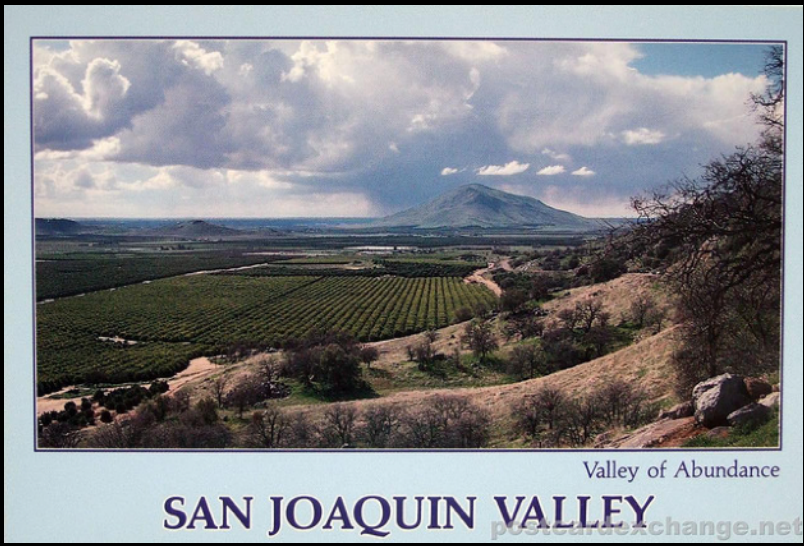
Characterization and Mitigation of the Factors Limiting Sweet Cherry Fruit Quality and Productivity

Todd Einhorn, Ph.D.
Michigan State University

WCHS Annual Conference, 2022


Valley of Abundance
SAN JOAQUIN VALLEY
postcardexchange.net

Growth Potential

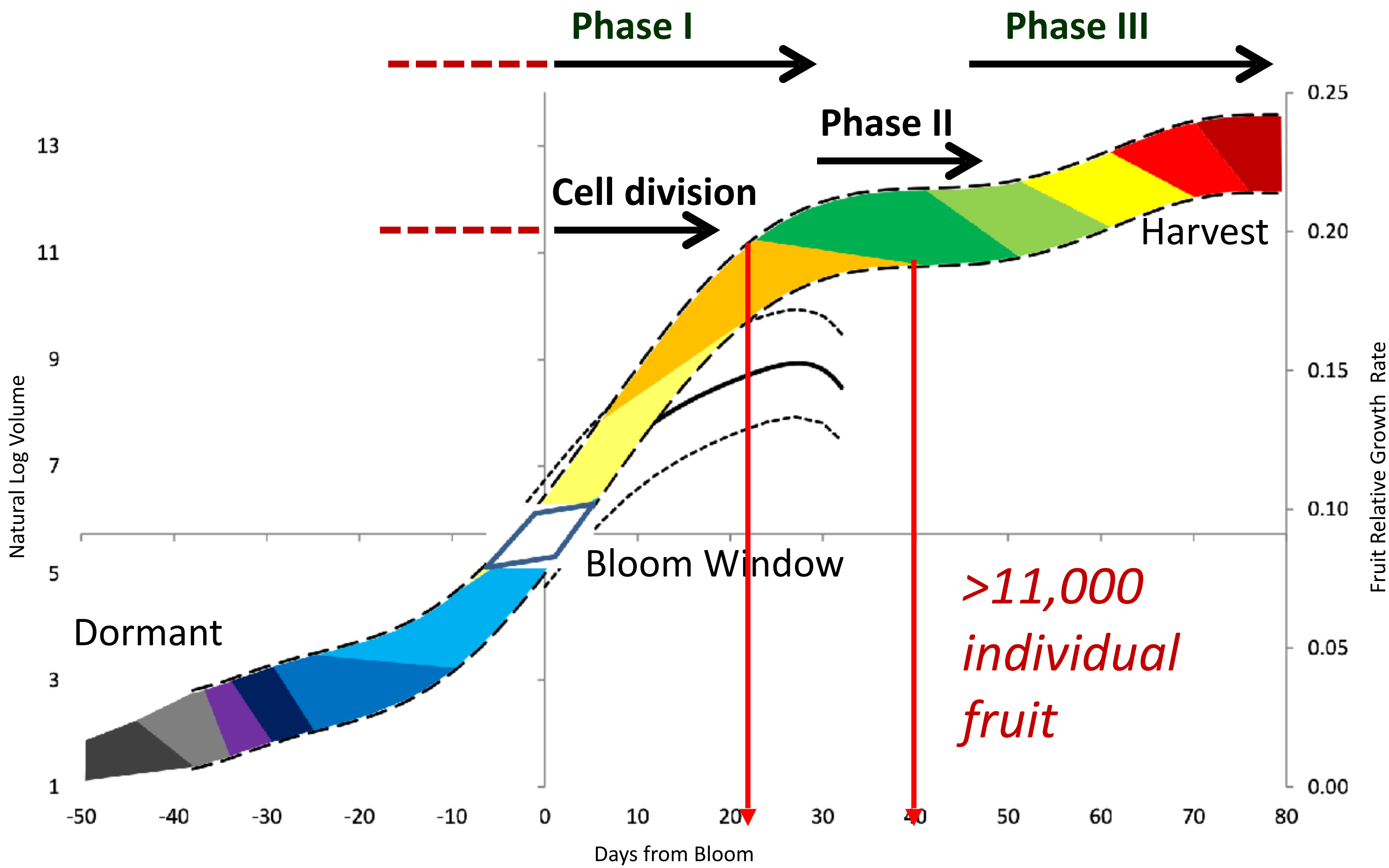
- The fruit physiologist, Ted DeJong (UC-Davis) described ***Potential fruit growth*** as analogous to compound interest, where…
- Fruit growth (e.g., financial growth) depends on,

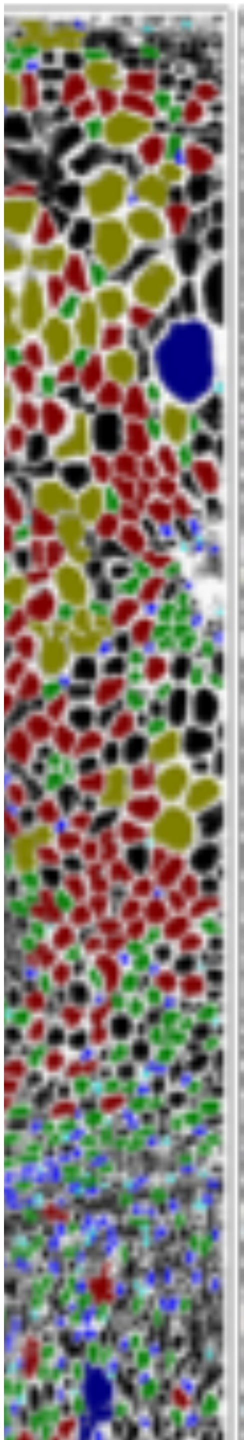
  1) fruit size (e.g., principal) at the start of any time interval, and

  2) the rate of growth (e.g., interest) during a given time interval

  – Thus, a small fruit at the beginning of a time interval &/or a rate of growth less than maximum during the interval will result in growth ***below*** the maximum potential, ***and***
  – Fruit that grow below their maximum potential **cannot** make up 'lost' growth during the next time interval… even if growth rate (e.g., interest rate) is maximum during the next timeframe

