2018 Metamitron: Phyto

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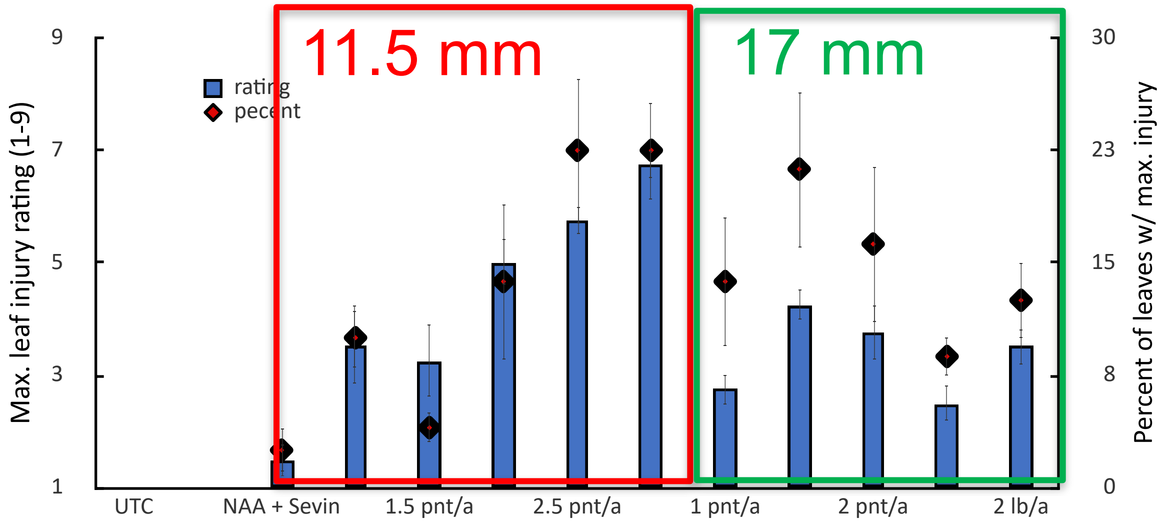
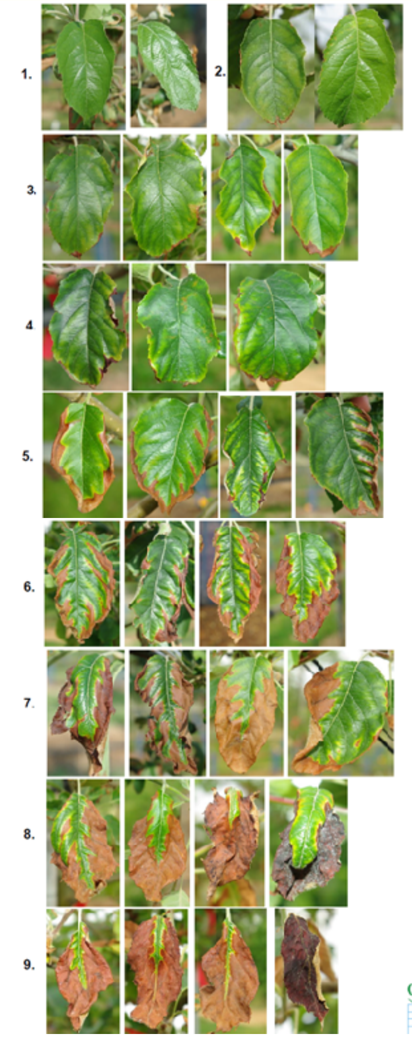
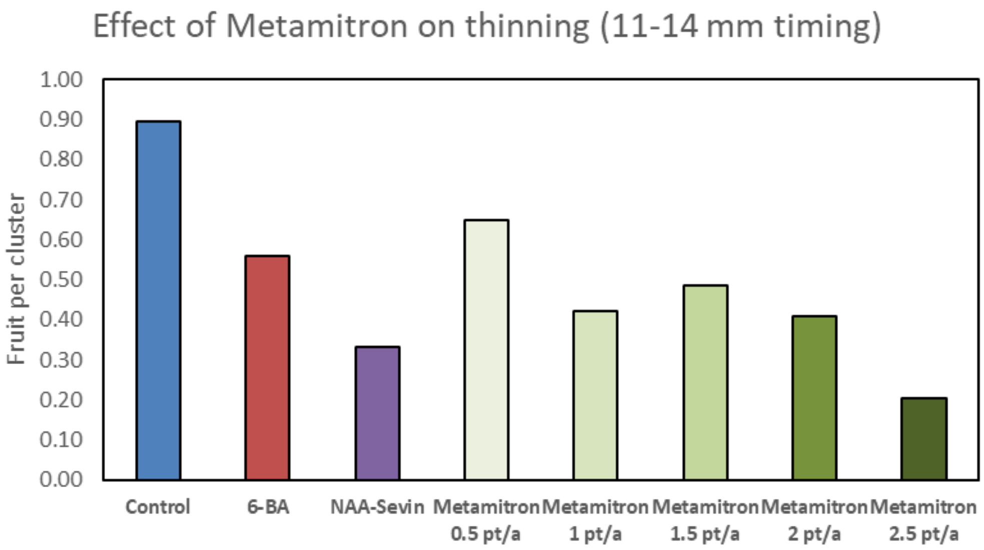




– Metamitron applied during heat led to relatively high levels of phytotoxicity
– Compound does not translocate in plant

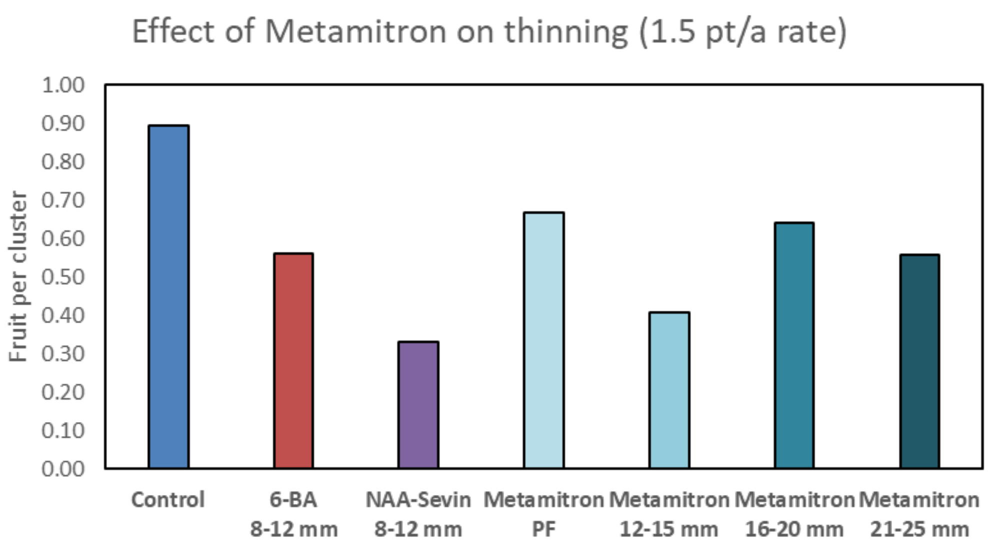
2019 Metamitron: Fruit set



- 2019 rate response more pronounced than 2017 and 2018

- Metamitron thinned quite well across a wide range of fruit developmental stages (petal fall to late, 24 mm)

- Strongest response at 12 mm



2019 Metamitron: Yield

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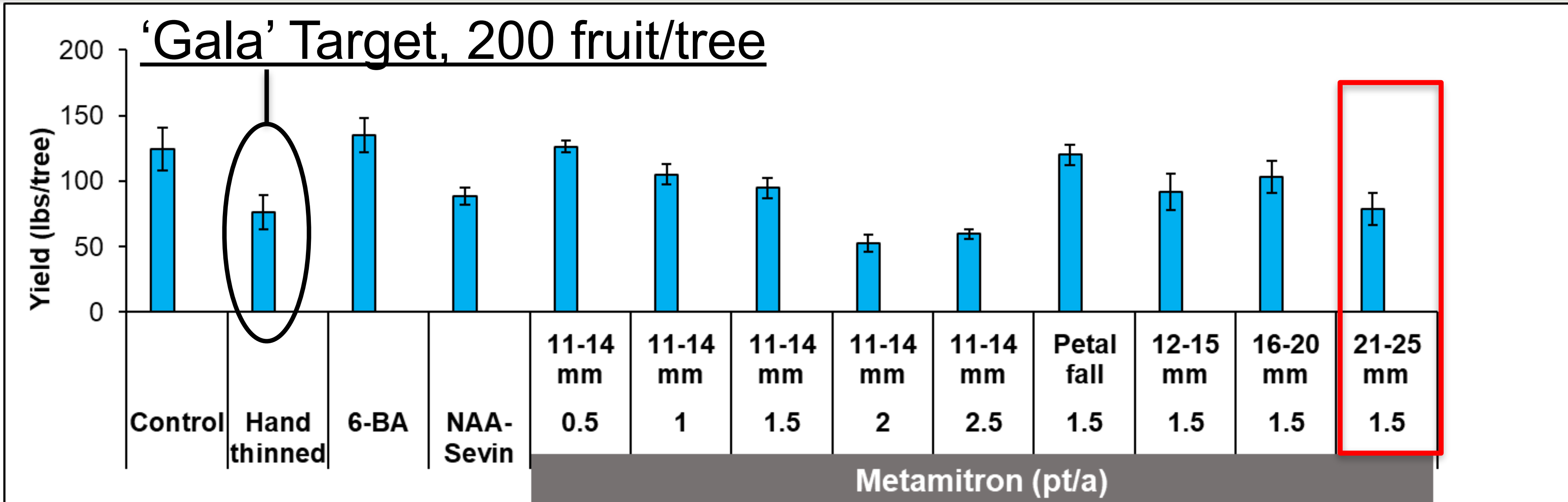

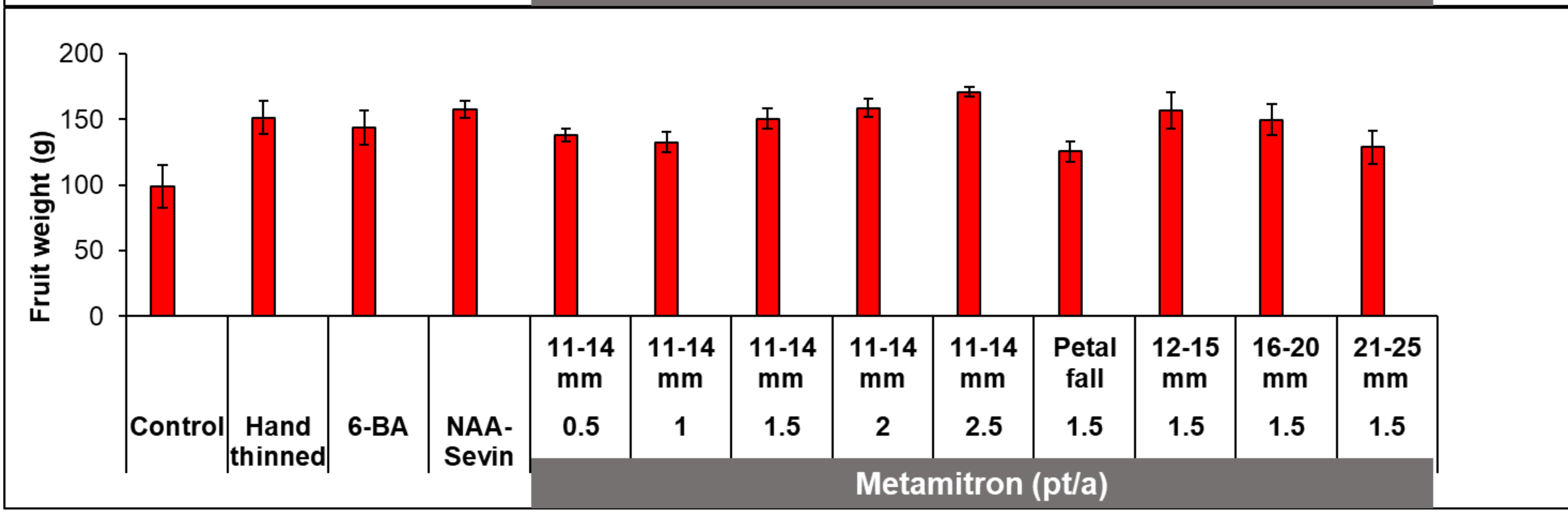

2020 Metamitron: FS, Yield

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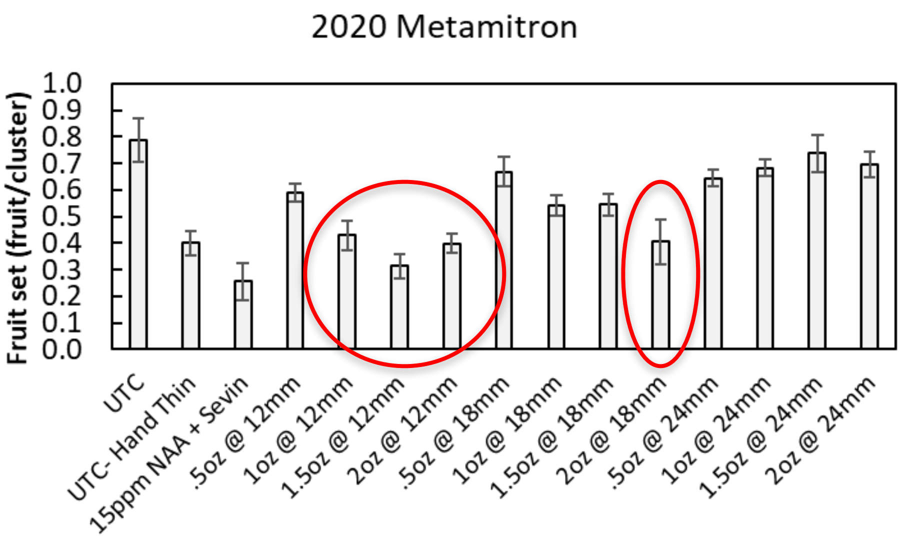
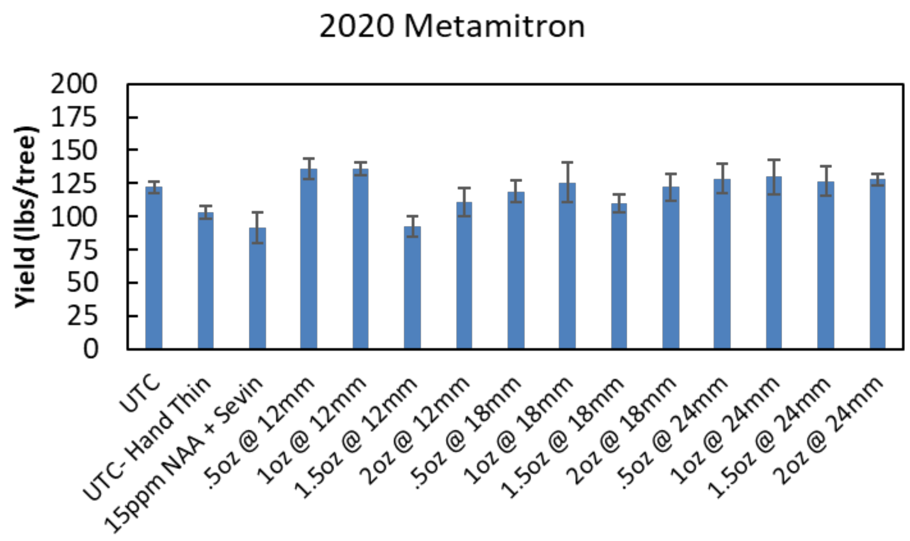


