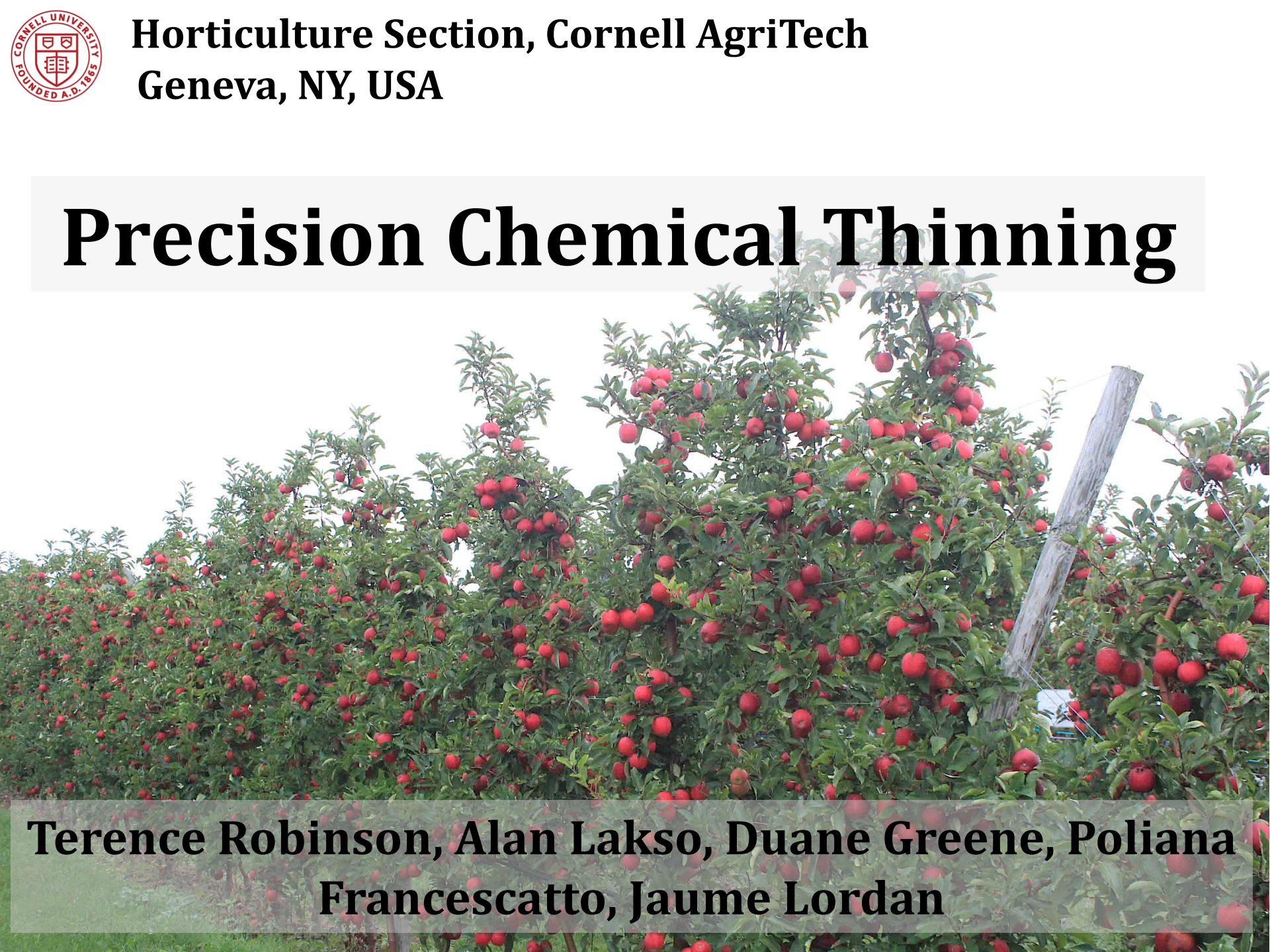
Horticulture Section, Cornell AgriTech
Geneva, NY, USA

Precision Chemical Thinning



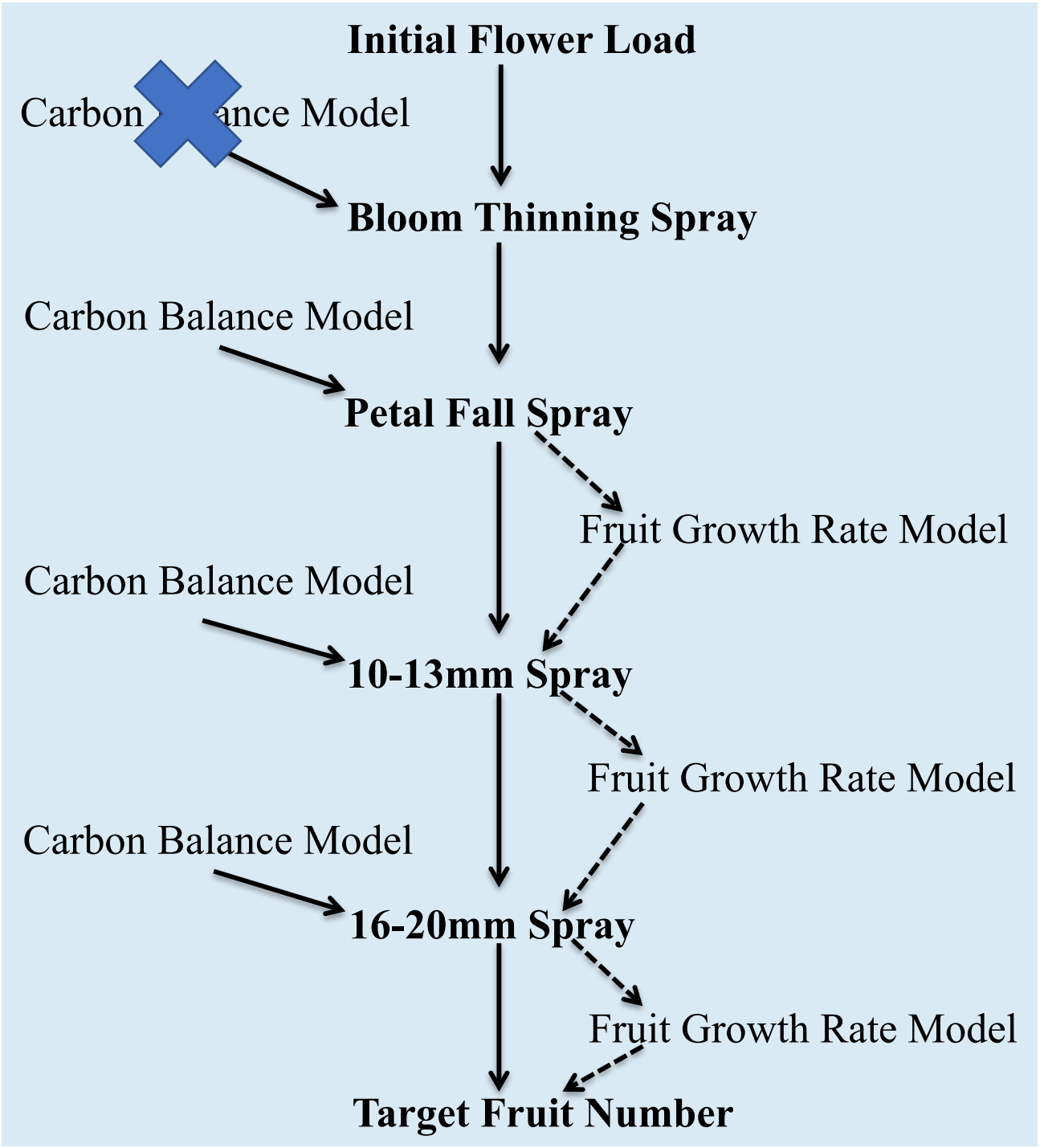
Terence Robinson, Alan Lakso, Duane Greene, Poliana Francescatto, Jaume Lordan

What is Precision Chemical Thinning?

Precision Chemical Thinning is a strategy to manage the chemical thinning process better by:

1. Identifying the target number of fruit per tree in each block
2. Count flower cluster number at pink or bloom per tree (5 trees/block)
3. Use multiple applications of chemical thinners to stepwise reduce the fruitlet number to the target number
3. Use the carbohydrate model to predict thinning response.
4. Assess results using the fruit growth rate model
5. Re-apply chemical thinners if needed.

