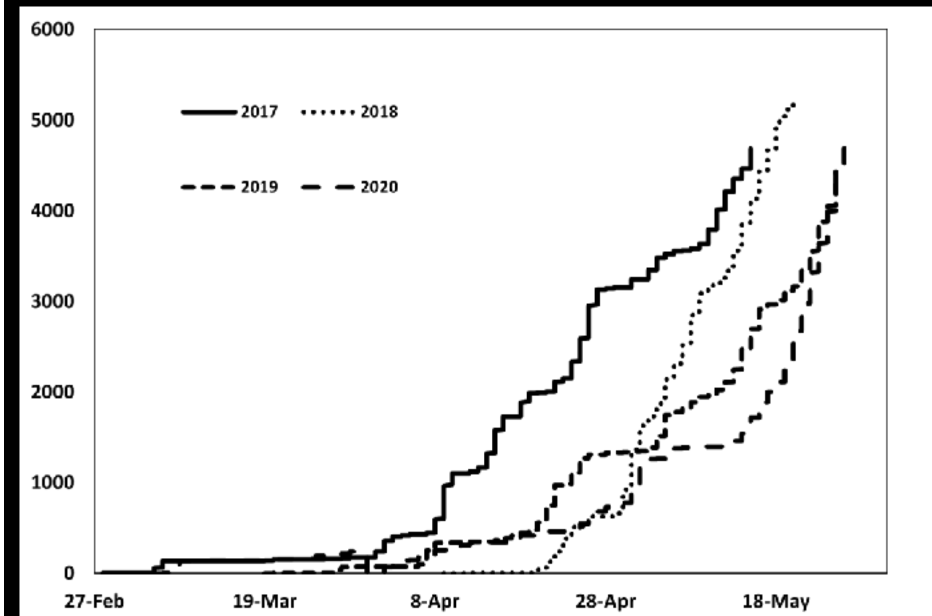
Development of Precision Decision Support Systems to Protect and Optimize Michigan Tree Fruit Production

DURATION OF PROJECT

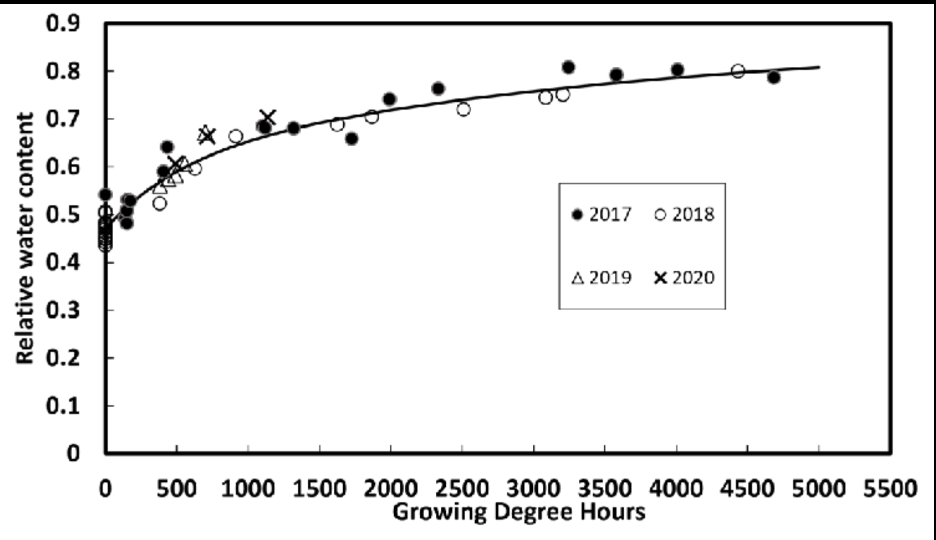
Start Date: October 1, 2018 **End Date:** April 30, 2020

