New Strategies to Optimize Crop Load Management and Profitability of Apple (and Pear) Orchards

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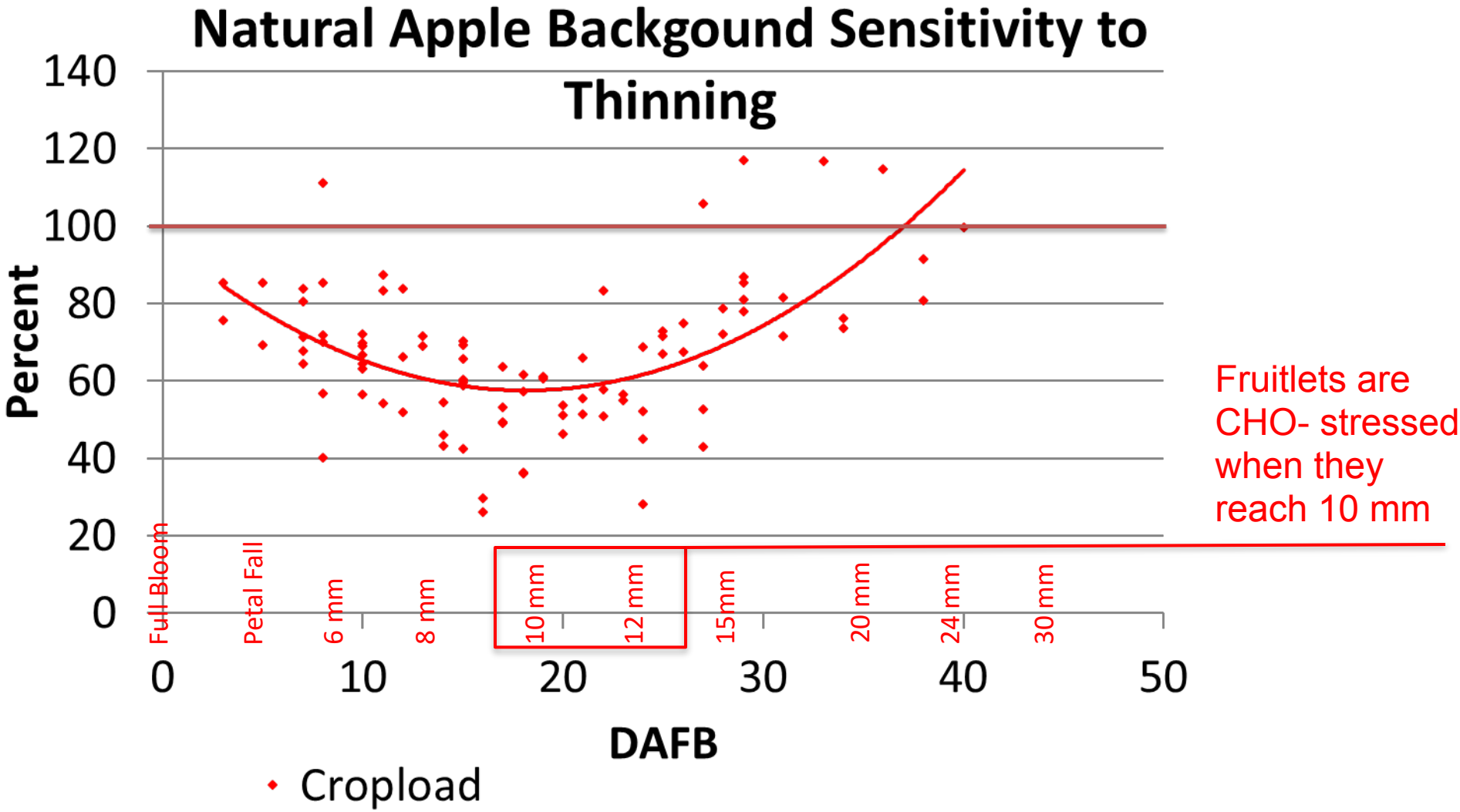
Thinning Strategies

- Take advantage of all *susceptible* developmental stages to reduce crop
- Begin early and frequently
- Consider the previous year
  - Water stress, freeze or frost damage
  - Crop load (possible effects on reserve CHO and return bloom)
- Use technology to improve precision
- Don’t wait until fruitlets are 10 mm



CROPLOAD = FRUIT/TREE as % OF UTC

DAFB=Days After Full Bloom

Slide Courtesy, P. Schwallier, MSU

Precision Cropload Flow Chart

Pruning to Target Bud → Initial Flower Load

Pollen Tube Growth Model

Bloom

Carb Model → Petal Fall

Carb Model → 10 mm

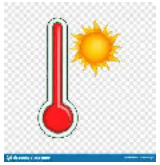
Carb Model → 16 mm

Carb Model → Target Fruit Number

Fruit Set Model

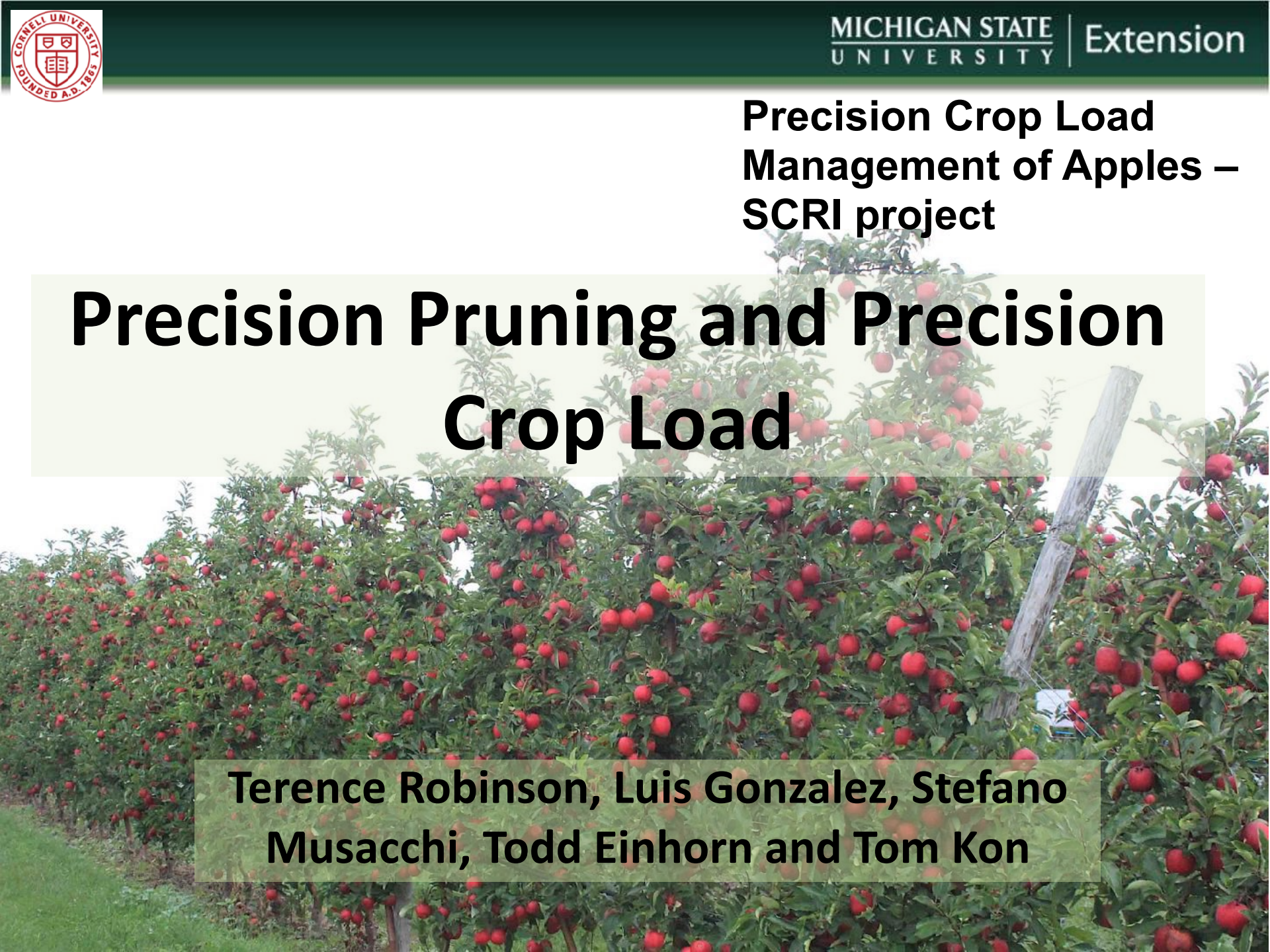
Fruit Set Model

Fruit Set Model



Hand Thinning

Slide based on T. Robinson, Cornell



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Precision Crop Load Management of Apples – SCRI project

Precision Pruning and Precision Crop Load

Terence Robinson, Luis Gonzalez, Stefano Musacchi, Todd Einhorn and Tom Kon

Managing Fruit Load Precisely

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Precision crop load management is a strategy to determine an optimum crop load and then to use

1. pruning,
2. chemical thinning and
3. hand thinning

to consistently obtain the optimum fruit load (Robinson, 2013)

The first step in precision crop load management is to establish a target of final fruit number.

- Gala Example: (1500 bu/ac * **100** count / 1,320 trees/acre = 113 fruits /tree
- HC Example: (1200 bu/ac * **80** count / 1,320 trees/acre = 73 fruits /tree

Precision Pruning

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1. Precision pruning is a process of reducing the number of flower buds to a predetermined number through pruning using the rules of Tall Spindle pruning and then spur extinction pruning. (Robinson, 2013).
2. How many flowering spurs to leave?

- Gala: 1.5 buds per final fruit number. (113*1.5=170 spurs)
- Honeycrisp: 1.8 buds per final fruit number. (73*1.8=131 spurs)

Determining Target Crop Load for Apple Trees

Table 1. Crop load recommendations for young apple trees based on trunk diameter

Trunk diameter (inches)[z]	TCA (cm^2)	Recommended Number of Fruits/Tree[y]: Weak Growing, Biennial, Varieties (Honeycrisp)	Strong Growing, Biennial Varieties (Fortune, Fuji, Golden Delicious, Jonagold, Mutsu, Spy)	Annual Varieties (Gala, Empire Mac, Rome, Idared) Idared)
0.25	0.3	1	2	2
0.5	1.3	5	6	8
0.75	2.9	11	14	17
1	5.1	20	25	30
1.25	7.9	32	40	48
1.5	11.4	46	57	68
1.75	15.5	62	78	93
2	20.3	81	101	122
2.25	25.7	103	128	154
2.5	31.7	127	158	190
2.75	38.3	153	192	230
3	45.6	182	228	274
3.25	53.5	214	268	321
3.5	62.1	248	310	372
3.75	71.3	285	356	428
4	81.1	324	405	486
4.25	91.5	366	458	549
4.5	102.6	410	513	616
4.75	114.3	457	572	686
5	126.7	507	633	760

z Trunk cross-sectional area=3.1416 X radius^2 Trunk diameter in inches = 2.54 * diameter in cm. Cross sectional area {cm^2} = ((diameter {inches} times 2.54) divided by 2)^2 times 3.1416.

y For Honeycrisp the recommended crop load = 4 fruits/cm^2 TCA. For other biennial bearing varieties the recommended crop load = 5 fruits/cm^2 TCA. For annual varieties the recommended crop load = 6 fruits/cm^2 TCA.