Steps in Precision Chemical Thinning



Variability in Thinning Efficacy is Caused by Sensitivity of the Tree

- The sensitivity is related to temperature (temperature affects photosynthesis and fruit respiration.
- The sensitivity is related to sunlight levels (sunlight level affects photosynthesis) (shading causes fruit drop).
- The sensitivity is related to fruit size with the maximum sensitivity at 10-12mm (as fruits grow they demand more carbohydrates to support them).
- This suggests that carbohydrate supply/demand balance is probably important in the sensitivity of apple trees to chemical thinners.

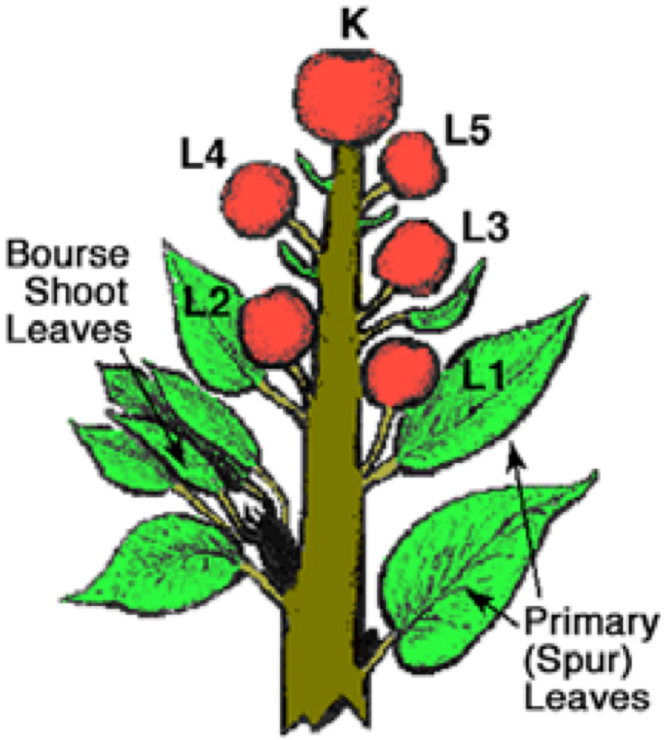
Summary of Observations on Weather Effects:

- Dark, cloudy weather of more than 1-2 day duration reduces carbohydrate supply and results in greater natural drop and greater chemical thinning.
- High night temperatures (>60°F, 15.5°C) increase carbohydrate demand and increase natural drop and chemical thinning response.
- Very high day-time temperatures (>85°F, 35°C) increase carbohydrate demand and causes excessive thinning.
- Very cool temperatures (<65°F, 17°C) reduce fruit demand and results in poor thinning response.

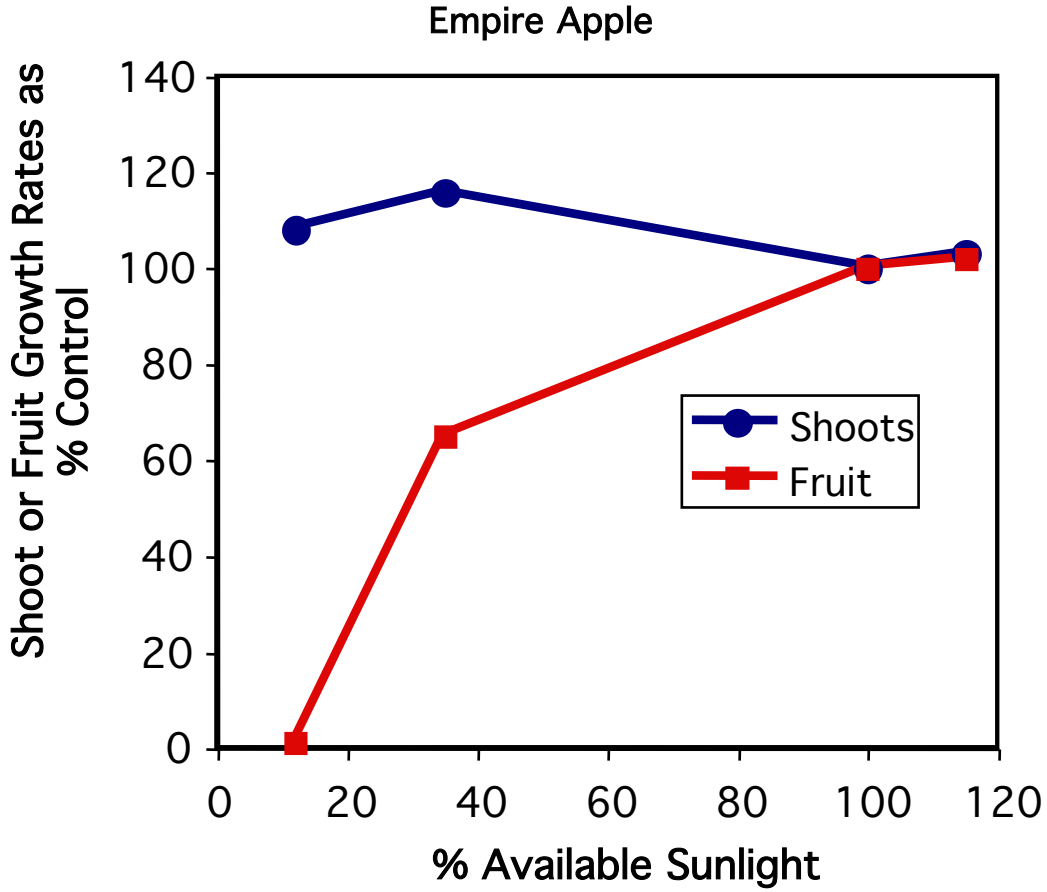
A Carbon Based Hypothesis of Fruit Growth and Abscission

Fruitlet sensitivity to chemical thinners is primarily a function of carbon supply available for fruit growth from current production.

- Temperature and sunlight influence the trees carbon production.
- Temperature affects demand from competing sinks and demand from fruits.
- When demand for fruit growth exceeds supply, the least competitive fruits abscise.
- Trees are more susceptible to chemical thinners when carbon supply is limiting and less susceptible when carbon is ample.



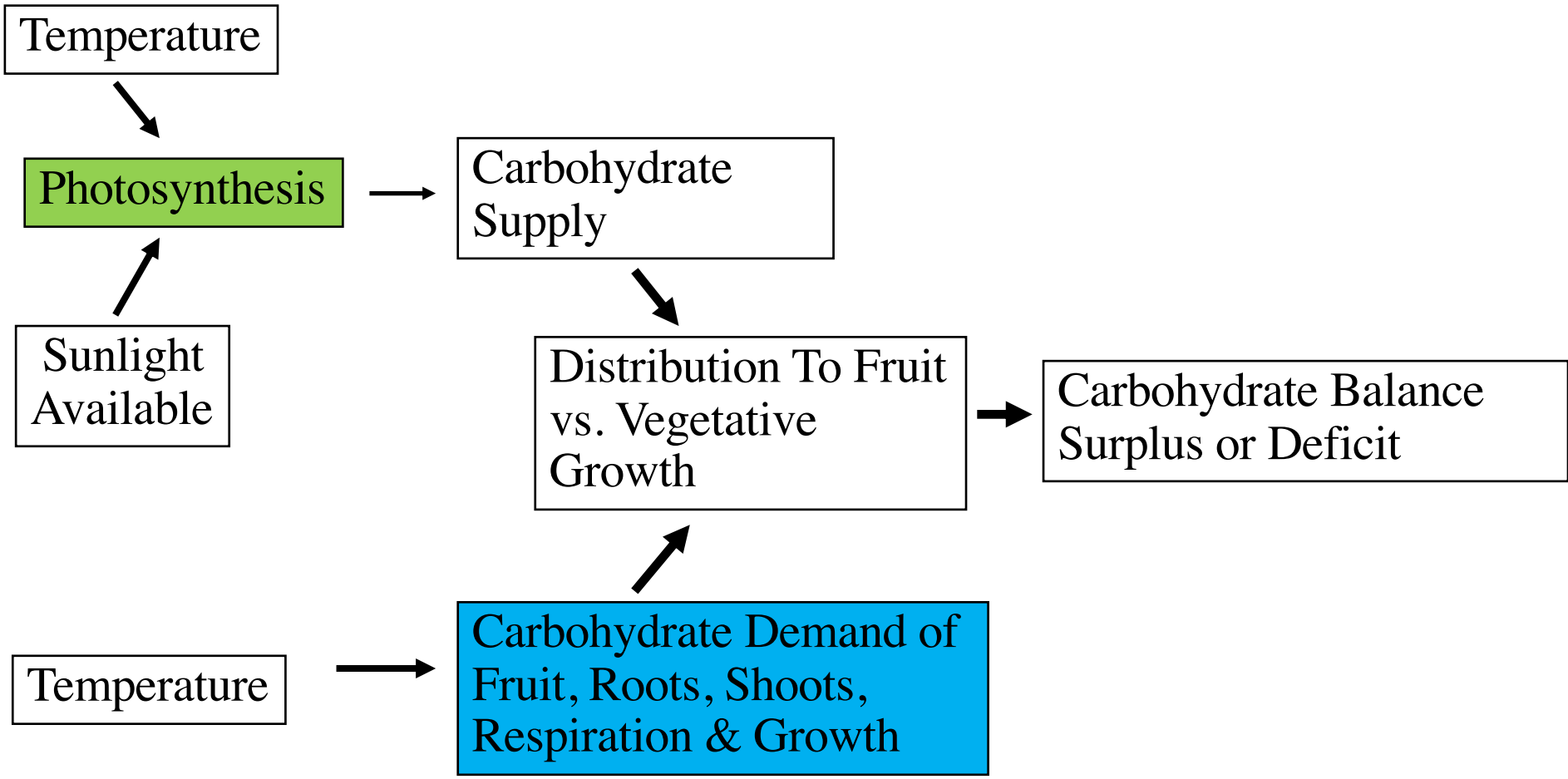
Competition between shoot growth and fruit growth in Empire apple trees at the time of thinning.