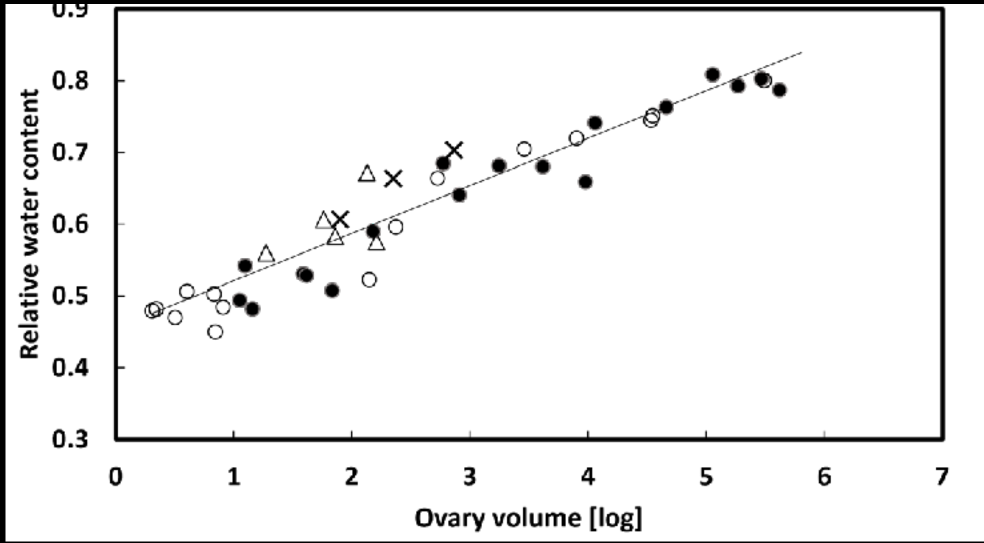
PROJECT PARTNER AND SUMMARY

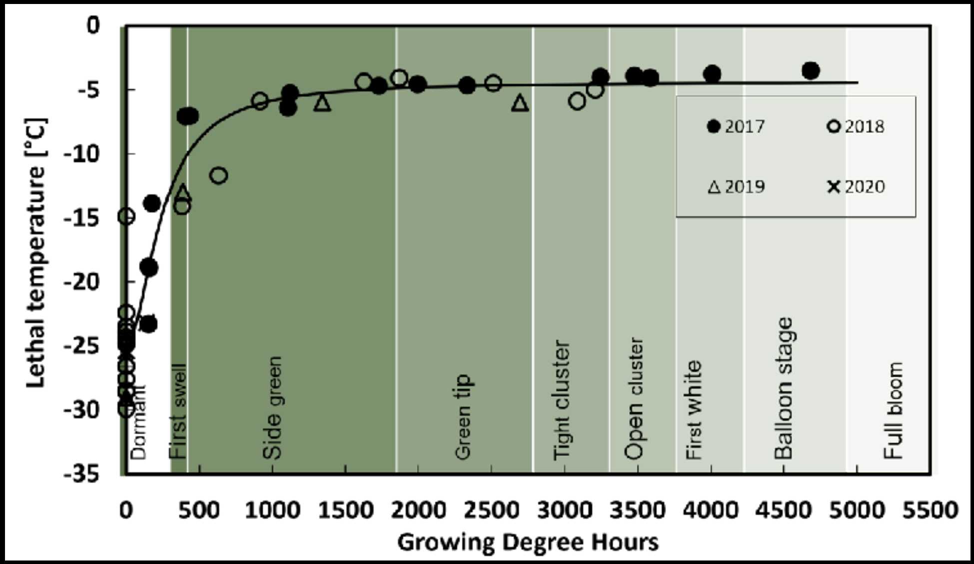
The Michigan Tree Fruit Commission, in partnership with Michigan State University's AgBioResearch horticultural scientists and Extension educators, will establish a network of season-long assessments for winter cold hardiness and spring crop loads across the state's major tree fruit production regions. Data from these networks will be used to develop and refine precision decision support systems for growers to better implement orchard measures that 1) reduce low temperature crop damage in winter and spring, and 2) improve spring crop load management procedures to optimize yields and fruit quality. Cold hardiness and crop load assessment technologies will be installed and methodologies taught to a team of MSU Extension educators located in the Southwest, Grand Rapids, West-central, and Northwest



Relationships Between RWC and Ovary Growth Remain Robust







Going Forward…

- Site selection is the most critical factor…
- If smaller canopies (via MSU dwarfing rootstocks) and OTR harvesting prove profitable, additional protection may be necessary via frost fans
- Alternative strategies to delay bloom are needed
  - Breeding/selection
  - Misting (J. Flore)
  - *Nanofilms*… ?

Critical Temperatures for Frost Damage on Fruit Trees

Marion Murray, IPM Project Leader

The following table, developed by Washington State University, lists Fahrenheit temperatures for each stage of development at which 10% and 90% bud kill occurs after 30 minutes exposure. The percentage bud kill which causes crop reduction will vary with each crop. For example, to have a full crop of cherries requires well over 50% bud survival in most years, while apples, pears, and peaches may only need 10-15% bud survival.