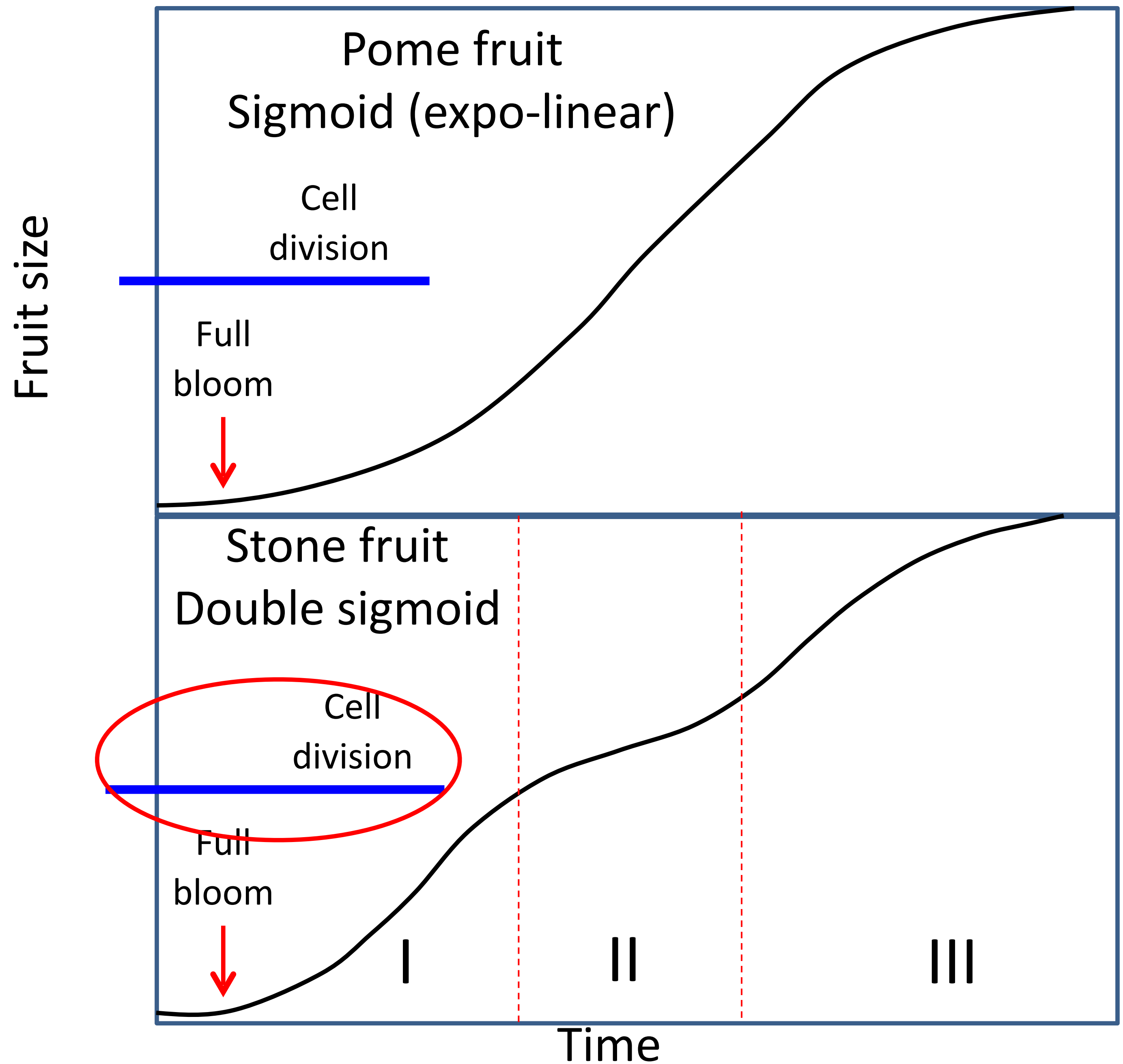
Sweet Cherry Growth Phases





- Cell division stage: Rapid increase 14 d pre-bloom to about 20 DAB
- Stage I : Growth potential set (-14 to 30 DFB)
- Stage II: Pit hardening
- Stage III: Growth potential realized? (44 DFB to harvest)

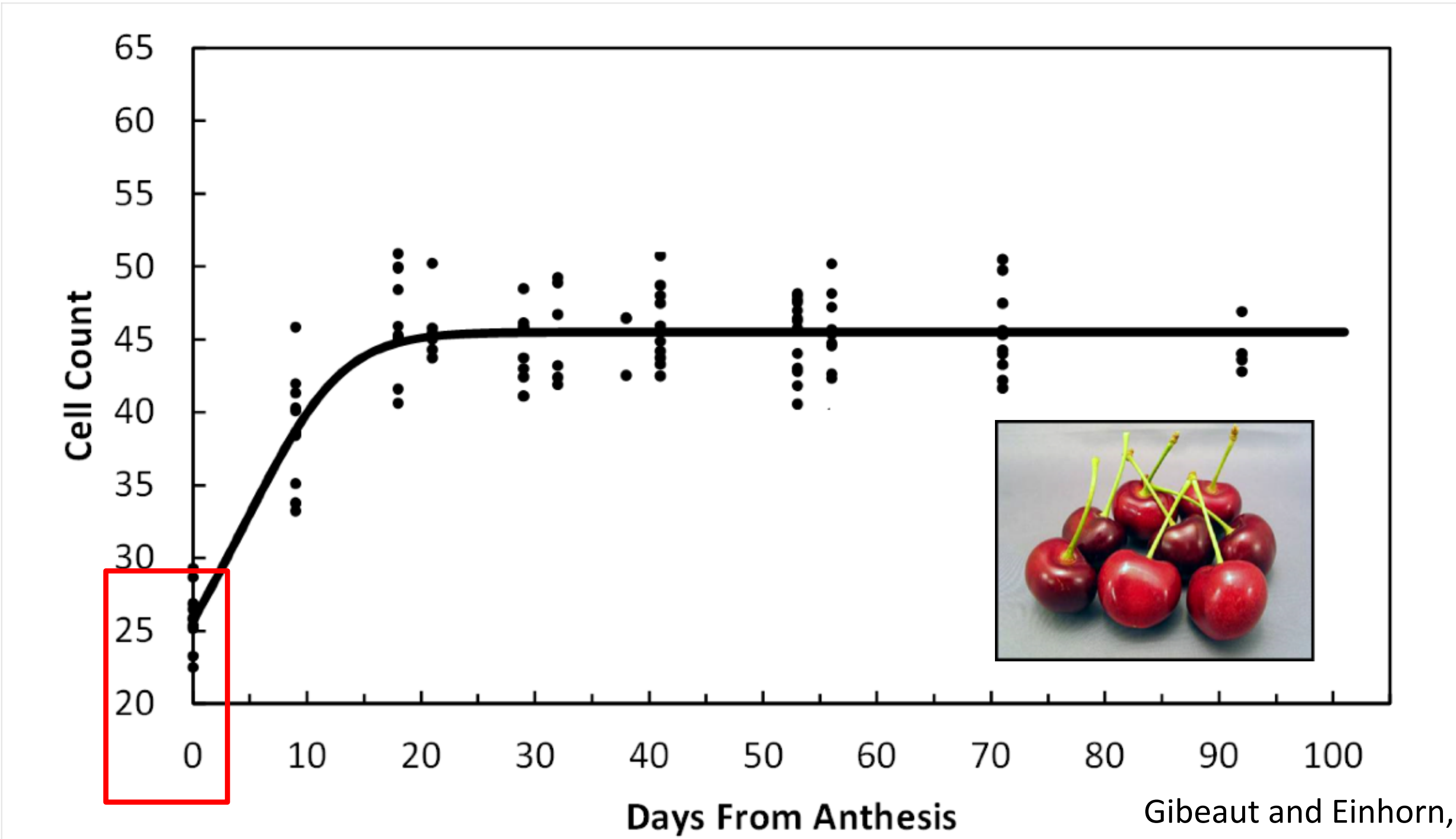
Fruit Growth Patterns



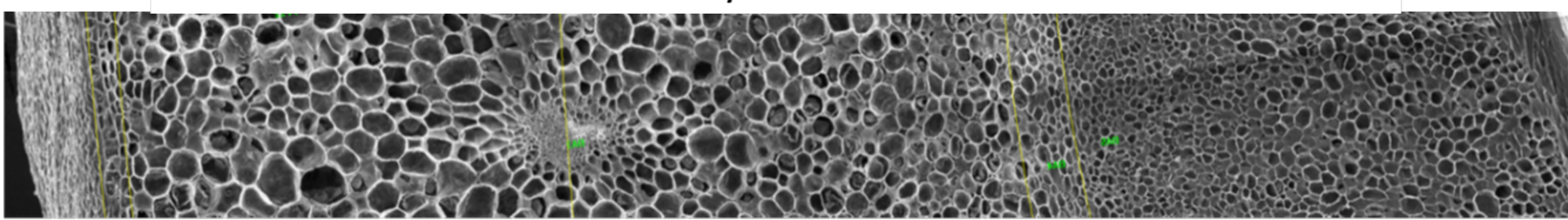
I. Cell division
II. Pit hardening (embryo growth)
III. Cell expansion

Cherry Growth & Development

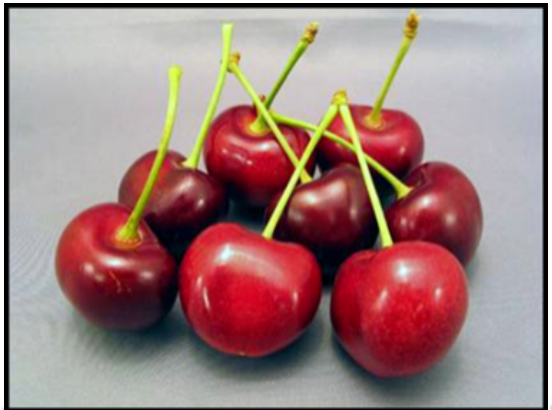
- ***Cell division in fruit is difficult to manipulate in managed systems***
- ***Cell division ceases ~14 days after bloom***



Gibeaut and Einhorn, unpublished



The Situation for CHERRY



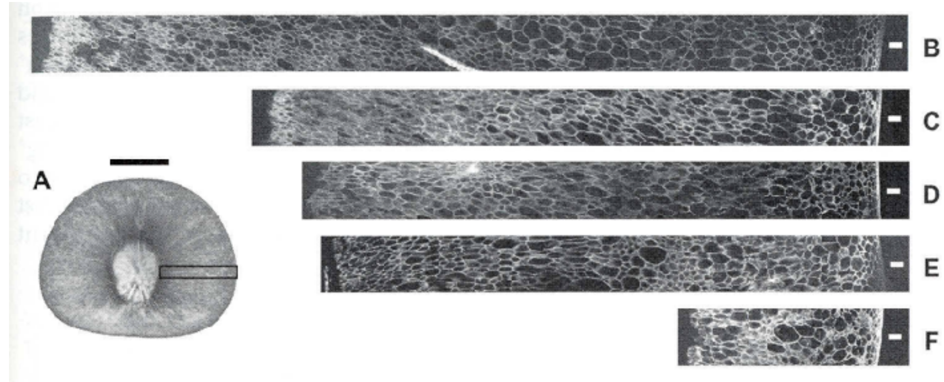


Table 3. Comparison of mean whole fresh fruit size, pit size, and mesocarp cell number (per radial section), and size measurements for populations of large and small fruit from 'Bing', 'Regina', and 'Selah' sweet cherries at harvest maturity.