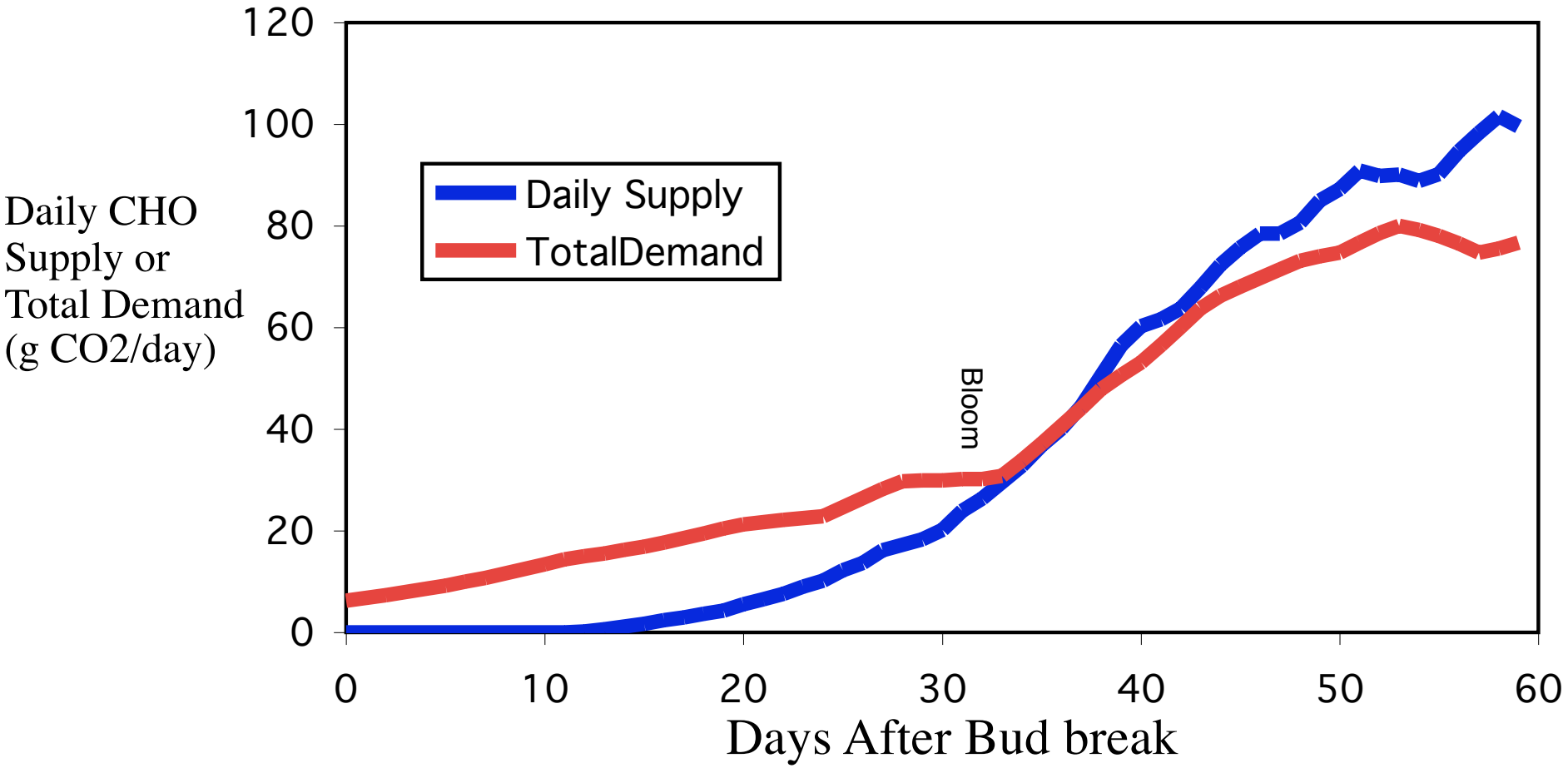
Shoot growth was not affected by the reduction in carbohydrate supply caused by shade, but fruit growth was severely reduced at lower light, defruiting the trees at the lowest light.

The Carbohydrate Model

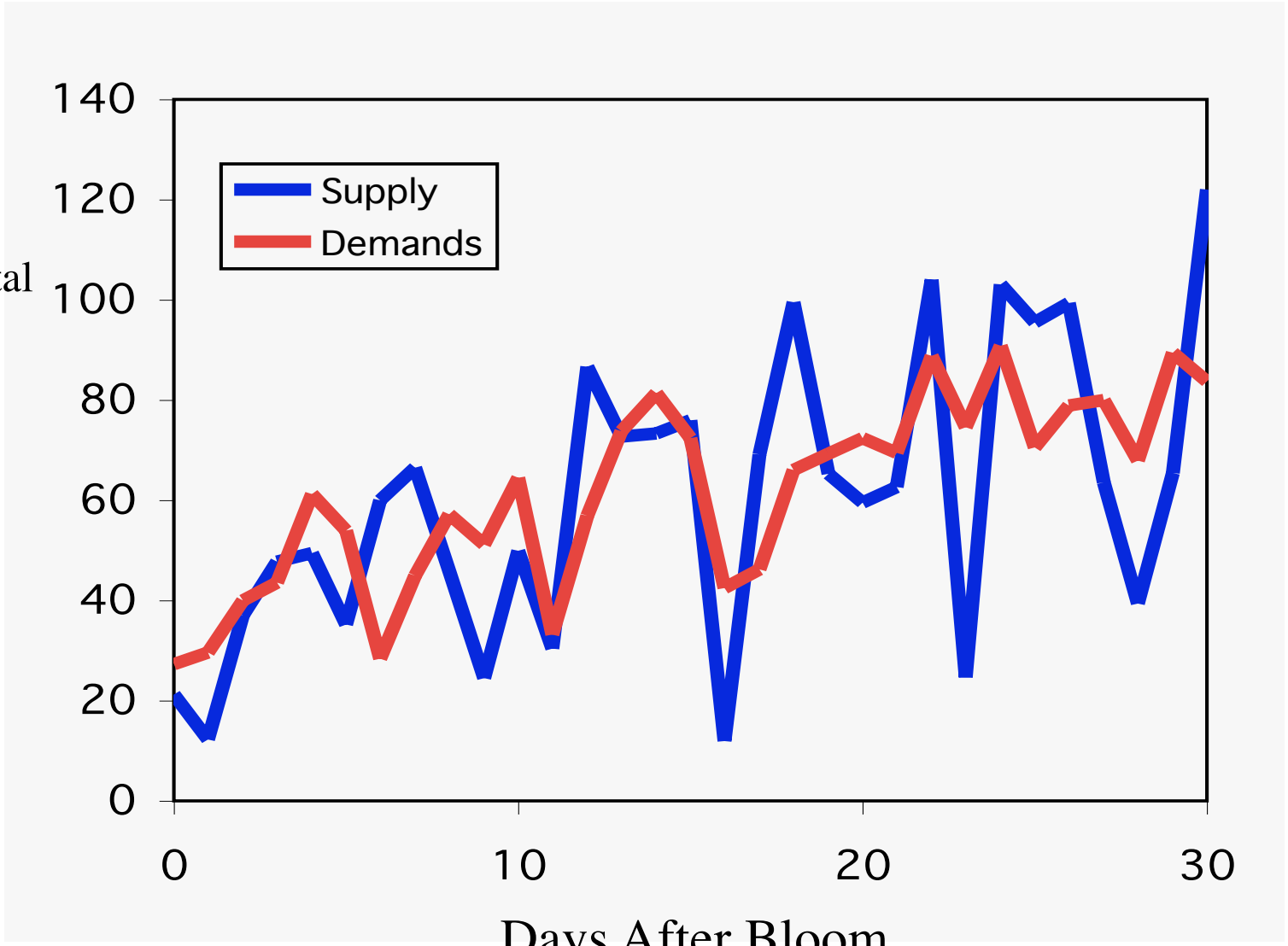
Developed by Alan Lakso et al.



