BLOOM THINNING OF APPLES IN THE MID-ATLANTIC REGION

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Virginia Tech
Invent the Future

Mid-Atlantic
Fruit and Vegetable Conference
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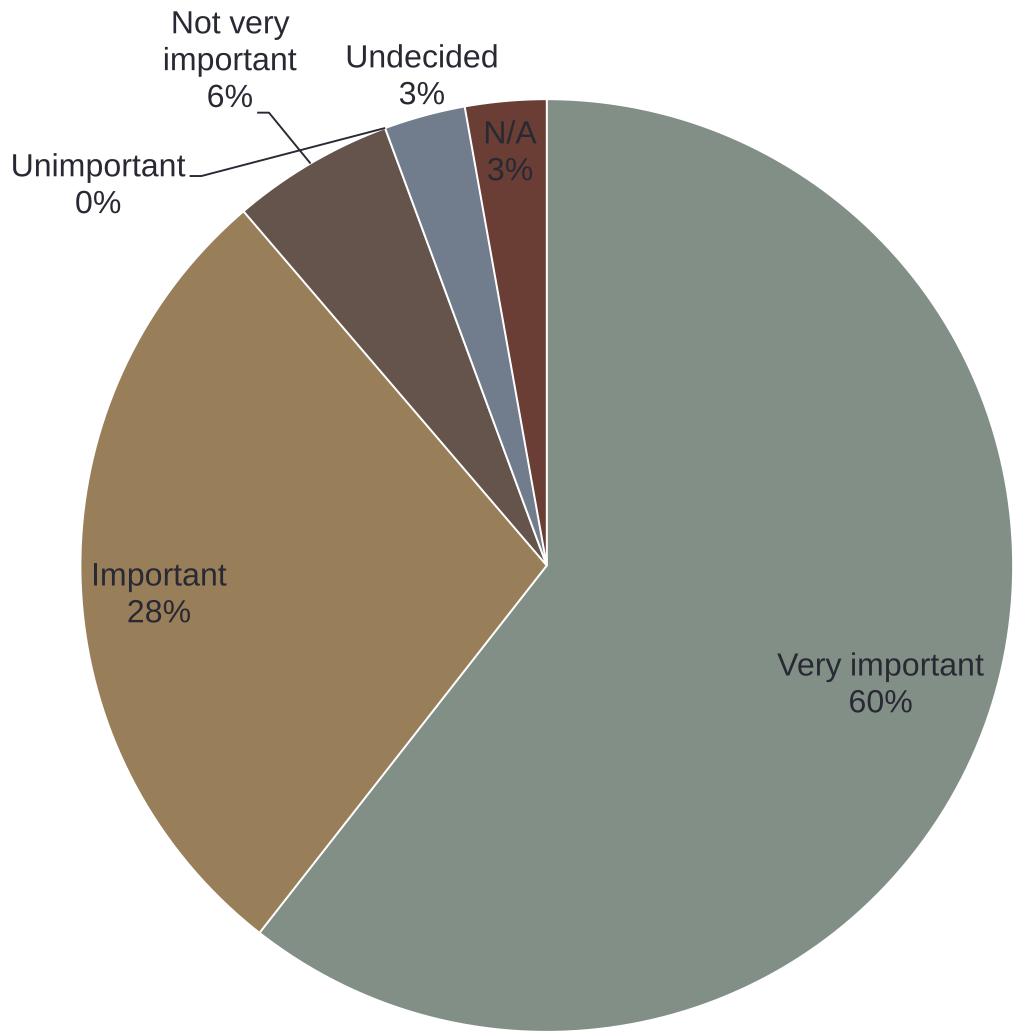
2011 Survey of Virginia Tree-Fruit Growers:

Importance of Apple fruit thinning strategies (materials, timing, cost, interaction with weather, etc.)



N = 74

Apple Thinning can be Stressful

- Apples produce several 100 times more fruit than we want for a commercial crop
- Fruit size & quality
- Branch breakage
- Return bloom & consistent yields
- Insect and disease control

Multiple Opportunities to Manage Crop Load and Reduce Stress

1. Pruning and training
2. Flower thinning
3. Petal fall thinning
4. 10 mm thinning
5. 18-25 mm thinning
6. Hand thinning (30 DAFB)
7. Return bloom sprays

Why bloom thin in the Eastern US?

CON

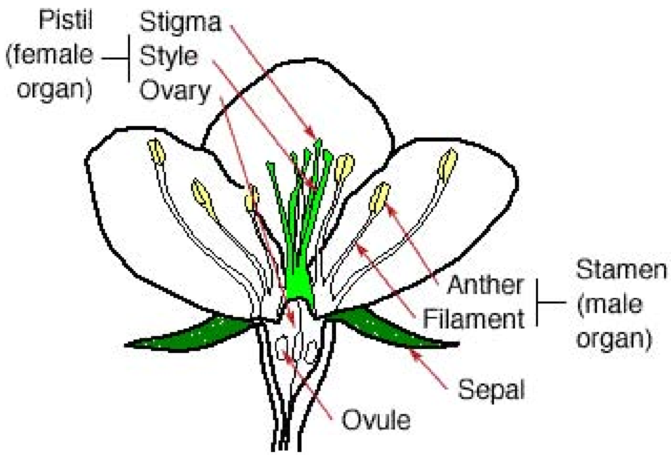
- Risk of spring frosts
- Limited empirical data and experience
- Timing for bloom spray has been subjective, and is usually based on the percent of full bloom that is open (e.g., an application at 20% and 80% full bloom)
- Lack of materials that don’t have negative side effects

PRO

- Larger fruit
- Greater return bloom in the following year and reduced biennial bearing
- Possible reduction in fungicide applications
- Creates thinning options for organic growers
- Virginia Tech developed pollen tube growth model allows for more precise applications
- Further reduce stress...

A Pollen Tube Growth Model

- In apple production, crop thinning during bloom produces the largest fruit, the greatest return bloom in the following year, and reduces biennial bearing



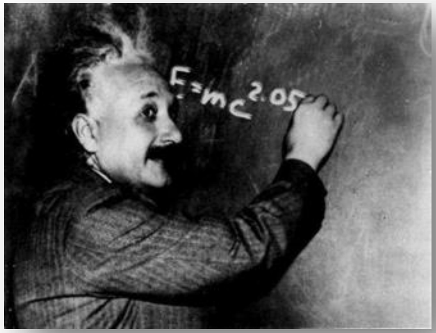
- However, the application timing for bloom spray has been subjective, and is usually based on the percent of full bloom that is open (e.g., an application at 20% and 80% full bloom)

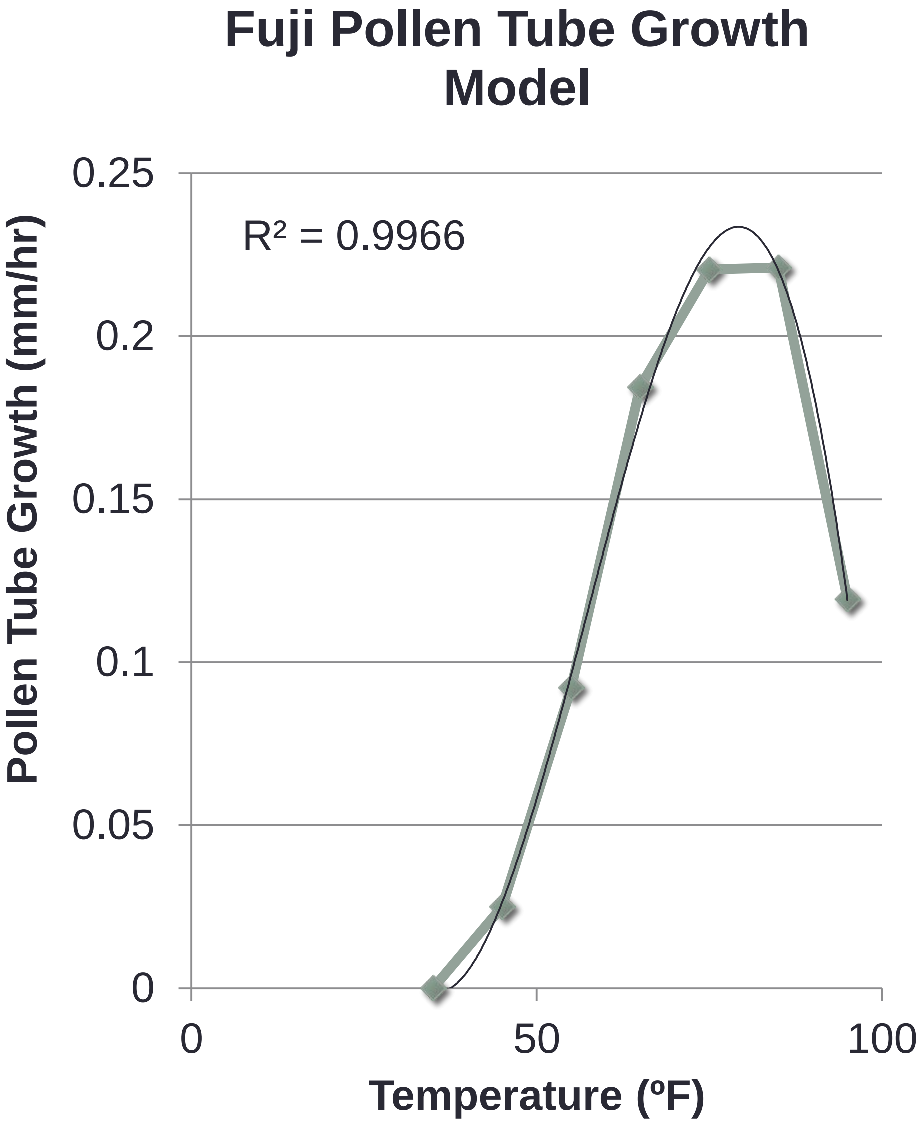
- A more precise application timing can be achieved through modeling

- The pollen tube growth model can help reduce risk of under- or over-thinning

Why use models?