CHERRY

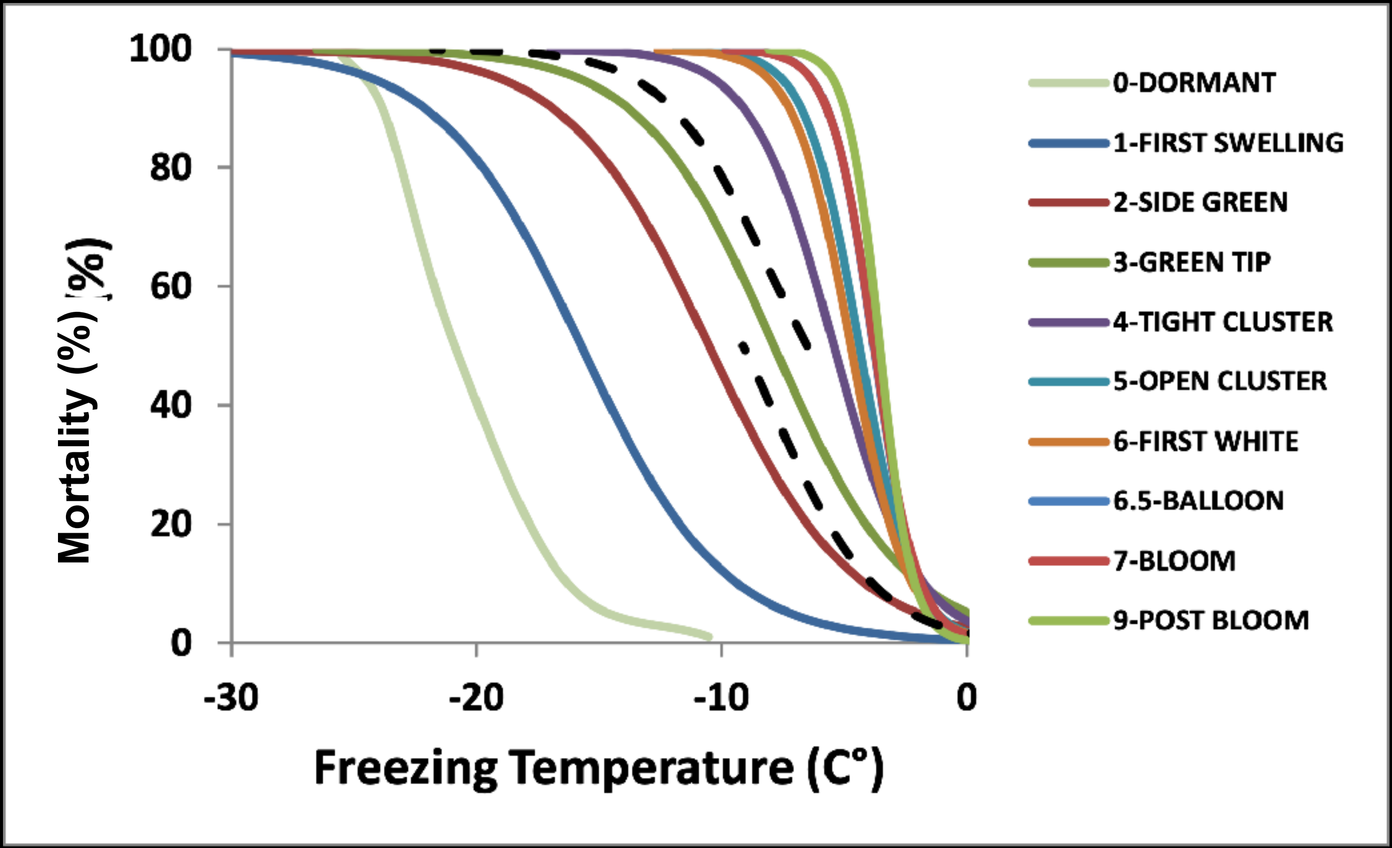






SWEET	Swollen Bud (First Swell)	Bud Burst (Green Tip)	Tight Cluster	White Bud (First White, Popcorn)	First Bloom	Full Bloom	Post-bloom
10%	17	25	26	27	28	28	28
90%	5	14	17	24	25	25	25
TART							
10%	15	26	26	28	28	28	
90%	0	22	24	24	24	25	

Objective: Develop Critical Temperature Bud-Kill Chart for Modern Sweet Cherry Cultivars



- Logistic regression by stage
  - Dormant series - DTA with some visual scoring
  - DTA (stages 0-1) and visual scoring (stages 2-9)