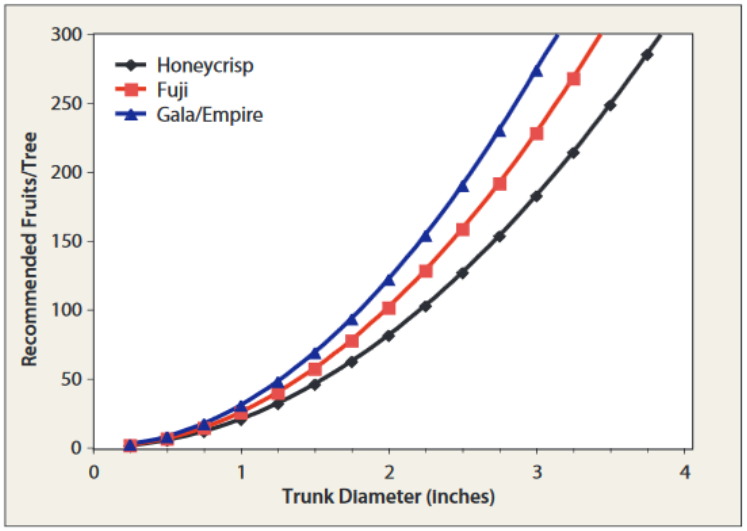

Figure 7. Crop load recommendations for young apple trees based on trunk diameter. For Honeycrisp the recommended crop load = 4 fruits/cm^2 TCA. For other biennial bearing varieties the recommended crop load = 5 fruits/cm^2 TCA. For annual varieties the recommended crop load = 6 fruits/cm^2 TCA.

- The relationships among crop load, fruit size, color, and profitability need to be established for specific regions

http://www.nyshs.org/pdf/fq/2008-Volume-16/Vol-16-No-2/Crop-Load-Management-of-New-High-Density-Apple-Orchards.pdf

Why is controlling flower bud number by pruning so important?

1. Excessive flower bud number divides the spring nitrogen, carbohydrates and cytokinin from the root system into many buds leaving each bud with less than optimum levels resulting in
   - weak buds that have low set
   - weak bud that produce small fruit
   - weak buds that are more biennial.

2. Excessive flower bud number results in excessive Gibberellins from seeds which inhibit flower formation for the next year

   - **HC example with recommended pruning:** 131 flowering spurs * 5 fruits/spur * 10 seeds per fruit = 6,550 seeds
   - **HC example with excessive flowering spurs**: 219 flowering spurs * 5 fruits/spur * 10 seeds per fruit = 10,950 seeds

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Natural fruitlet abscission as related to apple tree carbon balance estimated with the MaluSim model

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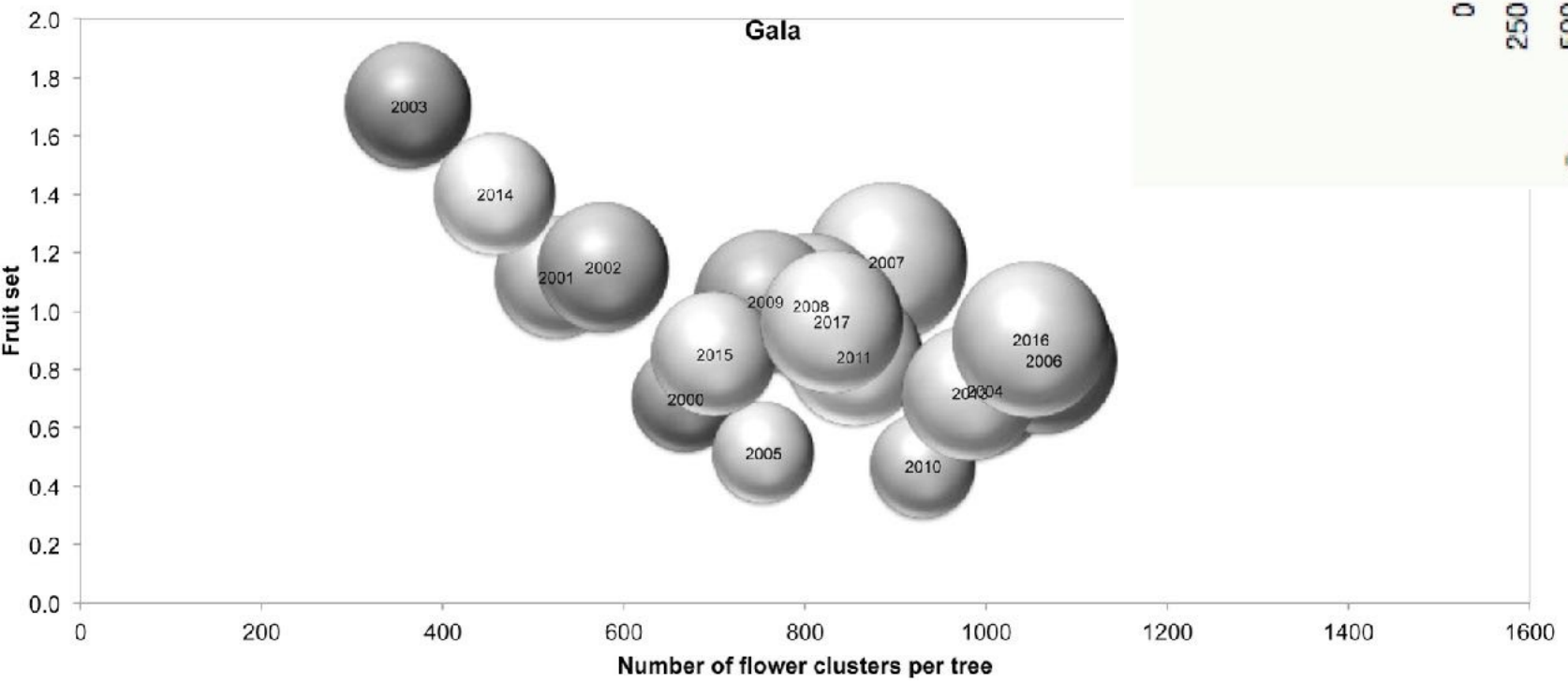
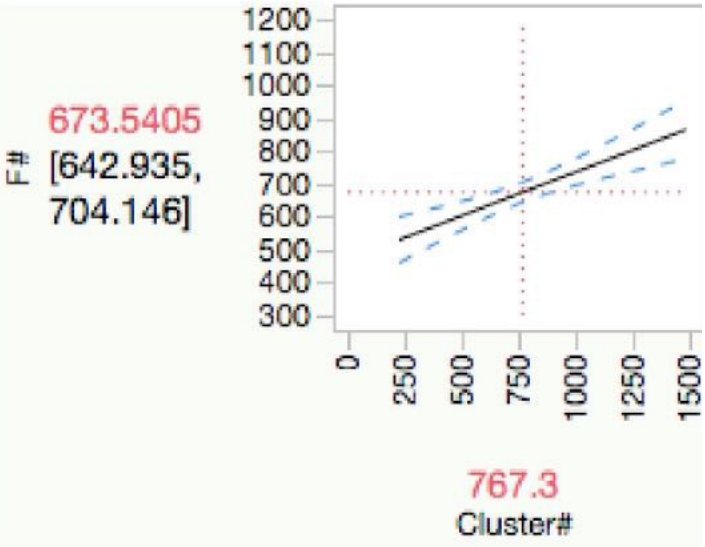
[c] Dept. of Agronomic Sciences, Universidad de Chile, Santiago, Chile





- The number of clusters per tree, CHO balance 0-60 GDD after bloom and 300-360 GDD after bloom explained up to 80% variability in fruit set/yield

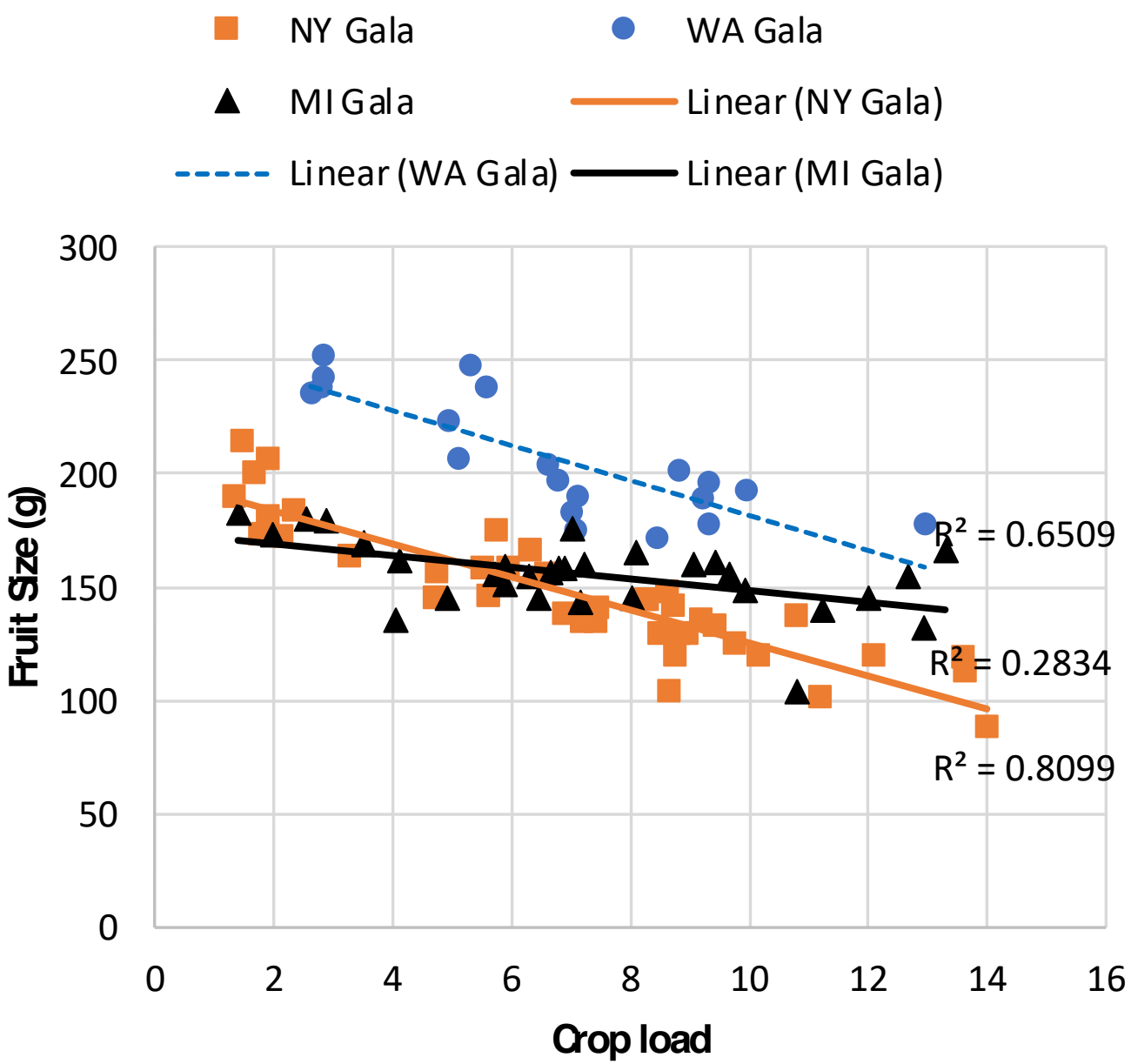
Pruning to Adjust Bud Load

- First opportunity to reduce flower load
- Identify ***Target*** crop load (fruit no./tree)
- Count fruit buds on ***representative*** trees
- Assume 1 fruit will set per bud
- Prune to reduce the number of fruit buds to 140***% of the target*** crop load

http://extension.psu.edu/plants/tree-fruit/presentations/2014-winter-fruit-meetings/precision-crop-load-management