- To simplify complex phenomena
- To be able to ask questions about future events
- And make reliable predictions





Model development: history

2002 – Ross Byers & Sue Wolf (VT) funded by WTFRC to investigate pollination & potential thinning agents

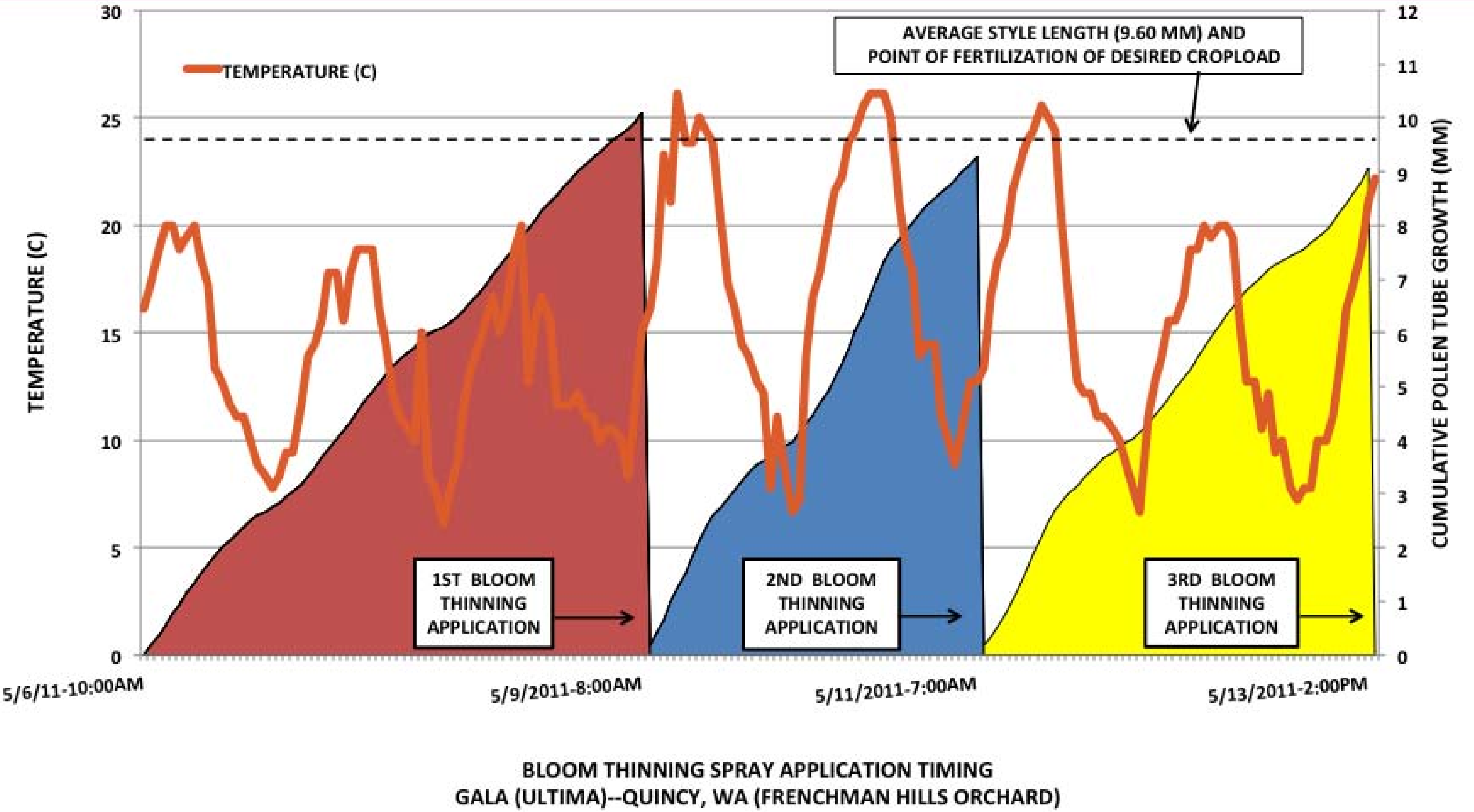
2005 – Keith Yoder (VT) joins project as PI

2008 – Rongcai Yuan (VT) joins project; first year of field data collected in WA

2009 – First field validation by WA industry beta testers

2011 – Greg Peck (VT), Gerrit Hoogenboom & Melba Salazar (WSU-AgWeatherNet) join project; beta testing hosted by AWN

How does the model work?



How was the model developed?

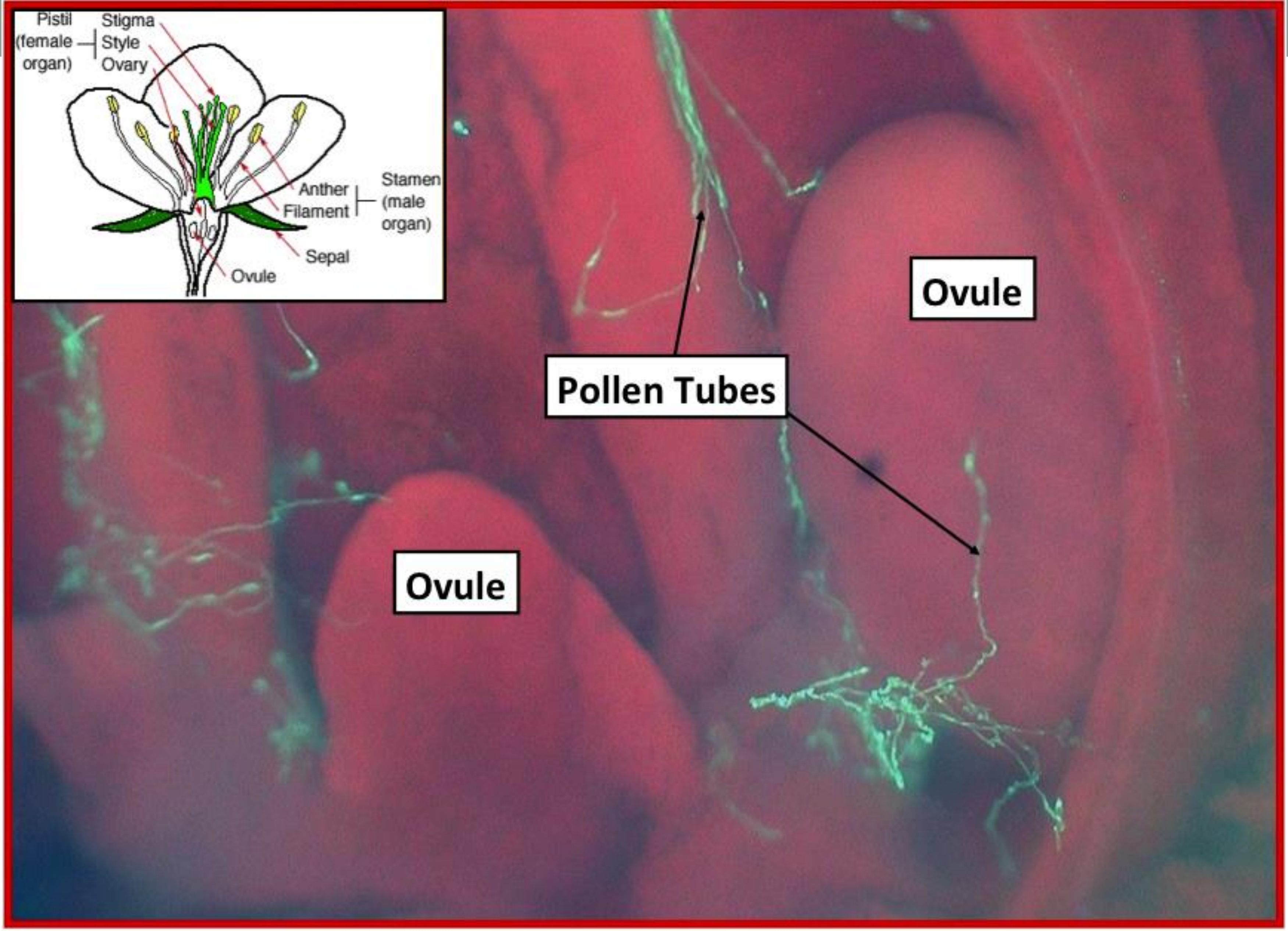
- Dwarfed root-bagged trees are forced to bloom in a greenhouse

- Trees can be held dormant in cold room

- Pollen from selected pollinizers is harvested and stored

- Flowers are emasculated at full balloon stage, hand-pollinated, and tree is placed in growth chamber under predetermined climatic conditions