	Bing				Regina				Selah			
	2004		2005		2004		2005		2005		2006	
	High wt	Low wt	High wt	Low wt	High wt	Low wt	High wt	Low wt	High wt	Low wt	High wt	Low wt
Fruit												
Wt (g)[z]	9.4***	7.6***	11.3***	7.5***	10.3***	7.7***	12.4***	8.3***	13.7***	8.8***	16.4***	7.8***
Diameter (mm)	26.7***	24.8***	27.6***	24.0***	27.7***	25.1***	28.8***	24.3***	30.0***	25.0***	32.1***	24.8***
Pit												
Wt (g)	0.57**	0.50**	0.56*	0.48*	0.64 NS	0.58 NS	0.64**	0.48**	0.55 NS	0.49 NS	—	—
Diameter (mm)	7.9**	7.4**	7.6 NS	7.3 NS	8.3 NS	8.0 NS	8.2*	7.5*	8.1***	7.2***	—	—
Mesocarp												
Cells (no.)	48.5 NS	48.3 NS	49.0 NS	48.0 NS	45.6 NS	43.8 NS	46.8 NS	47.0 NS	78.8 NS	78.2 NS	76.8 NS	74.2 NS
Length (µm)	196*	181*	208*	185*	214*	195*	219*	176*	137 NS	125 NS	146*	111*

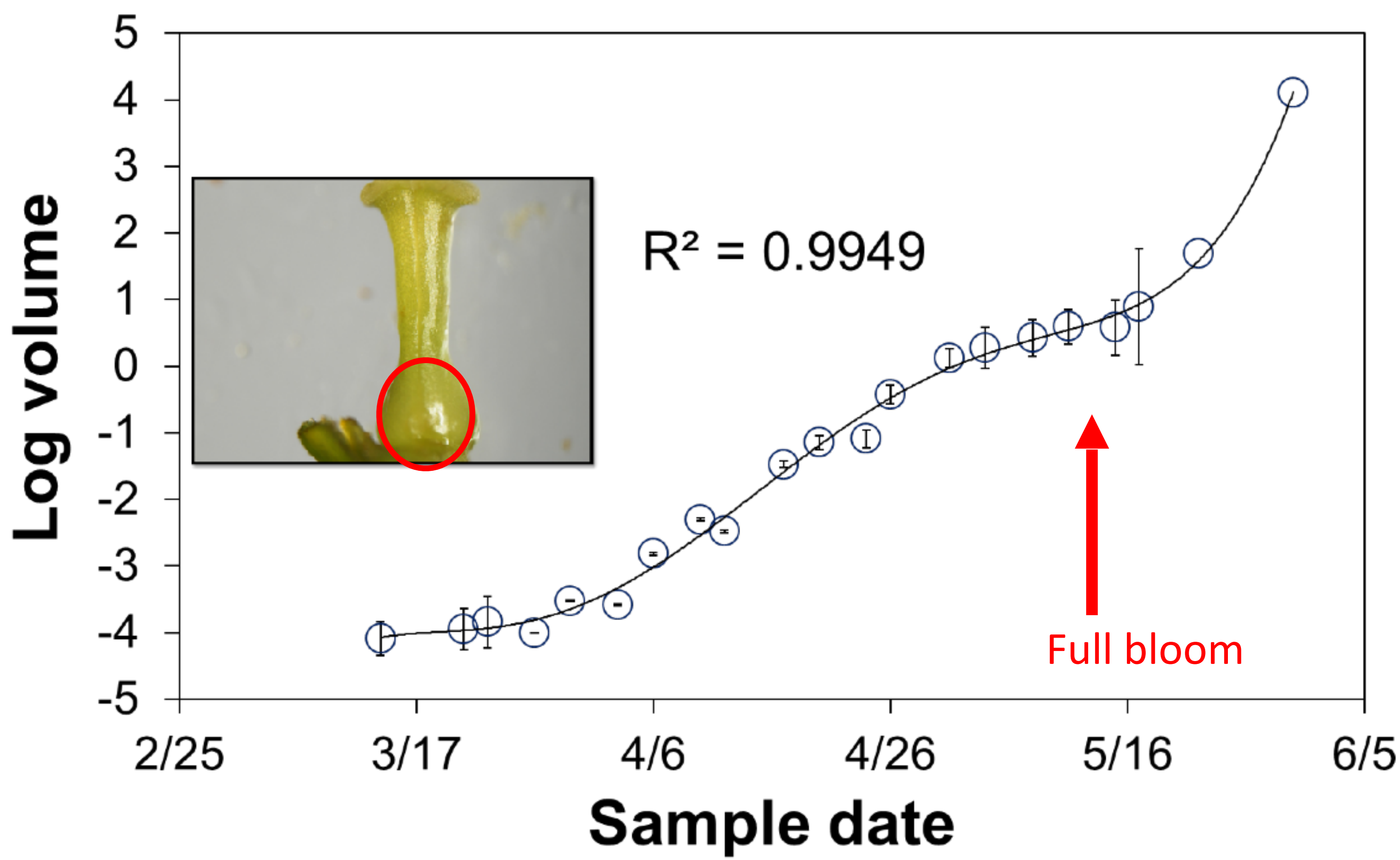
[z]Mean separation for paired treatments in rows by Fisher's LSD.

NS,*,**,***Nonsignificant and significant at $P < 0.05$, 0.01, and 0.001 respectively.

Olmstead et al., 2007

- Sweet cherry fruit size at harvest is dependent on cell size
- HOWEVER, cultivars with maximum potential fruit size have MORE cells than those with lower growth potential (not necessarily growth rate)

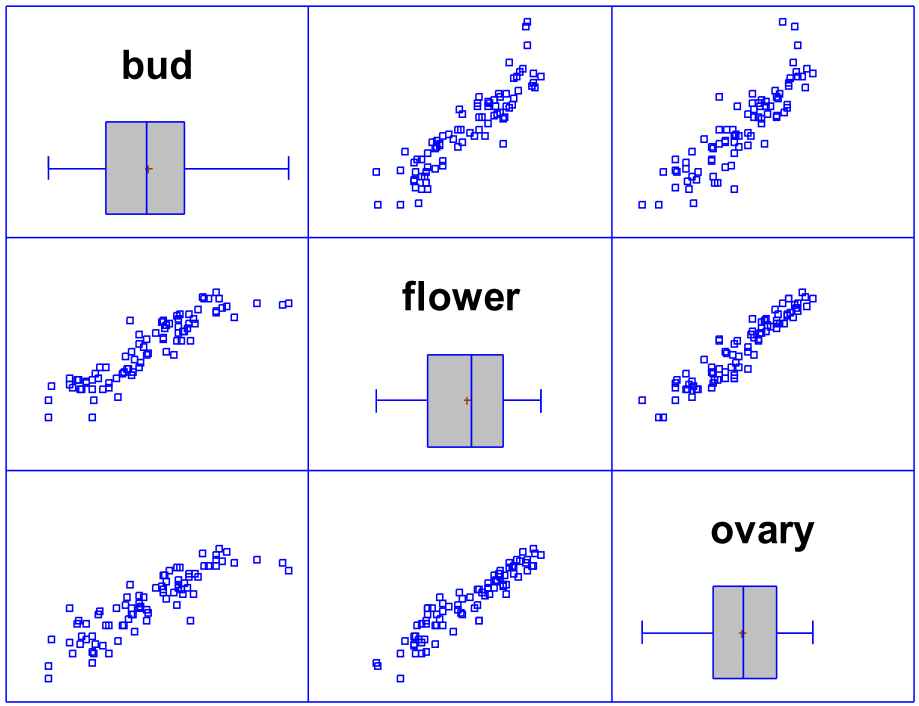
The Growth Rate of Cherry Ovaries Before Bloom Is Rapid



March 20 | April 03 | April 06 | April 14 | April 20 | April 26 | May 01 | May 08 | May 11

Relationships Among Sweet Cherry Reproductive Buds, Flowers and Ovaries (i.e., Future Fruit)