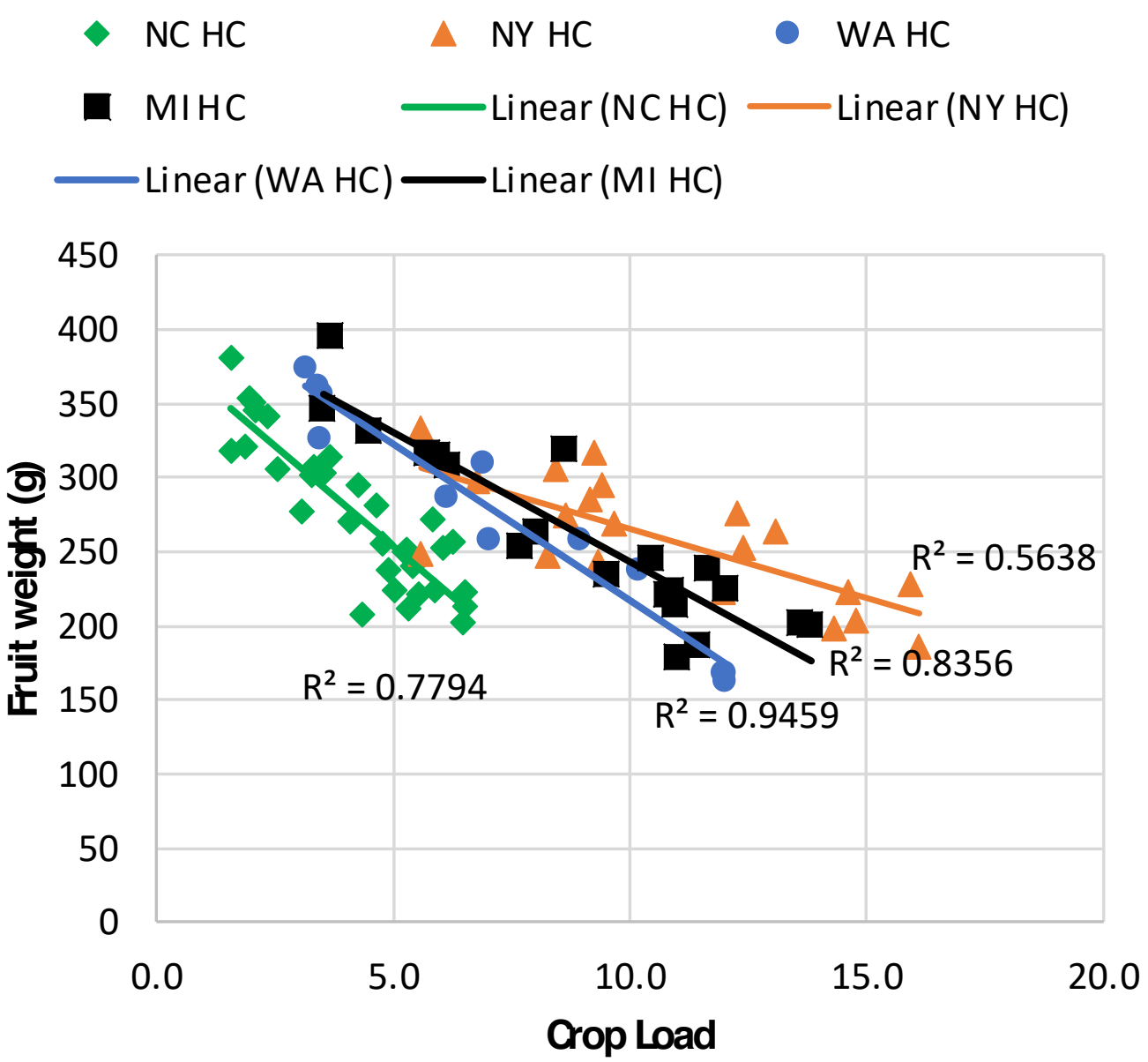
Hand thinning Gala

- At each location Ultima Gala trees were pruned to different flower bud loads
- At full bloom trees were hand thinned to single fruits per cluster
- The WA climate gave the largest fruit size at any crop load
- The NY climate had smaller fruit at any crop load
- The MI climate was similar to NY at lower crop loads but similar to WA at high crop loads

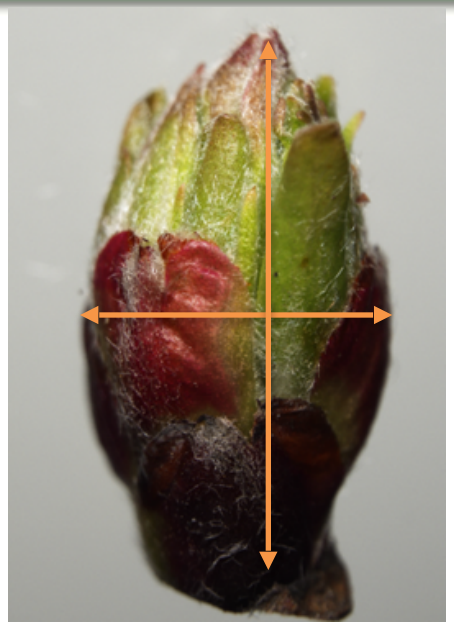


Hand thinning HC

- At each location Honeycrisp trees were pruned to different flower bud loads
- At full bloom trees were hand thinned to single fruits per cluster
- The NY, WA and MI climate gave the largest fruit size at any crop load
- The NC climate had smaller fruit at any crop load
- The WA and MI climates gave similar fruit size to NY at lower crop loads but smaller fruit size at high crop loads



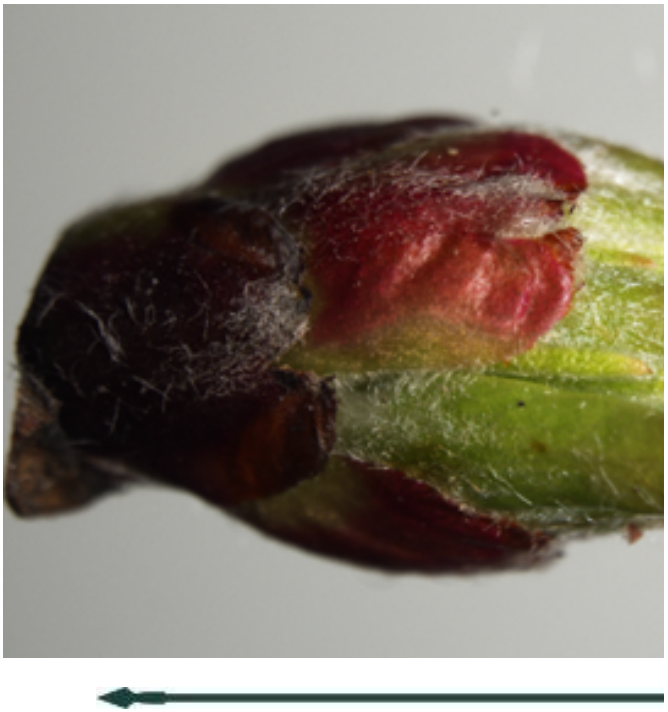
Bud Detection

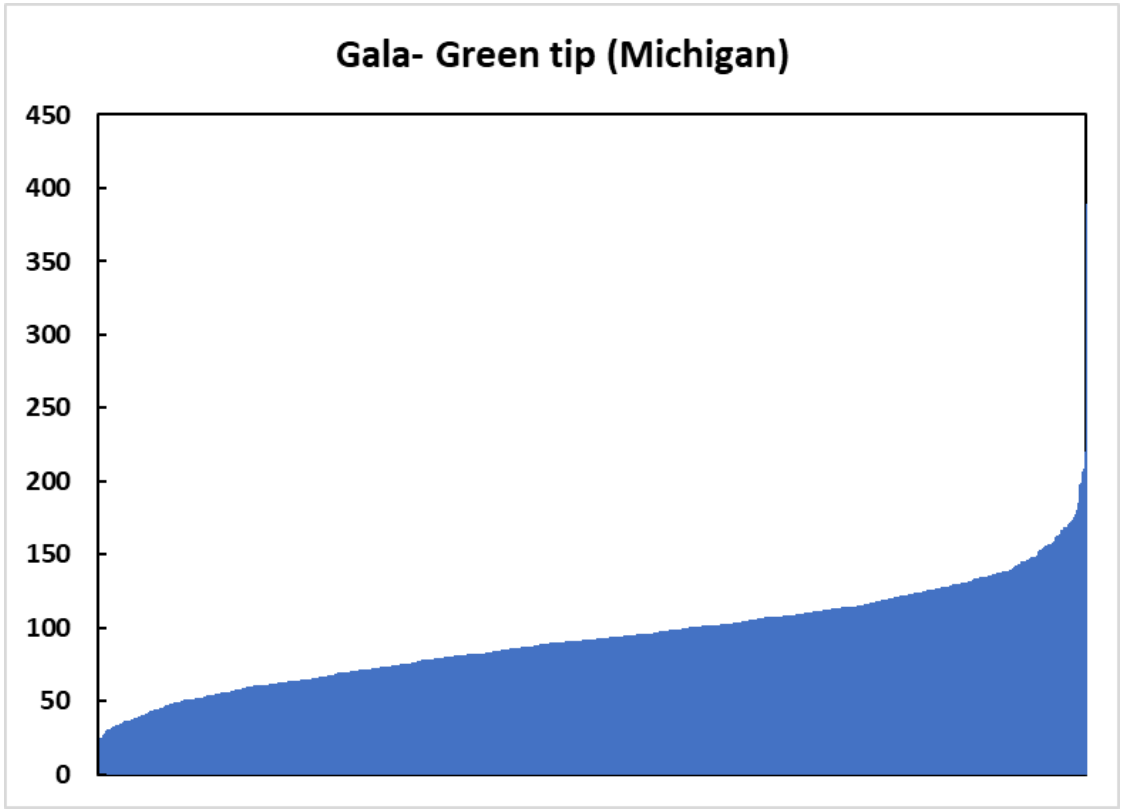


- If, bud detection and imaging by, say, an autonomous vehicle, then
  - Bud count data georeferenced to trees (whose trunks will be measured) can produce estimates for bud removal, but capturing and handling these data is expensive
  - In combination with worker assisted automation, pruning to bud count would be simplified
  - Nascent technology, potentially, will remove buds (say, at green tip) to precisely establish potential crop load on a tree basis