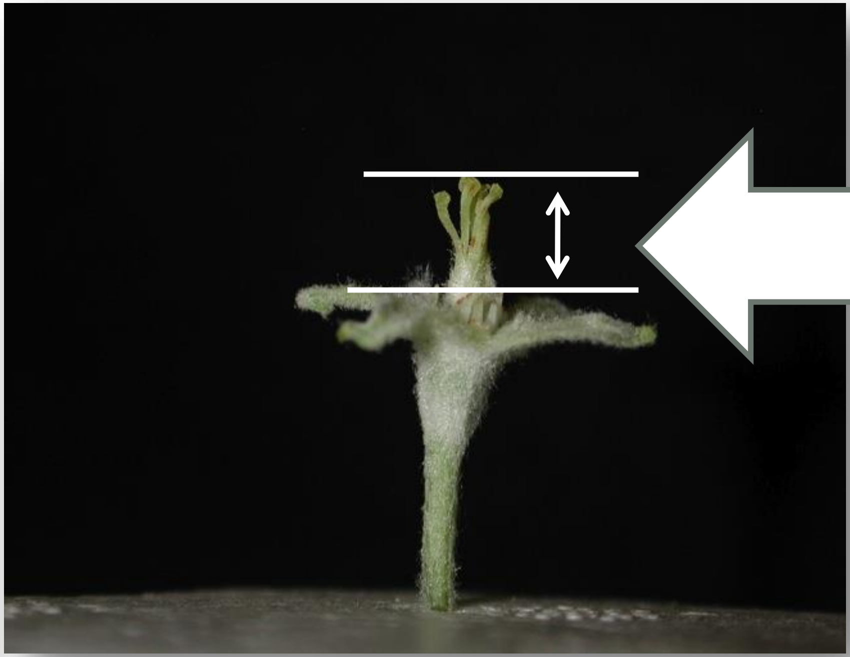
By measuring pollen tube growth rates under controlled environmental conditions in growth chambers, we have developed a model that calculates the time required to fertilize the king bloom after pollination.



Fertilization is determined by evaluating stained pollen tubes using fluorescence microscopy.

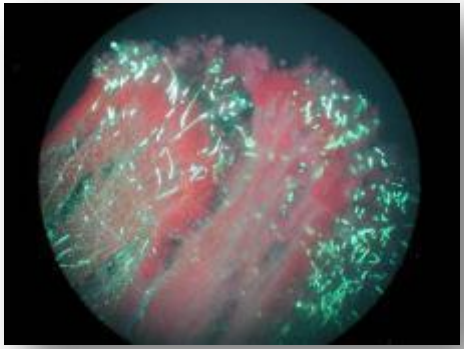
Measuring Style Length

ANTHERS AND PETALS REMOVED FOR EASIER MEASURING OF STYLES



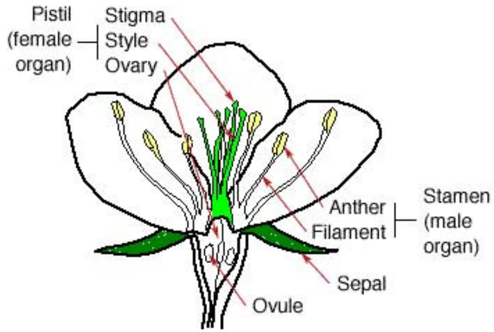
MEASURE STYLES AS SHOWN FOR FLOWER STYLES MEASURED WITHOUT REMOVING FROM TREE

- Blossoms collected at planned intervals; pistils and ovules processed and stained to observe pollen tubes in the style.
- Fluorescence microscopy gives a view of germinating pollen grains and progression of pollen tubes down the style.
- This shows tube growth over time at the selected temperature and indicates how soon fertilization would occur, based on style length.
- Fixed blossoms can be held for later analysis.

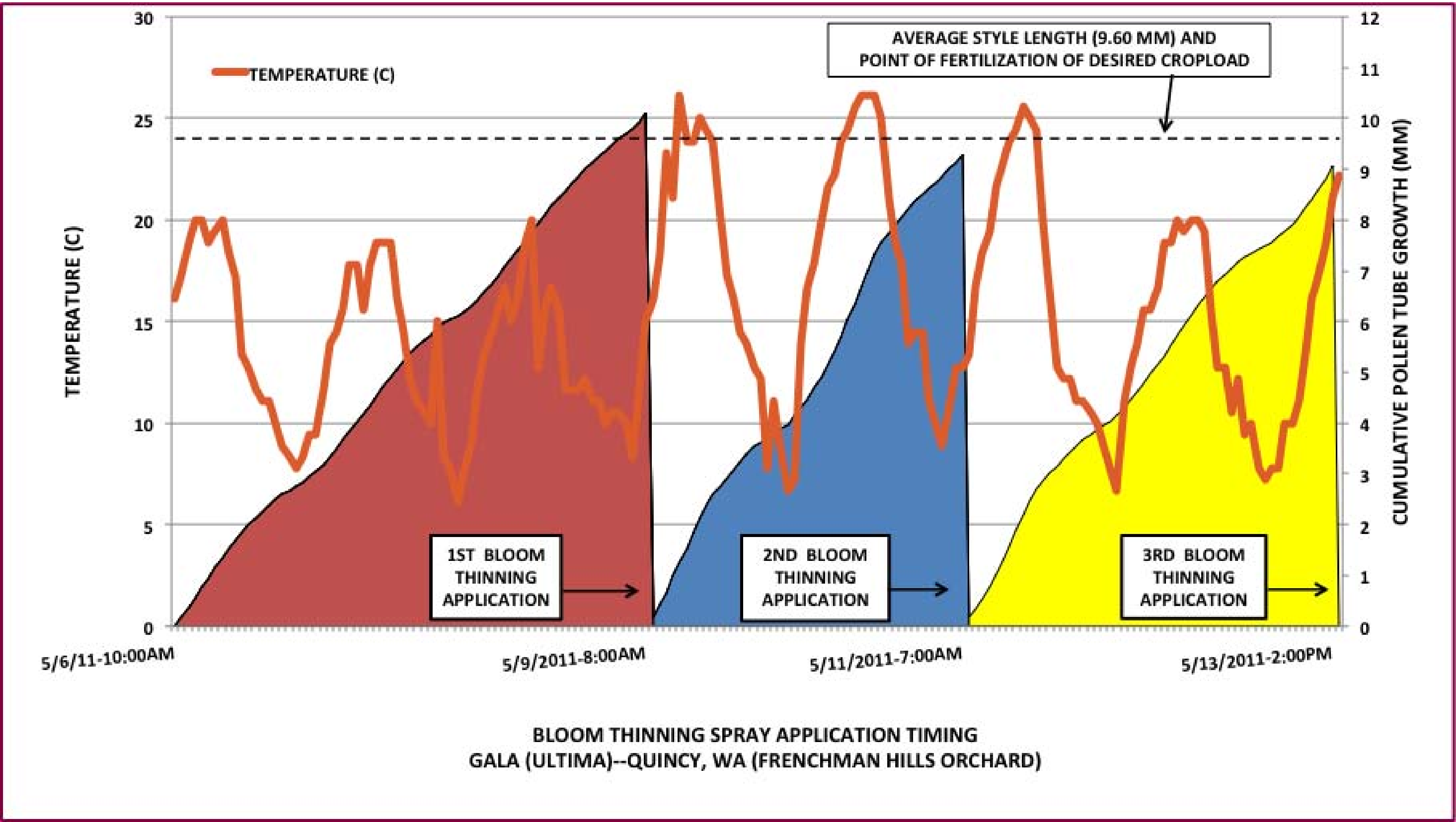


Starting the model "clock"

- Sufficient king bloom open to provide desired cropload
  - Count the number of flowers per branch cross-sectional area
  - Can be estimated based on experience
- The model starts when the last flower that you need to achieve the desired crop load has been pollinated
- First thinning spray is applied when the pollen tube growth has been modeled to grow beyond the longest style
  - In other words, the flower has been fertilized
- Additional thinning sprays prevent additional fertilization
- Other considerations
  - Warm temperatures (>50ºF) for bee flight
  - Within tree and within orchard variability