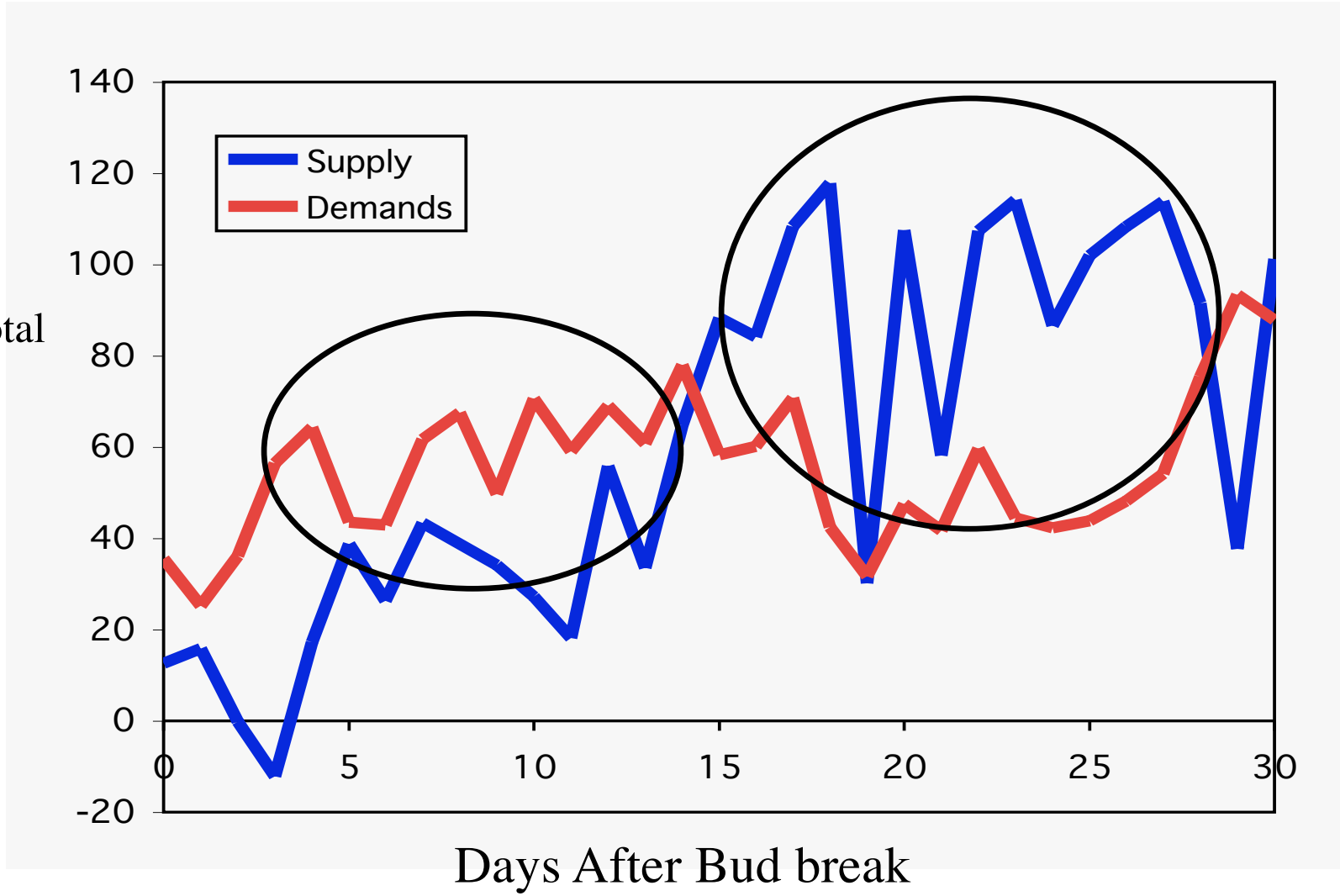
Model Simulation of Tree CHO Supply vs. Total Demand of All Organs (Crop Set at 300 Fruits with long-term average temperature and sunlight data from Geneva



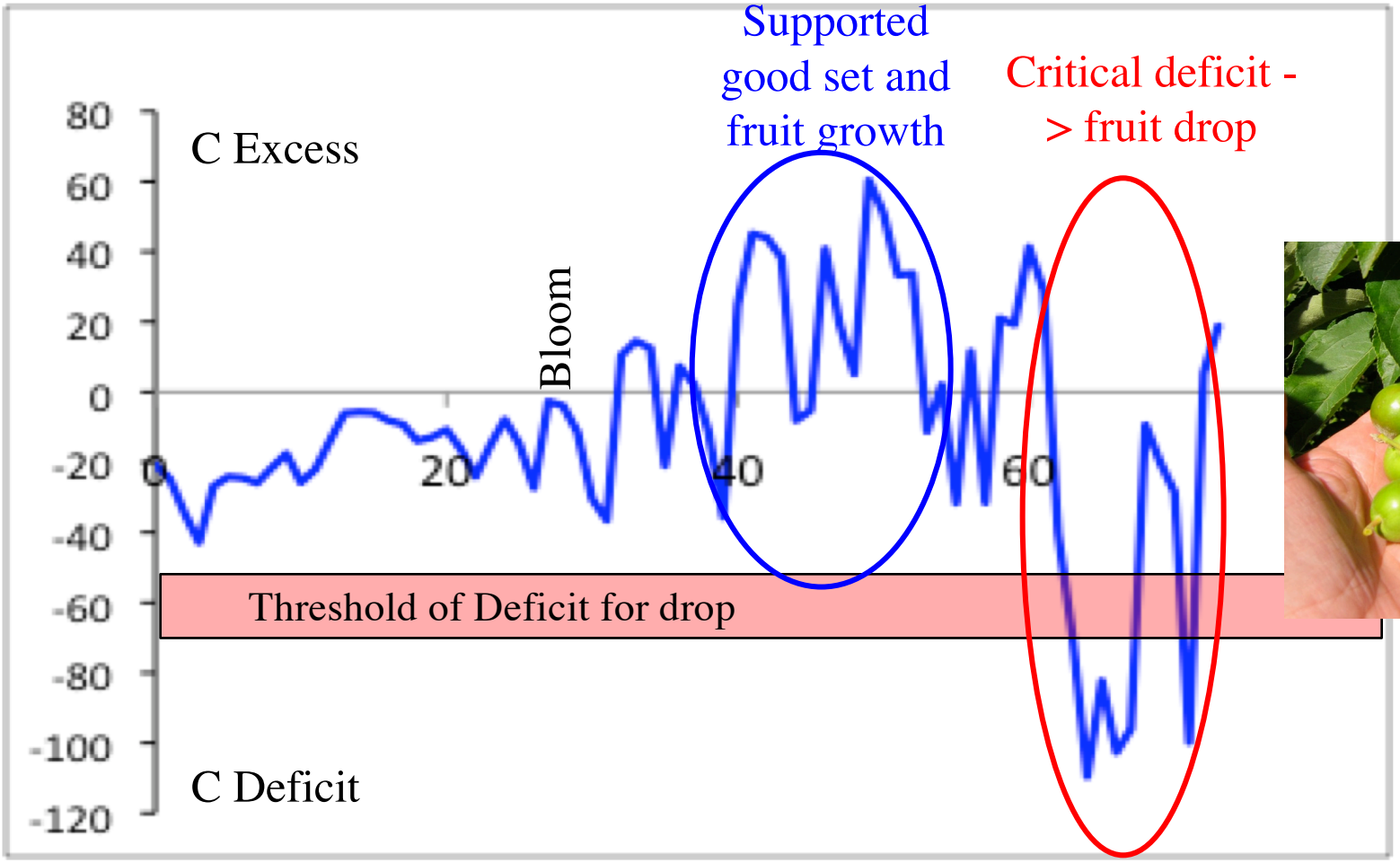
Model Simulations of 2003 Tree CHO Supply vs. Total Demand of All Organs (Crop Set at 300 Fruits)