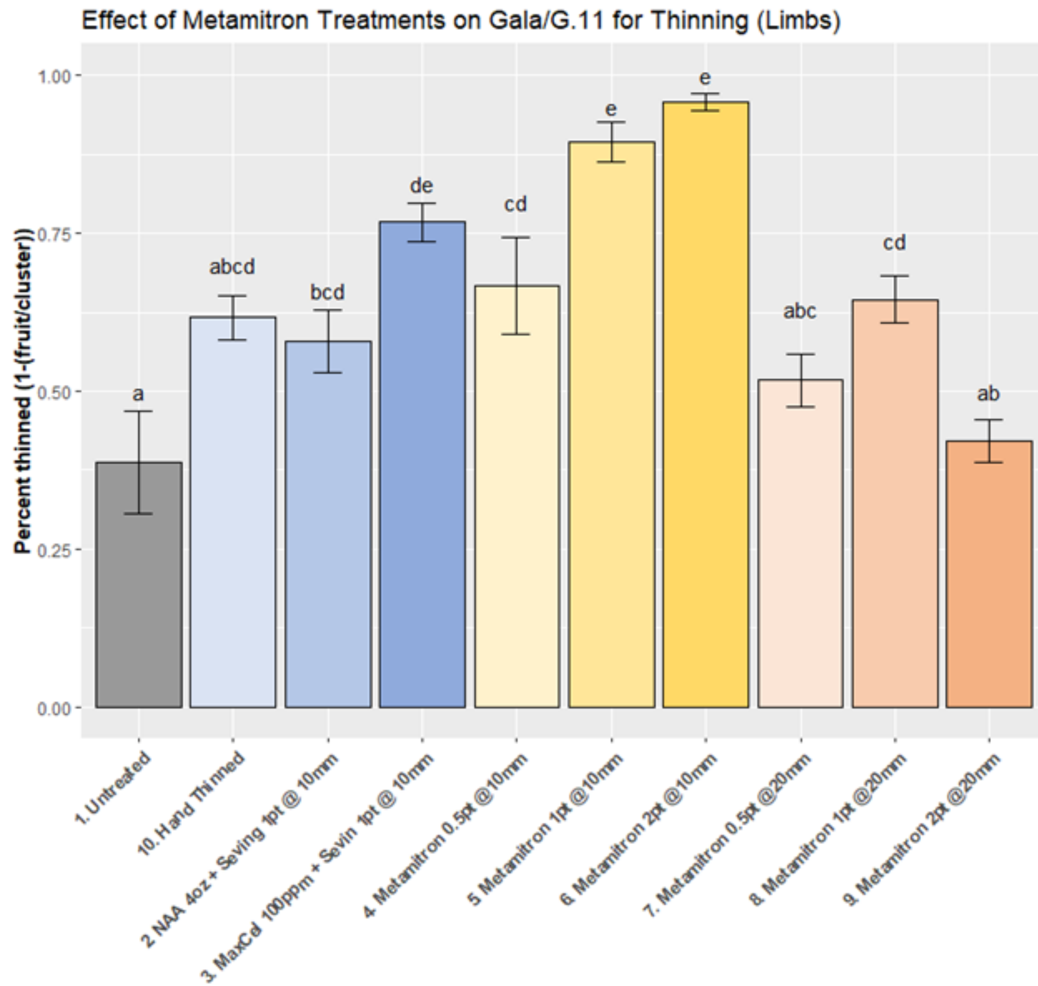


- 2020 rate response detectable
- Metamitron was not efficacious at late timing (24 mm), unlike previous year
- Strongest response was observed at 12 mm

2021 Metamitron

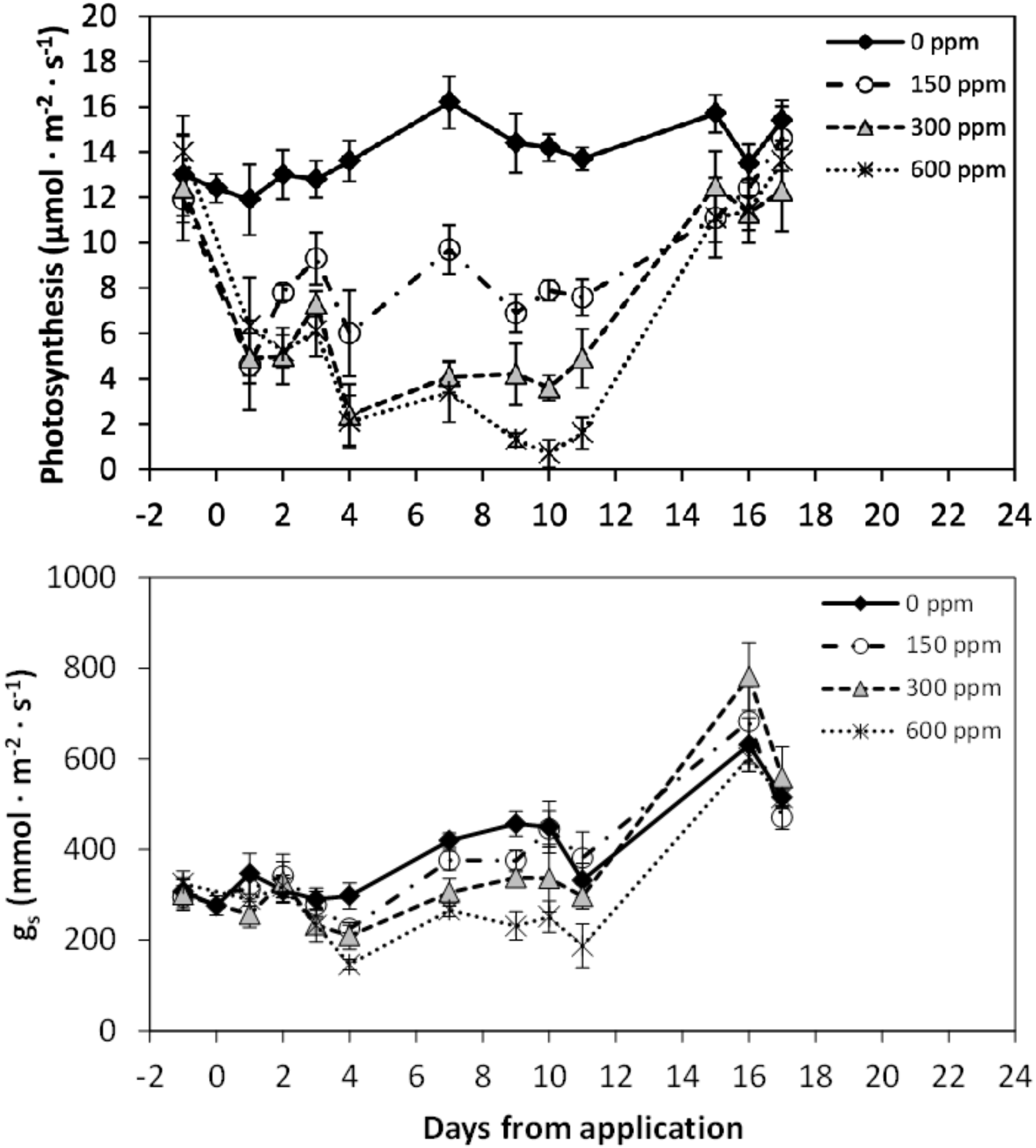
5-yr summary (2017-2021)

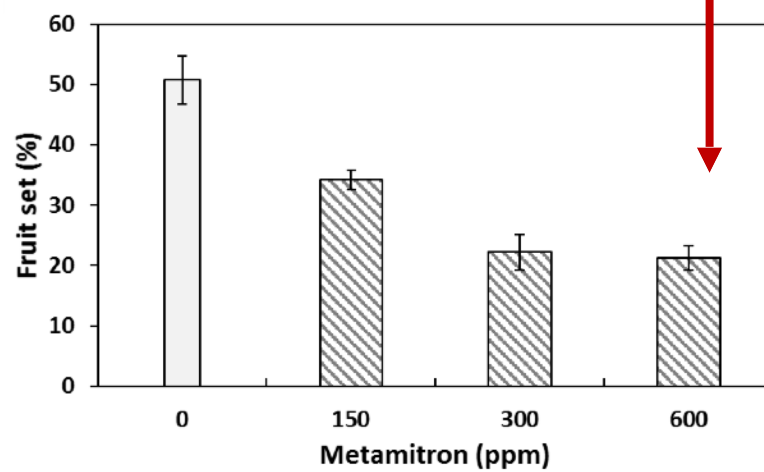
- Early rate response was poor (possibly an issue with formulation)
- Moderate to high rates (recommended) generally overthinned
- Efficacy at moderate to low rates for a wide range of developmental stages (6 mm up to 20 mm)
- Optimum response at 12 mm



A. Wallis and T. Einhorn

Metamitron Trials (60-year-old Bartlett): Year 1



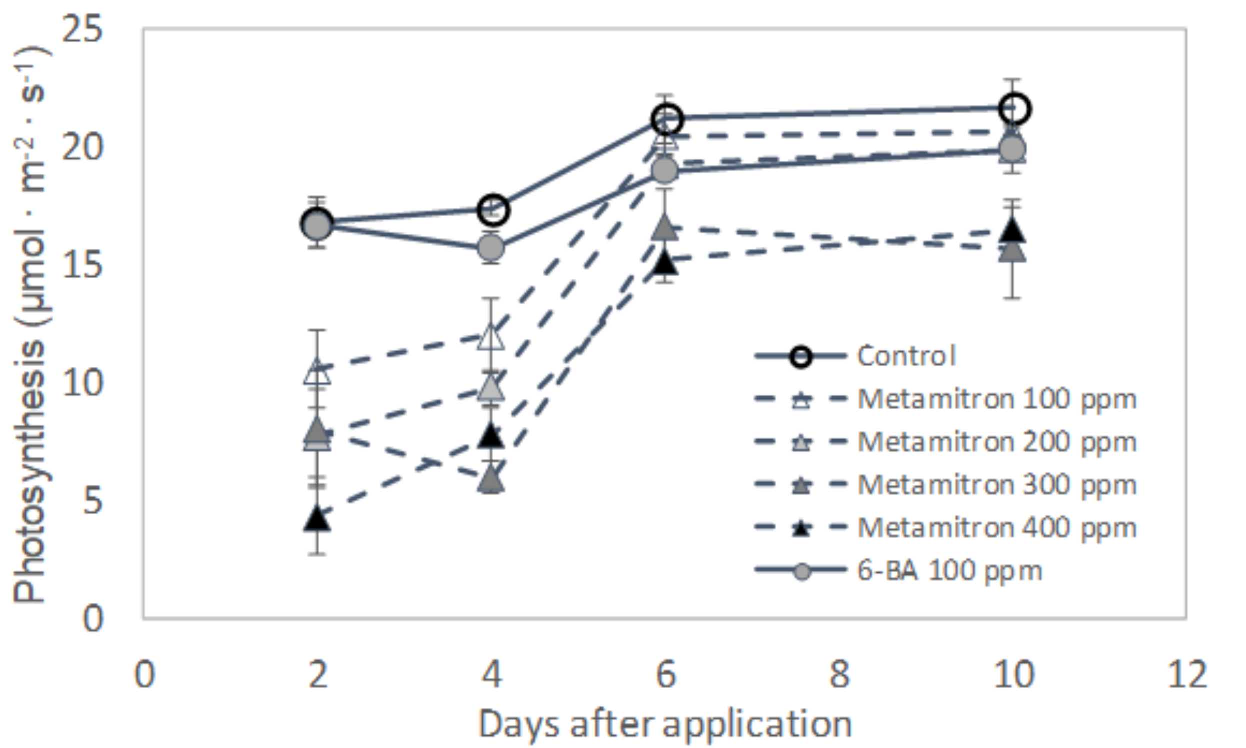


Metamitron Trials (60-year-old Bartlett)

Treatment		Fruit set	Yield		Fruit weight	Fruit volume	SS	TA	FF
Time	ppm	(no./cluster)	(no./tree)	(kg/tree)	(g)	(cm^3)	(%)	(%)	(lb f)
Control		0.51	1021.5	172.0	189.1	923.0	12.1	0.37	17.7
7.2 mm	150	0.46	919.8	160.5	192.3	1181.2	12.1	0.39	17.3
7.2 mm	300	0.43	752.8*	128.1	186.9	1133.2	12.4	0.37	17.2
7.2 mm	600	0.46	734.4*	138.8	210.34*	1214.8	11.5	0.42	17.4
Significant (linear)		NS[z]	*	NS	*	NS	NS	NS	NS
Adjusted R-squared			0.3		0.2				
10.9 mm	150	0.36*	484.6***	102.4***	233.68***	1323.7	12.0	0.44***	18.2
10.9 mm	300	0.304**	436.2***	98.36***	237.92***	1324.6	11.9	0.44***	18.4
10.9 mm	600	0.202***	330***	75.29***	246.92***	1383.0	12.3	0.46***	18.9*
Significant (linear)		***	***	***	***	NS	NS	***	*
Adjusted R-squared		0.64	0.8	0.7	0.7			0.79	0.2
7.2+10.9 mm	150	0.34**	490.4***	109.8***	240.8***	1349.5	11.9	0.41	17.8
7.2+10.9 mm	300	0.22***	393.4***	87.66***	250.6***	1380.1	11.8	0.46**	18.3
7.2+10.9 mm	600	0.21***	342.5***	72.24***	236.53***	1323.0	12.1	0.45**	18.6
Significant (linear)		***	***	***	***	NS	NS	**	NS
Adjusted R-squared		0.73	0.87	0.79	0.20			0.41	

- Early timing had a slight effect at higher rates
- Linear rate response at 11 mm timing

Metamitron Trials (11-year-old Bartlett)



- Excellent thinning with all compounds
- A strong metamitron rate response but saturating ~ 300 ppm

Treatment		Fruit set	Before Hand Thinning	Hand Thinned	Yield		Avg. Fruit wt.
Product	ppm	(fruits/cluster)	(no. fruit/tree)	(no. fruit/tree)	(lbs/tree)	bins/acre	(g)
Control	0	1.06 a	732 a	227 a	202 a	41	189 c
Metamitron	100	0.66 b	703 a	219 a	201 a	41	196 bc
Metamitron	200	0.65 b	550 ab	162 ab	168 ab	34	206 ab
Metamitron	300	0.55 b	387 b	100 b	126 b	26	197 abc
Metamitron	400	0.59 b	424 b	101 b	146 ab	29	214 a
6-BA	100	0.44 b	415 b	115 b	136 b	27	213 ab
Pr>F		*0.0002*	*0.011*	*0.0007*	*0.05*		*0.027*

New and Future THINNERS

- ABA
- METAMITRON (aka, Brevis)
- ACC

Precision Cropload Flow Chart

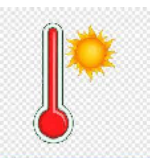
Pruning to Target Bud → Initial Flower Load

Pollen Tube Growth Model → Bloom

Initial Flower Load ↓ Bloom ↓ Petal Fall ↓ 10 mm ↓ 16 mm ↓ Target Fruit Number ↓ Hand Thinning