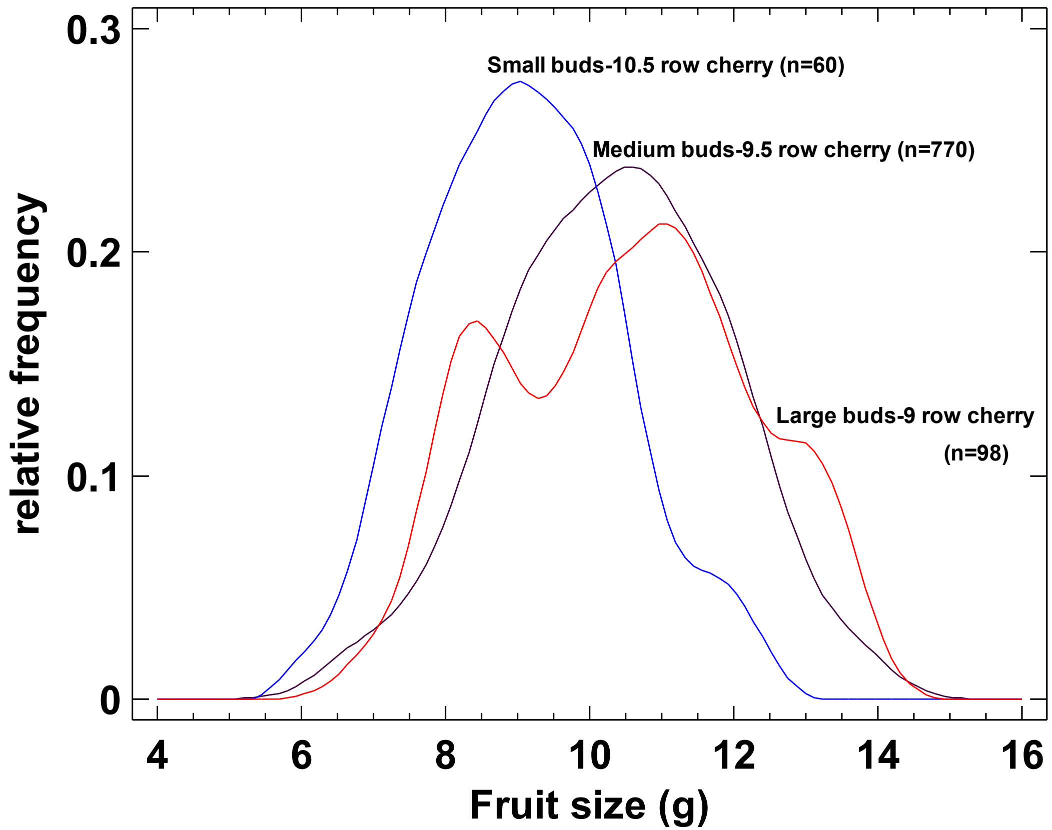
-33 days from bloom



-7 days from bloom

- The data suggest that LARGER buds have relatively LARGER flowers and ovaries than smaller buds
- **Cultural Implications: Bud Removal (fruit thinning)**

Potential Fruit Size of Cherry Is Established Early



- Large buds produced the largest fruit
- Bud size was also related to time of flowering
  - Large buds began flowering -3 DFB
  - Small buds began flowering +1 DFB

Slide compliments of M. Whiting, WSU

Early-Opening Flowers Represent the Largest Fruit at Harvest

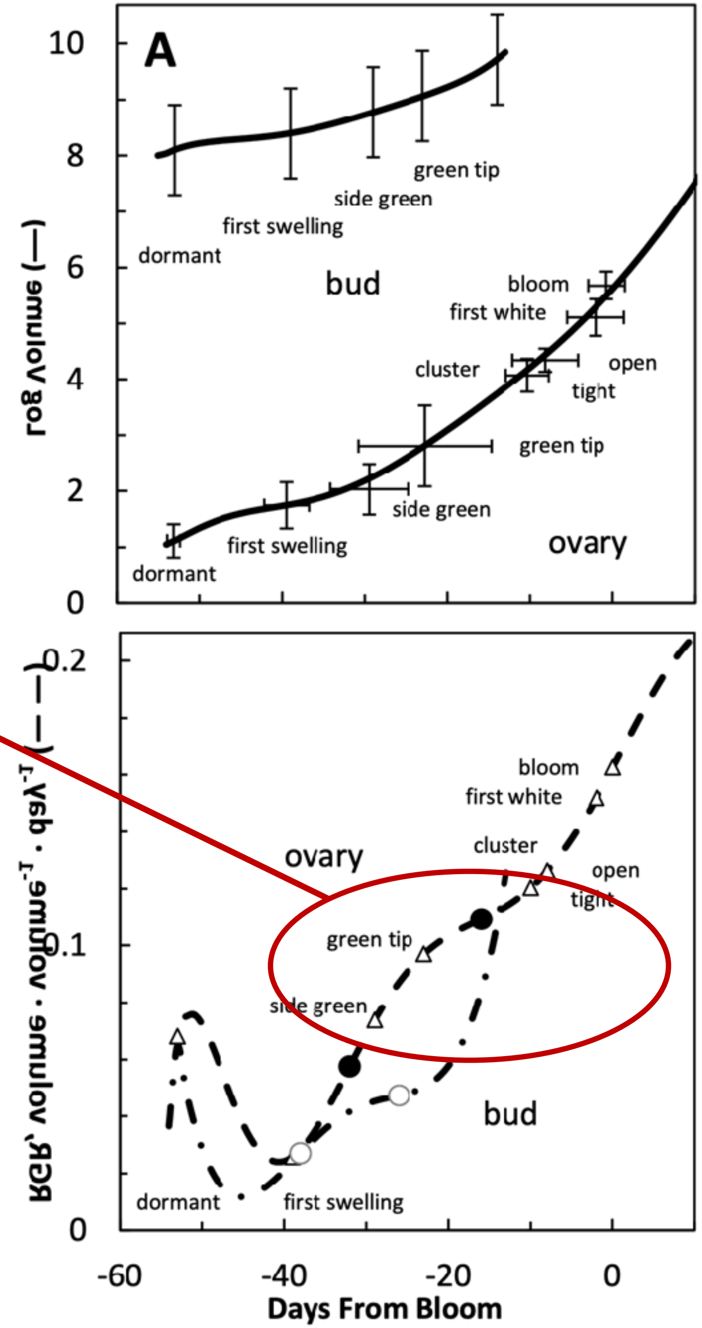
Flower Timing	Fruit diameter mm	Row size	Sugars %	Firmness g/mm	Skin color CTIFL
Day 1	**28.5 a**	**9.5**	**20.3 a**	**291 b**	**4.4 a**
Day 4	27.1 ab	10	18.5 ab	311 a	3.8 b
Day 7	25.9 b	10.5	17.2 b	325 a	3.5 b

** Flower timing= first blooms to open on trees were tagged (= day 1) and compared to flowers that opened 3 days later (d 4) or 6 days later (d 7).*

- The time of flowering has a large impact on fruit size because
  - The development and growth of 'early' flowers tends to be higher than later blooming flowers
  - One-time harvest events do not allow fruits from late-blooming flowers to 'catch-up'
- **Cultural Implications: Protect early phenology stages from frost; Remove bees earlier than later if weather was good for fruit set**

Can Pre-Bloom Ovary Growth Be Manipulated?

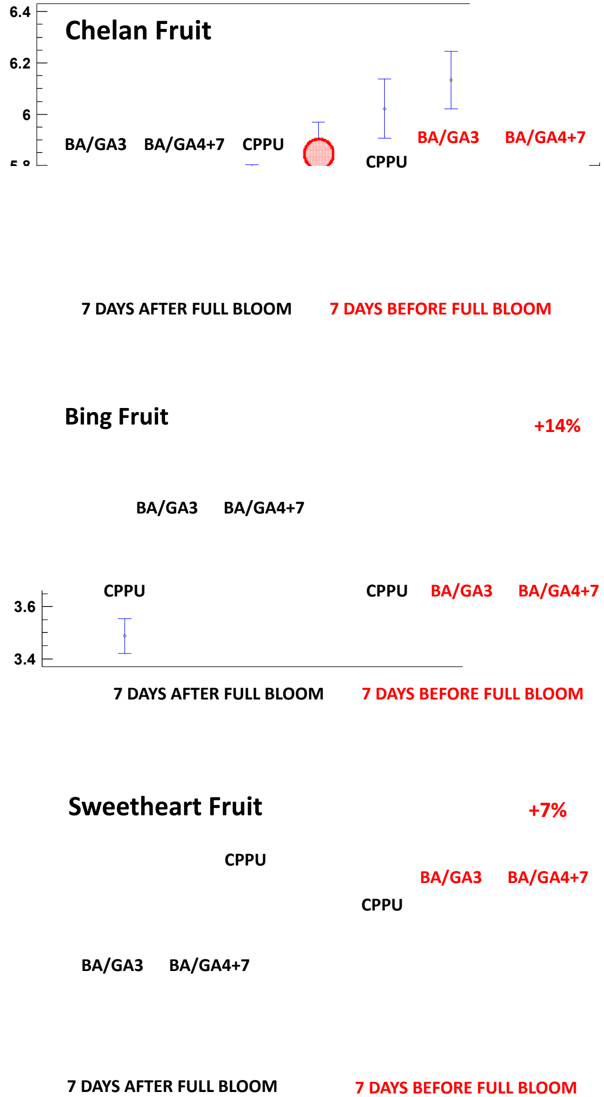
- Ideally, a PGR that stimulates cell division would be timed with the occurrence of this process,
- Challenges with penetration at early bud stages given the lack of absorptive surface area