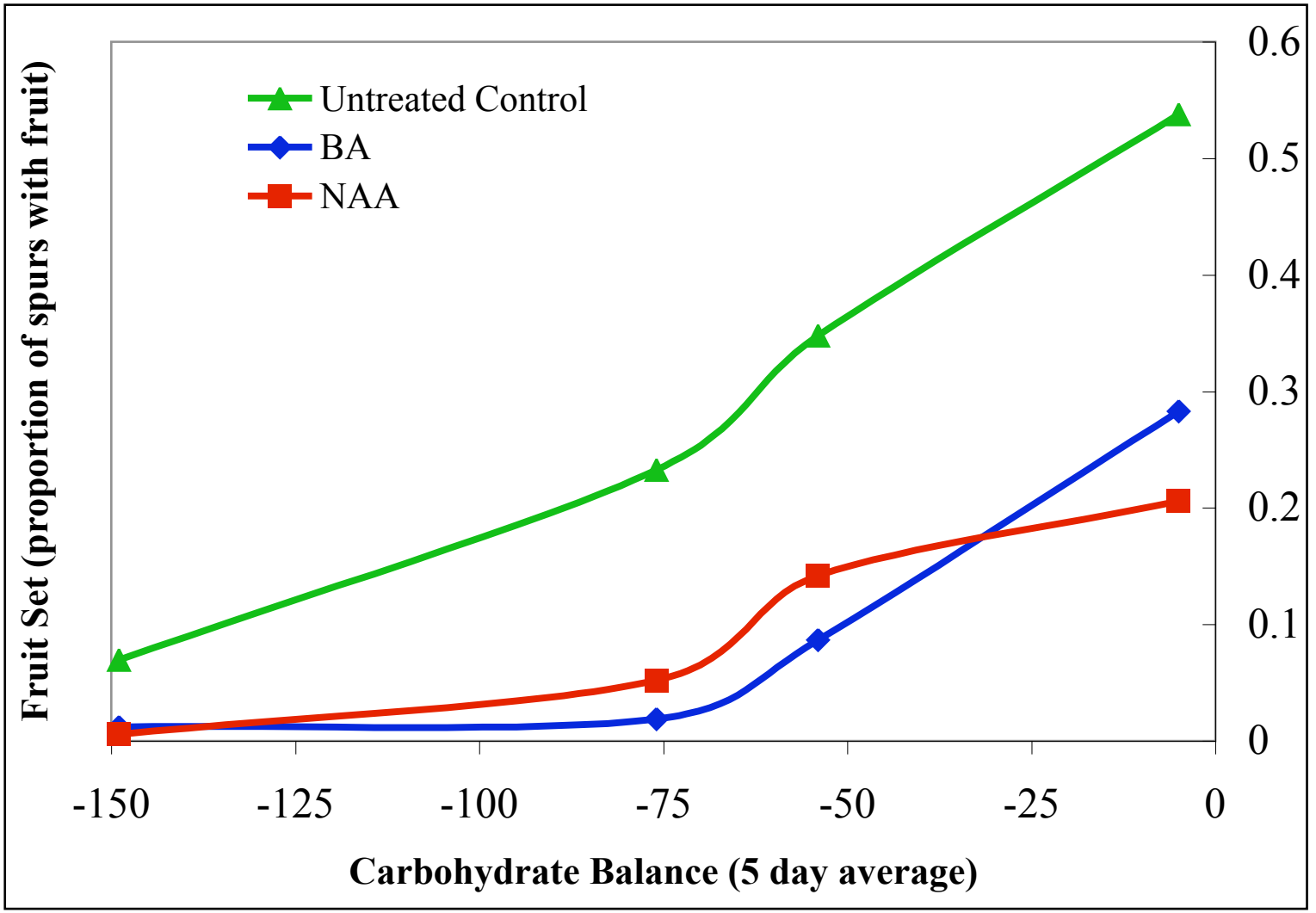
Model Simulations of 2004 Tree CHO Supply vs. Total Demand of All Organs (Crop Set at 300 Fruits)



Weather effects on natural drop are consistent with carbohydrate supply/demand (Uruguay)



Relationship between carbohydrate balance for 5 days after application of thinners and fruit set of Empire/M.9 apple trees.



Decision Rules We Use to Make Recommendations

4-Day Av. Carb. Balance	Thinning Recommendation
+20g/day to +40g/day	Increase Chemical Thinning Rate by 30%
+20g/day to 0g/day	Increase Chemical Thinning Rate by 15%
0g/day to -20g/day	Apply Standard Chemical Thinning Rate
-20g/day to -40g/day	Decrease Chemical Thinning Rate by 10%
-40g/day to -60 g/day	Decrease Chemical Thinning Rate by 20%
-60g/day to -80 g/day	Decrease Chemical Thinning Rate by 30%
< than -80g/day	Do not thin (many fruits will fall off naturally)

New York State Integrated Pest Management Program

NEWA Network for Environment and Weather Applications

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Apple Carbohydrate Thinning

Cornell Apple Carbohydrate Thinning Model

Weather Station: Williamson (Demarree)

Select Date: 06/08/2013

Continue

Map | Results | More info

Apple Carbohydrate Thinning Model for Williamson (Demarree)

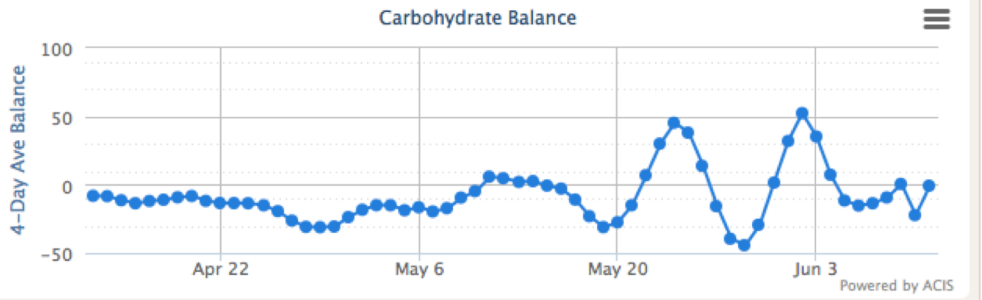
Change green tip and/or bloom date and click "Calculate" to recalculate results.