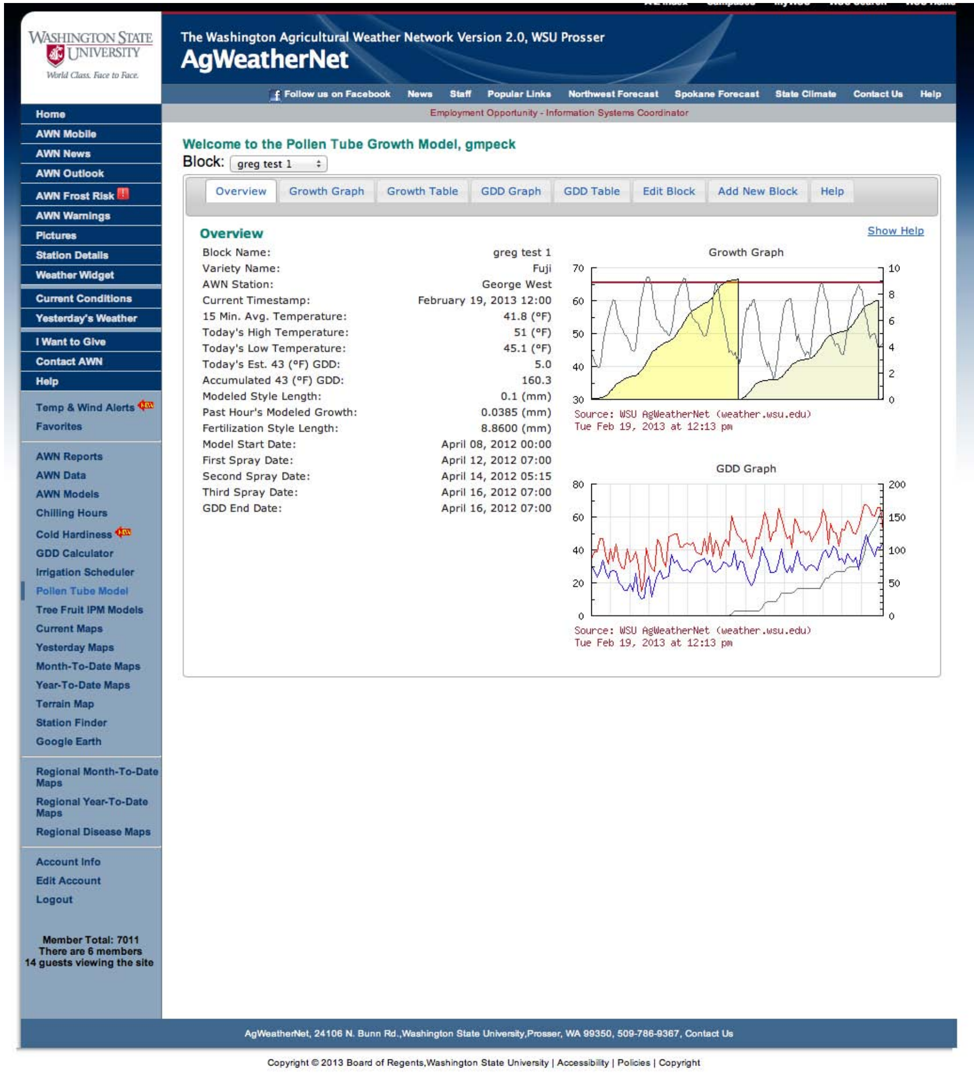


How does the model work?



Where is the PTGM being used?

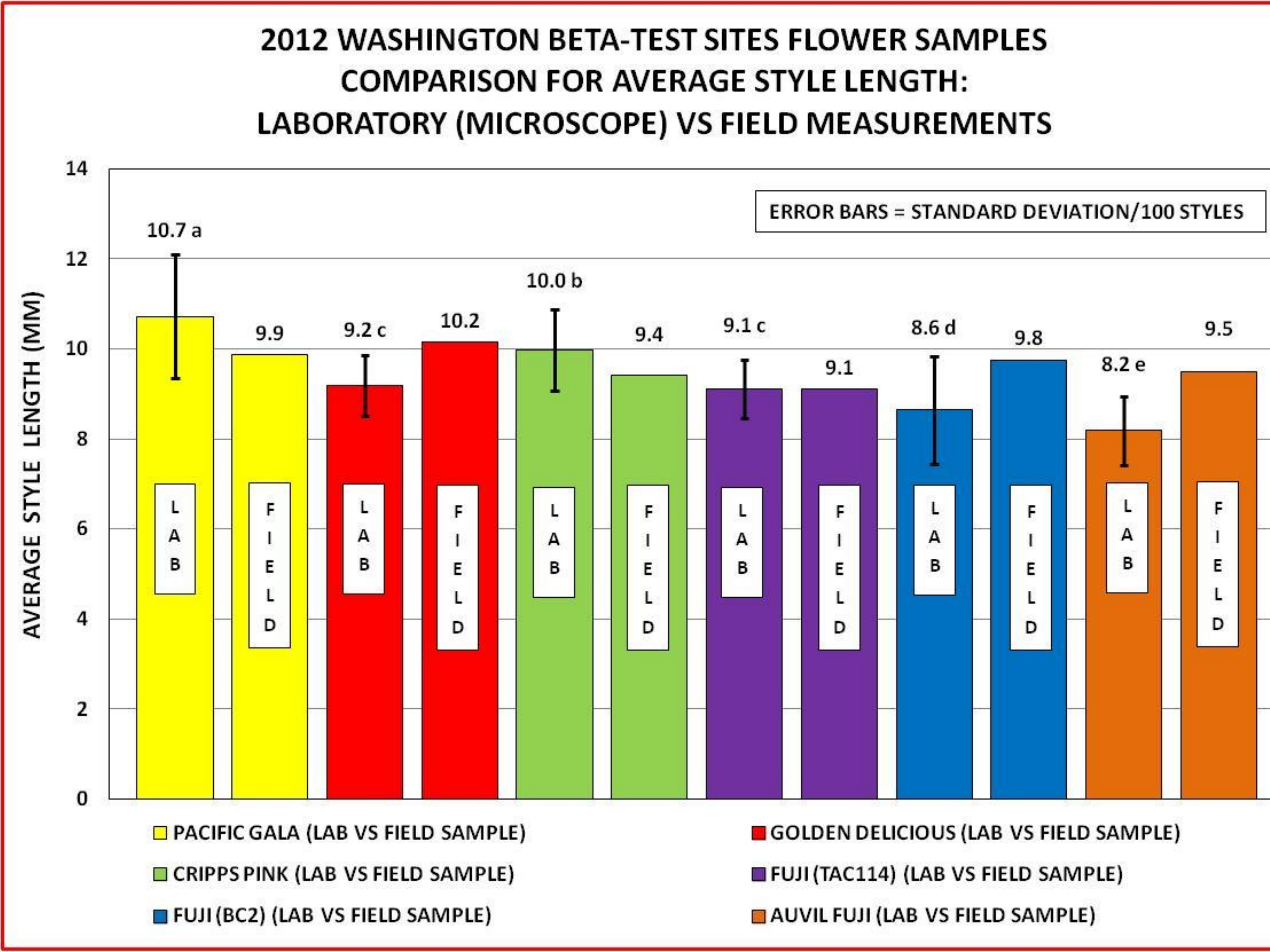
- Models have been developed for:
  - Golden Delicious
  - Gala
  - Fuji
  - Cripps Pink (Pink Lady)
  - Honeycrisp (New for 2013)
- Model now available through WSU's AgWeatherNet website
- In 2012 & 2013, worked with over 200 beta-test sites in Washington State
- 2011-2013 bloom thinning tests in Virginia

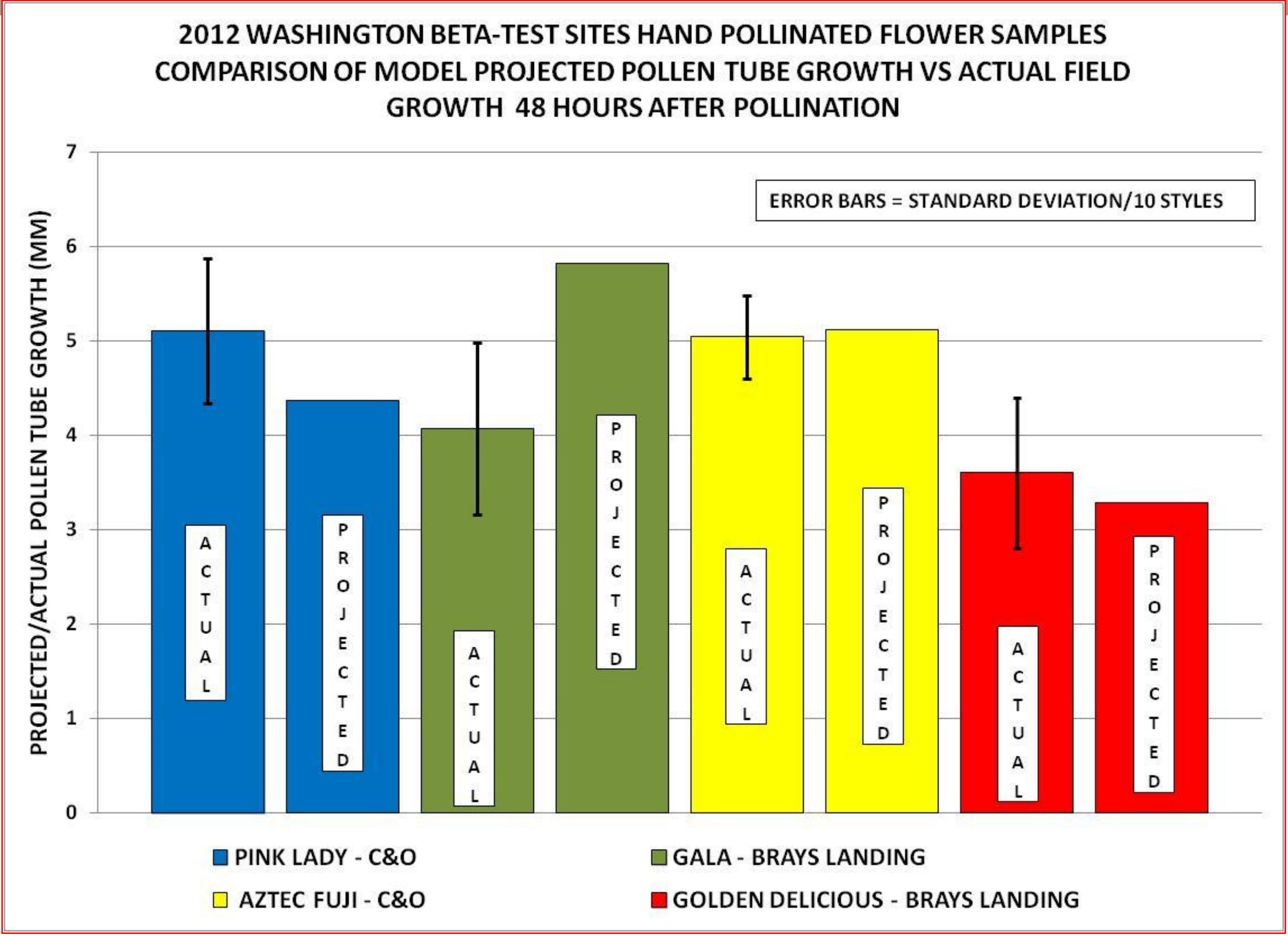


Model limitations

- Assumes optimal bee activity and pollen availability/viability
- No models for secondary or niche varieties
- Unresolved questions about role of pollen source
- Normal use requires overly simplistic assumptions about efficacy of chemical thinners
- Mode of action for many bloom thinners is still open for debate