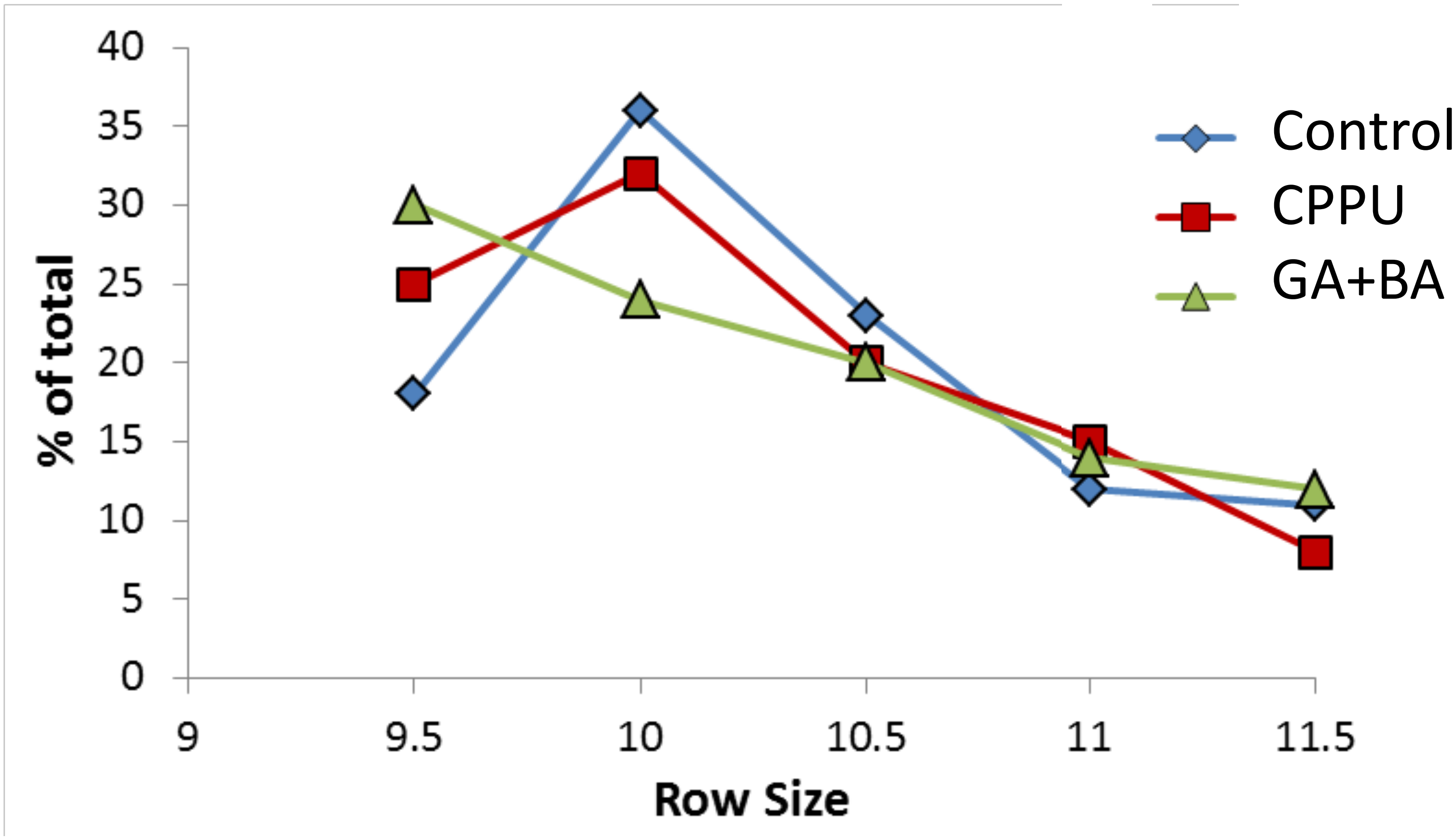
PGR Objectives:
Match Growth Process with Compound

PGR	CLASS	TIMING	RATE
CPPU FineAmericas	Cytokinin	First White	20 ppm
CPPU FineAmericas	Cytokinin	~7 dafb	20 ppm
6-BA/GA_{4+7}	Cytokinin Gibberellin	First White	250 ppm
6-BA/GA_{4+7}	Cytokinin Gibberellin	~7 dafb	250 ppm
6-BA/GA_3	Cytokinin Gibberellin	First White	1 gal/100 gal
6-BA/GA_3	Cytokinin Gibberellin	~7 dafb	1 gal/100 gal

Timing application & a.i. with growth process of interest

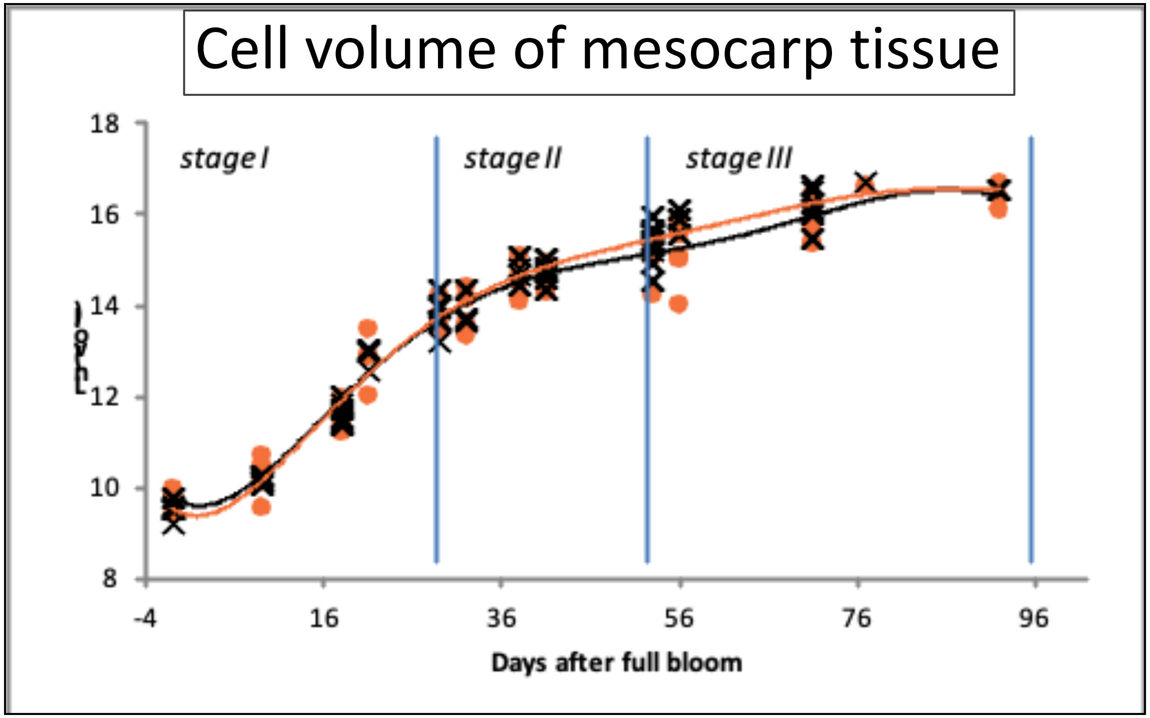


Bing Fruit Distribution at Harvest

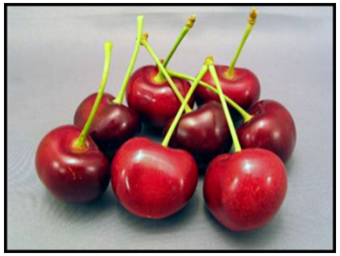


- Increase in mean fruit size was ~½ row size
- Data are means of ~4,000 fruits per treatment
- Returns: CPPU $1.01/lb; GA/BA $0.99/lb; Control $0.86/lb