Green tip date	Bloom date	Calculate
4/13/2013	5/6/2013	

Apple Carbohydrate Thinning Model Results

Date	Max Temp (°F)	Min Temp (°F)	Solar Rad (MJ/m2)	Tree Carbohydrate Status (g/day)				Thinning Recommendation
				Production	Demand	Balance	4-Day Ave Balance	
4/13	48	41	0.4	0.00	5.76	-5.76	-8.09	-
4/14	44	33	1.0	0.00	3.93	-3.93	-8.35	-
4/15	73	34	4.1	0.00	10.23	-10.23	-11.36	-
4/16	66	43	0.3	0.00	12.42	-12.42	-13.54	-
4/17	52	35	6.0	0.00	6.84	-6.84	-11.89	-
4/18	74	39	12.0	0.00	15.95	-15.95	-11	-
4/19	73	44	0.3	0.00	18.95	-18.95	-9.21	-
4/20	44	34	1.5	0.00	5.82	-5.82	-8.23	-
4/21	40	27	6.0	0.00	3.29	-3.29	-11.82	-
4/22	59	28	6.2	0.00	8.77	-8.77	-13.37	-
4/23	62	40	13.9	0.39	15.41	-15.03	-13.43	-
4/24	67	41	2.6	0.00	20.18	-20.18	-13.54	-

6/2	77	57	20.7	89.58	69.55	20.03	52.36	thinner rate by 30%
6/3	62	51	26.5	114.67	46.25	68.42	35.26	Increase chemical thinner rate by 30%
6/4	67	46	27.2	119.81	46.45	73.36	7.33	Increase chemical thinner rate by 30%
6/5	67	52	22.1	103.28	55.65	47.62	-11.56	Apply standard chemical thinner rate
6/6	58	54	2.3	0.46	48.83	-48.37	-15.26	Apply standard chemical thinner rate
6/7	60	55	3.8	12.01	55.31	-43.30	-13.56	Apply standard chemical thinner rate
6/8	64	55	10.9	58.45	60.63	-2.18	-9.33	Apply standard chemical thinner rate
6/9	76	56	26.2	112.14	79.34	32.80	0.57	Increase chemical thinner rate by 30%
6/10	69	57	6.9	32.78	74.34	-41.56	-22.25	Decrease chemical thinner rate by 15%
6/11	65	56	8.3	43.76	70.13	-26.37	-0.73	-
6/12	73	53	25.8	116.44	79.03	37.42		-
6/13	66	54	3.7	11.99	70.49	-58.50		-
6/14	70	53	26.4	120.09	75.55	44.54		-



After 10 years what is the value of the Carbohydrate Model

The model is based on physiological responses.

- Photosynthesis response curve to temperature
- Photosynthesis response curve to sunlight
- Respiration response curve to temperature of each organ
- Sink strength of each organ
- Initial flower bud load

It should be robust and applicable in a wide range of climates

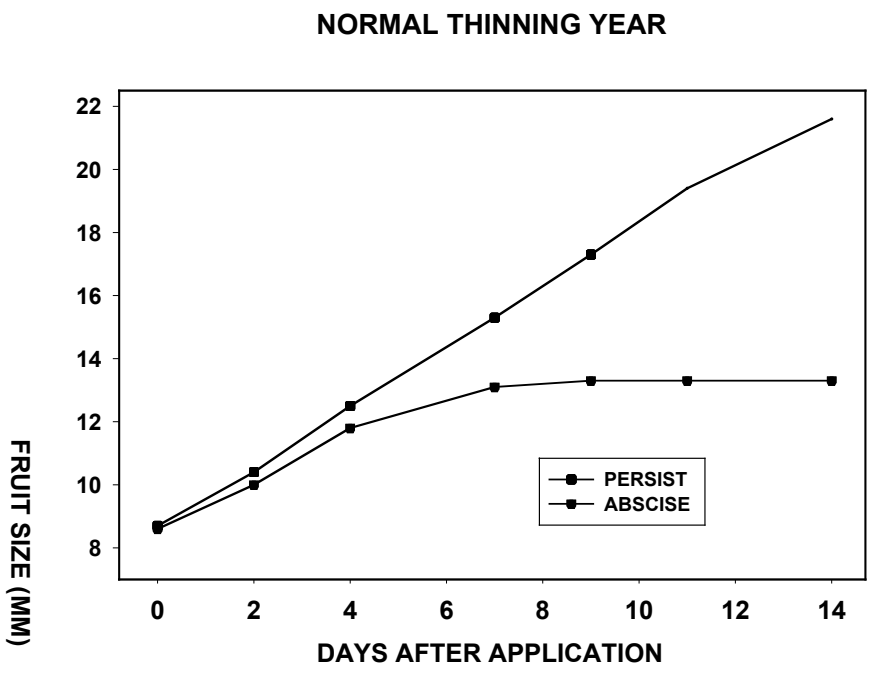
In NY and other Eastern US regions we see both carbohydrate deficits and surpluses depending on the year.

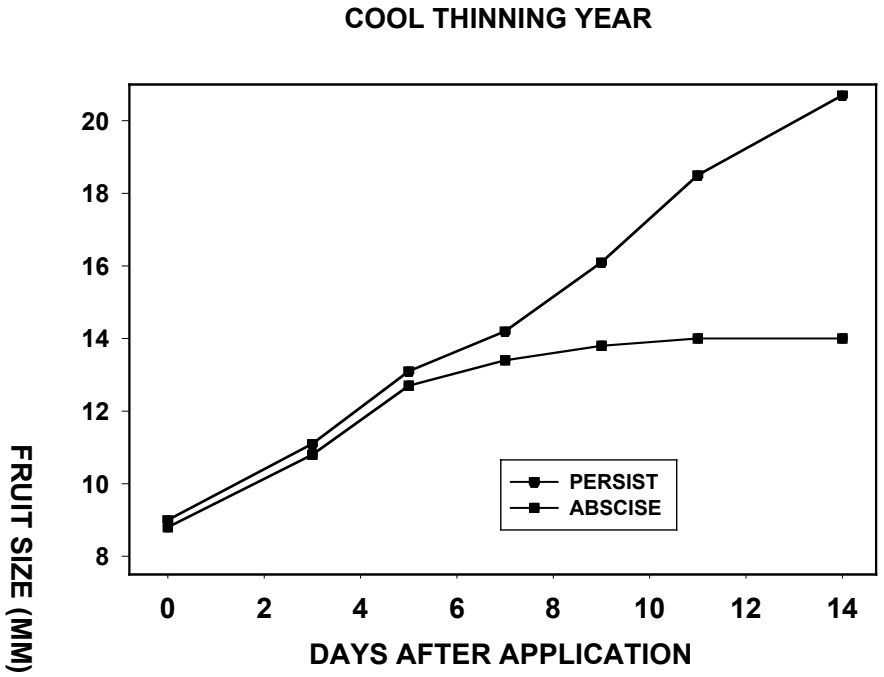
In Chile we see very few carbohydrate deficits.

In Washington there are fewer deficits than NY but they do occur.

The model imperfectly predicts thinning response and serves as a guide to avoid overthinning and to give confidence.

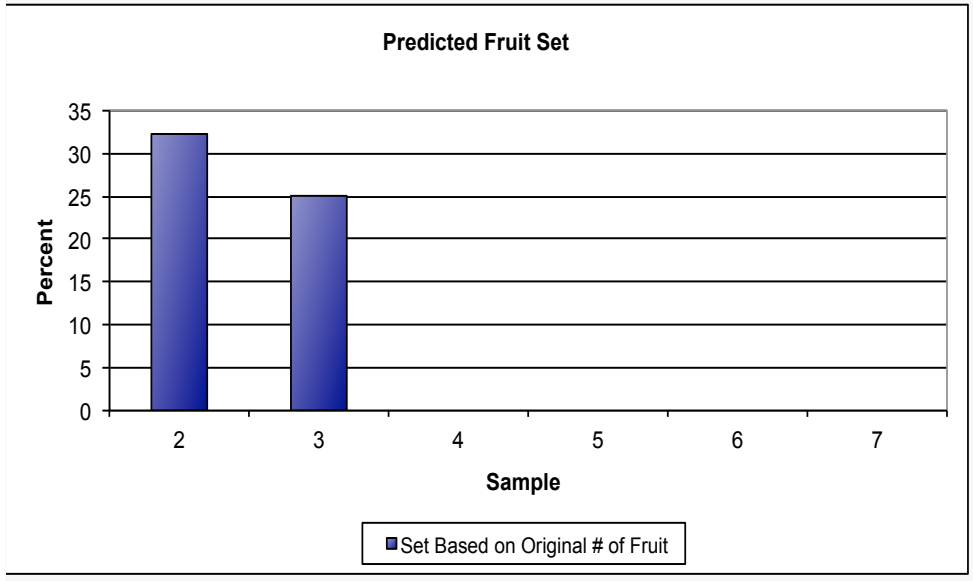
The Fruit Growth Rate Model





The Fruit Growth Rate Model (Greene, Lakso and Robinson)