Bud Thinning

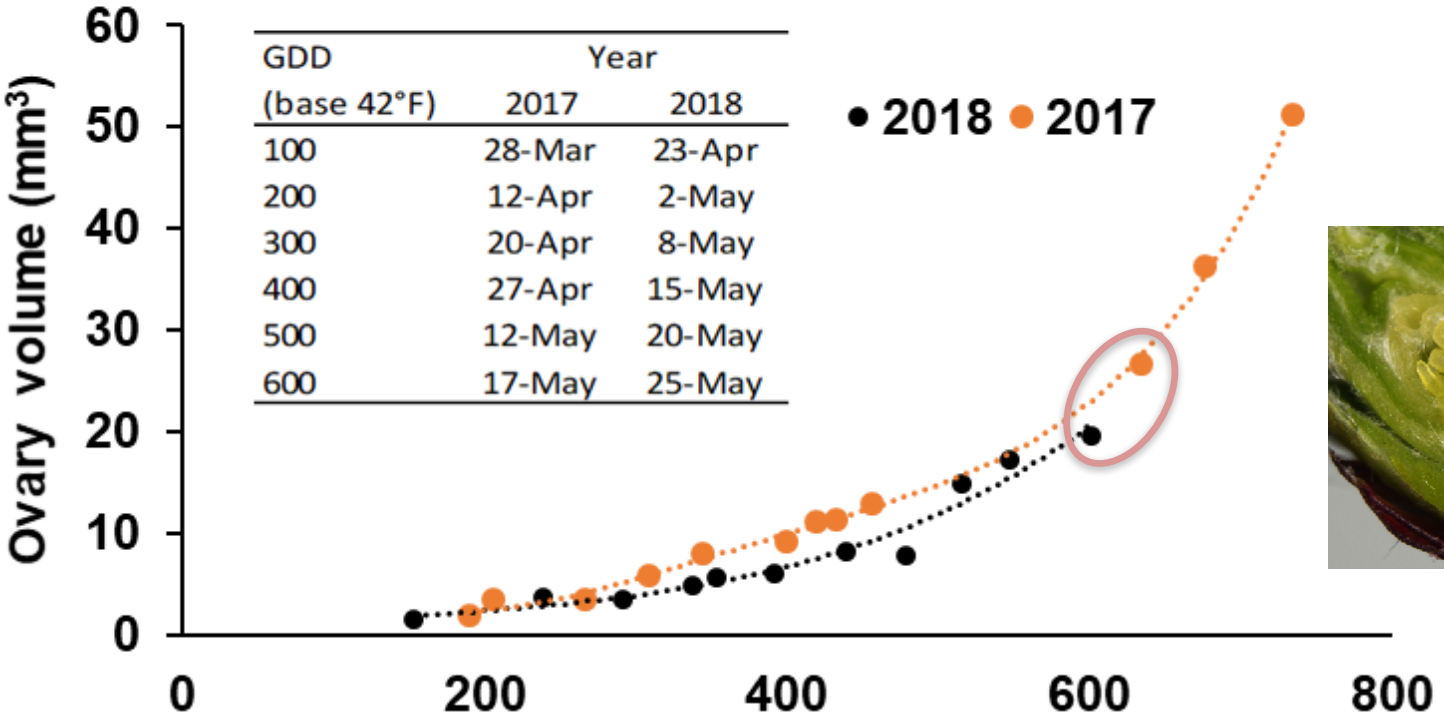
- Assuming technologies will be able to detect, image and discriminate buds, it might be useful to know…
  - If there is a relationship between bud size and ovary size of king and lateral flowers within the bud
  - Or, if the size of a mixed bud relates to the vegetative organs (LA)





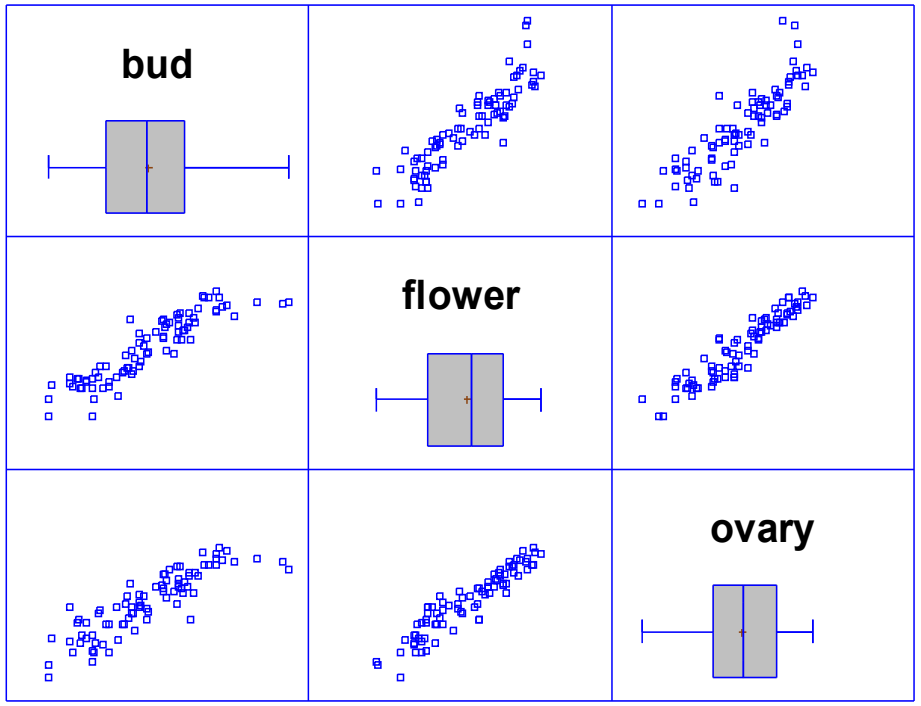
- Honeycrisp ovary volume increases ~20x between green tip and bloom

GDD (base 42°F)	Year 2017	2018
100	28-Mar	23-Apr
200	12-Apr	2-May
300	20-Apr	8-May
400	27-Apr	15-May
500	12-May	20-May
600	17-May	25-May



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

-33 days from bloom



-7 days from bloom

- The data show that larger buds have larger flowers… and larger flowers have larger ovaries…
- **Cultural Implications: Bud Removal (fruit thinning)**