Seasonal Cherry Growth & Development

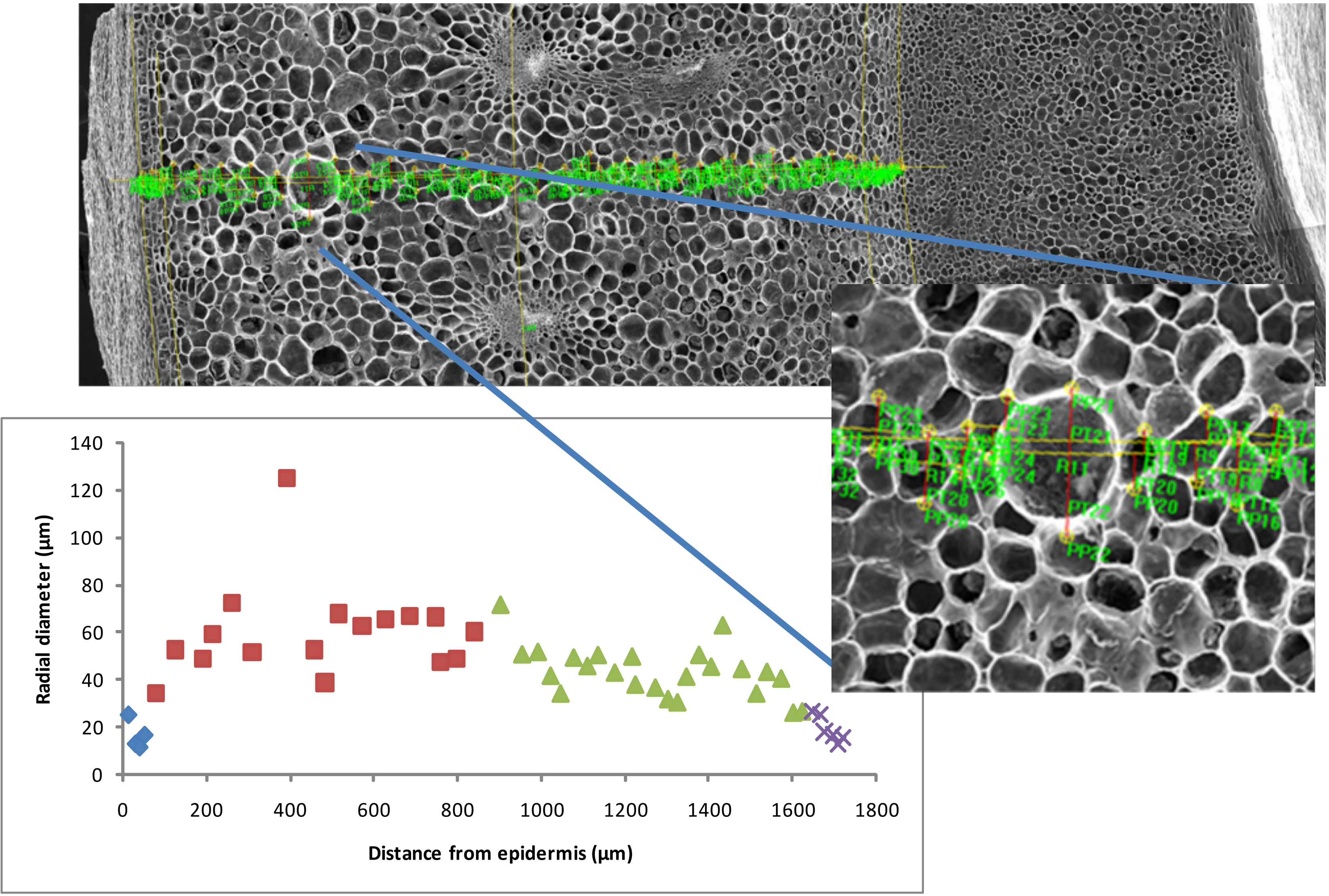


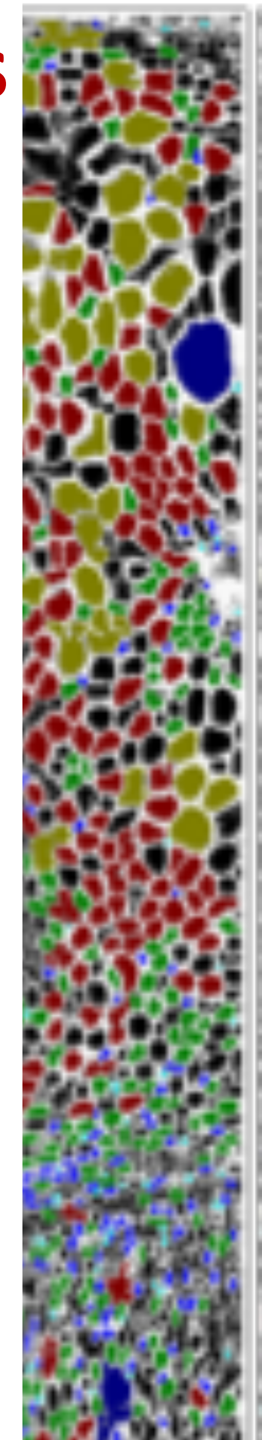
Gibeaut and Einhorn, unpublished



- ***Cells grow the entire season- not just in the 'cell expansion' phase***
- ***However, 60-75% of growth occurs after pit hardening***
- ***PGRs that capitalize on cell expansion processes are widely utilized in sweet cherry production***

Variation in Sweet Cherry Mesocarp Cells





GA_3: Pre-harvest application timing

GA Rates	2010 Sweetheart	2010 Skeena	2010 Staccato	2011 Skeena	2012 Sweetheart	2012 Lapins
0	380 a	371 c	320 b	316 b	298 b	261 b
0+ surfact.				336 b	305 b	250 b
10				**370 a**		
20	**417 a**	**405 b**	**459 a**	**373 a**		
25					**331 a**	**297 a**
30	**416 a**	**414 ab**	**448 a**	**377 a**		
30 (20+10)	**418 a**					
40	**419 a**	**443 a**	**474 a**	**390 a**		
40 (20+20)	**414 a**	**441 a**		**383 a**		
40 (30+10)		**435 ab**				
50					**345 a**	**281 a**
60	**417 a**	**447 a**	**440 a**	**394 a**		
60 (20+40)	**417 a**	**427 ab**		**373 a**		
100					**352 a**	**262 b**

Data from Einhorn et al., 2013

- Firmness was the most consistently affected attribute
- Response saturated at low concentrations (10 to 25 ppm)
- A fruit size effect from GA was only observed in one year
- Response was not influenced by cultivar

GA Effects on Cherry Skin Color

- GA delays color
  - inconsistent rate response
- Delay in color allows fruit more time on tree *potentially* resulting in greater size (this is NOT a direct growth effect) and higher SSC

GA_3: Pre-harvest application timing

Main effects	Yield (kg/tree)	Average fruit weight (g)	Rain cracking (%)	Fruit firmness (g/mm)	Total soluble solids (%)	pH	Titratable acidity (% malic acid)
GA Treatment							
Control	8.0	9.7	17.8	273	20.9	3.92	1.0
T1	8.5	10.9	30.2	324	21.8	3.74	1.17
T2	8.0	10.6	23.1	318	21.6	3.81	1.16
T3	10.0	10.7	23.0	314	22.6	3.80	1.21
T4	8.6	10.4	19.6	295	22.0	3.79	1.18
Significance	0.8063	<0.0001	0.1189	<0.0001	0.0567	0.0010	<0.0001

T1= 10-14 d prior to straw; T2= 4-7 d prior to straw; T3= straw; T4= 7 d after straw

Kappel and MacDonald, 2007

- Fairly wide window for timing (± 10d from straw)
- Early 'green' fruit applications are efficacious
- Increased risk of cracking when applications are made near rain events- weather forecasting to time sprays
- GA_3 may be more efficacious than GA_{4+7}

GA to Manage Sweet Cherry Crop

Effects of GA_3 application on return bloom of 'Bing' sweet cherry (modified from Proebsting and Mills, 1974).

Application date[z]	Flower buds per 25 cm on 2-year-old wood
5/10	76
5/30	68
6/21	95
7/11	100
8/1	110
8/22	107
Untreated	116

[z] *Single application, 100 mg active ingredient/liter water.*

Elfving and Visser, 2005

'Skeena', data from Einhorn et al., 2013

Treatment[z] GA (ppm)	Avg fruit wt. (g)	Avg fruit diam. (mm)	FF ($g \cdot mm^{-1}$)	Return Bloom buds/spur (no.)	Return Bloom flowers/bud (no.)
0	12.2	30.7	231 b[x]	3.5	2.9 a
25	12.1	30.7	268 a	3.7	2.8 ab
50	11.4	30.0	278 a	3.4	2.3 b
100	11	29.6	267 a	2.5	1.1 c

GA: Crop Regulation of Cherry

- For cultivars prone to developing/inducing too many flower buds on current-season wood
- Cherry buds are simple (either flower or vegetative)
- The year following fruiting, nodes which had flower buds on 1-year-old wood become **blind**
- GA is applied to ***inhibit*** floral buds from developing – for productive cvs this increases spur production and future yields
- GA concentration depends on species and age (sour cherry, 25 to 50 ppm single app to young trees [3-year-old]; 10 to 20 ppm older trees + 0.1% NIS; Sweet cherry cultivars ~ 100 ppm)
- Timing is 5 to 7 leaves on extension shoots or 3 to 4 weeks after bloom