BETA-TESTING IN WA STATE


2012 WASHINGTON BETA-TEST SITES FLOWER SAMPLES
COMPARISON FOR AVERAGE STYLE LENGTH:
LABORATORY (MICROSCOPE) VS FIELD MEASUREMENTS
ERROR BARS = STANDARD DEVIATION/100 STYLES
AVERAGE STYLE LENGTH (MM)
14
12
10
8
6
4
2
0
10.7 a
9.9
9.2 c
10.2
10.0 b
9.4
9.1 c
9.1
8.6 d
9.8
8.2 e
9.5
LAB
FIELD
PACIFIC GALA (LAB VS FIELD SAMPLE)
GOLDEN DELICIOUS (LAB VS FIELD SAMPLE)
CRIPPS PINK (LAB VS FIELD SAMPLE)
FUJI (TAC114) (LAB VS FIELD SAMPLE)
FUJI (BC2) (LAB VS FIELD SAMPLE)
AUVIL FUJI (LAB VS FIELD SAMPLE)



2012 WASHINGTON BETA-TEST SITES HAND POLLINATED FLOWER SAMPLES
COMPARISON OF MODEL PROJECTED POLLEN TUBE GROWTH VS ACTUAL FIELD
GROWTH 48 HOURS AFTER POLLINATION
ERROR BARS = STANDARD DEVIATION/10 STYLES
PROJECTED/ACTUAL POLLEN TUBE GROWTH (MM)
0
1
2
3
4
5
6
7
ACTUAL
PROJECTED
ACTUAL
PROJECTED
ACTUAL
PROJECTED
ACTUAL
PROJECTED
PINK LADY - C&O
GALA - BRAYS LANDING
AZTEC FUJI - C&O
GOLDEN DELICIOUS - BRAYS LANDING

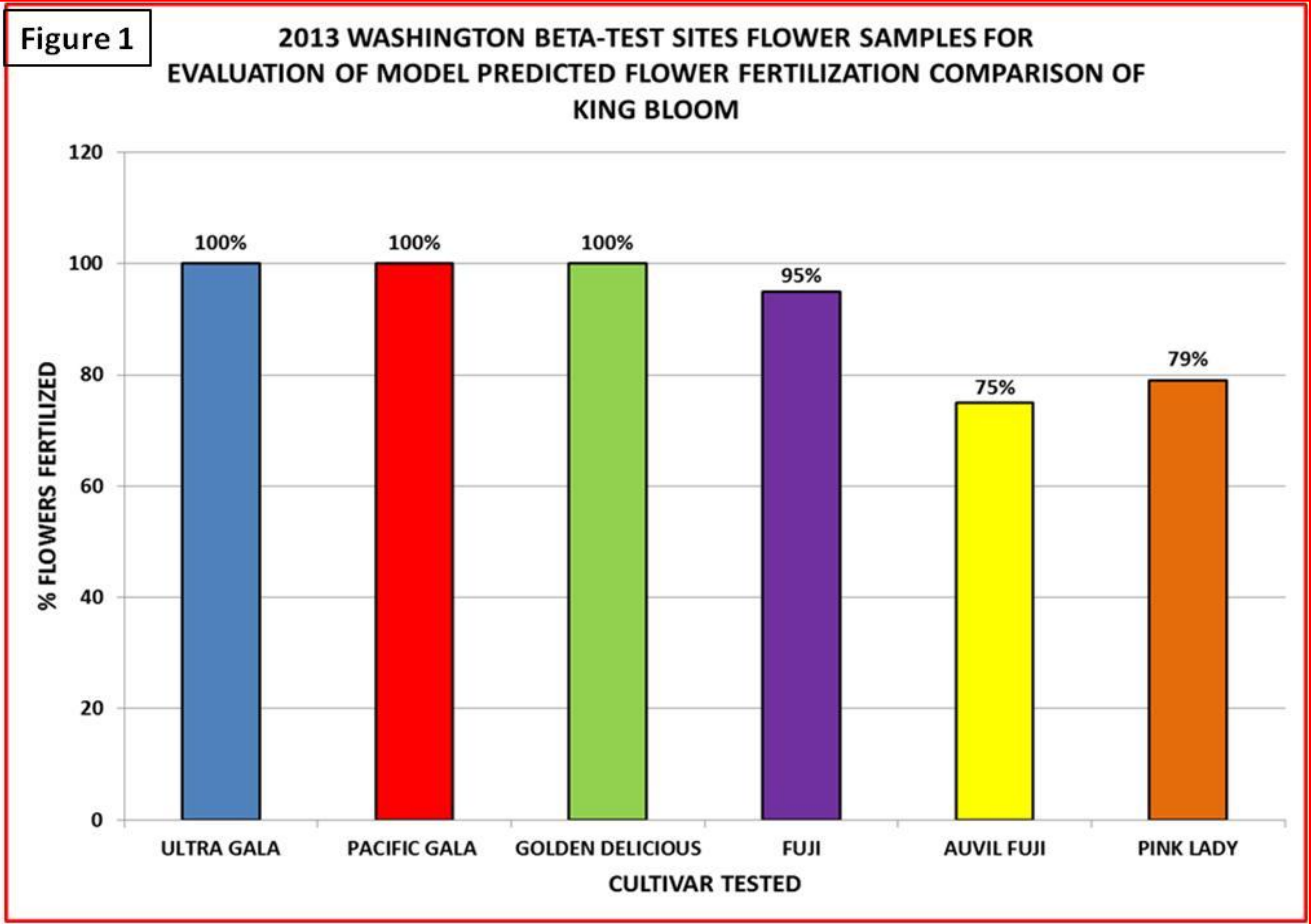


Figure 1
2013 WASHINGTON BETA-TEST SITES FLOWER SAMPLES FOR EVALUATION OF MODEL PREDICTED FLOWER FERTILIZATION COMPARISON OF KING BLOOM
% FLOWERS FERTILIZED
120
100
80
60
40
20
0
100%
100%
100%
95%
75%
79%
ULTRA GALA
PACIFIC GALA
GOLDEN DELICIOUS
FUJI
AUVIL FUJI
PINK LADY
CULTIVAR TESTED

Cultivar (strain)	Location (orchard name)	Mean style length (mm)	Model predicted pollen tube growth at first application	Number of bloom thinning sprays applied	Grower estimated percent of desired crop load achieved
Golden Delicious	Quincy, WA (Lucky 4 Ranch)	8.6	8.3	2	97%
Golden Delicious	Quincy, WA (Winchester Ranch)	8.1	8.4	3	96%
Gala (Ultra Red)	Quincy, WA (Lucky 4 Ranch)	8.3	7.9	3	98%
Gala (Ultima)	Quincy, WA (Frenchman Hills)	9.6	10.2	3	76%
Gala (Pacific)	Quincy, WA (Winchester Ranch)	9.2	9.7	2	78%
Fuji (TAC 114)	Quincy, WA (Winchester Ranch)	7.5	6.8	2	69%
Cripps Pink	Quincy, WA (Winchester Ranch)	7.1	7.1	3	86%

WHAT ABOUT BLOOM THINNING IN THE MID-ATLANTIC

We’re stressed out, too!