Carb Model → Petal Fall

Carb Model → 10 mm



Carb Model → 16 mm

Carb Model → Target Fruit Number

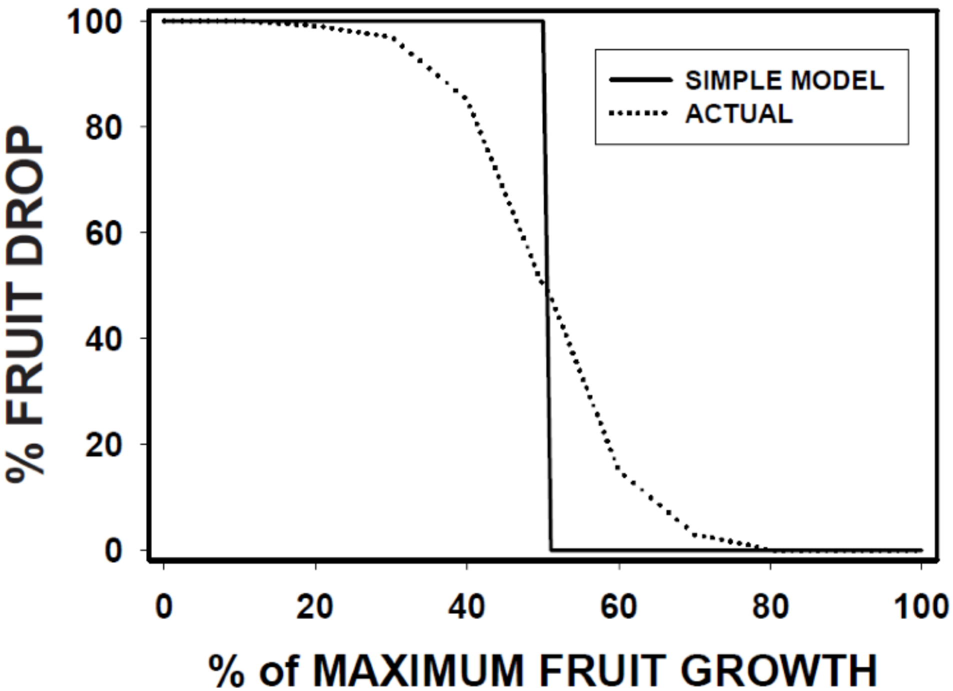
Petal Fall ⇢ Fruit Set Model ⇢ 10 mm

10 mm ⇢ Fruit Set Model ⇢ 16 mm

16 mm ⇢ Fruit Set Model ⇢ Target Fruit Number

Slide based on T. Robinson, Cornell

Prediction of Fruit Set is Based on Actual Fruit Growth Data

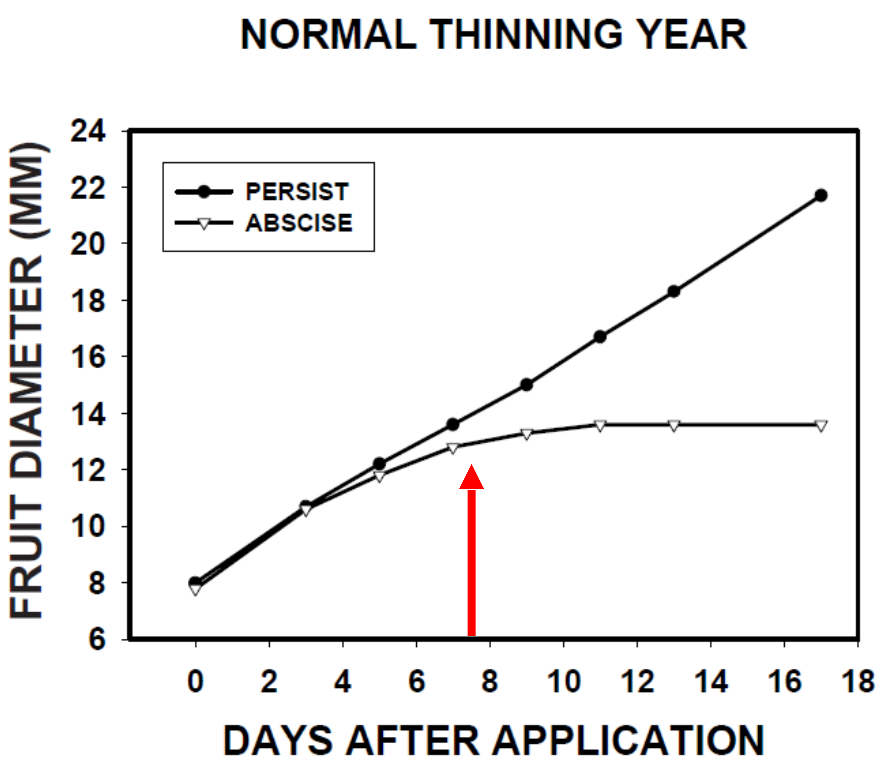


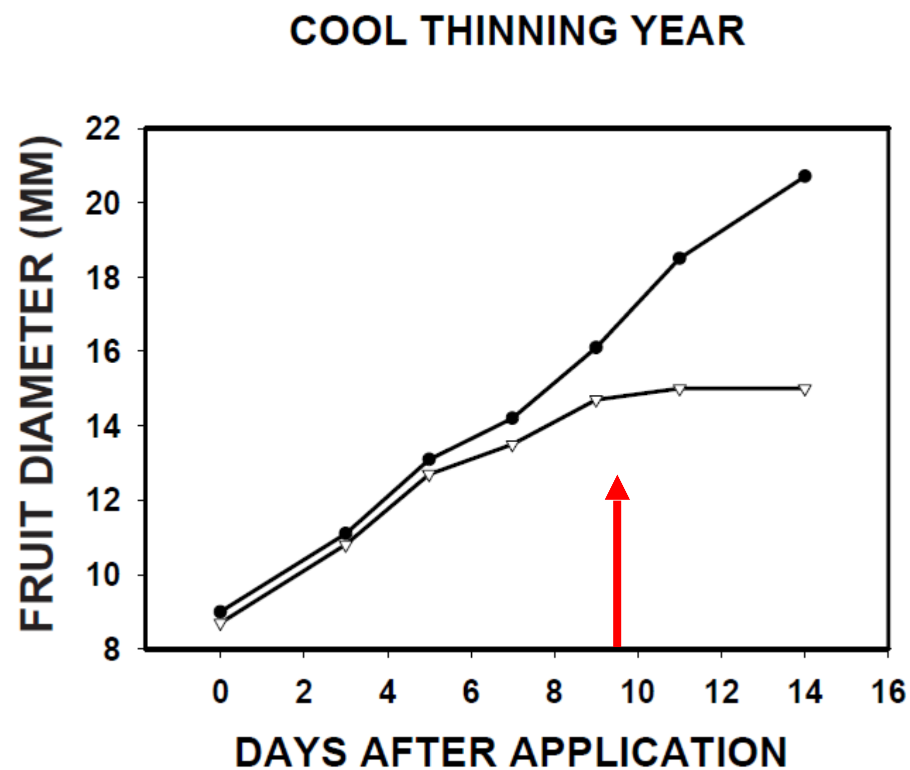
Greene and Lakso, 2005

- Begin 6mm (75 spurs)
- Measure prior to thinning, 3, 6, and potentially 9 days after thinning

- Precision thinning model is based on the principle that fruit whose growth rate is 50% or less than the most rapidly growing fruit will abscise

Prediction of Fruit Set is Based on Actual Fruit Growth Data





Greene and Lakso, 2005

Slowing of fruit growth precedes abscission by 7 to 12 days, depending on environmental factors

FGR Model- Precision Thinning

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- We would like to eliminate repeated measures of fruit
- The FGR model is based on relative growth rates
- Our aim was to develop an alternative approach to predict fruit set by assessing fruit size of a sample population (destructively harvested)
- This approach is less time consumptive than the FGR model and may inform fruitlet imaging technology

How would this work...?

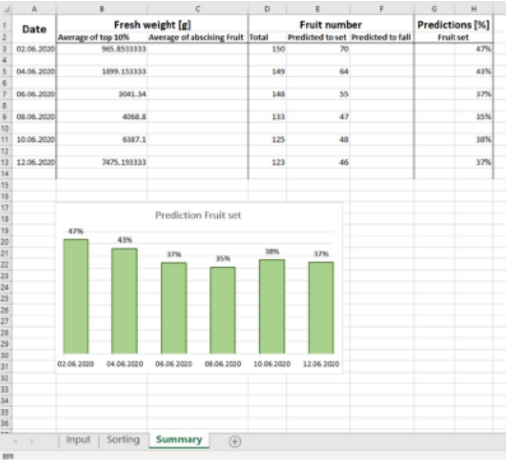
5 trees

100 spurs

100 spurs

Individual fruit from spurs

Single fruit mass imported to Excel

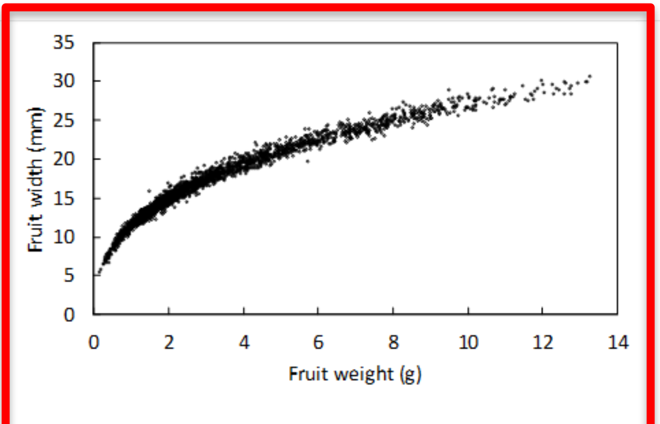


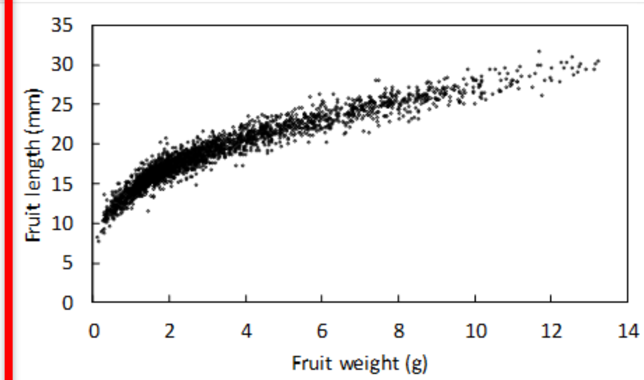
Date	Fresh weight [g]		Fruit number			Predictions [%]
	Average of top 10%	Average of abscising Fruit	Total	Predicted to set	Predicted to fall	Fruit set
02.06.2020	965.8533333		150	70		47%
04.06.2020	1899.153333		149	64		43%
06.06.2020	3041.34		148	55		37%
08.06.2020	4068.8		133	47		35%
10.06.2020	6387.1		125	48		38%
12.06.2020	7475.193333		123	46		37%

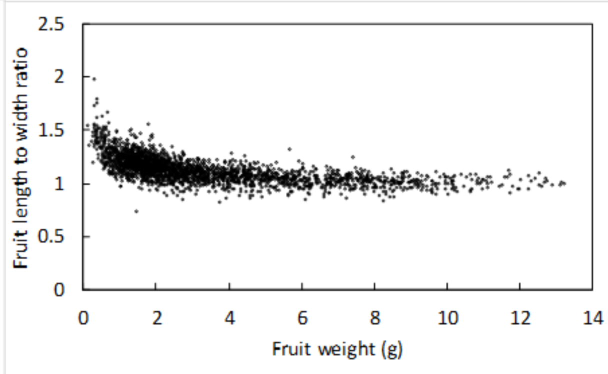
Prediction

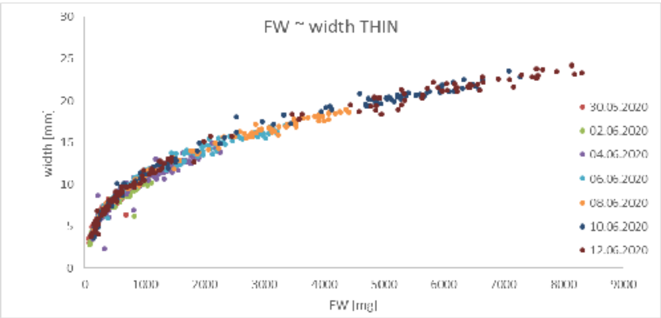
Developing an Alternative Model

Relationship between fruitlet diameter and fresh weight is predictable







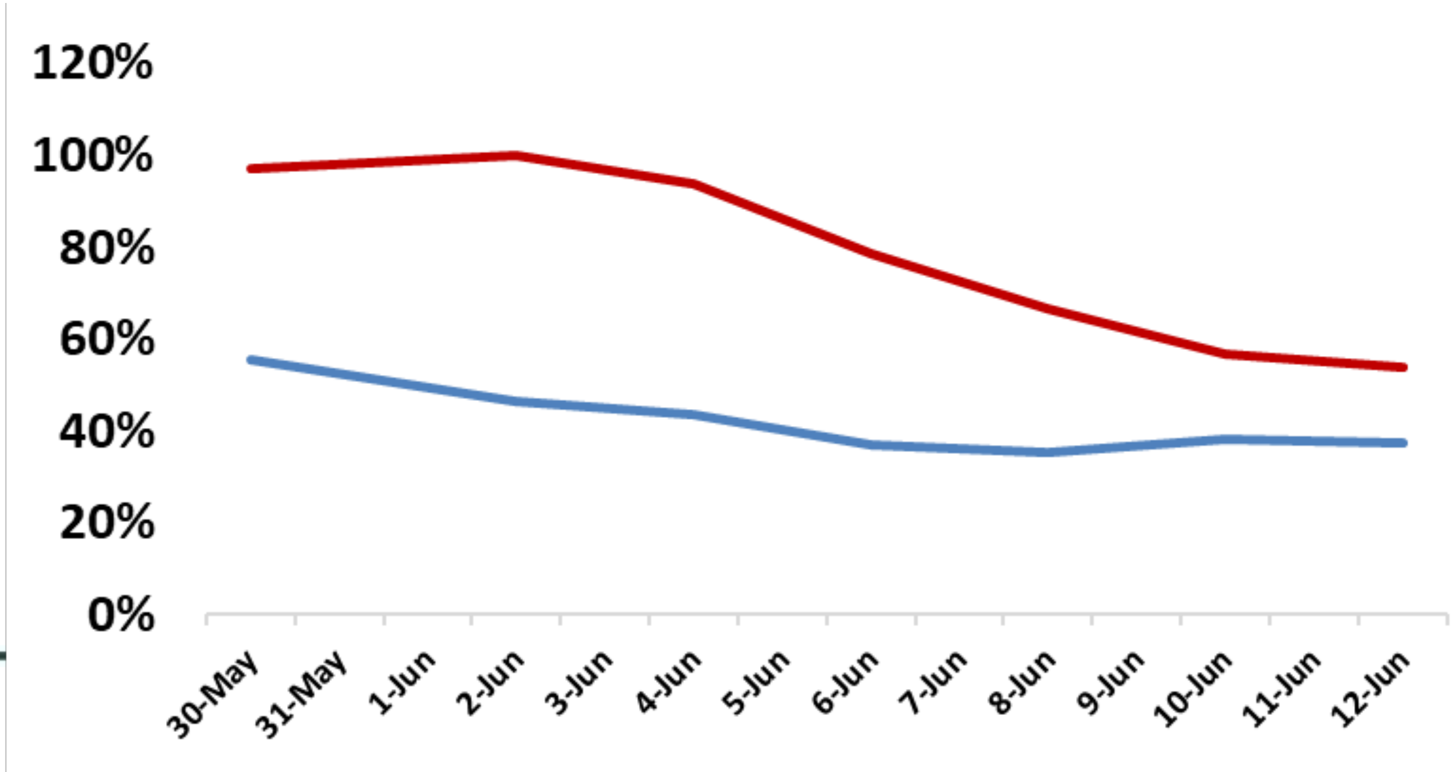


- Relationship provides several options for measurement
- Weighing is likely easier than digital caliper
- Imaging (in the future) is likely easier than weighing

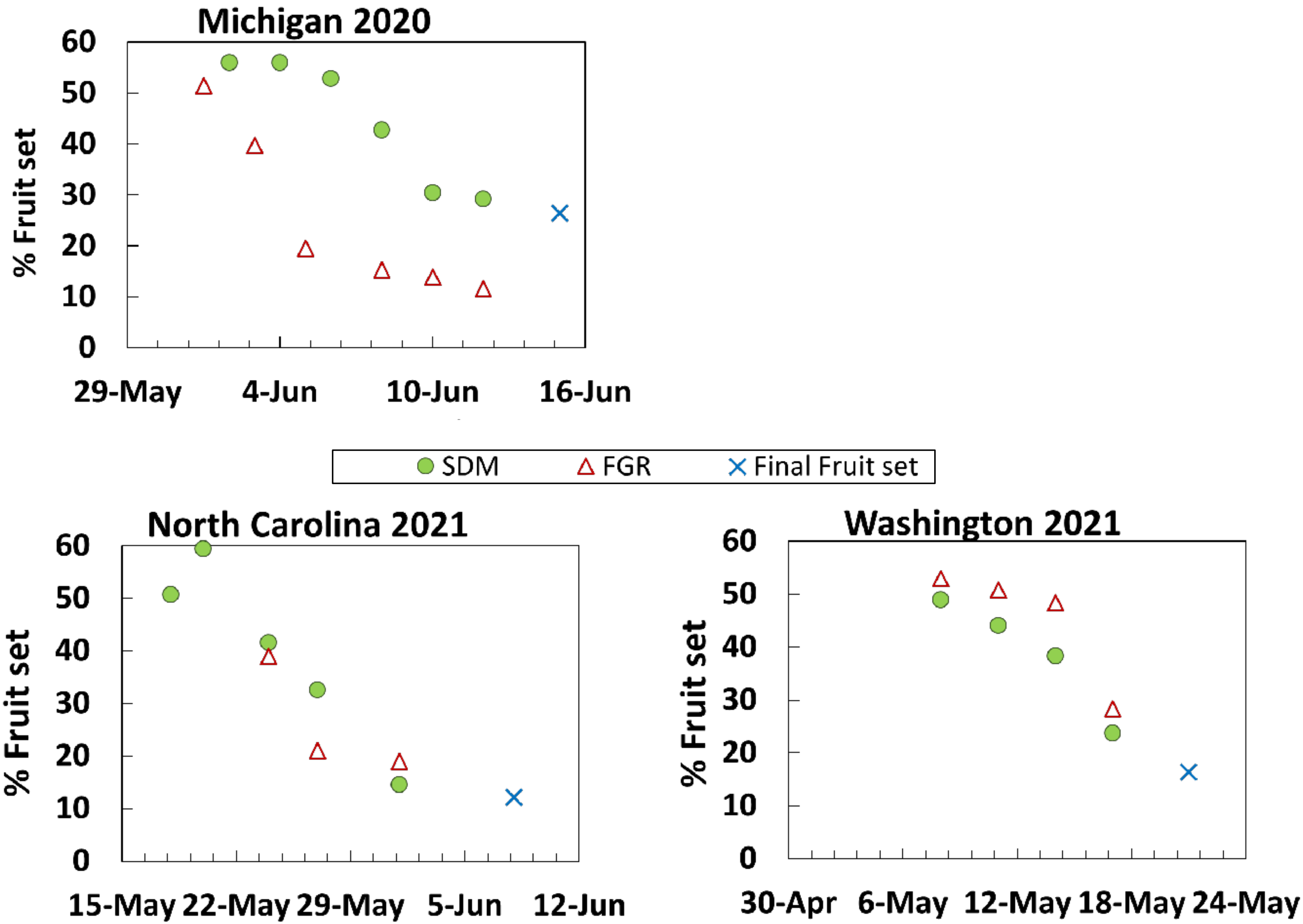
Developing an Alternative Model

Alternative Prediction Model- 100 spurs sample every few days

- Two treatments were compared: Control & 6mm thinner
- Prediction of fruit estimated to abscise based on fruit whose size was ≤50% of the largest fruit (top 10%)
- Actual number of fruit that have already abscised (number of fruit from sampled spurs / no. of spurs * 6 [max, possible fruit])