‘Ultima’ Gala

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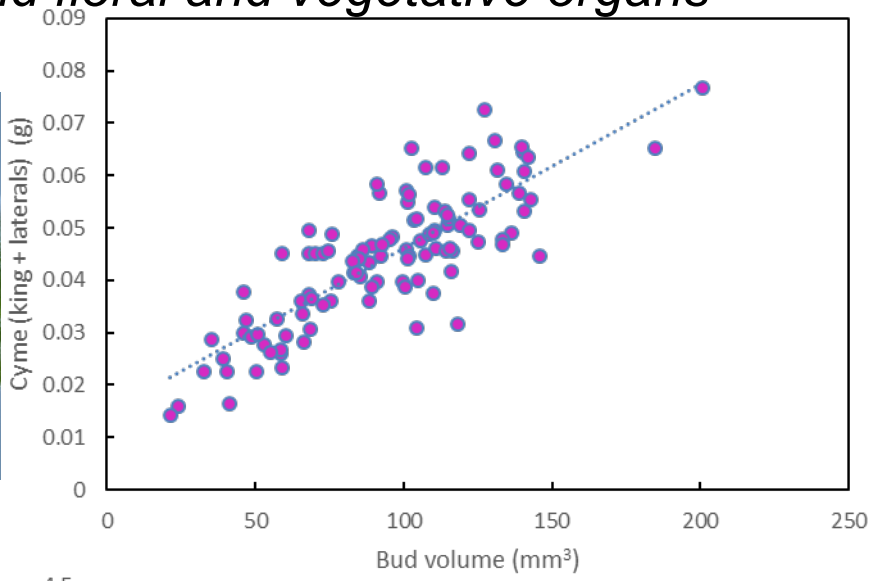
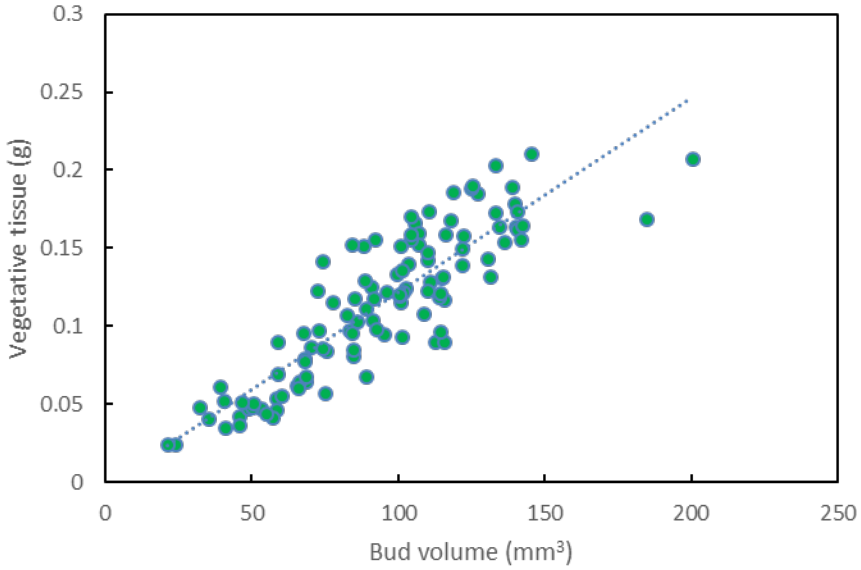
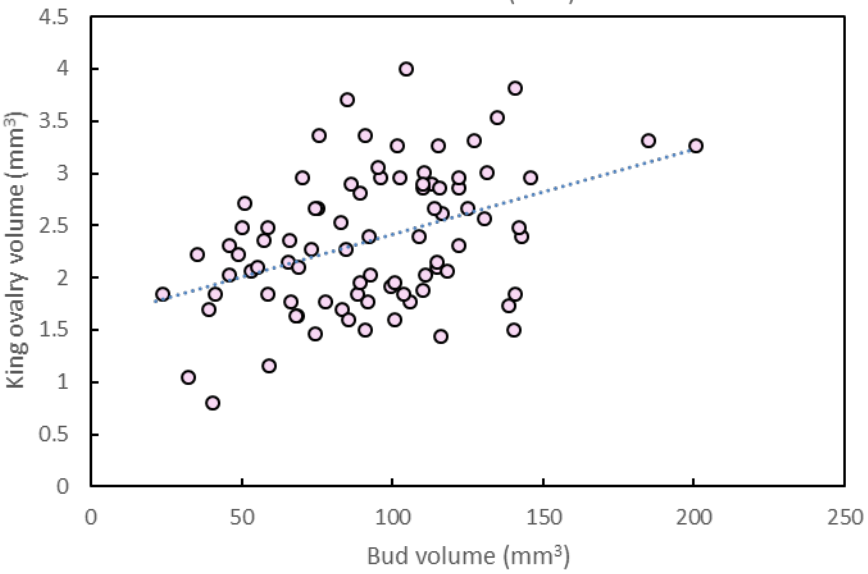
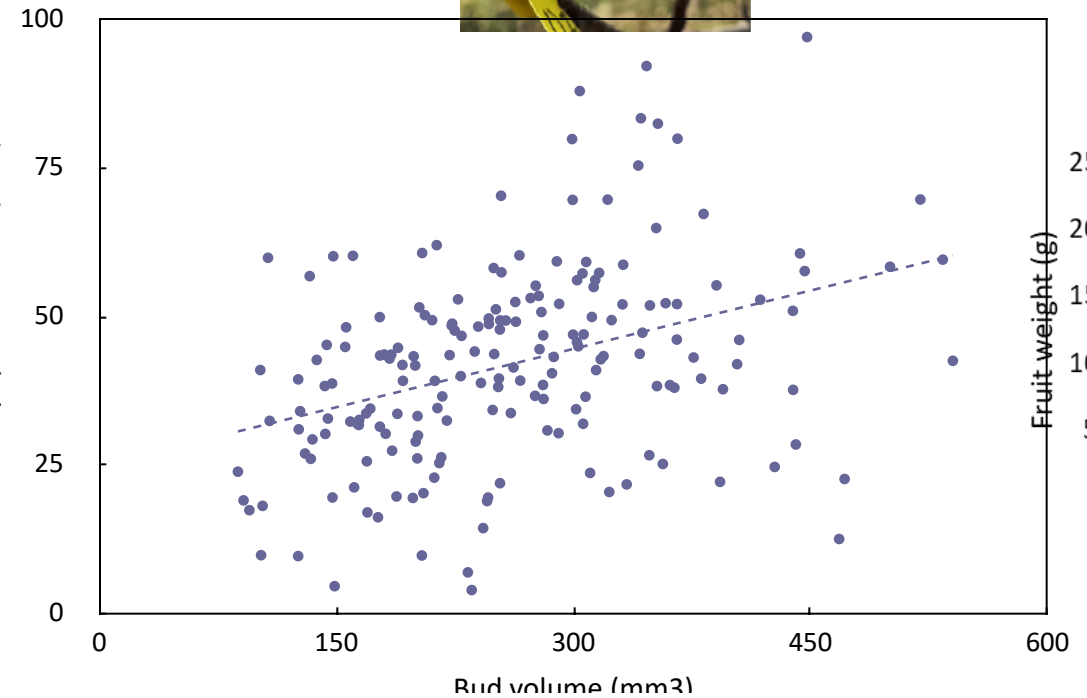
Relationships among flower bud volume and floral and vegetative organs

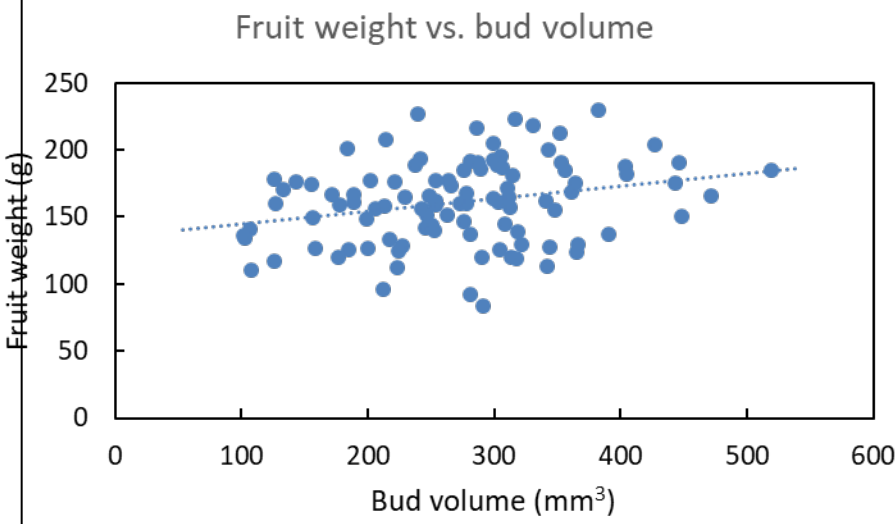






Field validation of the effect of bud volume on fruit size at harvest





At low crop load, the relationship between initial bud size and fruit weight at harvest was weak

New and Future THINNERS

- ABA
- METAMITRON (aka, Brevis)
- ACC

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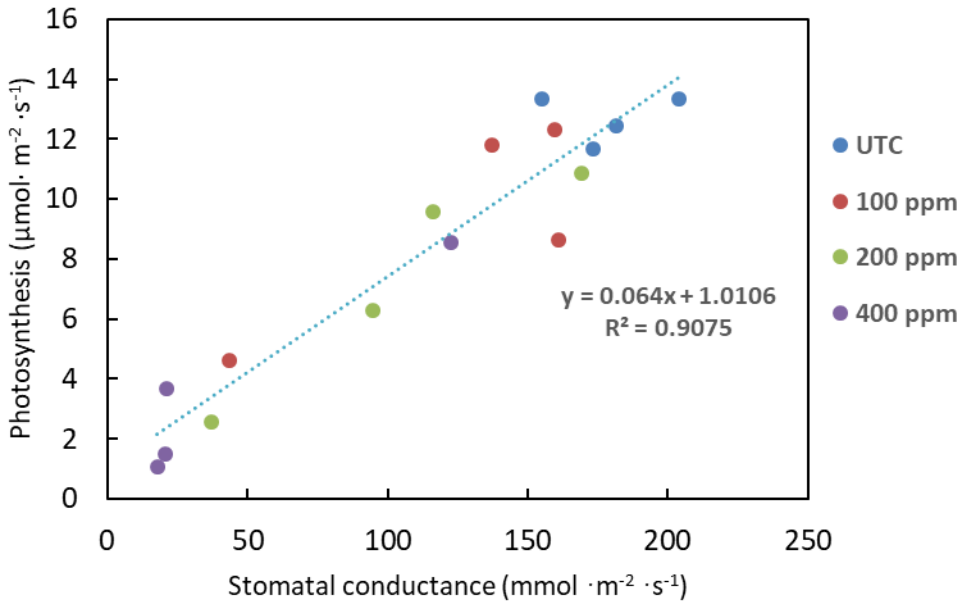
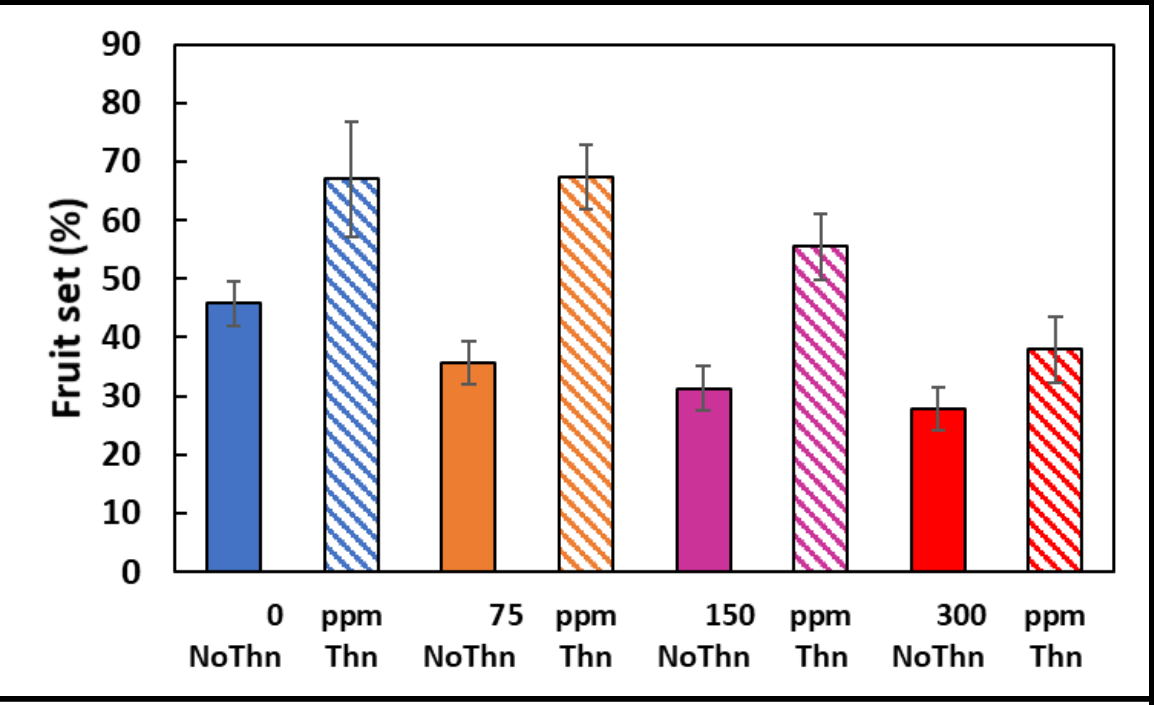
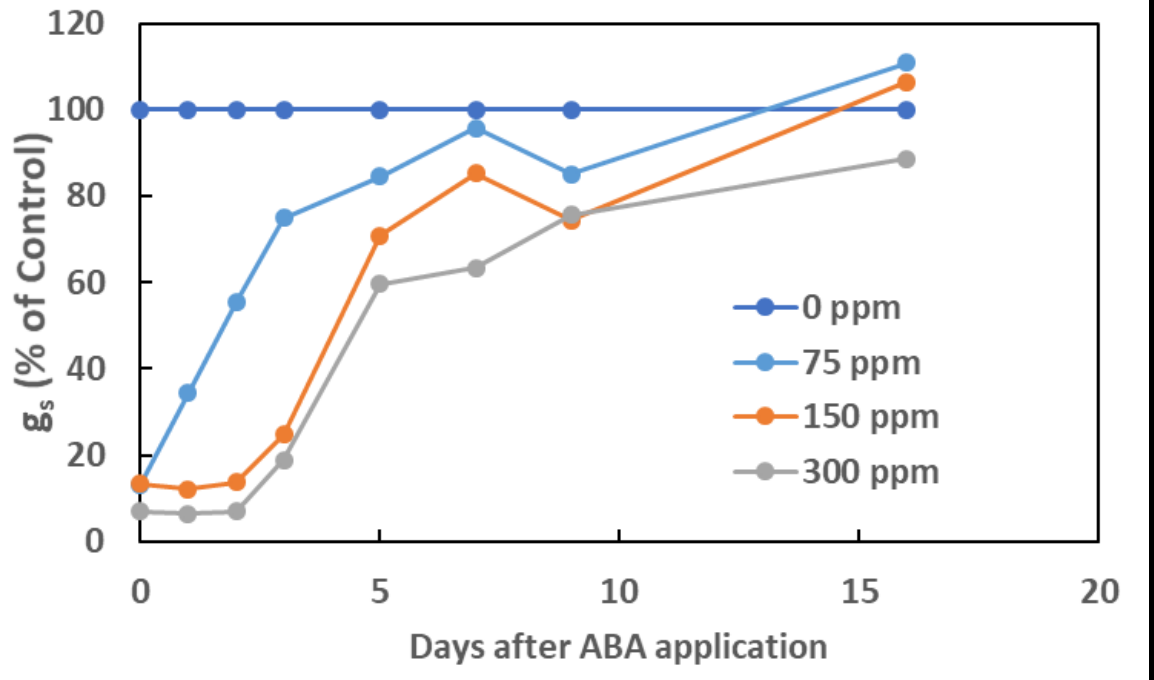
ABA- Thinning Mode of Action