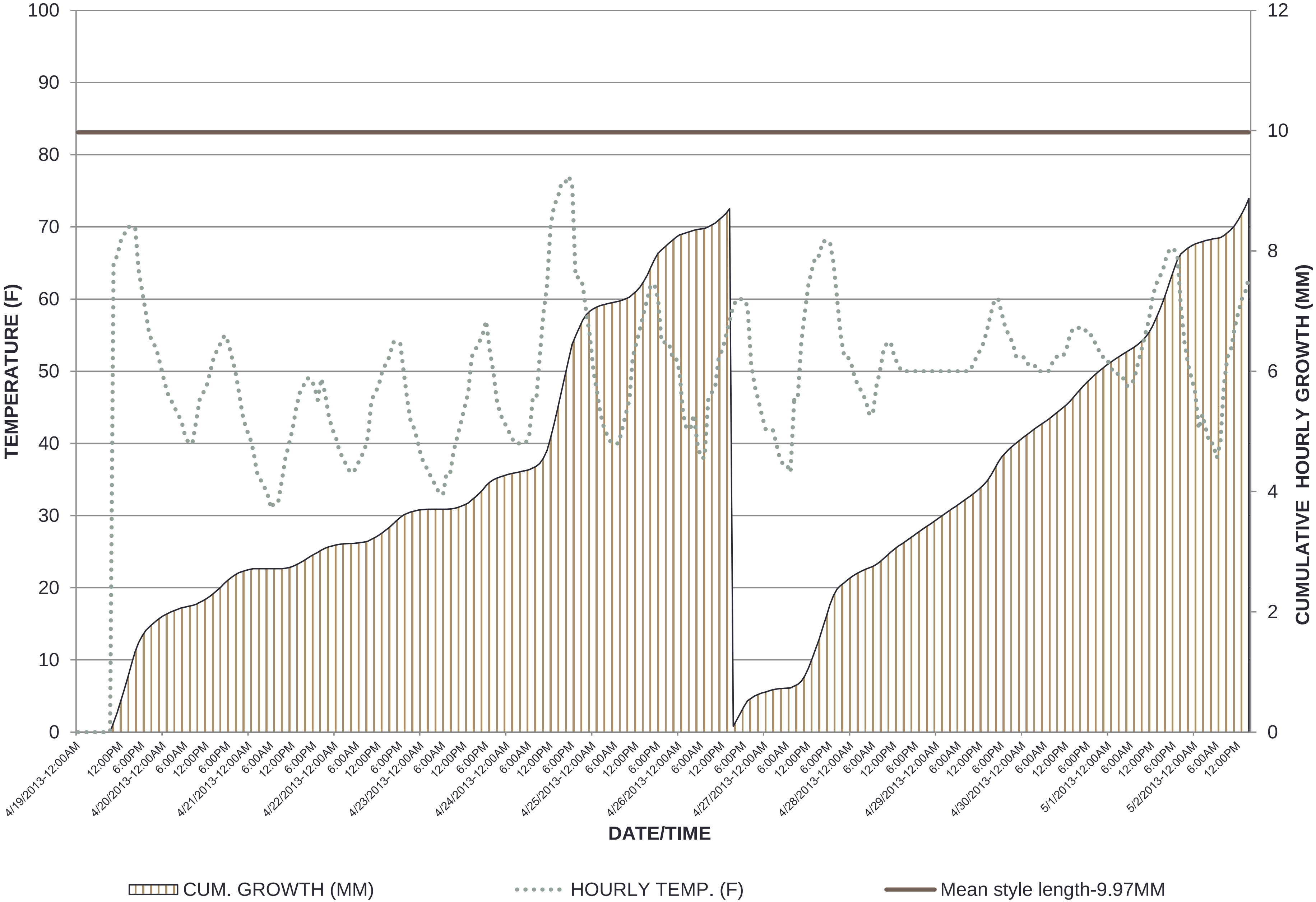
2013 GOLDEN DELICIOUS

Objective: Test chemistries that might be used for bloom thinning in organic orchards

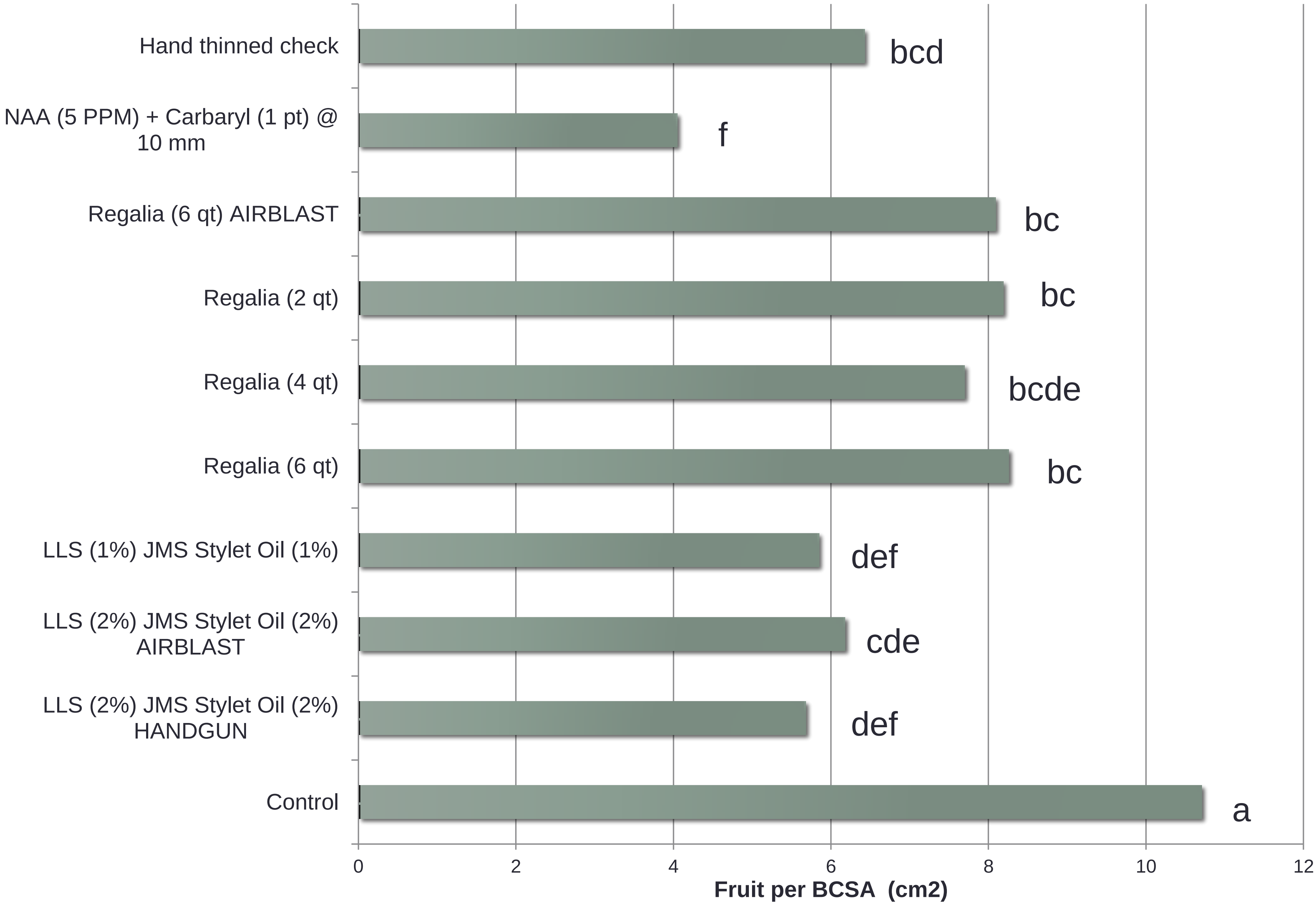
Also to compare airblast and handgun application methods

RCBD with 4 single-tree replicated blocks. M.9 rootstock. Post-hoc mean separation using Tukey HSD.