Predictions-Thinned



Fruit Set Prediction Model Conclusions

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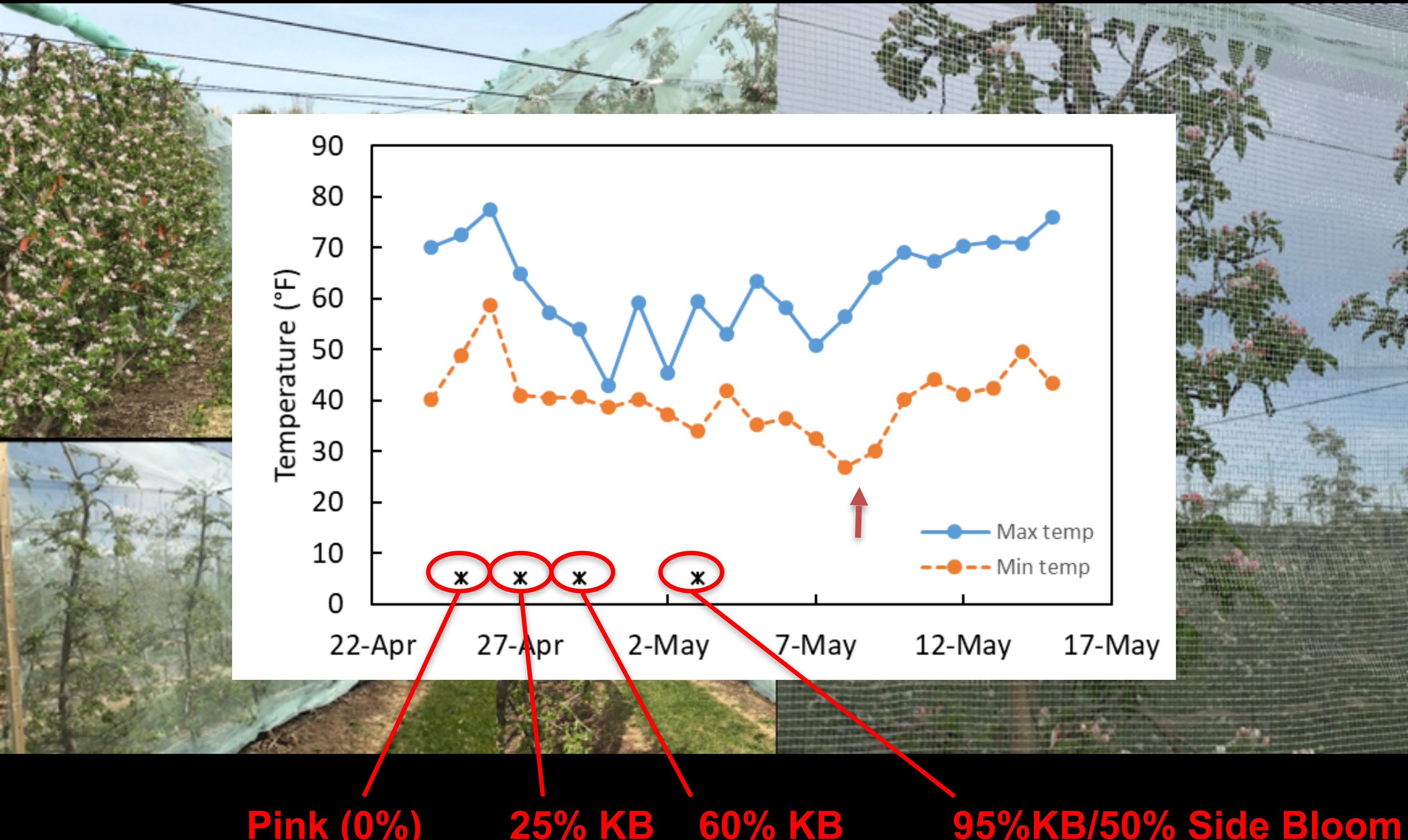
- After two years of data, the proposed model has potential to generate an accurate estimation of fruit set that is markedly more time efficient to implement compared to the FGR model
- Currently the alternative model has similar to improved accuracy in the prediction but lags by ~2-3 days
- Producing an early estimate is critical to any decision support thinning model; a statistical analysis of the data is forthcoming to identify factors that delay the prediction of the proposed size distribution model

Objectives

- Determine if enclosing apple trees in netting at specific percentages of open bloom could reduce pollination, fruit set, and thinning
- A secondary objective was to evaluate the effect of nets on productivity, fruit size, and quality
- *<u>Hypothesis</u>: Netting will produce a range of crop loads depending on the percentage of open bloom accessible to pollinators prior to the time of canopy enclosure.*

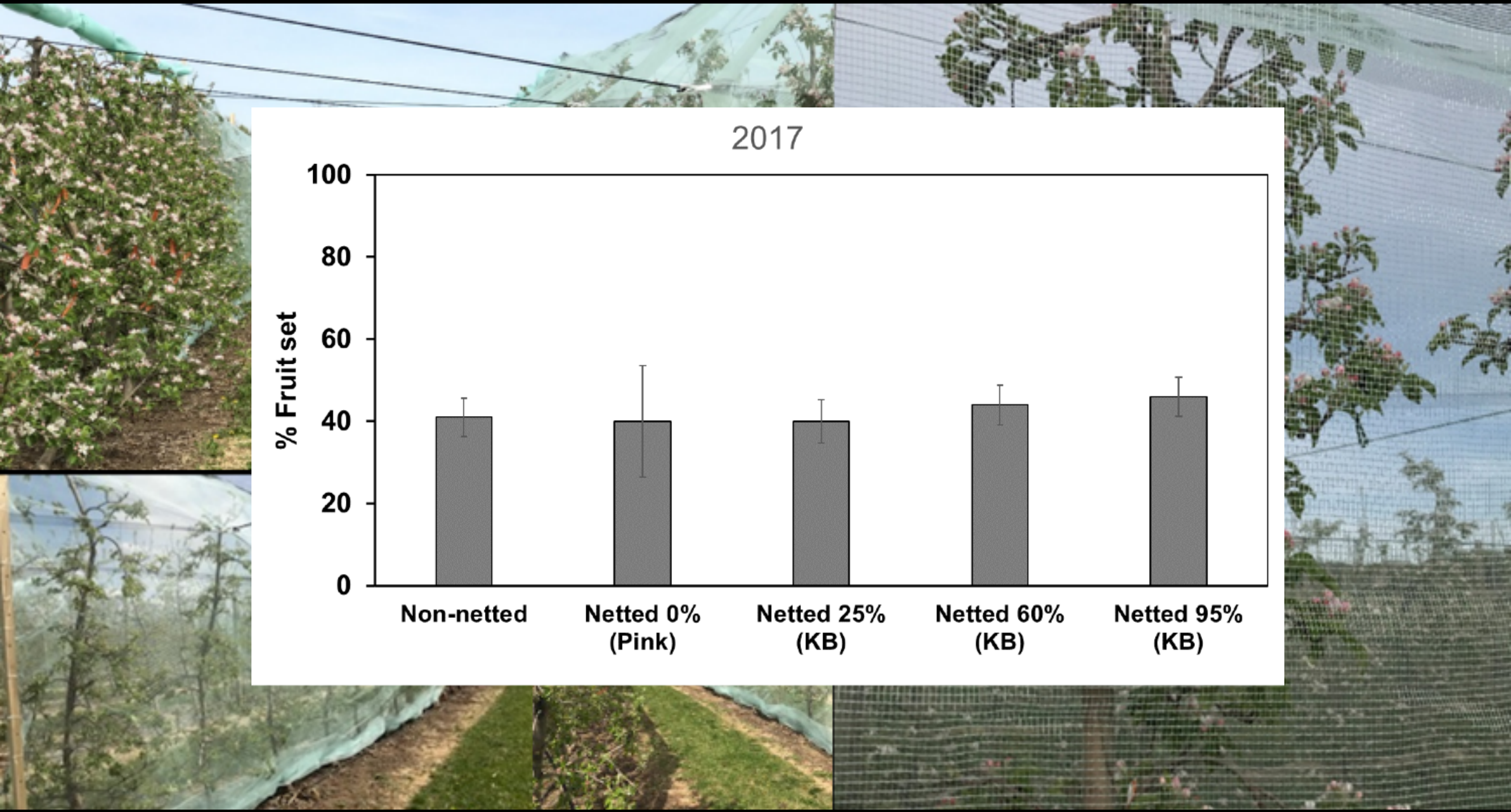
(Photo credit: S. Musacchi.)

2017/2018: Netting Trial to Reduce Thinning Needs: Gala



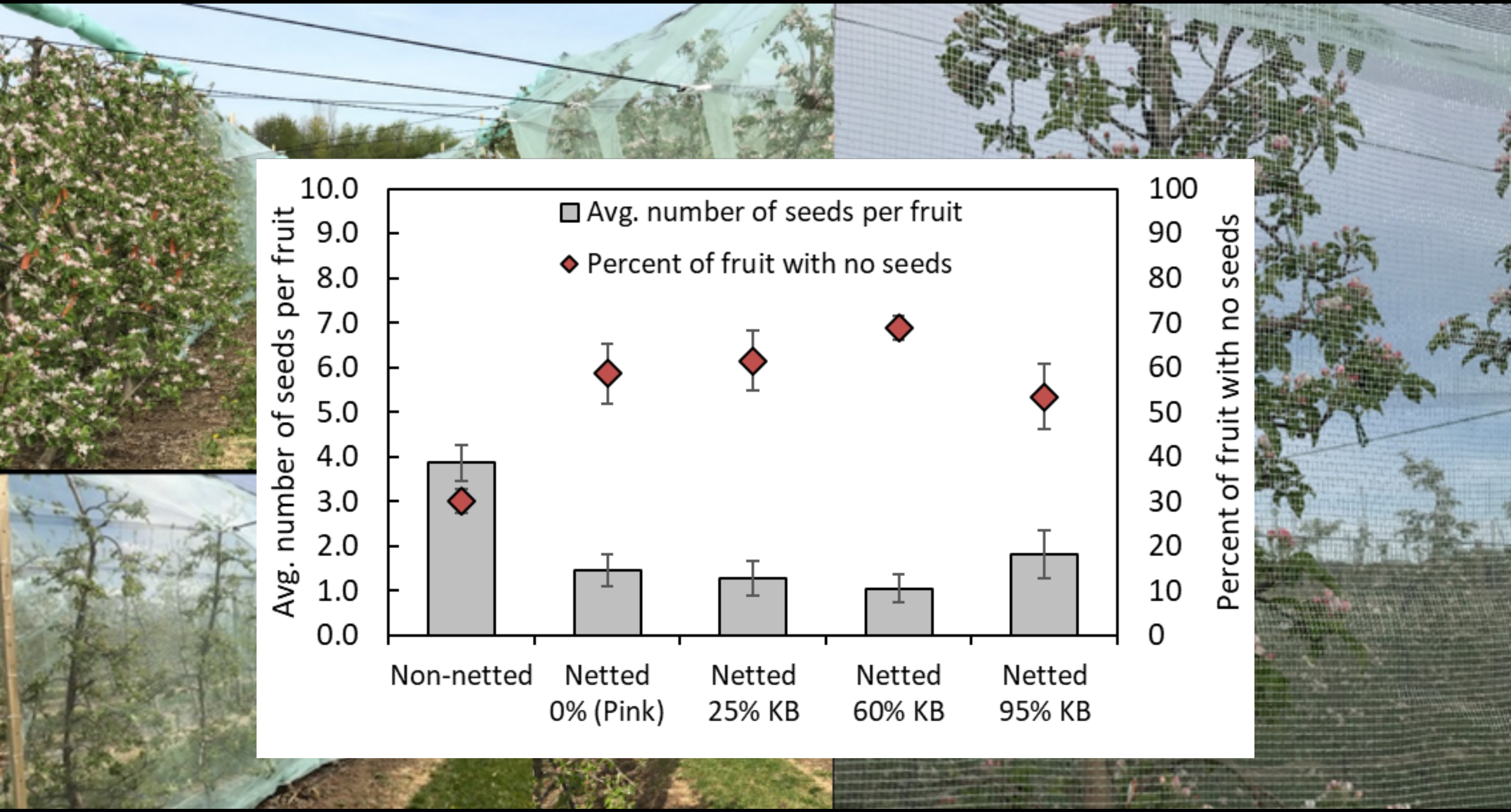
- Nets lowered at predetermined percentages of bloom

2017/2018: Netting Trial to Reduce Thinning Needs: Gala



- Despite netting trees as early as Pink (0% open flowers), netting had no effect on ‘Gala’ fruit set

2017/2018: Netting Trial to Reduce Thinning Needs: Gala



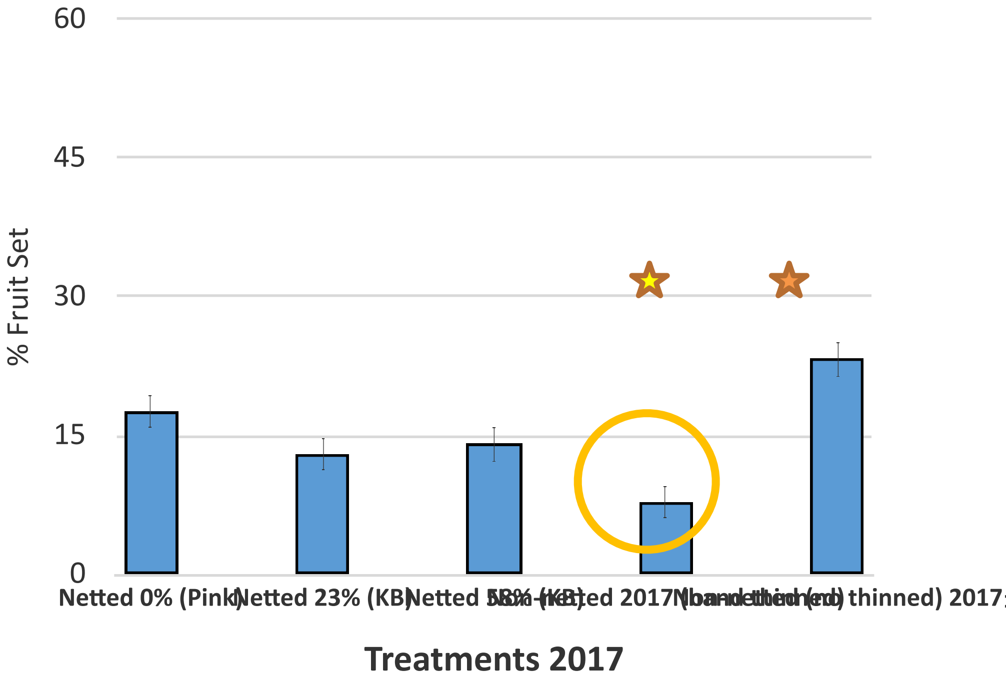
- Netting reduced seed number and increased the percentage of seedless fruit

2017/2018: Netting Trial to Reduce Thinning Needs: Gala

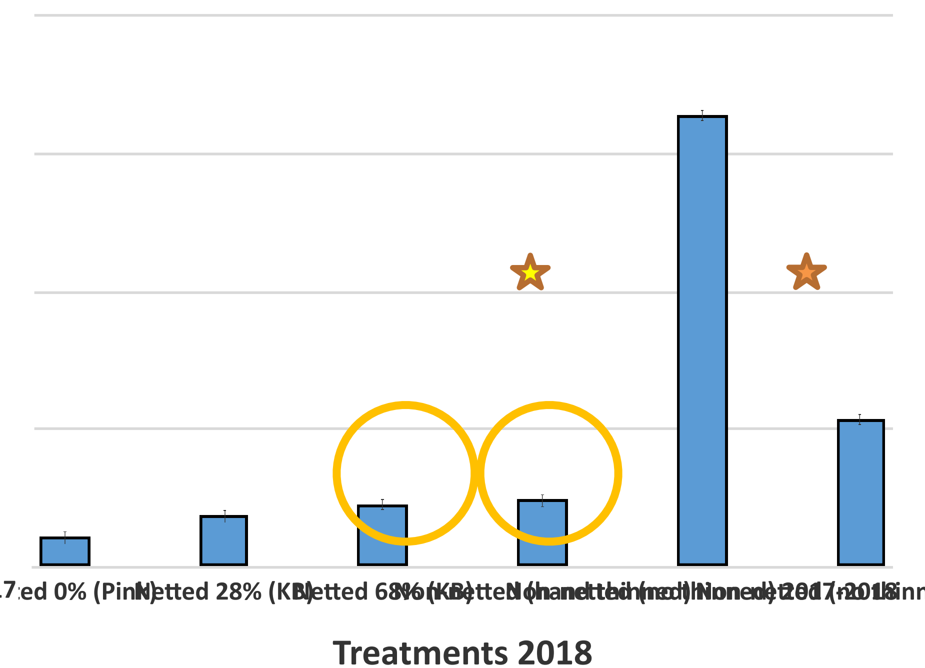
Treatment	Avg. Tree Yield		Fruit weight	Red overcolor	Firmness	SSC	Shape
	(Kg)	(no.)	(g)	(%)	(Kg)	(%)	(l:w)
Non-netted	23.0	181.1	127.2	39	3.83 ay	12.1	1.10
Netted 0% (Pink)	20.6	160.3	128.2	41	3.68 ab	12.0	1.09
Netted 25% (KB)	21.5	164.5	130.5	36	3.57 bc	11.9	1.09
Netted 60% (KB)	21.5	159.0	135.5	33	3.51 c	11.8	1.08
Netted 95% (KB)	20.9	162.6	128.4	35	3.76 a	11.8	1.10