GA Can Mitigate Pitting Incidence

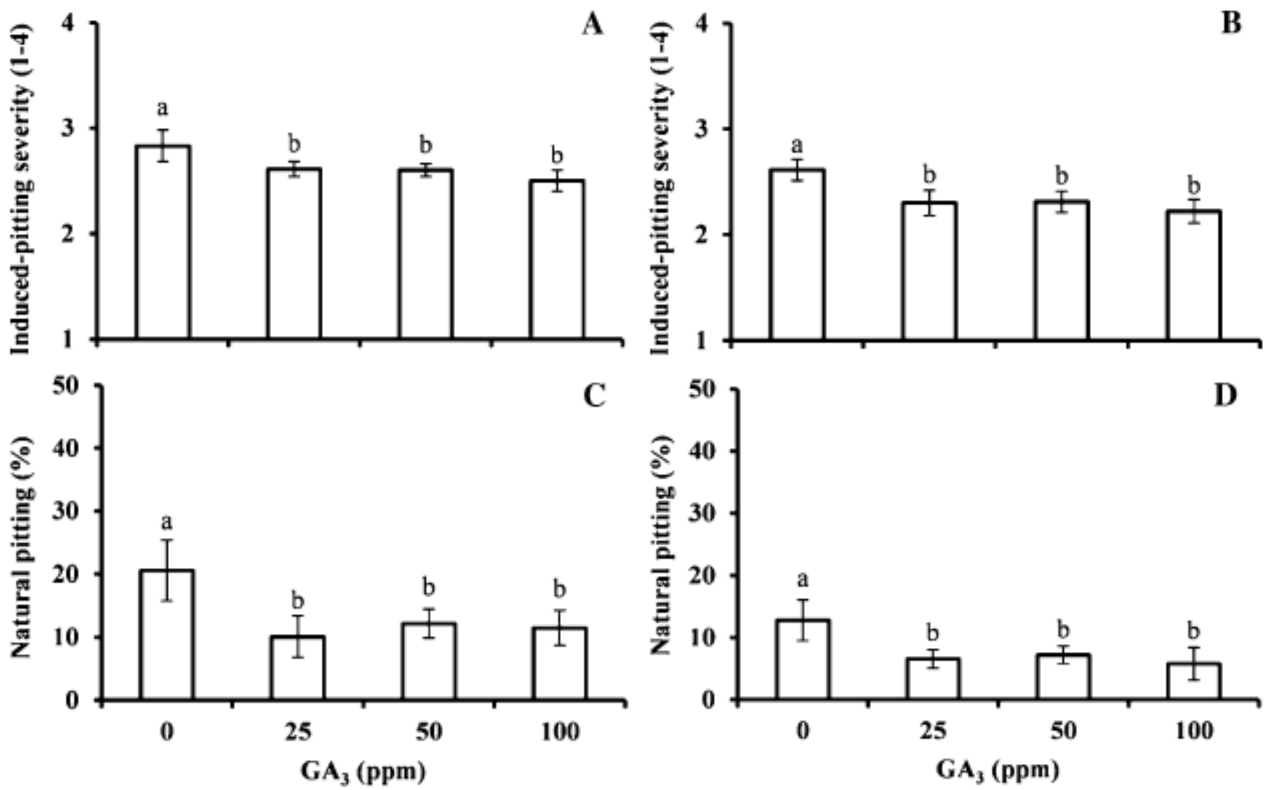


Fig. 1. Effect of preharvest gibberellic acid (GA_3) treatments on induced pitting severity and natural pitting incidence of 'Lapins' (**A**, **C**) and 'Sweetheart' (**B**, **D**) cherries after 2 weeks of storage at 0 °C. Vertical bars represent SD. Means were separated between treatments by Fisher's protected least significant difference test (LSD) ($P < 0.05$), whereby means associated with different letters are significantly different.

Factors That Affect Cell Expansion & Growth

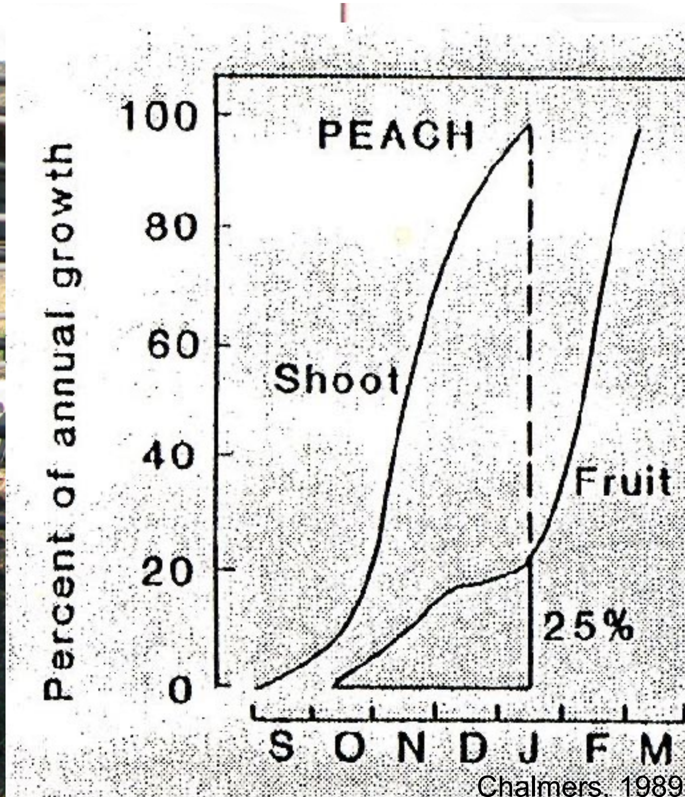
- Light – limited supply leads to reduced CHO- increasing shade with increasing canopy thickness
- Temperature- what are the optima temperatures for the growth and development of sweet cherry, leaf photosynthesis, and respiration of fruit and vegetative organs?
- Crop load- Imbalanced crop loads decrease fruit size
- Nutrient availability- dependent on supply, source, microbial activity, irrigation, soil conditions/temp, rootstock, fertilizer (rate, supply, forms, etc.)
- Water – water stress reduces growth. The amount of stress that organs can withstand prior to reduced growth is necessary information to schedule the volume and frequency of irrigations

Key Factors that influence Water Use
and Tools/Information Needed to Manage

- Solar radiation/Light: Energy source
  Weather station/ET Models
- Humidity: VPD is the gradient that drives Transpiration
  Weather station/ET Models
- Wind: aerodynamic component that serves to disperse boundary layers and increase VPD
  Weather station/ET Models
- Canopy leaf area: directly proportional to water use
  Tree architecture/training system, vigor control
- Crop load: Perhaps only to a limited degree in sweet cherry (unlike pome fruits)
  Thinning/Crop load management, pruning…
- Drought/soil moisture reserves
  Soil moisture monitoring, soil texture analysis/soil maps, excavation and observation of rooting depth, etc.

Regulated Deficit Irrigation (RDI)

- Providing irrigation below plant demand at specific time intervals throughout the season based on different patterns of growth *and/or,*
- Differential sensitivity of tissues, organs and growth processes to water stress



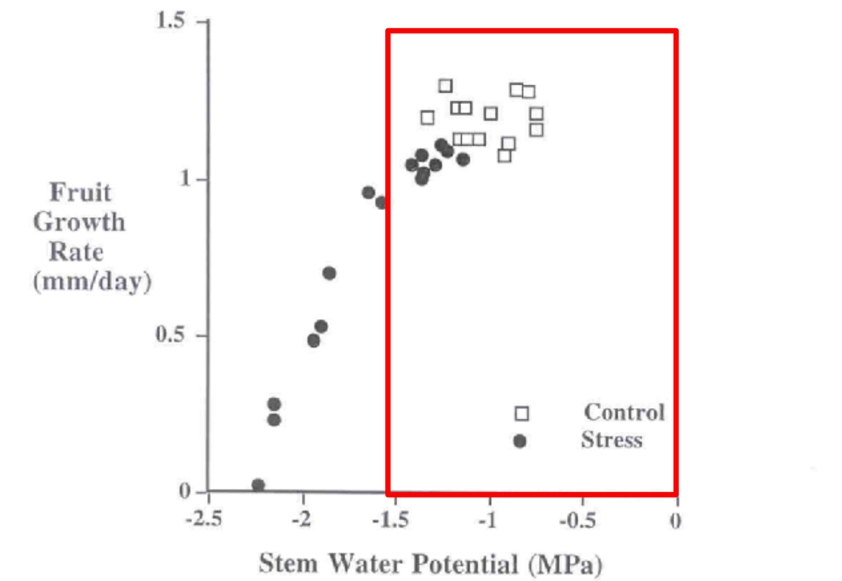
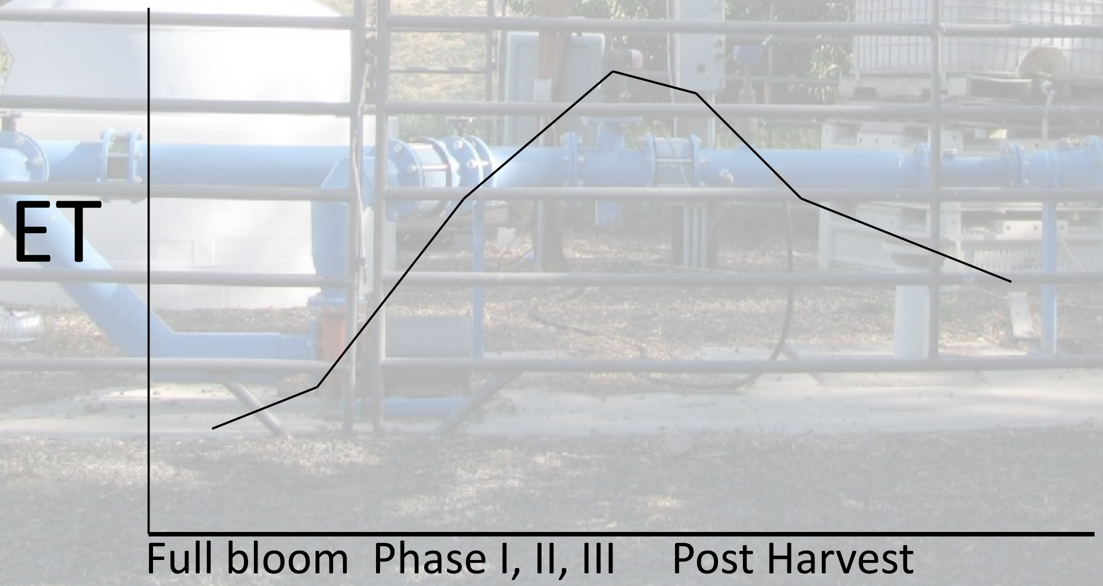


Fig. 8.9. Fruit growth rates as affected by declining stem water potentials with water stress (M. Al-hazmi and A. Lakso, 1996 unpublished results).

When to apply RDI to sweet cherry trees?