- The physiological activity of ABA on leaves is (partial) stomatal closure
- The consequence of this activity is reduced Photosynthesis
- Low photosynthesis rates equate to reduced CHO
- CHO deficit is likely the primary mechanism for ABA thinning, thus bloom and pf timings not expected to be efficacious

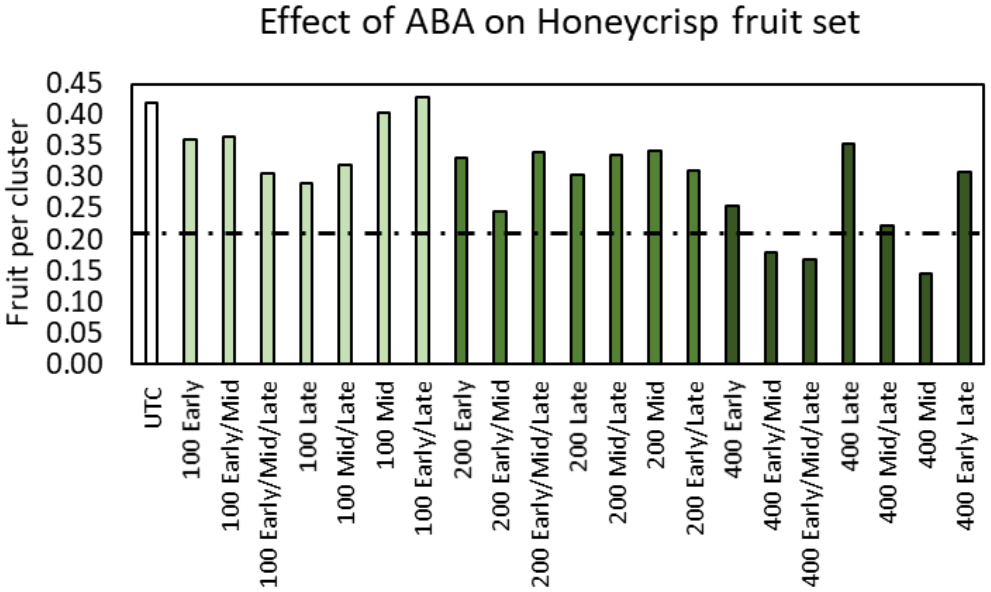
2018 Honeycrisp Trial

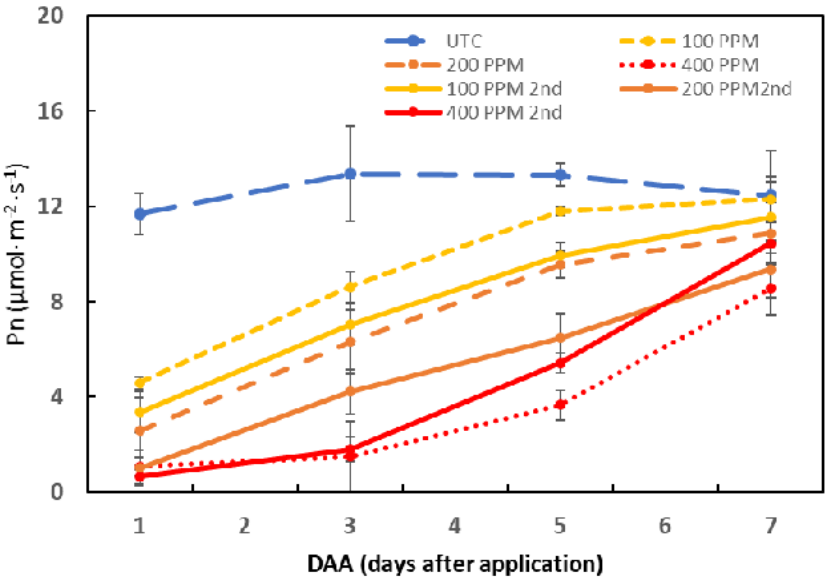




- NoThn = not thinned, ~300 clusters per tree
- Thn= hand flower thinned, 60 clusters per tree

2019 ABA: Fruit set





- ABA was tank mixed with Tri-Fol at 8 oz/100 gal (to reduce pH) and Regulaid (surfactant) at 8 oz/100 gal.
- Thinning was responsive to rate - good efficacy at 400 ppm
- Thinning occurred primarily at mid timing (3 weeks afb) with additive effect from petal fall timing and little improvement from 17 mm timing

2019 ABA: Yield

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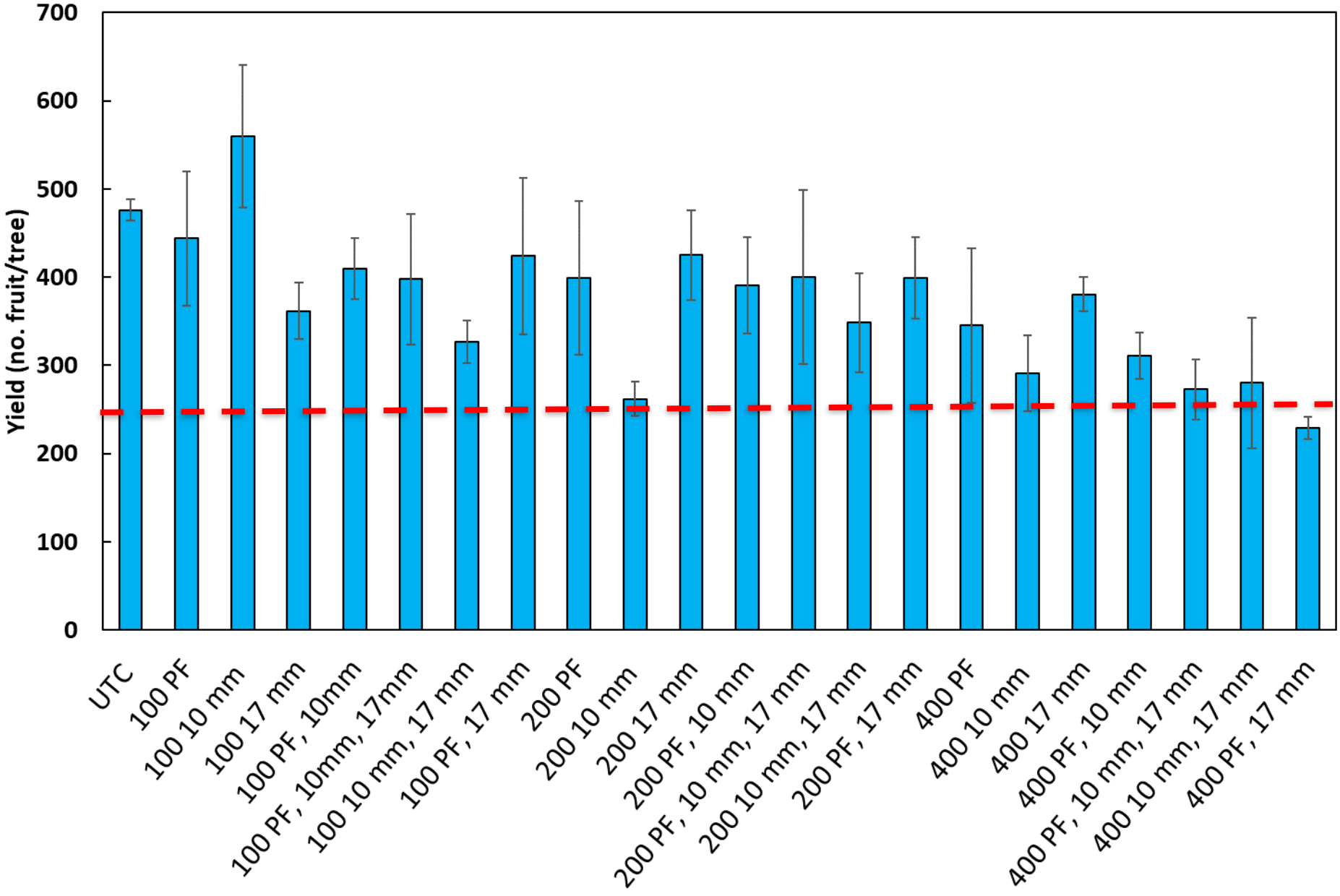
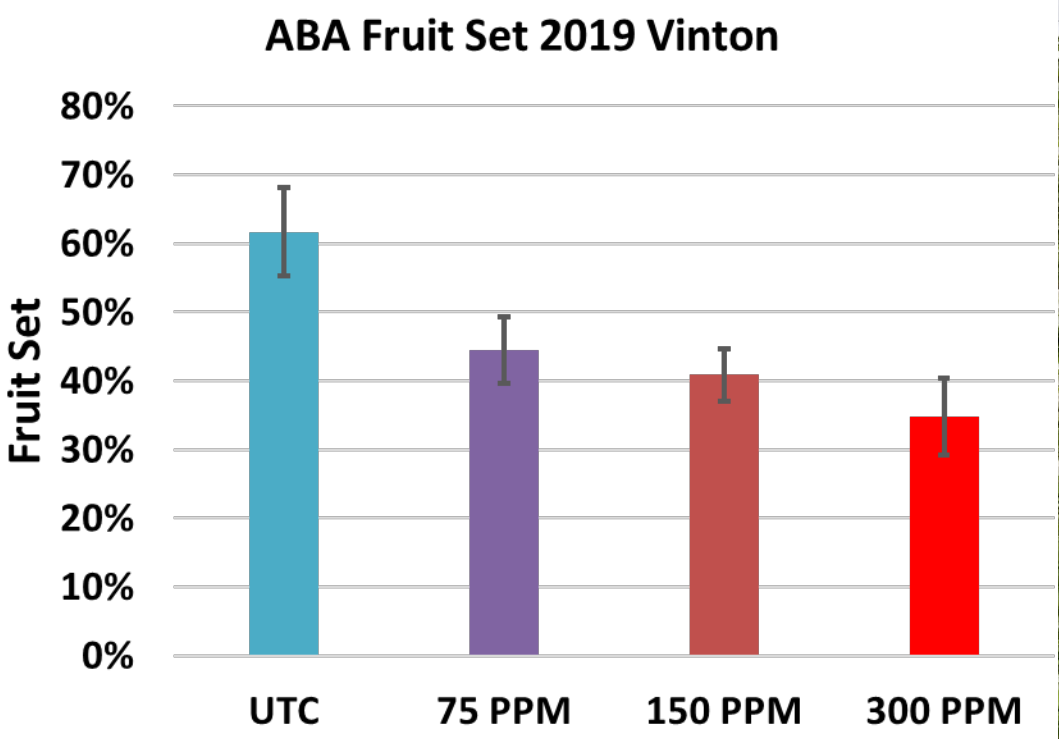