Results: Fruit set (2017-2018)

Honeycrisp (WA) 2017: comparison fruit set %



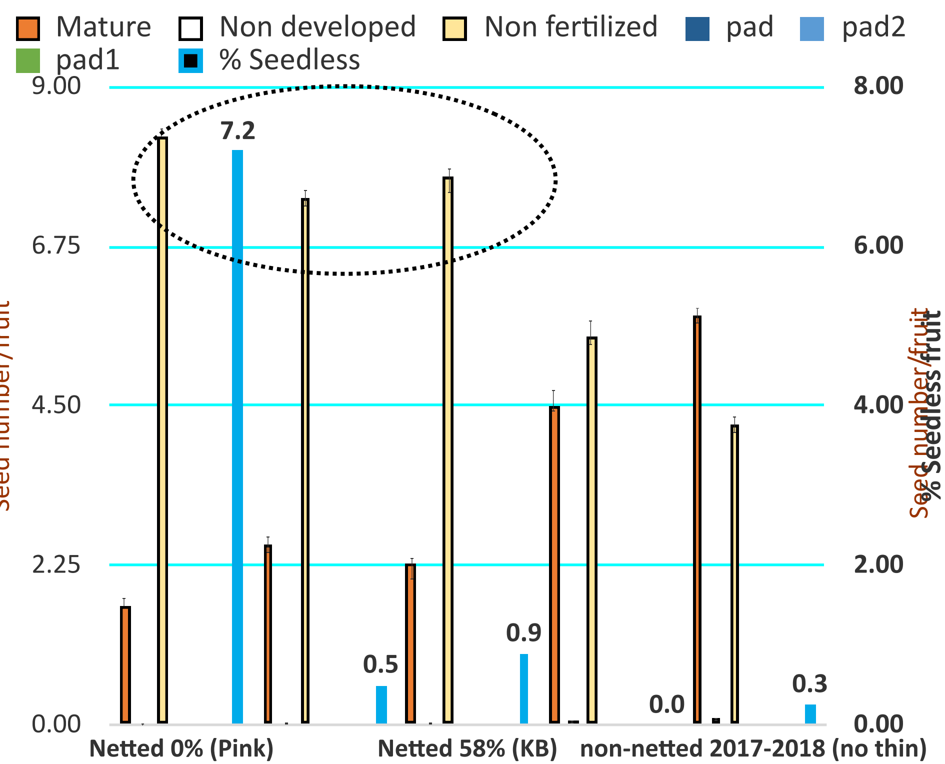
Honeycrisp (WA) 2018: comparison fruit set %

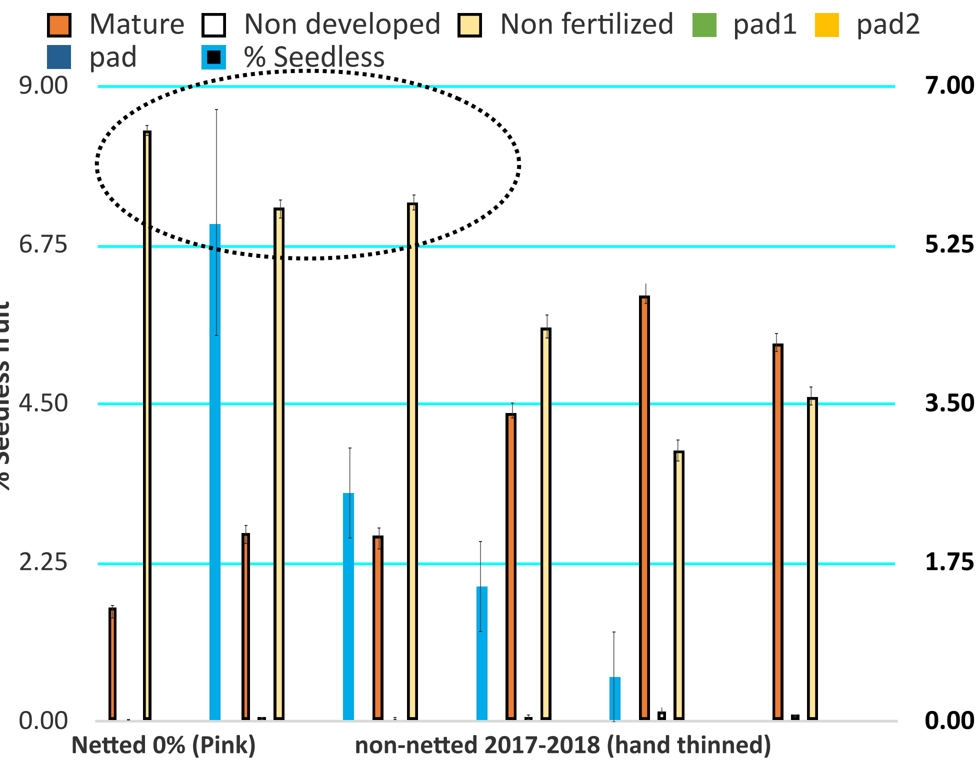


- Fruit set and yield under nets similar to hand thinned non-netted control

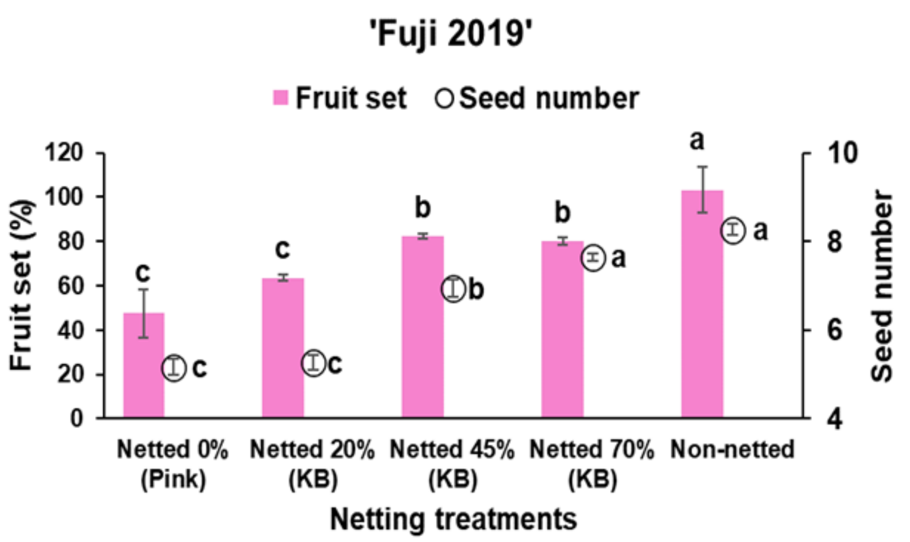
Results: Seed analysis (2017-2018)

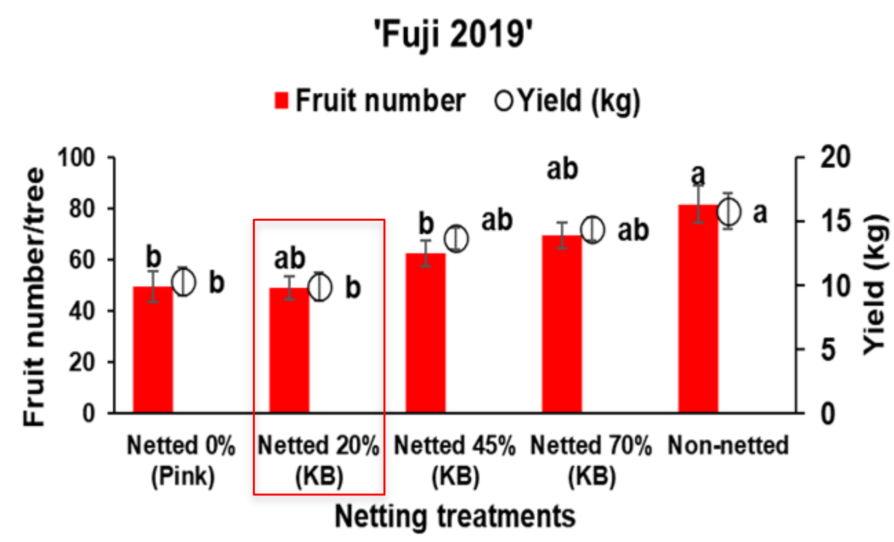
Elsysy, Serra, Schwallier, Musacchi, Einhorn, 2019 Agronomy (submitted)





2019 Netting Trial: Fuji





Treatment Fuji	Fruit wt. (g)	Misshapen L:W	Seeds Mature	Seeds Non-mature	Seeds Non-fertilized
No net	199 b	1.15	7.9 a	0.11	1.05 b
Net Pink	214 ab	1.11	5.6 b	0.18	2.07 a
Net 20%	218 a	1.26	5.1 b	0.12	2.53 a
Net 45%	226 a	1.12	8.2 a	0.07	0.61 b
Net 70%	222 a	1.07	7.9 a	0.09	0.67 b

2019 Netting Trial: Sweet Tango

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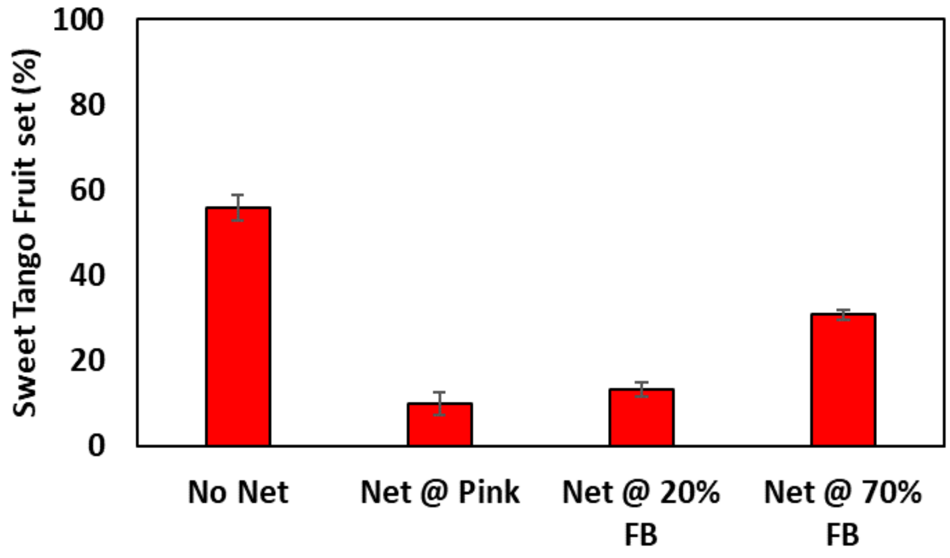
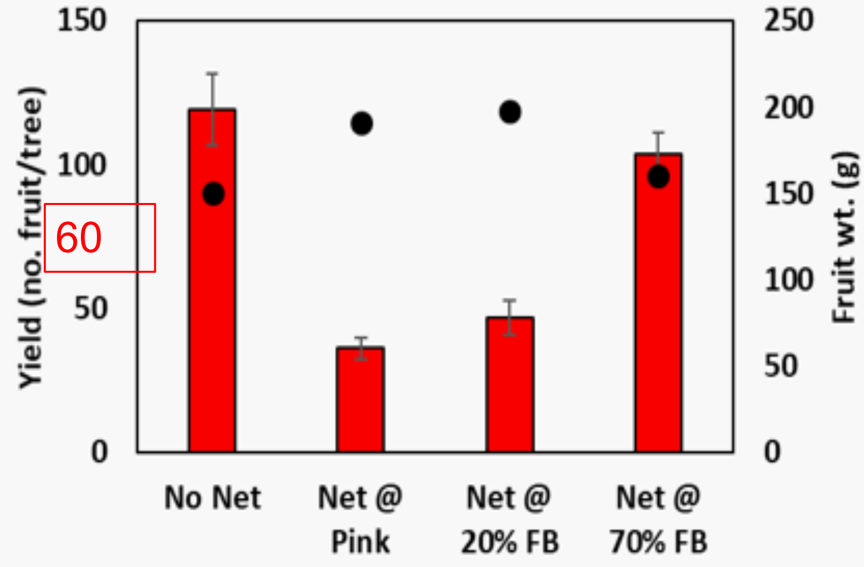
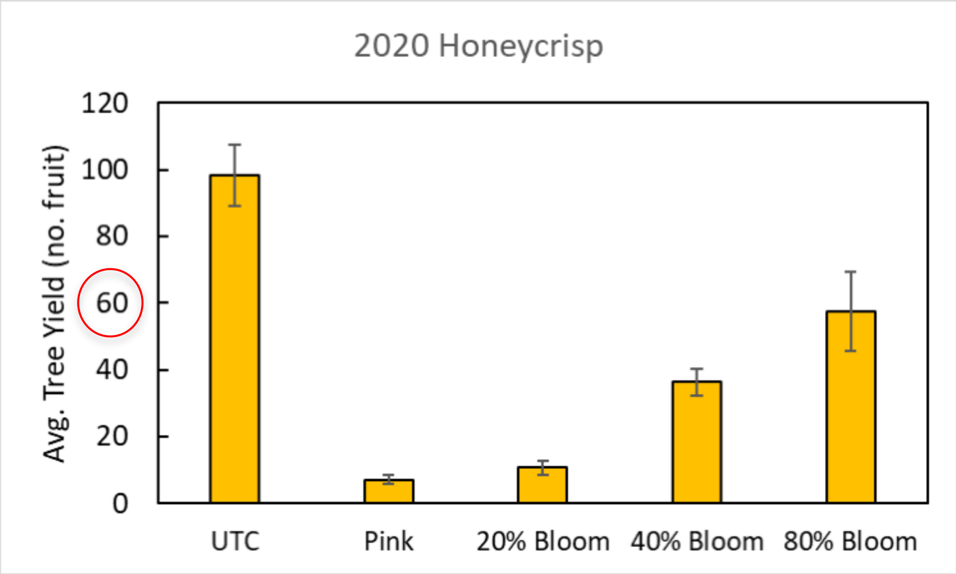
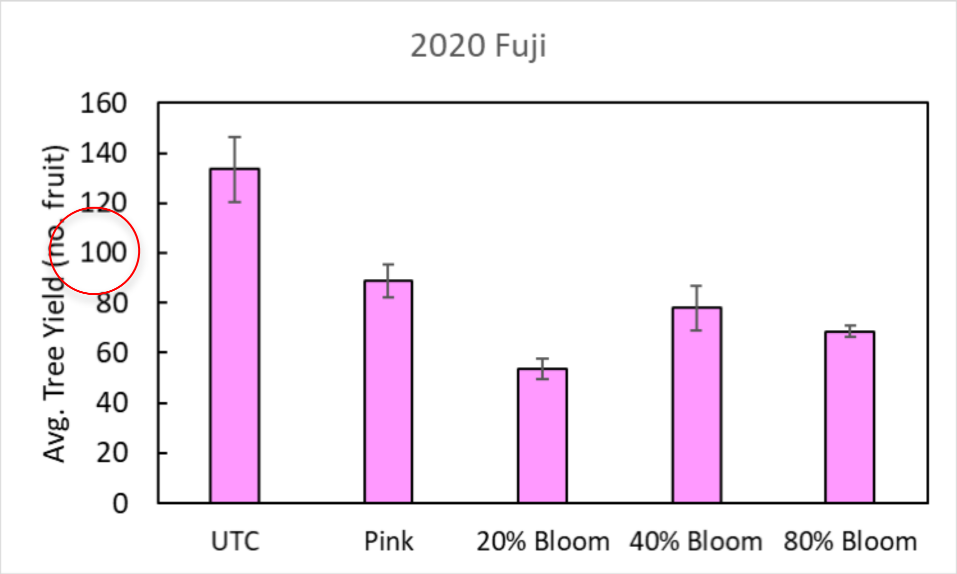