2013 Golden Delicious Pollen Tube Growth Model, Winchester, VA



Golden Delicious Crop Load



2013 Golden Delicious Microscopy Data

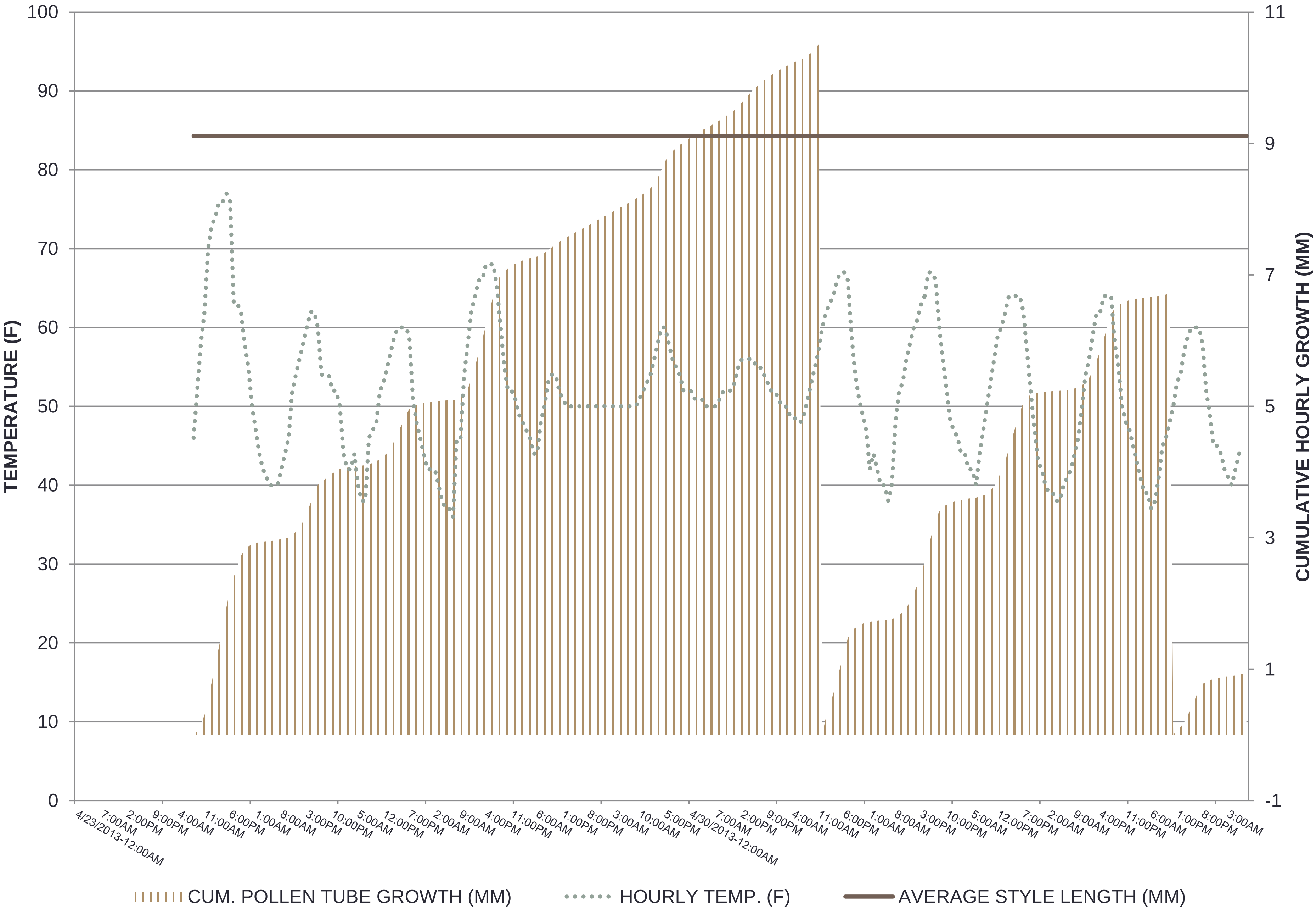
Treatment rates per 100 gal dilute (or per acre)	Crop load at harvest (Fruit/trunk cross-sectional area)	Pollen tubes in stigma (visual rating-0-10)[y]	Average number of visible pollen tubes / style penetrating stigma base	Average length of longest pollen tubes in style (mm)	Average number of visible pollen tubes at end of styles	% of styles with pollen tubes at end of styles	Average length of styles (mm)
No treatment	10.71 a	3.30 bcd	26.2 bc	5.44 ab	0.84 abc	42.5 a	8.05 c
Carbaryl 2 pt + NAA 5 ppm + Regulaid 11 fl oz (conventional timing, ~8mm)	4.05 f	---	---	---	---	---	---
Lime Sulfur 2 gal + JMS Stylet-Oil 2 gal	5.68 def	3.72 ab	30.8 ab	4.67 cd	0.50 bcd	30.0 ab	8.56 a
Lime Sulfur 1 gal + JMS Stylet-Oil 1 gal/100 gal dilute	5.85 def	3.31 bcd	27.8 b	3.94 d	0.40 cd	27.5 ab	8.08 c
Lime Sulfur 2 gal + JMS Stylet-Oil 2 gal/A ***airblast***	6.18 cde	3.43 abc	28.3 b	4.31 cd	0.47 bcd	32.5 ab	7.85 d
Regalia 4 qt + B-1956 8 fl oz	7.70 bcde	3.08 cd	25.2 bc	4.08 cd	0.19 d	30.0 ab	8.54 a
Hand-thinned control	7.79 bcd	---	---	---	---	---	---
Regalia 6 qt + B-1956 8 fl oz /A ***airblast***	8.09 bc	2.84 d	20.9 c	4.02 d	0.93 ab	30.0 ab	8.52 a
Regalia 2 qt + B-1956 8 fl oz	8.19 bc	3.86 a	35.1 a	5.71 a	1.31 a	30.0 ab	8.59 a
Regalia 6 qt + B-1956 8 fl oz	8.26 bc	3.39 abc	29.0 ab	4.80 bc	0.51 bcd	22.5 b	8.36 b

2013 HONEYCRISP

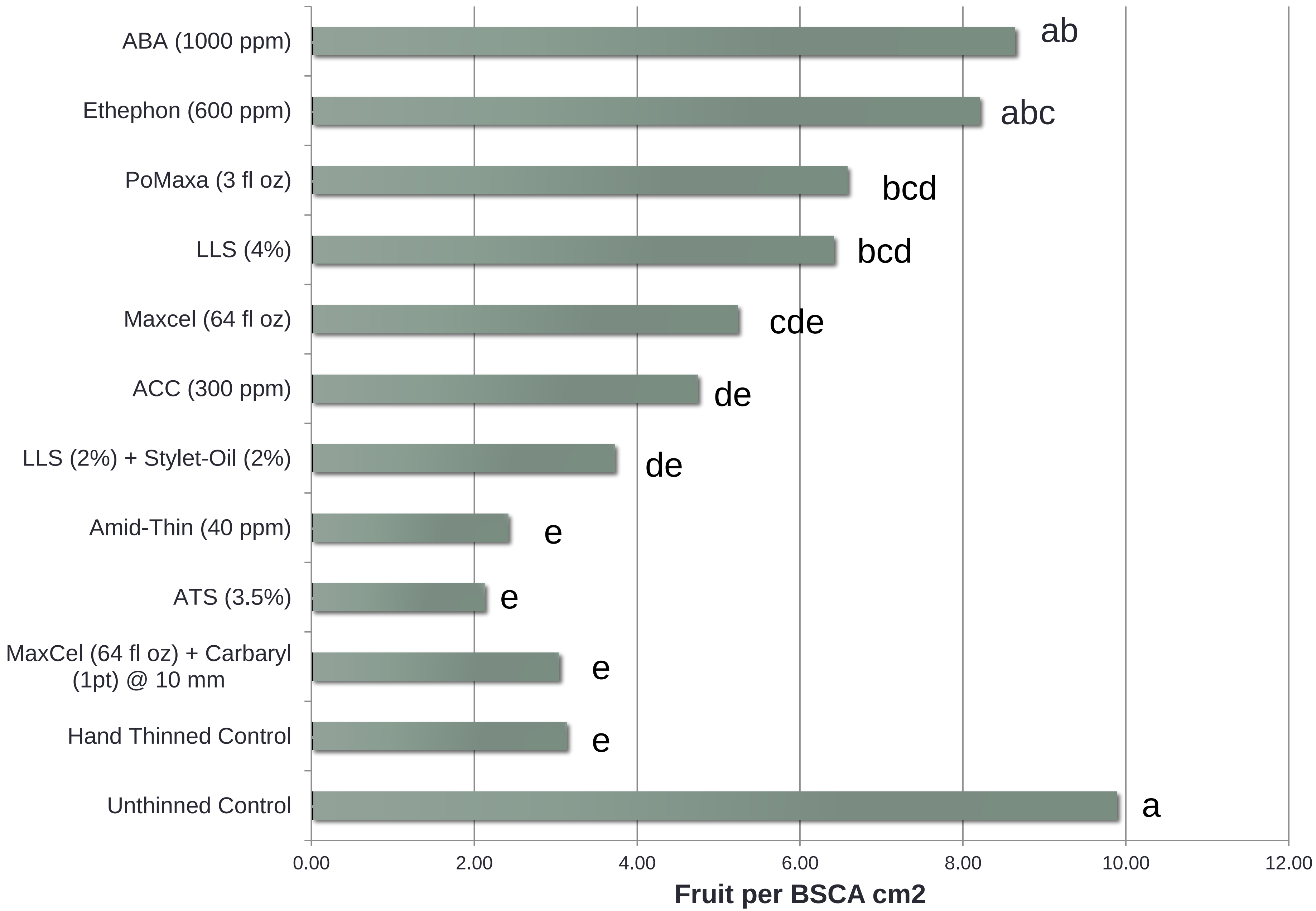
Objective: Test chemistries that might be used for bloom thinning in Eastern US orchards—not restricted to organically approved materials

RCBD with 5 single-tree replicated blocks. MM.111 rootstock. Post-hoc mean separation using Tukey HSD.

2013 Honeycrisp Pollen Tube Growth Model, Winchester, VA



2013 Honeycrisp Crop Load



LLS 2% + Stylet-Oil (2%)

ATS (3.5%)

No bloom thinner

2013 Honeycrisp Microscopy Data

Rate/100 gal	Fruit/cm2 limb cross sectional area (8 July, 2013)	Pollen tubes in stigma (visual rating-0-10)[Y]	Average number of visible pollen tubes at end of styles	Percent of side bloom flowers fertilized	Percent of side bloom styles fertilized
Untreated Control	9.89 a	4.51 a	3.29 a	84 ab	68 ab
ATS (3.5%)	2.13 e	2.42 c	0.55 f	40 c	24 d
Amid-Thin (40 ppm)	2.42 e	3.88 b	1.81 bcd	68 abc	50 abcd
MaxCel (64 fl oz)+Carbaryl (1 pt)	3.04 e	Not sampled	--	--	--
Hand thinned Control	3.14 e	Not sampled	--	--	--
Liquid Lime Sulfur (2%)	3.72 de	2.48 c	0.82 ef	56 bc	36 cd
ACC (300 ppm)	4.74 de	4.06 ab	2.33 b	80 ab	46 abcd
MaxCel (100 ppm)	5.24 cde	4.01 ab	1.06 def	72 abc	41 bcd
Liquid Lime Sulfur (4%)	6.42 bcd	2.22 c	1.47 bcde	64 abc	41 bcd
PoMaxa (7.5 ppm)	6.58 bcd	3.98 b	2.10 bc	92 a	70 a
Ethephon (600 ppm)	8.21 abc	3.95 b	1.32 cdef	76 ab	55 abc
ABA (1000 ppm)	8.64 ab	4.22 ab	2.11 bc	76 ab	57 abc

Disease control by lime sulfur and oils applied as bloom thinners Ginger Gold, Virginia Tech AREC, 2011

- Except for Rally on fruit scab, all treatments gave significant control of all diseases.
- Supplemental app. of LS + Crocker's Fish Oil 19 or 20 Apr and treatments of Stylet Oil (1 or 2%) with Lime Sulfur all gave more foliar scab control than the Rally alone.
- Scab control by Rally may have been affected by SI-resistant scab in the test area.
- All treatments gave control of mildew; no sig. differences among treatments whether considering only terminal shoot leaves 1-10 (early season), all leaves or percent area affected of all leaves.