- **<u>Stage 1</u>:** If soil moisture profile is full, then withholding or reducing irrigation to allow utilization of deeper soil moisture reserves can save water. This requires knowledge of the rooting profile (i.e., depth) and soil moisture. *Reducing irrigation during early-season is unlikely to create soil moisture deficits that affect fruit growth by cell division.*



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- **<u>Stage 2</u>:** Ideal, but duration of pit-hardening may be insufficiently long to achieve large savings
- **<u>Stage 3</u>:** Ideally, frequent irrigations at full ETc (kc values ~1) throughout Phase III, possibly reduced ~10-14 days prior to harvest

Leaf Area & Function- Sweet Cherry

Figure 2. Year 1—new shoot growth with single leaves at each node.

Figure 3. Year 2—first season growth forms non-fruiting spurs, with greater spur density in the terminal portion and a few basal non-spur fruit buds.

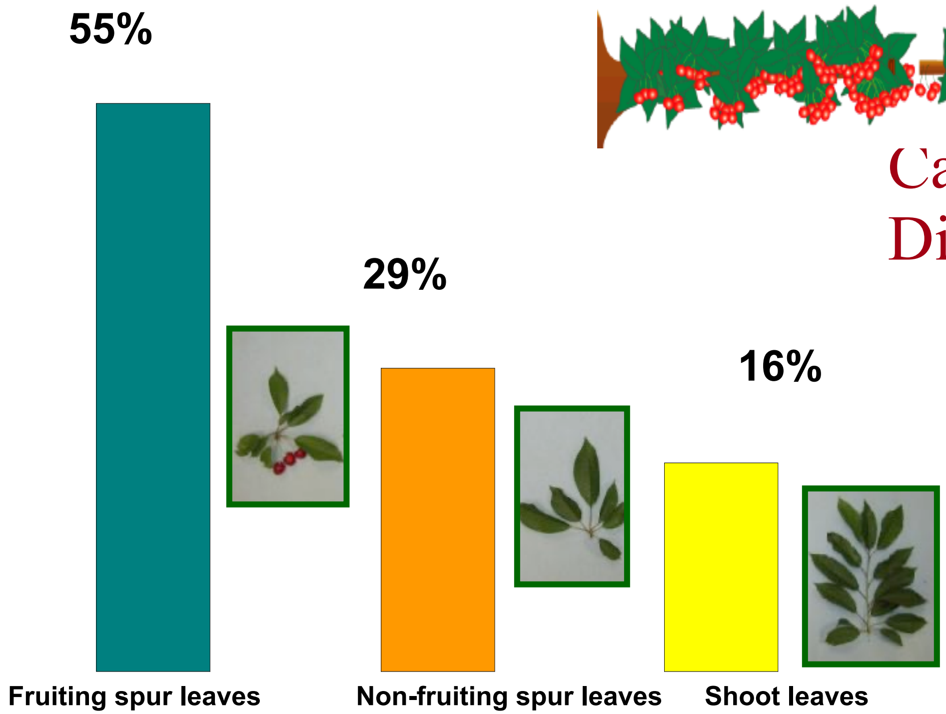
Figure 4. Year 3—first season growth forms fruiting spurs, with more flower buds per spur (and greater spur density) in the terminal portion.

Long et al., 2015 PNW 667

- Leaf populations photosynthesize at the same rate irrespective of their origin (i.e., current, 1-yr-old, 2+ yr-old
- ~200 cm^2 of LA per fruit is required to attain commercial fruit size (i.e., 4-5 leaves/fruit)
- Increase leaf area with late fall foliar urea or early spring (green tip) GA or GA/BA to increase CHO

Sweet Cherry Leaf Area and Location Effects

Carbon Sources and Distribution to Fruit



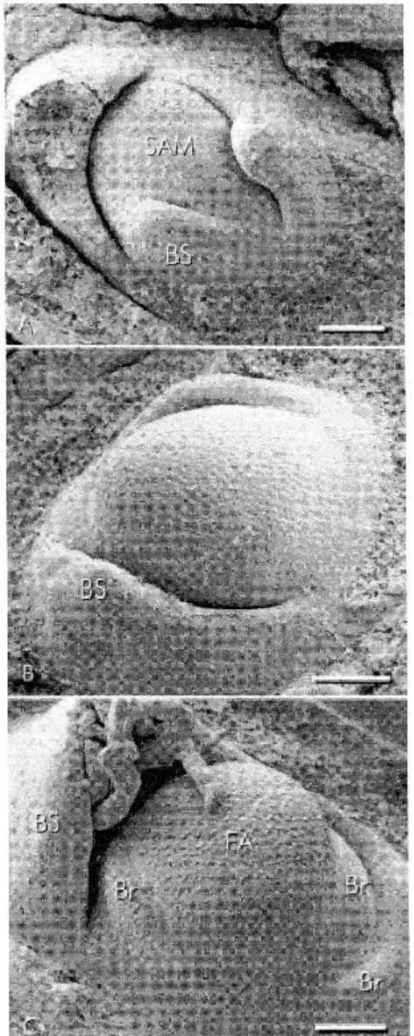
- Large healthy leaves, in close proximity of fruit, are critical for fruit to achieve maximum size and quality

Data: Ayala and Lang, 2004

Slide compliments of G.Lang

When to apply RDI to sweet cherry trees?

- **PH**: **Possibly 50% ET but caution required for applying extreme stress during floral bud development as well as limiting CHO reserves**



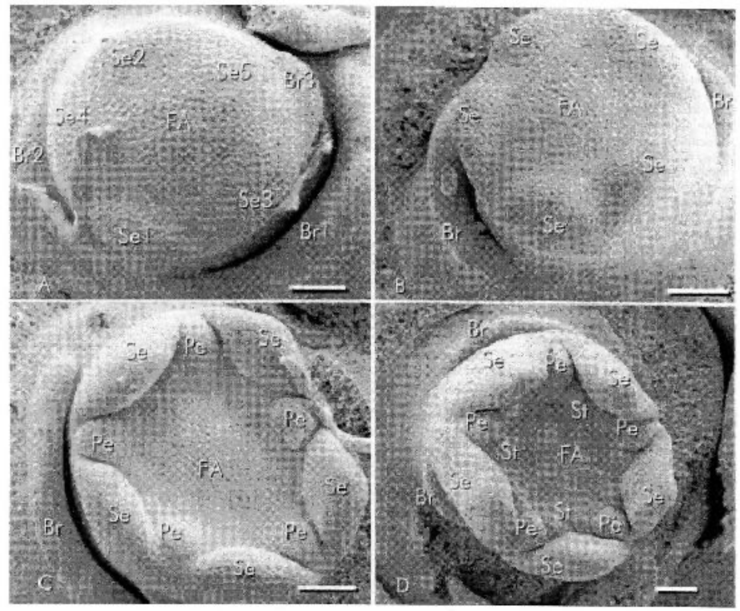
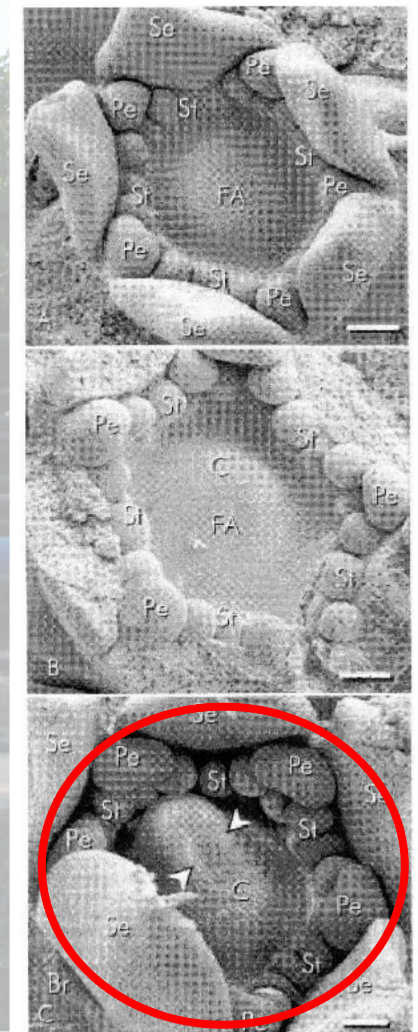


Fig. [illegible]. Scanning electron micrographs of almond bud apices showing initiation of floral organs through stamen initiation. (A) Stage 3. Bract and sepal initiation at the floral apex follows a spiral phyllotaxy. The three bract primordia are numbered from the oldest to youngest (Br1–Br3). The sepal primordia are labeled similarly. The site of initiation of the final sepal primordium is indicated (Se5) but the primordium had not yet formed when this bud was dissected. (B) Stage 3. The floral apex, subtended by bracts, with initiation of the five sepal primordia complete. (C) Stage 4. Petal primordia form alternate to the sepal primordia. (D) Stage 5. The stamen primordia form opposite to the petal primordia. Note the fused bases of the sepal, petal, and stamen primordia that form the hypanthium. Br = bract; FA = floral apex; Pe = petal; Se = sepal; St = stamen. Scale bars

Lamp et al., 2001



Inflorescence meristems of Peach and Sweet Cherry have both been shown to undergo initiation (early-mid summer) and carpel development (late summer)
(Bustamente-Garcia, 1980; Diaz et al., 1981; Handley and Johnson, 2002)

Physiological fruit disorders related to water stress

Twinning, doubles and deep suture of peach, plum and sweet cherry due to incomplete or retarded floral bud differentiation and carpel development