Treatment Sweet Tango	Fruit wt. (g)	Misshapen L:W	Seeds Mature	Non-mature	Non-fertilize
No net	160 b	1.04	5.3 a	0.33 a	3.7 b
Net Pink	197 a	1.03	3.8 b	0.08 b	5.5 a
Net 40%	210 a	1.03	4.1 ab	0.05 b	5.2 a
Net 75%	164 b	1.05	4.4 ab	0.07 b	4.8 ab

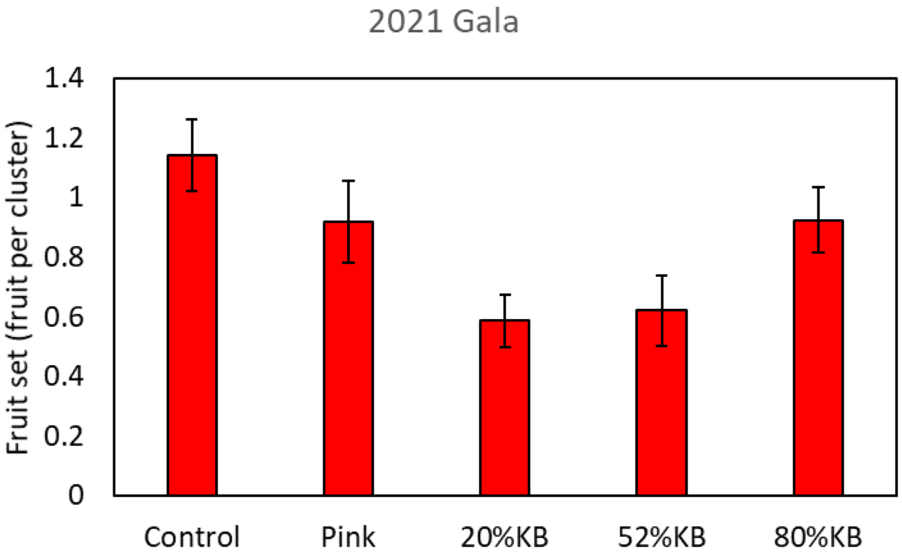
2020 Fuji and Honeycrisp

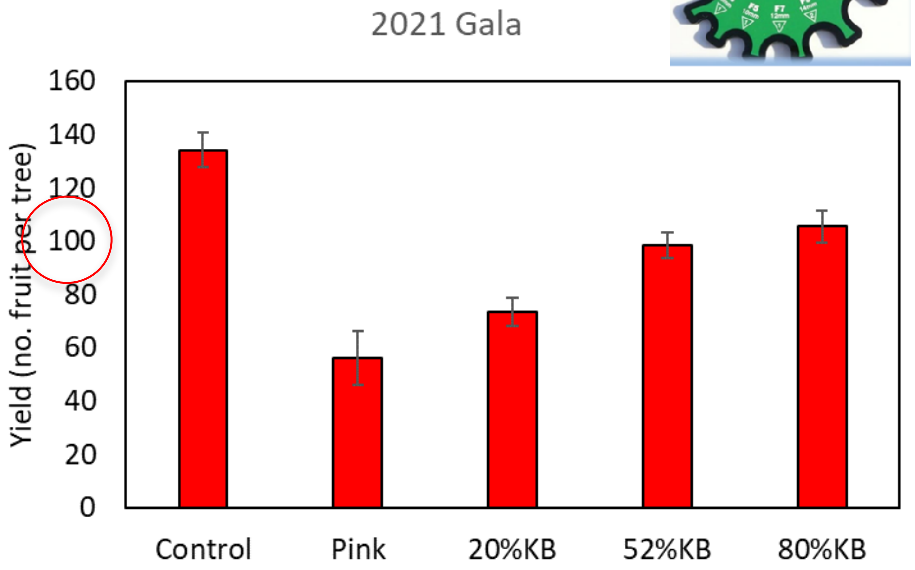




- Similar response to 2019
- Honeycrisp would require greater percent of open bloom, as similarly observed in WA trials
- Fuji seems to have no problems setting netted flowers
- WAA benefiting from exclusion of natural predators

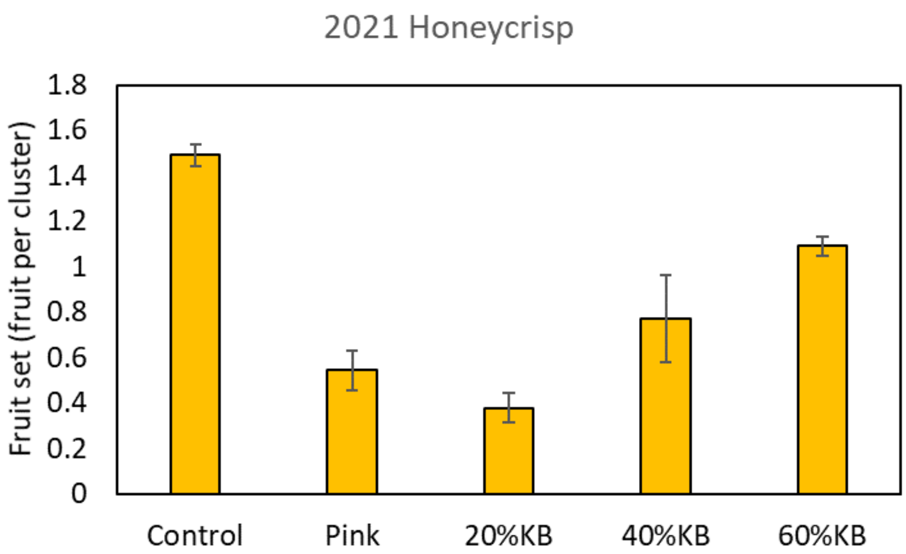
2021 Gala

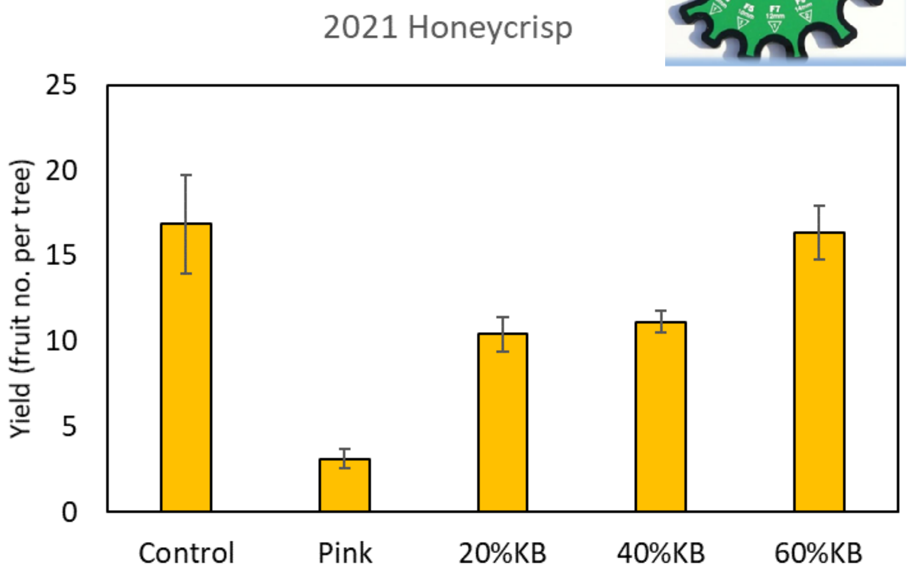




- All branches set to 4 spurs per lcsa with equilidisc
- Gala fruit set quite high for all netted treatments (marked variation among timings)
- All clusters pinched to a single fruitlet 1 month after bloom

2021 Honeycrisp





- All branches set to 4 spurs per lcsa with equilidisc
- Honeycrisp fruit set severely limited by frost- previous data indicates that ~80% KB is ideal timing for Honeycrisp
- All clusters pinched to single fruitlet 1 month after bloom

Thank you for your attention

- Thanks to the Michigan Apple Committee, MSU AgBioResearch (ProjectGreeen), MSU Extension, USDA-SCRI for project support and funding
- Phil Schwallier (collaboration), Gail 'Peach' Byler and Denise Ruwersma, and Dan Platte and CRC farm crew for technical support
- Dr. Tom Sharkey, Dr. Mokhles 'CC' Elsysy, Laura Hillmann (Ph.D. candidate), Chayce Griffith (MS candidate), Austin Chase, Wesley Banning

MICHIGAN APPLES

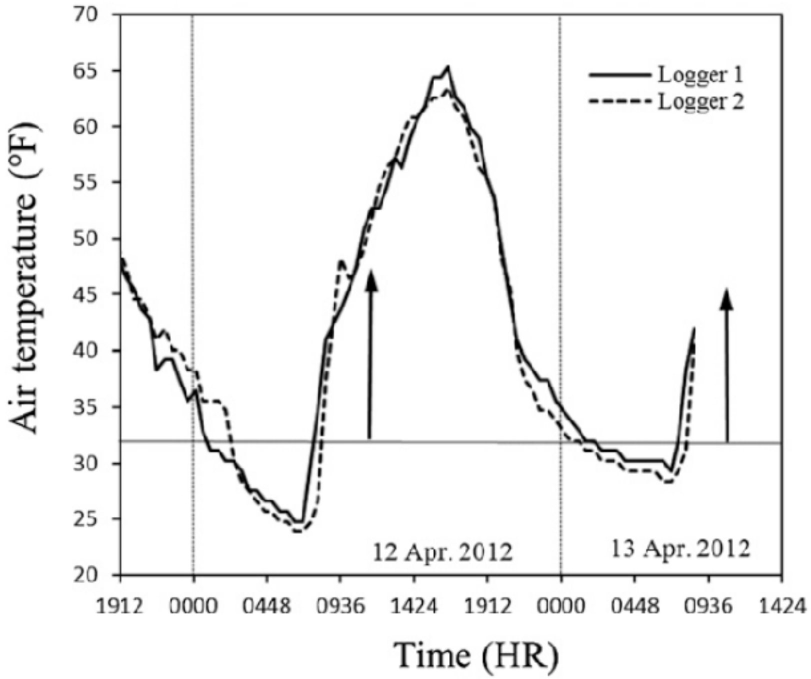
USDA

Precision Crop Load Management of Apples: USDA-NIFA-SCRI SREP 2020-51181-32197. 09/30/2019 – 08/31/2023.

Freeze Injury

- Rescue remedies for ovular and/or ovarian tissue injury?

GA + BA (Promalin)



- Combinations of Cytokinins & GAs may have a synergistic effect on fruit set
- Over several regions and years, 3 of 5 trials resulted in greater yield from GA+6-BA applications

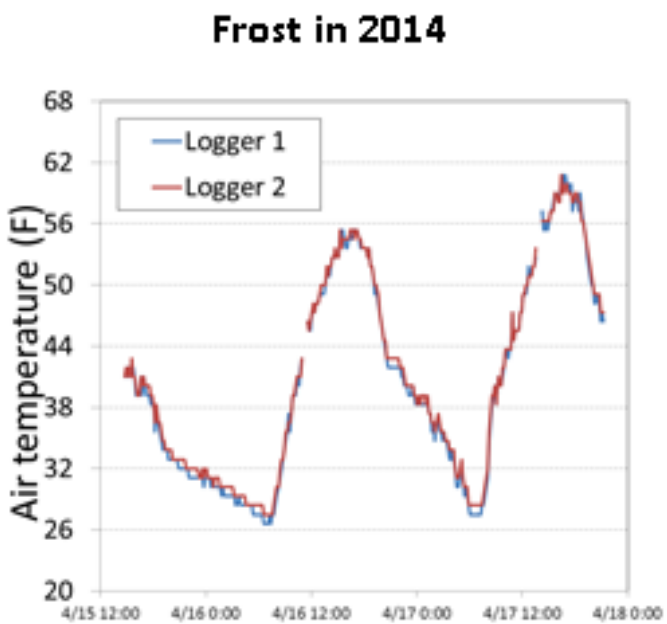
Table 1. Effects of gibberellin $A_4 + A_7$ and 6-benzyladenine (GA_{4+7} plus 6-BA) treatments after freezes during full bloom on 12 and 13 Apr. 2012 on fruit set, total yield, fruit number per tree, and mean fruit weight of 'Taylor Spur Rome'/'M.7' apple in Henderson County, NC.

Treatment[z]	Fruit set (fruit/100 clusters)	Yield (kg/tree)[z]	Yield (bu/acre)[z]	Fruit (no./tree)	Mean fruit wt (g)[z]	Crop value ($/acre)[y]
Untreated control	2.6 a[x]	11.7 a	94 a	58 a	198	1965
GA_{4+7} plus 6-BA (25 mg·L^{-1})	17.7 b	36.8 b	296 b	195 b	185	5807
GA_{4+7} plus 6-BA (50 mg·L^{-1})	14.9 b	33.9 b	273 b	185 b	182	5328
Significance[w]	**	***	***	***	NS	***

[z]1 mg·L^{-1} = 1 ppm, 1 kg = 2.2046 lb, 1 42-lb (19.1 kg) bushel (bu) per acre = 47.0757 kg·ha^{-1}, 1 g = 0.0353 oz.

McArtney et al., 2014

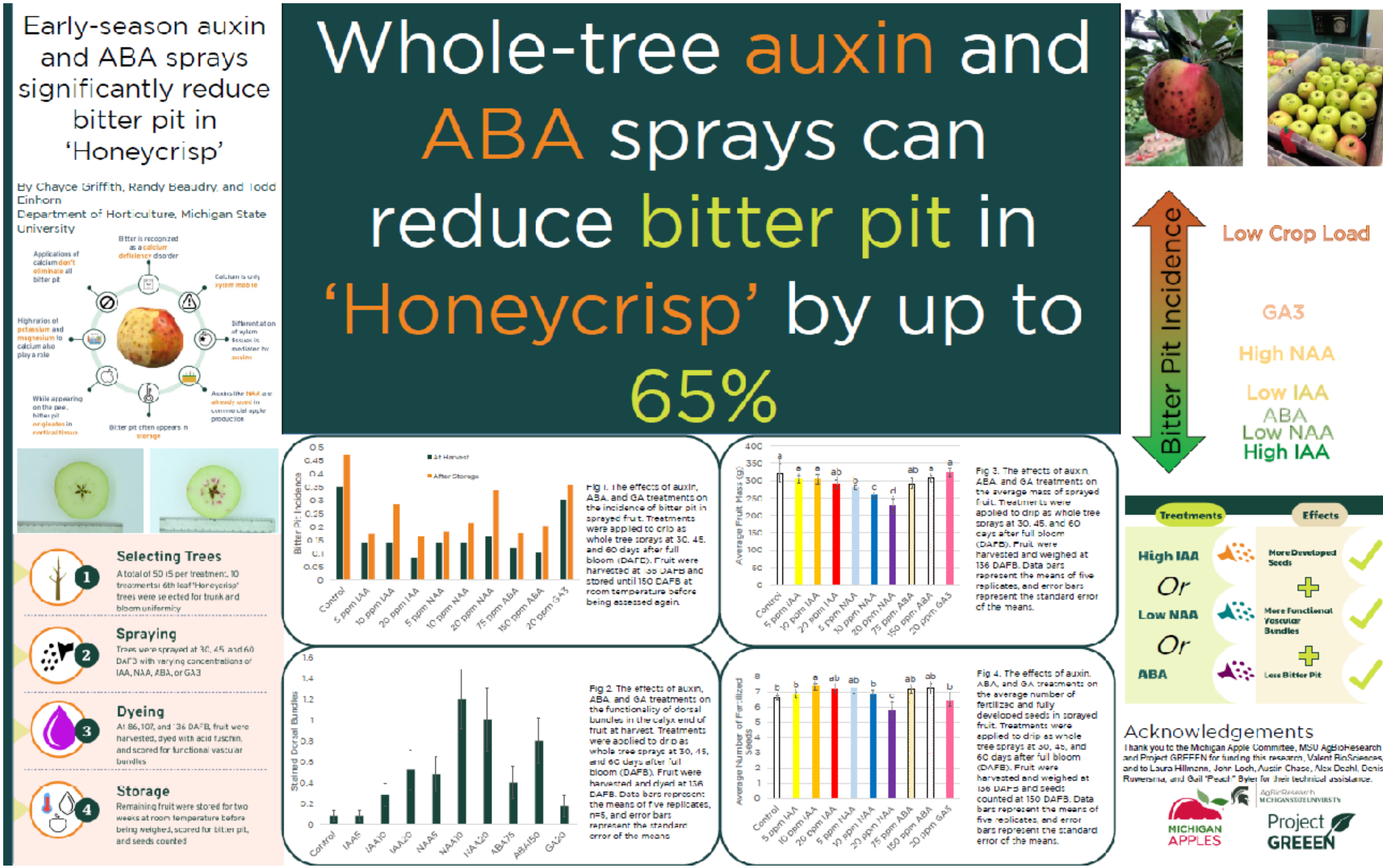
Do frost rescue PGRs need to be applied w/in 24 hours of an event?