	Bloom treatment and rate/ 100 gal; (all trts covered with Rally 12 May-5 Jul)	Bloom timing	Scab, % infection			Mildew , % inf., leaves		
			lvs 1-10	all lvs	fruit	lvs 1-10	all lvs	area
0	No fungicide	---	29 c	26 d	88 c	48 b	72 b	46 b
1	Lime Sulfur 2% + Crocker's Fish Oil 2%	4/19, 22, & 27	7 a	8 ab	19 ab	21 a	36 a	5 a
2	Lime Sulfur 2% + Crocker's Fish Oil 2%	4/20, 22, & 27	8 a	6 a	18 ab	21 a	32 a	4 a
3	Lime Sulfur 2% + Crocker's Fish Oil 2%	4/22 & 27	10 ab	12 bc	33 b	22 a	34 a	5 a
4	Lime Sulfur 2% + JMS Stylet Oil 2%	4/22 & 27	7 a	9 ab	15 a	21 a	33 a	4 a
5	Lime Sulfur 1% + JMS Stylet Oil 1%	4/22 & 27	6 a	8 ab	35 b	19 a	36 a	5 a
6	Lime Sulfur 1% + JMS Stylet Oil 1% + Rally 1.25 oz	4/22 & 27	6 a	7 ab	24 ab	16 a	28 a	4 a
7	Rally 40W 1.25 oz	4/22 & 27	18 b	19 cd	77 c	20 a	33 a	4 a

Mean separation by Waller-Duncan K-ratio t-test (p=0.05). Four single-tree replications.
Treatments applied 4/19 (trt. #1 only, pink to petal fall); 4/20 (trt. #2 only, pink to petal fall); 4/22 (all trts, full bloom); 4/27 (follow up for late bloom thinning, all treatments, petal fall).

Foliar data counts of ten terminal shoots each of four single-tree reps 17 Jun.
Fruit counts are of 25-fruit samples / rep on the tree (russet rating), at harvest 16 Jul.

Fruit finish by lime sulfur and oils applied as bloom thinners
Ginger Gold, Virginia Tech AREC, 2011

- All Lime Sulfur treatments increased the percent of fruits with russet and percent area russetted.
- Combinations of Lime Sulfur with JMS Stylet Oil tended to have more area russetted than those with Crocker's Fish Oil.
- The 20 Apr app. of Lime Sulfur 2% + Crocker's Fish Oil 2% was the only treatment that resulted in a significantly higher stem end russet rating.

			Fruit finish assessments**		
		Bloom spray timing	% of fruits with side russet, on tree 14 Jul	post-harvest russet ratings	
	Bloom treatment and rate/ 100 gal			% fruit area russetted	stem-end russet (0-5)
0	No fungicide	---	4 a	0.8 a	1.1 a
1	Lime Sulfur 2% + Crocker's Fish Oil 2%	4/19, 22, & 27	28 b	9.7 bc	1.7 ab
2	Lime Sulfur 2% + Crocker's Fish Oil 2%	4/20, 22, & 27	34 b	7.0 b	2.3 b
3	Lime Sulfur 2% + Crocker's Fish Oil 2%	4/22 & 27	29 b	7.2 b	1.8 ab
4	Lime Sulfur 2% + JMS Stylet Oil 2%	4/22 & 27	30 b	12.8 cd	1.8 ab
5	Lime Sulfur 1% + JMS Stylet Oil 1%	4/22 & 27	49 b	14.0 d	1.3 a
6	Lime Sulfur 1% + JMS Stylet Oil 1% + Rally 1.25 oz	4/22 & 27	45 b	12.6 cd	1.6 ab
7	Rally 40W 1.25 oz	4/22 & 27	3 a	0.5 a	1.1 a

Mean separation by Waller-Duncan K-ratio t-test (p=0.05). Four single-tree reps.
Applications: 4/19 (trt. #1 only, pink to petal fall); 4/20 (trt. #2 only, pink to PF); 4/22 (all trts, full bloom); 4/27 (follow up for late bloom thinning, all trts, PF).

** Fruit russet ratings means of 25-fruit /rep on tree or after harvest 19 Aug. Stem russet rated on a scale of 0-5 (5= severe russet).

Concluding remarks

- Bloom thinning can and should be practiced in the Eastern US
  - Bloom thin varieties where fruit size is essential for profitability, e.g. Gala
  - Bloom thin biennial bearing varieties during the "on year", e.g. Fuji, York
  - Focus on later blooming varieties, e.g. Honeycrisp
- Bloom thinning may reduce the need for 1-2 fungicide sprays
- Bloom thinning with liquid lime sulfur may increase russet
  - Avoid varieties that are prone to russet; Golden Delicious, Ginger Gold
  - Alternative bloom thinning materials are needed
- The Pollen Tube Growth Model can help reduce "stress-induced bloom thinning paralysis"

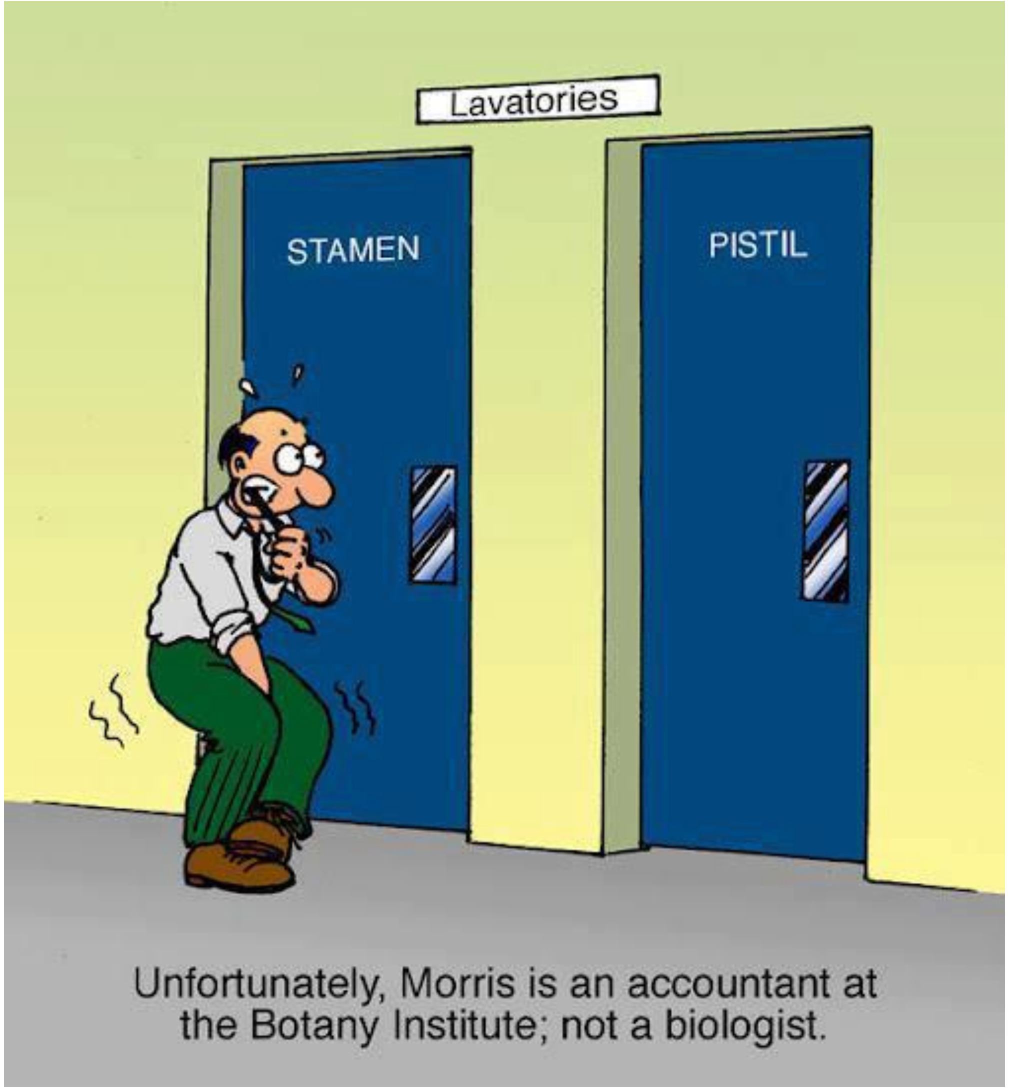
What's next?

- Additional beta testing and validation
- New models: Honeycrisp (2014) and Red Delicious (2015)
- Understanding the paternal (pollen) effects on pollen tube growth rates (MS student Candace DeLong)
- Integrating mechanical pollination with bloom thinning
- Elucidating the specific modes of action for bloom thinning chemicals
- Understanding flower morphological features that impact bloom thinning, such as style fusion and pollen tube callose plugging
- Integrating bloom thinning with whole-orchard management, including tree nutritional status and disease management
- Developing bloom thinning programs for Eastern US and organic apple growers. Integrating the PTGM into mesonet websites.

ACKNOWLEDGMENTS

- Washington Tree Fruit Research Commission, particularly Tory Schmidt
- Stemilt Growers, Washington Fruit & Produce Co., Roche Fruit, C & O Nursery, Columbia Basin Nursery, Dovex Fruit
- JMS Flower Farms, Marrone Bio Innovations, Miller Chemical & Fertilizer Corp., Crocker's Fish Oil, Valent BioSciences
- May hours of assistance from technicians and student workers

And, if you're Morris...



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