2019 ABA



- 300 ppm reduced Control fruit set by 50%
- 3 apps (every 10 d)

Summary of 5 ABA Pear Thinning Trials
Percent of Control Fruit Set

ABA (ppm)	2012 Hood River 8-year-old	2013 Hood River 18-year-old	2013 Parkdale 10-year-old	2014 Hood River 19-year-old	2014 Hood River 10-year-old
0	100	100	100	100	100
50		100	71	95	
100		100	57 *	86	
125	59 *				65 *
150		96			
200		78	18 *	79 *	
250	12 *				
400			7 *	58 *	
500	2 *				

ABA applied between 10 to 12 mm fruit diameter.

- 125-250 ppm between petal fall and 12 mm fruitlet diameter- 0.1% surfactant (Regulaid) ~100 gal/a

New and Future THINNERS

- ABA
- METAMITRON (aka, Brevis)
- ACC

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2017 Metamitron: Fruit set

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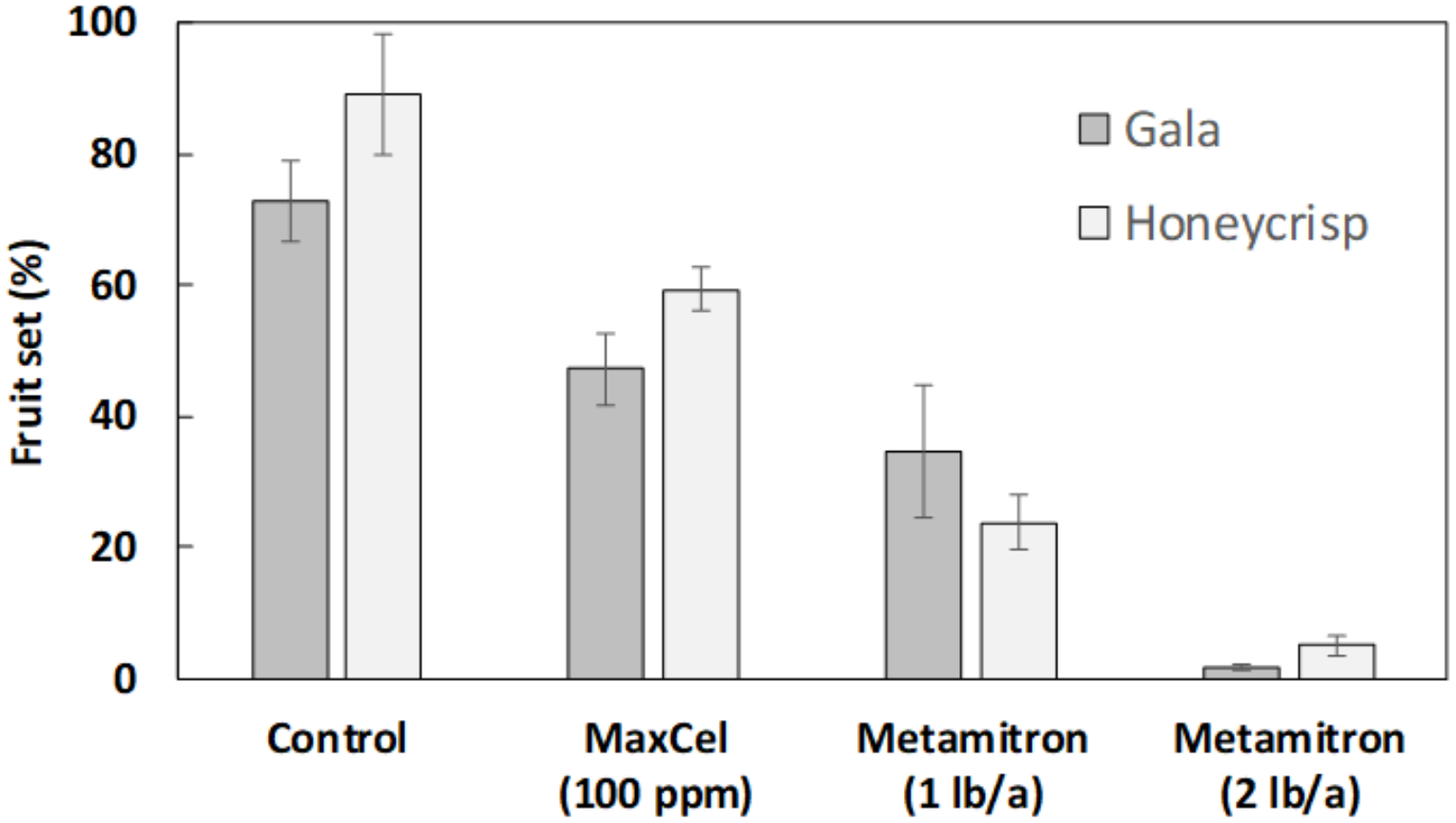

- Applied to whole-canopies at ~11 mm
- Thinning response of Gala and Honeycrisp similar
- Thinning was responsive to rate

2017 Metamitron: Yield

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Gala- target 200 fruit/tree

Effect of metamitron and BA on Gala yield and fruit weight.

Treatment	Yield		Avg. fruit wt.
Thinners applied at 10 mm	(lb/tree)	(no./tree)	(g)
Control	129.9 a	518 a	126.2 d
BA (100 ppm)	81.8 b	262.8 b	148.6 c
Metamitron (1lb/a)	60.1 bc	135.6 c	169 b
Metamitron (2lb/a)	8.7 d	30.8 d	192.1 a

means are based on 7 two-tree replicates

means assigned different letters within columns are significantly different at $P<0.05$, HSD

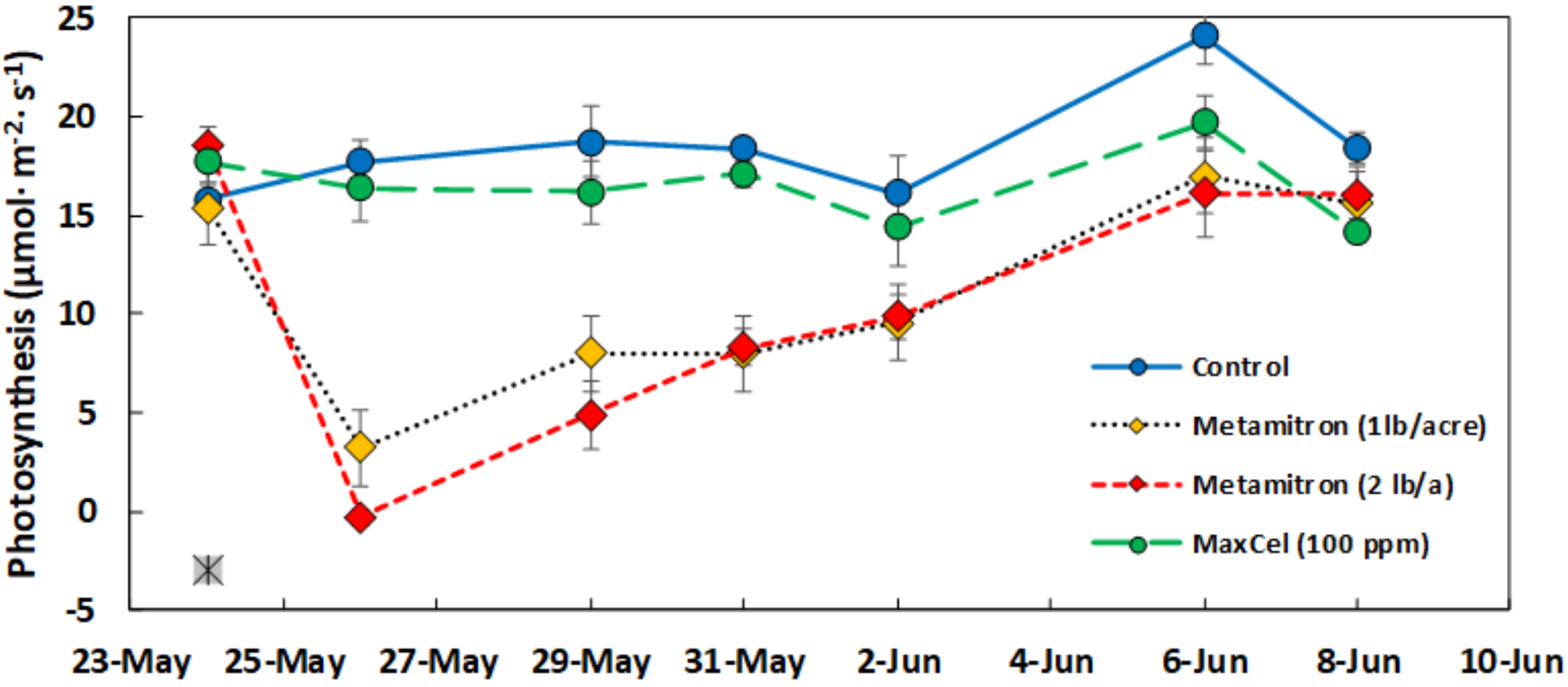
– Low rate of Metamitron (1 lb/a) over-thinned