SUMMARY			Variety, Strain					0	2007
			Treatment		0	Block	1		
Sampling			Diameter (mm)			Number of Fruit			Predicted %	
Number	Date	Days between sample dates	Mean of all measured fruitlets	Mean growth of up to 3 fastest growing fruitlets per tree	50% of fastest growing fruitlets	>50% fastest	<50% fastest	Measured	Set Based on Original # of Fruit	Drop Based on Original # of Fruit
1	5/25	0	6.49					471		
2	5/29	4	8.16	4.90	2.45	152	208	360	32.3	67.7
3	6/1	3	9.38	4.14	2.07	118	191	309	25.1	74.9
4				0.00	0.00	0	0	0	0.0	100.0
5				0.00	0.00	0	0	0	0.0	100.0
6				0.00	0.00	0	0	0	0.0	100.0
7				0.00	0.00	0	0	0	0.0	100.0



Counting Buds, Flowers or Fruits is Easier on Simple Trees

Tall Spindle

Super Spindle

V-Trellis

Bi-axis

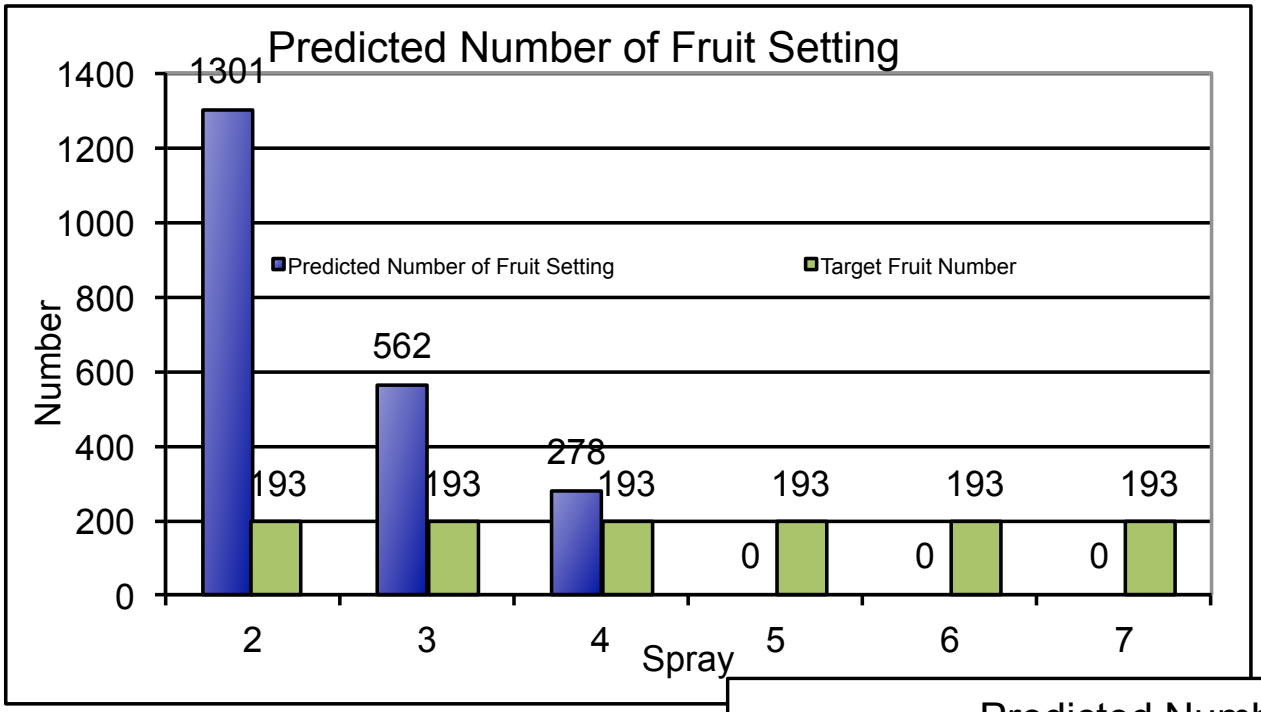
2D Robot Ready

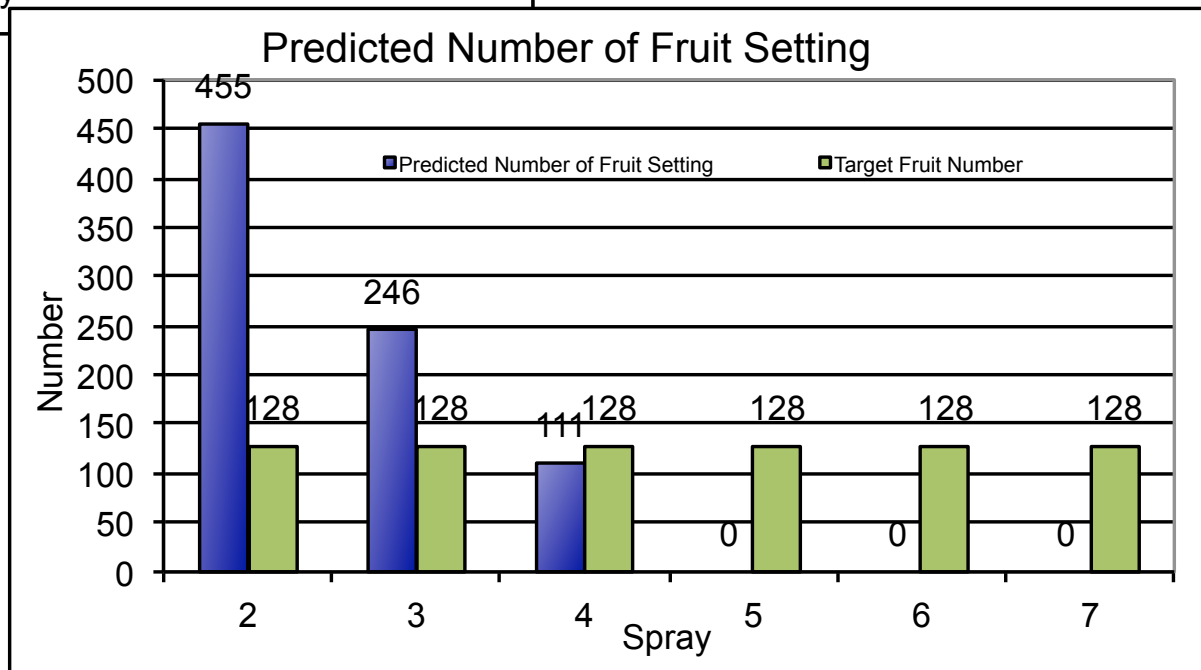
Fruiting Wall - Hedged

Example of Precision Thinning with Gala

- Bloom
  - ATS (2.0 %) (1-3 applications guided by pollen tube growth model
- Petal Fall (5-6mm)
  - NAA (7.5ppm) + carbaryl (600ppm)
- 12mm
  - BA (100ppm) + carbaryl (600ppm) (directed at only the upper part of the tree)
- 15-18 mm
  - BA (100ppm) + carbaryl (600ppm) + oil (0.1%) (directed at only the upper part of the tree)