Date	Frost			
	Start	Finish	Duration	Low Temp
15-Apr	20:54	8:34	9.5 hr	26.6
17-Apr	4:24	8:04	3.5 hr	27.5

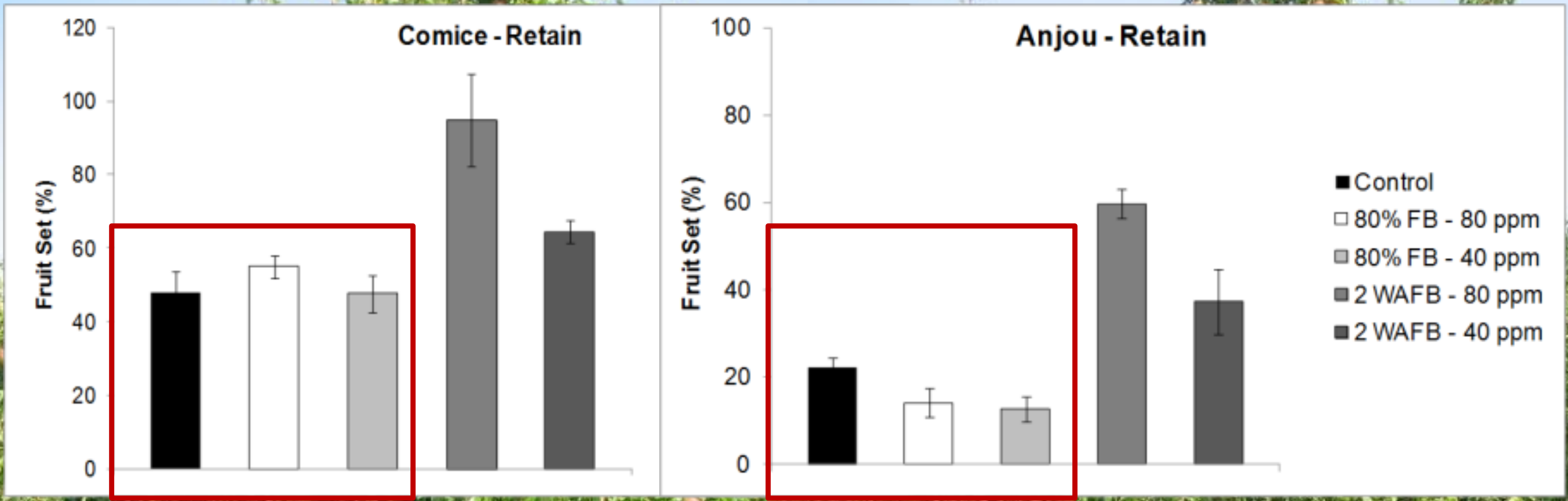
Staton Brookfield Gala/M.7 (2014)			
Flag Color	Treatment	Fruit set (%)	
White	Control	11.7	a
Orange	Promalin on April 16	20.2	bc
halloween	Promalin on April 17	21.9	bc
blue	Promalin on April 18	16.1	ab
Pink	Promalin on April 20	18.9	bc
Yellow	Promalin on April 21	24.1	c

Data compliments of Dr. Steve McArtney


Early-season auxin and ABA sprays significantly reduce bitter pit in 'Honeycrisp'
By Chayce Griffith, Randy Beaudry, and Todd Einhorn
Department of Horticulture, Michigan State University
Bitter is recognized as a calcium deficiency disorder
Calcium is only xylem mobile
Differentiation of xylem tissue is mediated by auxins
Auxins like NAA are already used in commercial apple production
Bitter pit often appears in storage
While appearing on the peel, bitter pit originates in cortical tissue
High ratios of potassium and magnesium to calcium also play a role
Applications of calcium don't eliminate all bitter pit
Selecting Trees
1
A total of 50 (5 per treatment, 10 treatments) 6th leaf 'Honeycrisp' trees were selected for trunk and bloom uniformity
Spraying
2
Trees were sprayed at 30, 45 and 60 DAFB with varying concentrations of IAA, NAA, ABA, or GA3
Dyeing
3
At 86, 107, and 136 DAFB, fruit were harvested, dyed with acid fuschin, and scored for functional vascular bundles
Storage
4
Remaining fruit were stored for two weeks at room temperature before being weighed, scored for bitter pit, and seeds counted
Whole-tree auxin and ABA sprays can reduce bitter pit in 'Honeycrisp' by up to 65%
At Harvest
After Storage
Bitter Pit Incidence
Control
5 ppm IAA
10 ppm IAA
20 ppm IAA
5 ppm NAA
10 ppm NAA
20 ppm NAA
75 ppm ABA
150 ppm ABA
20 ppm GA3
Fig 1. The effects of auxin, ABA, and GA treatments on the incidence of bitter pit in sprayed fruit. Treatments were applied to drip as whole tree sprays at 30, 45, and 60 days after full bloom (DAFB). Fruit were harvested at 136 DAFB and stored until 150 DAFB at room temperature before being assessed again.
Average Fruit Mass (g)
Fig 3. The effects of auxin, ABA, and GA treatments on the average mass of sprayed fruit. Treatments were applied to drip as whole tree sprays at 30, 45, and 60 days after full bloom (DAFB). Fruit were harvested and weighed at 136 DAFB. Data bars represent the means of five replicates, and error bars represent the standard error of the means.
Stained Dorsal Bundles
Control
IAA5
IAA10
IAA20
NAA5
NAA10
NAA20
ABA75
ABA150
GA20
Fig 2. The effects of auxin, ABA, and GA treatments on the functionality of dorsal bundles in the calyx end of fruit at harvest. Treatments were applied to drip as whole tree sprays at 30, 45, and 60 days after full bloom (DAFB). Fruit were harvested and dyed at 136 DAFB. Data bars represent the means of five replicates, n=5, and error bars represent the standard error of the means
Average Number of Fertilized Seeds
Fig 4. The effects of auxin, ABA, and GA treatments on the average number of fertilized and fully developed seeds in sprayed fruit. Treatments were applied to drip as whole tree sprays at 30, 45, and 60 days after full bloom (DAFB). Fruit were harvested and weighed at 136 DAFB and seeds counted at 150 DAFB. Data bars represent the means of five replicates, and error bars represent the standard error of the means.
Bitter Pit Incidence
Low Crop Load
GA3
High NAA
Low IAA
ABA
Low NAA
High IAA
Treatments
Effects
High IAA
Or
Low NAA
Or
ABA
More Developed Seeds
More Functional Vascular Bundles
Less Bitter Pit
Acknowledgements
Thank you to the Michigan Apple Committee, MSU AgBioResearch and Project GREEEN for funding this research, Valent BioSciences, and to Laura Hillmann, John Loch, Austin Chase, Alex Deahl, Denise Ruwersma, and Gail "Peach" Byler for their technical assistance.
MICHIGAN APPLES
AgBioResearch MICHIGAN STATE UNIVERSITY
Project GREEEN

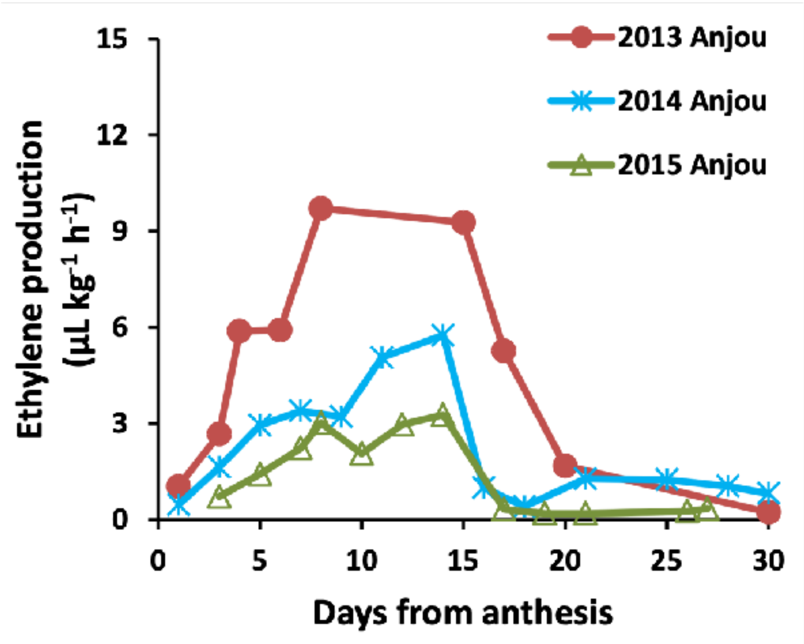
Objective: Evaluate AVG for 'Hard-To-Set' Cultivars

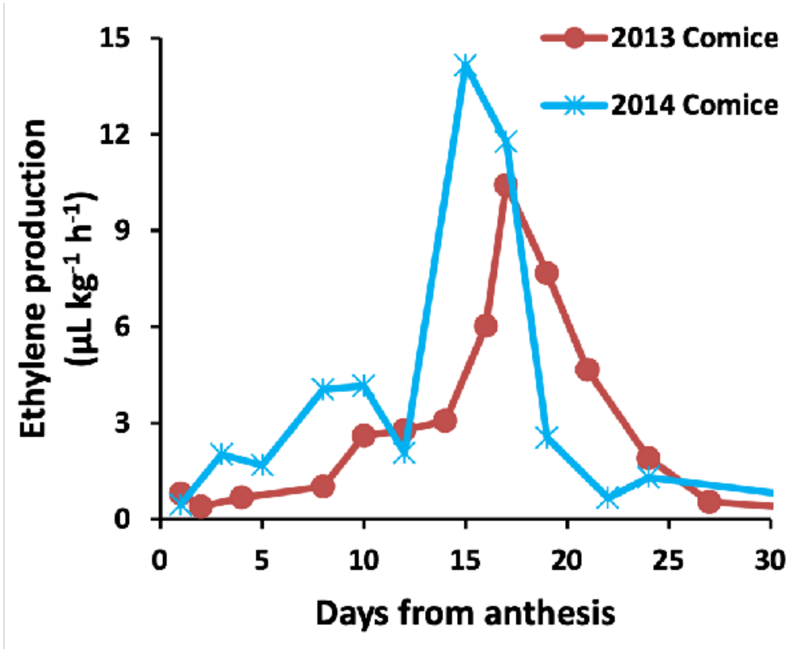
Control AVG 80 ppm



Treatment	Yield (lbs per tree)	Fruit no. per tree
Control	88 b	172 c
80 ppm ReTain (80% FB)	52 c	111 cd
40 ppm ReTain (80% FB)	57 c	118 cd
80 ppm ReTain (2 WAFB)	198 a	558 a
40 ppm ReTain (2 WAFB)	160 a	409 b

Objective: Evaluate AVG for 'Hard-To-Set' Cultivars

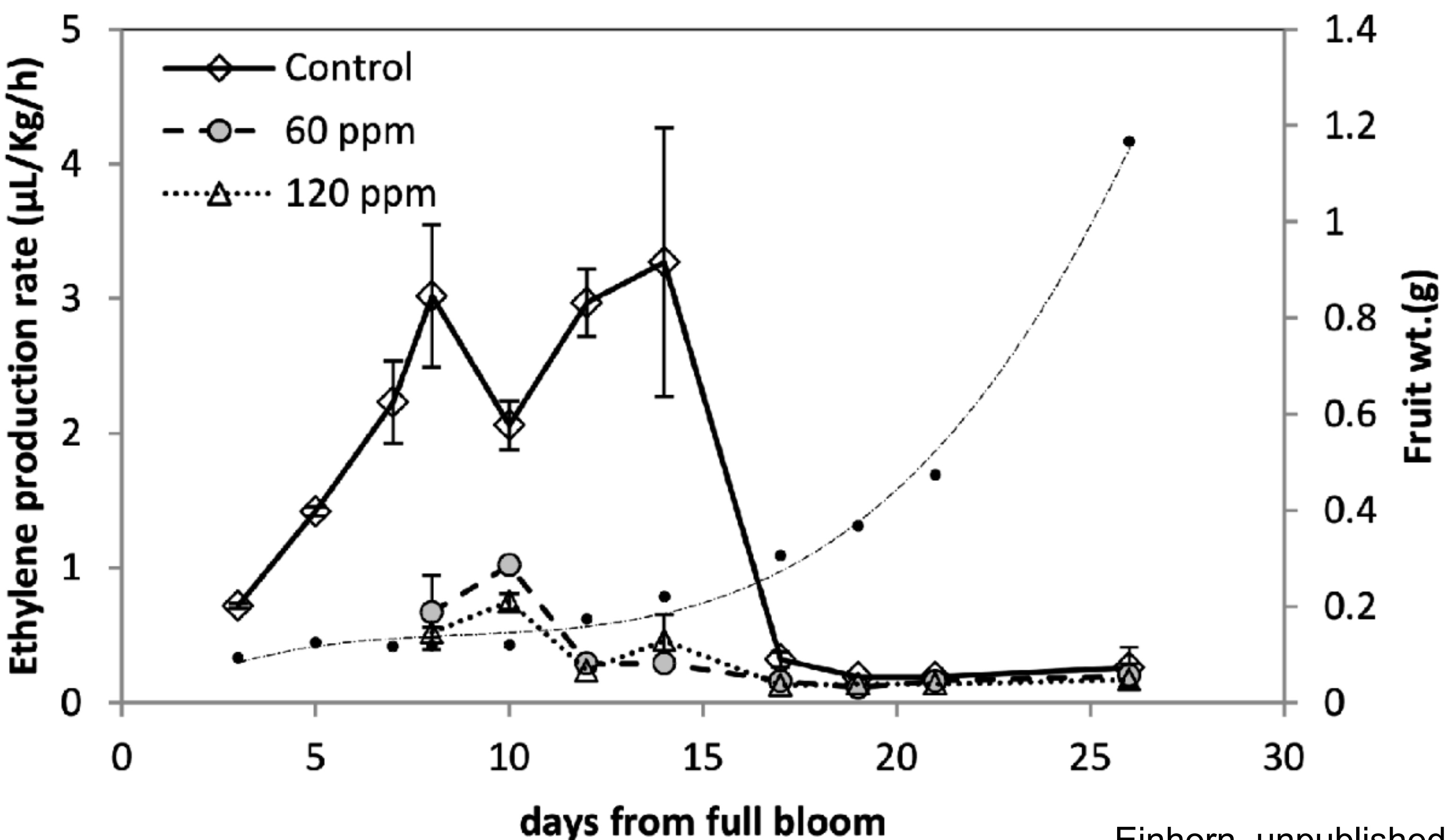




Einhorn, unpublished

Treatment	Seed no. per fruit	
	'd'Anjou'	'Comice'
Control	4.9	5.4
ReTain 40 ppm	4.1	5.6
ReTain 80 ppm	4.0	5.8