Control **BA**

Metamitron

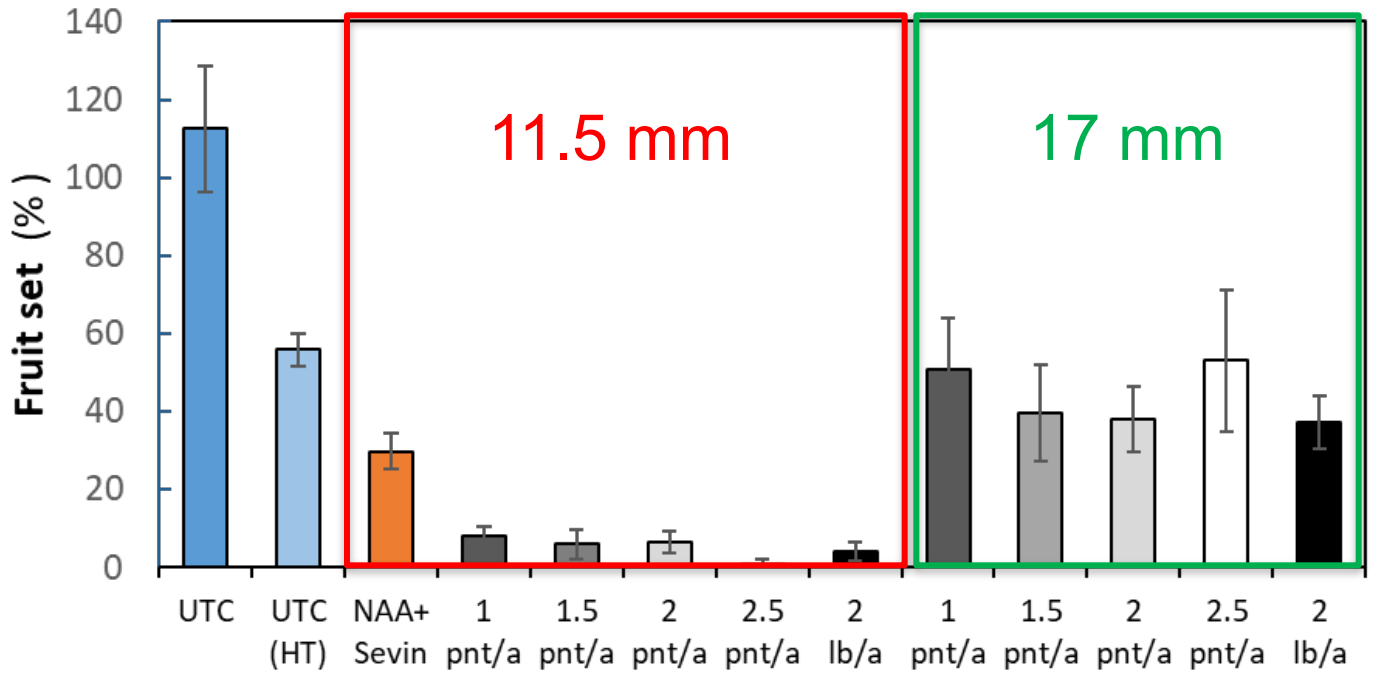
1 lb/a **2 lb/a**

2017 Metamitron: PN



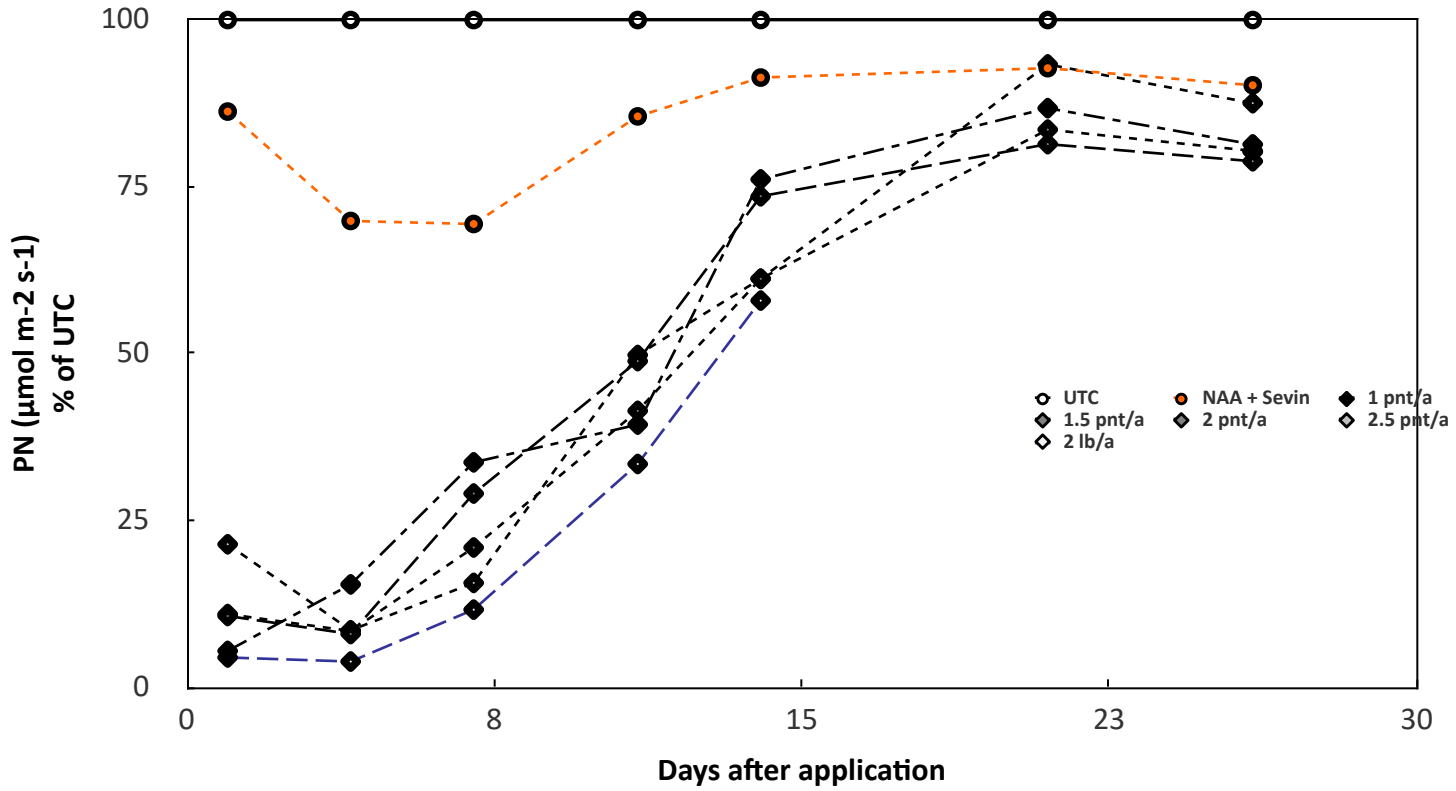
- The mode of action is PN inhibition
- Spur leaves chlorotic at 2 lb/a (but reversible)
- Persistent ~14 d

2018 Metamitron: Fruit Set



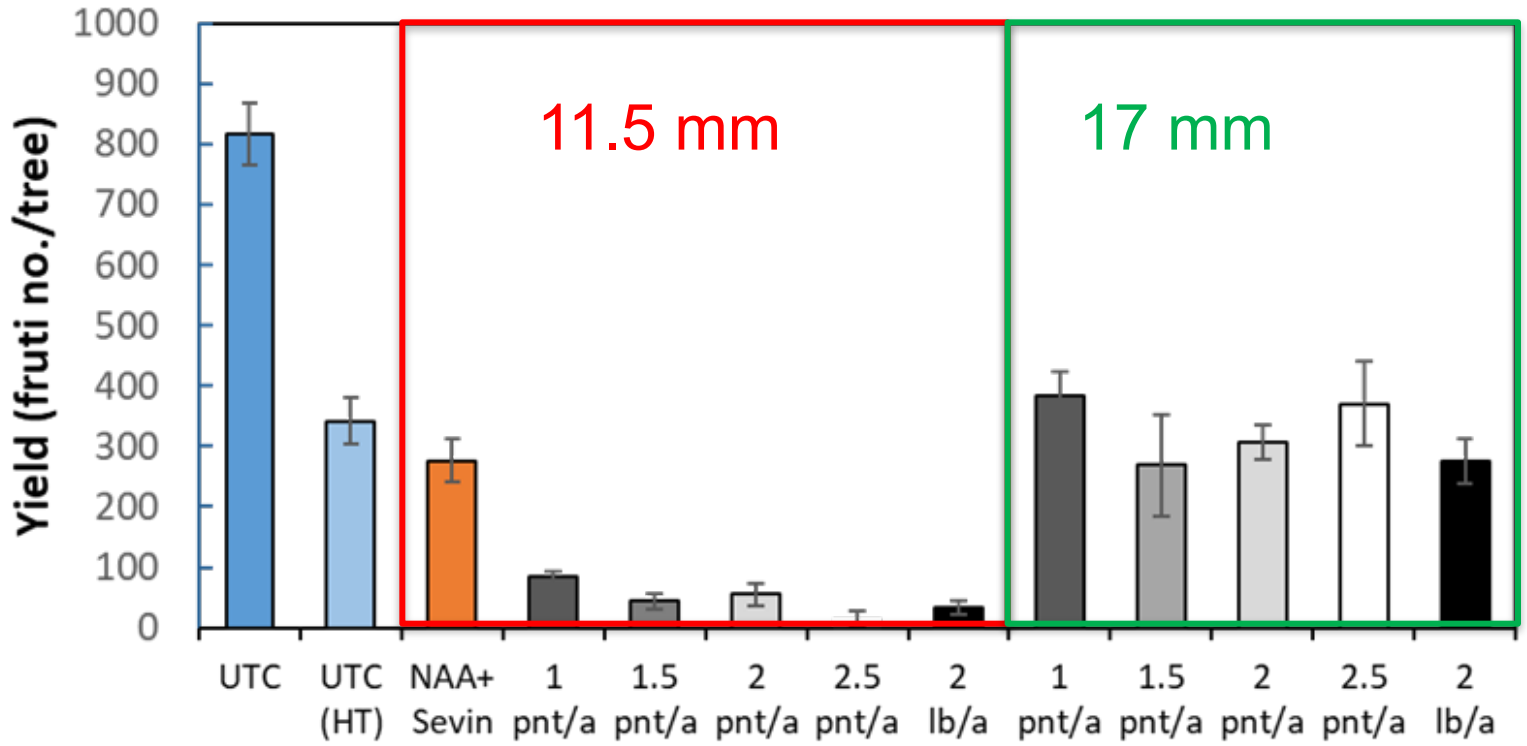
- SEVERE over-thinning at 11.5 mm (85°F)
- Thinning at 17 mm was excellent
- NO Rate Response at either timing
- NAA thinned well

2018 Metamitron: PN



- In 2018, there was no rate response
- Metamitron can be very persistent in plant…25 days

2018 Metamitron: Yield



- Yield response similar to fruit set
- Target levels achieved when thinned at 17 mm