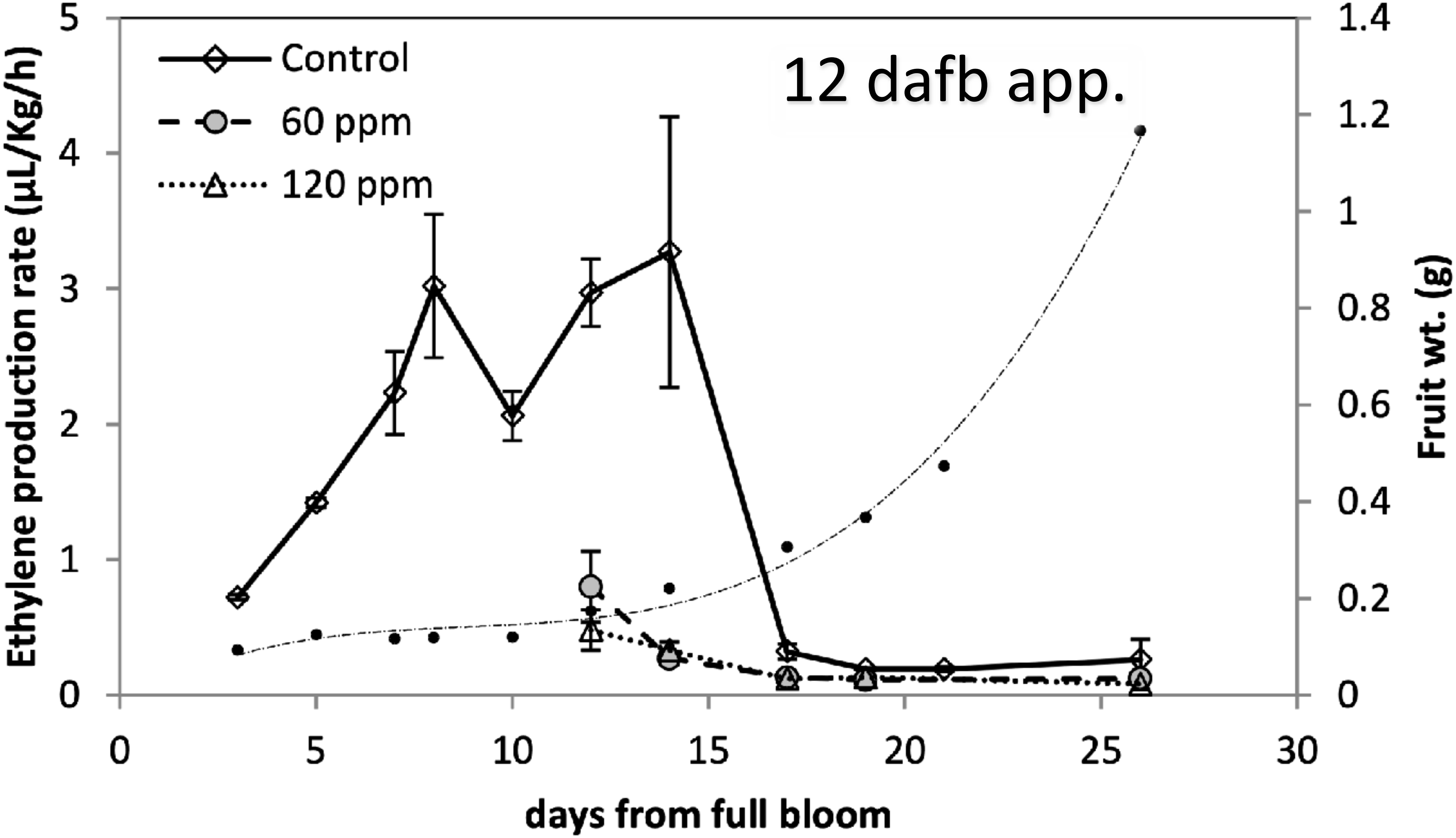
ReTain (AVG)- 2015 ‘d’Anjou’



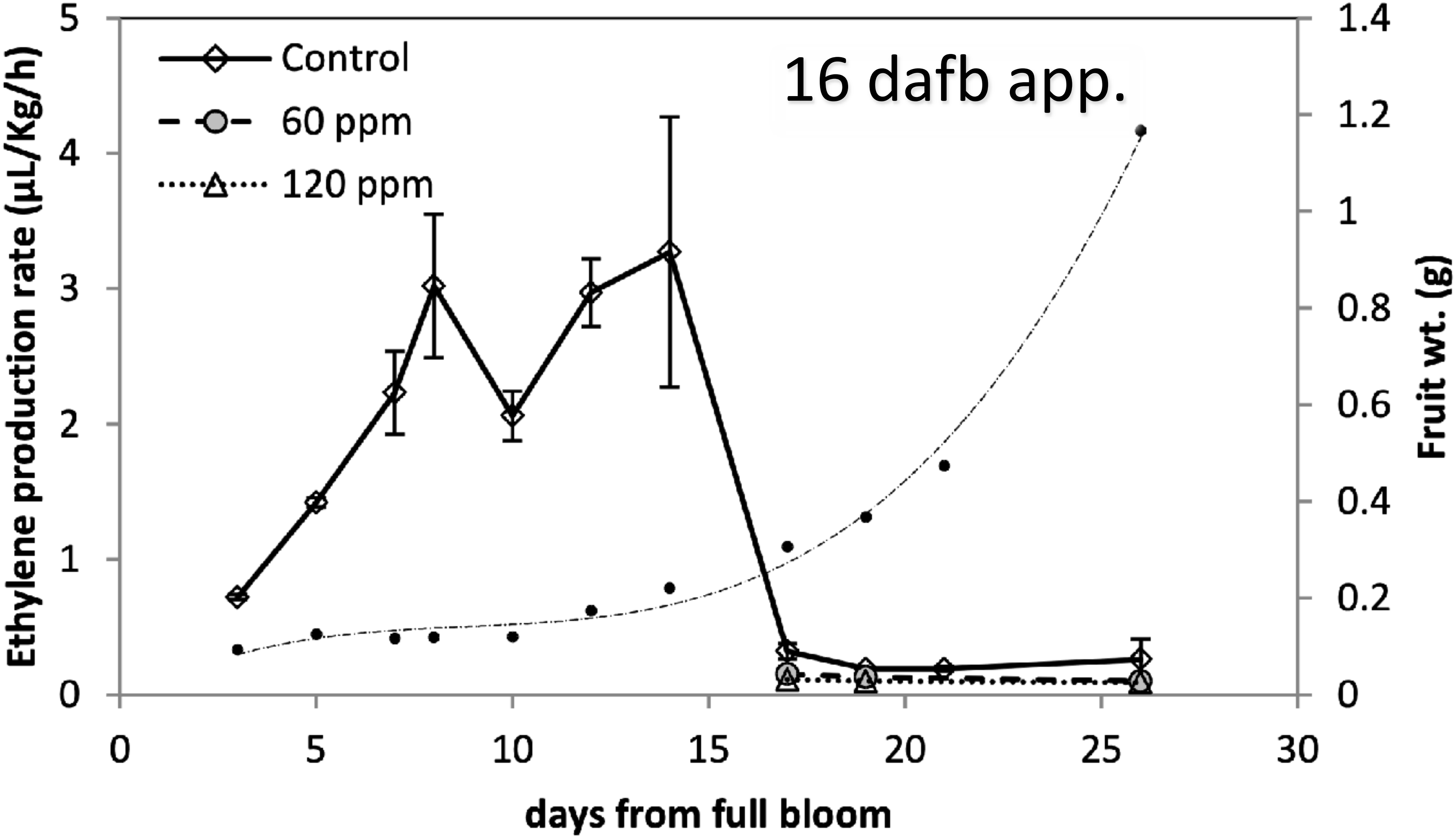
Einhorn, unpublished

- AVG persisted for ~10 days after apps

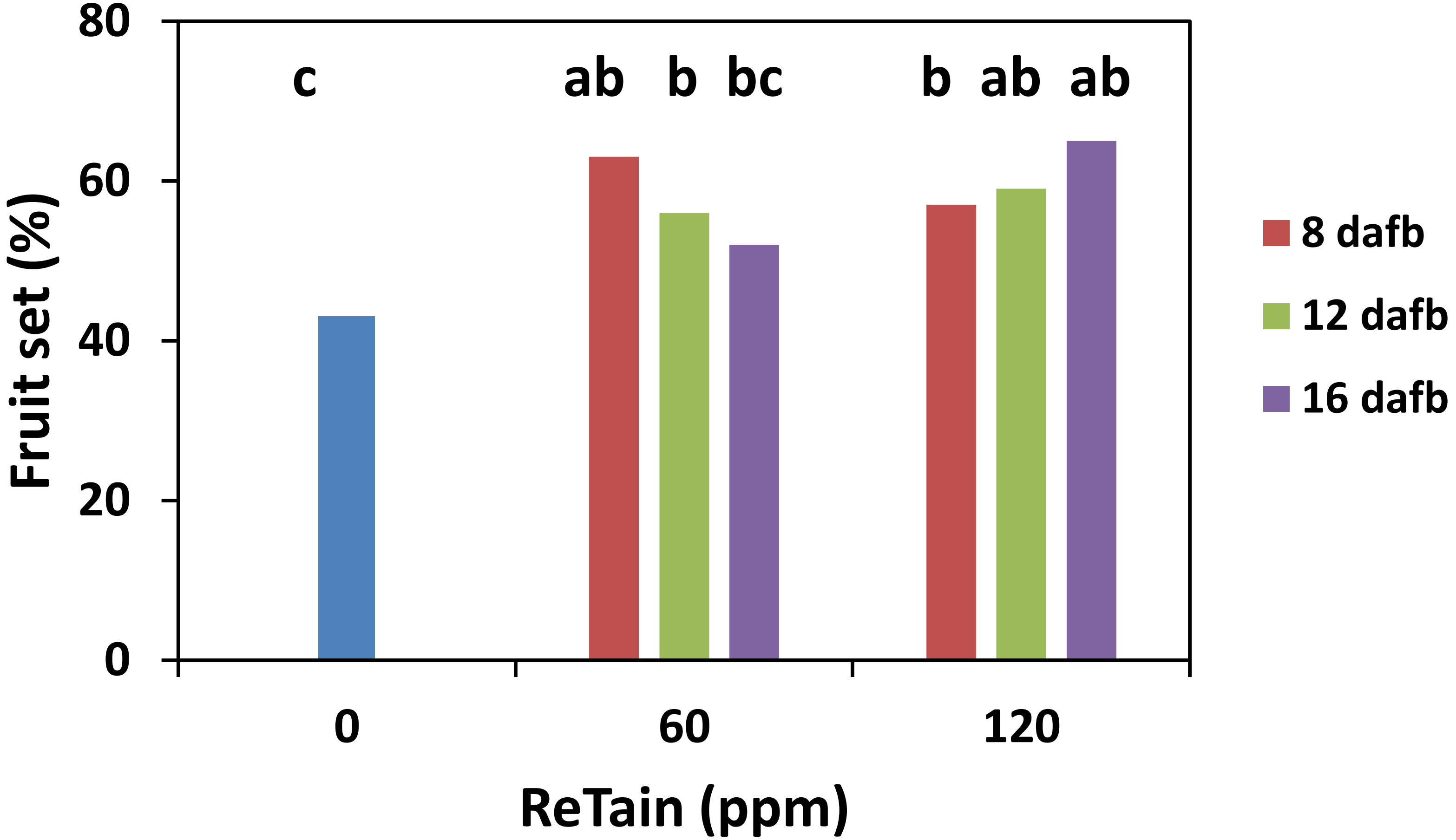
ReTain (AVG)- 2015 'd'Anjou'



ReTain (AVG)- 2015 'd'Anjou'



ReTain (AVG)- 2015 'd'Anjou'



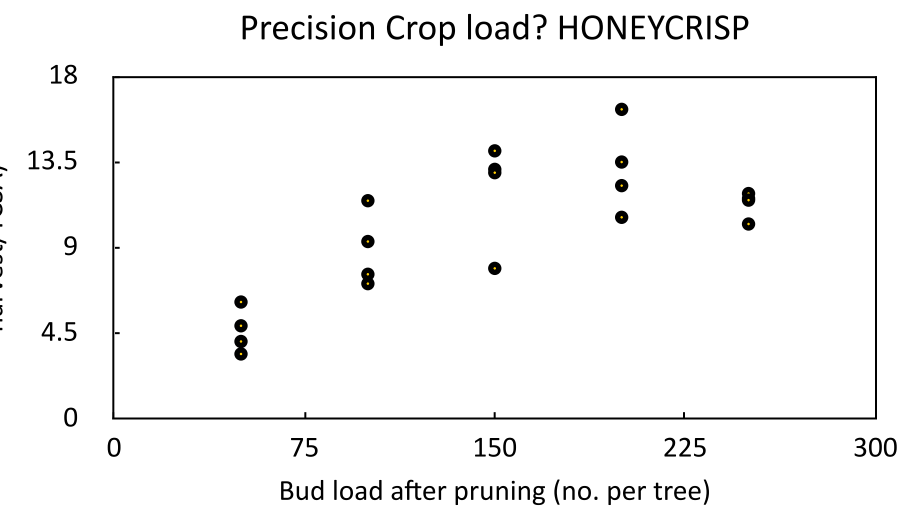
- All treatment timings improved fruit set
- 16 dafb app likely improved fruit set for the small percentage of delayed blooms (compared to the mean)

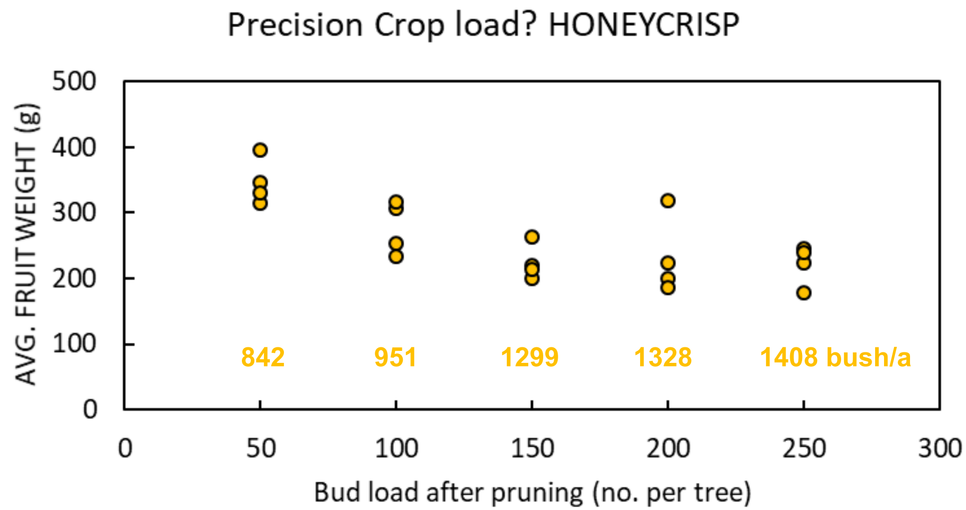
ReTain (AVG)- 2015 'd'Anjou'

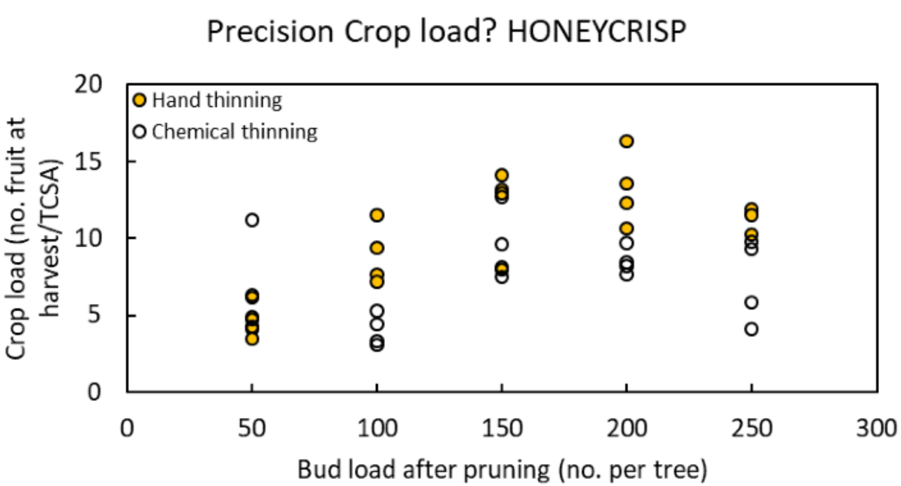
Treatment	Harvest	
	Yield (lbs/tree)	Fruit wt. & seed no.
Control	347 c	207 (4.6)
ReTain 8 dafb	421 a	211 (5)
ReTain 12 dafb	390 ab	208 (4.6)
ReTain 16 dafb	434 a	213 4.9)

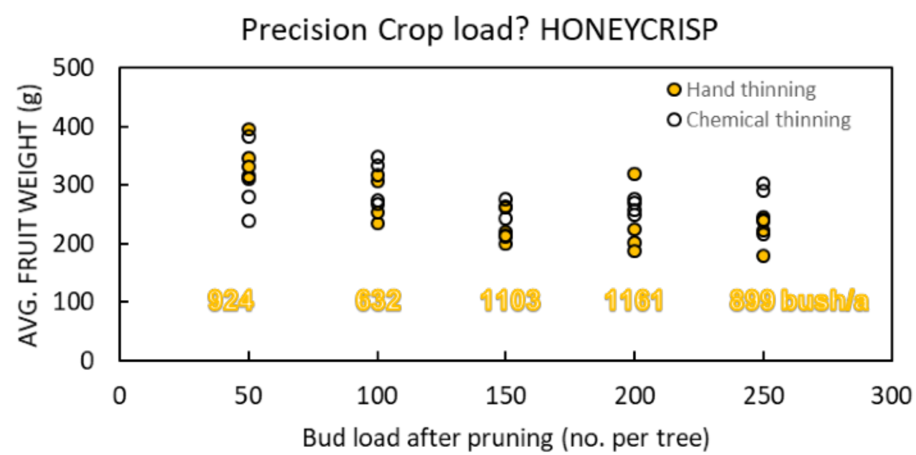
- ***All treatment timings increased*** yield
- No effect on fruit size or seed no.

Pruning to bud load + thinning









Chemical Thinning: 1) Lime sulfur (at ~80% bloom), 2) NAA/Sevin (at petal fall), and 3) Maxcel/Sevin (at 10-12 mm) if necessary.