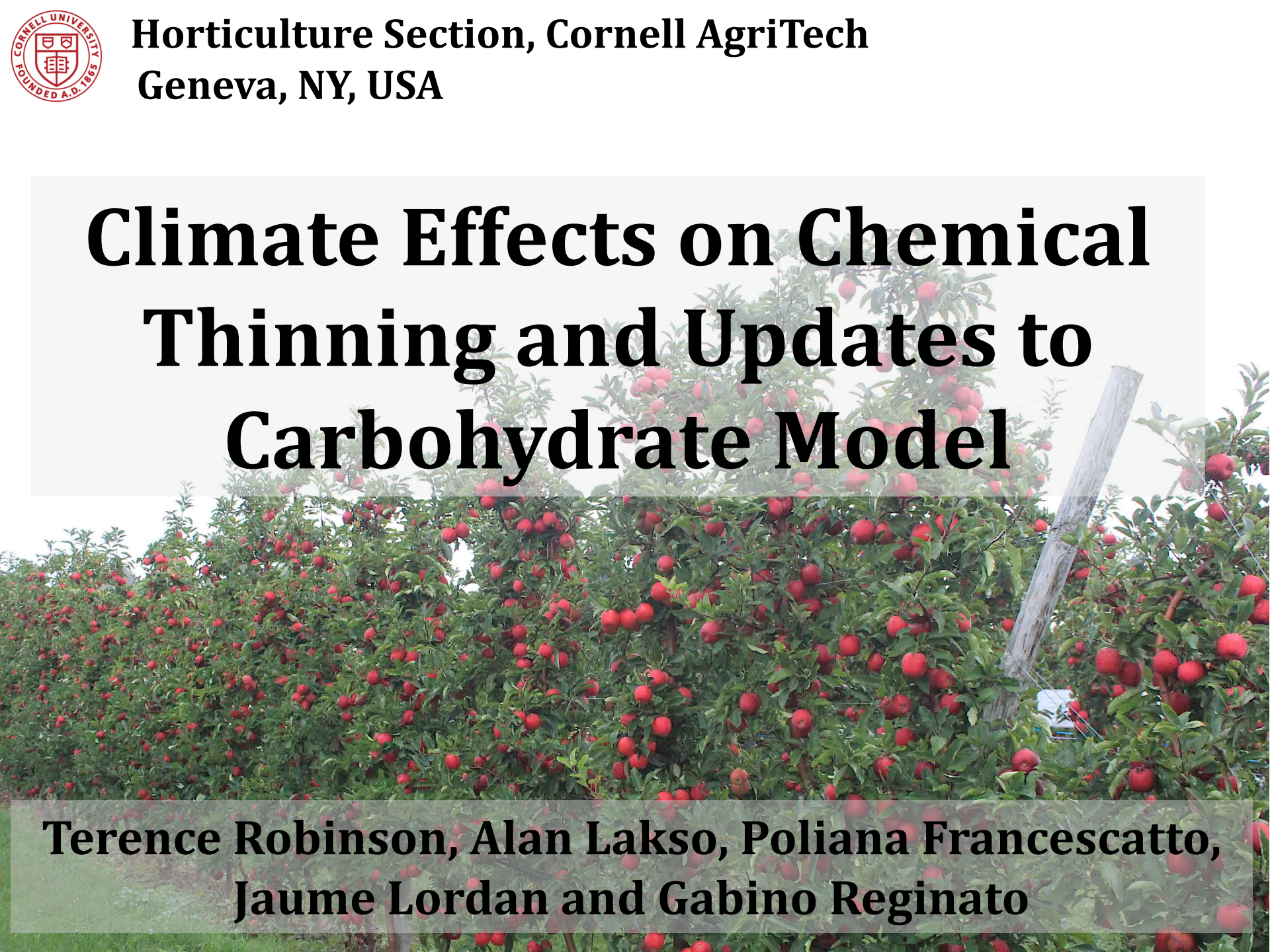
Example Results of Precision Chemical Thinning





Horticulture Section, Cornell AgriTech
Geneva, NY, USA

Climate Effects on Chemical Thinning and Updates to Carbohydrate Model



Terence Robinson, Alan Lakso, Poliana Francescatto, Jaume Lordan and Gabino Reginato

Material and Methods

Studied the effect of time of application of thinners and year to year variability in thinner response from 2000-2017

Application of either 100ppm Maxcel + 1pt of Carbaryl or 7.5ppm NAA + 1pt of Carbaryl were made at different timings each year

Beginning at Petal fall or 3 every 3-4 days until 21 days after petal fall.

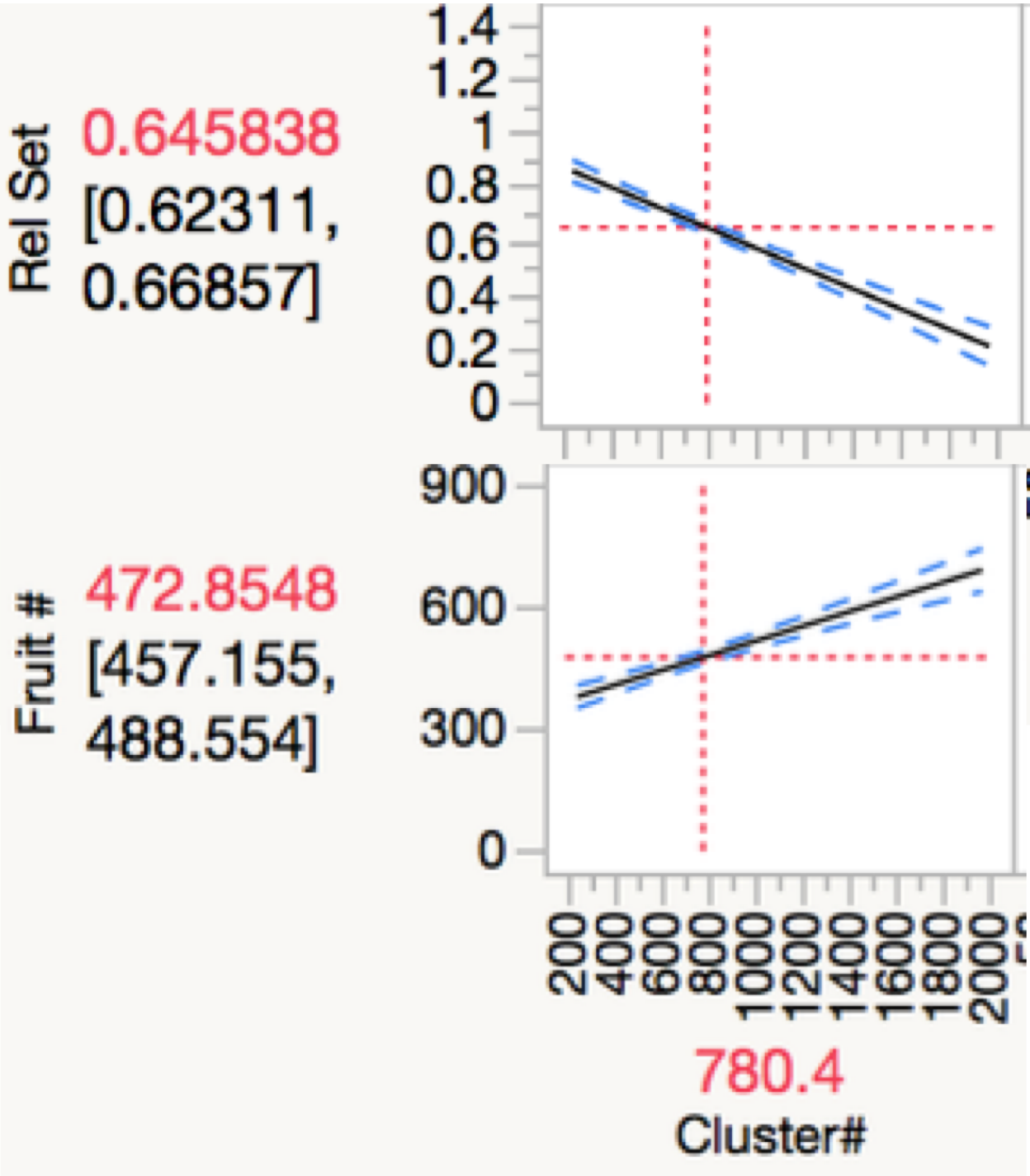
Analyzed the effect of climate on thinning response from chemicals using data for all years through multiple regression

Results – Chemical Thinning

Fruit set was reduced as the number of flower clusters increased.

Final fruit number was increased as the number of flower clusters increased.

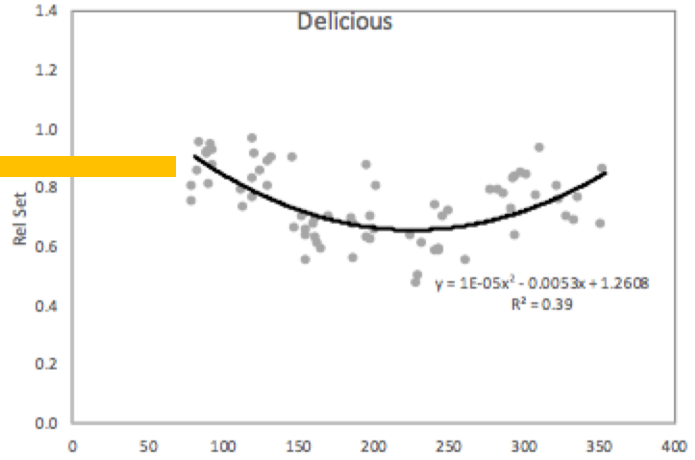
Bottom Line: If you start with a lot of flowers you end up with too many fruits even after chemical thinning and a large hand thinning job.

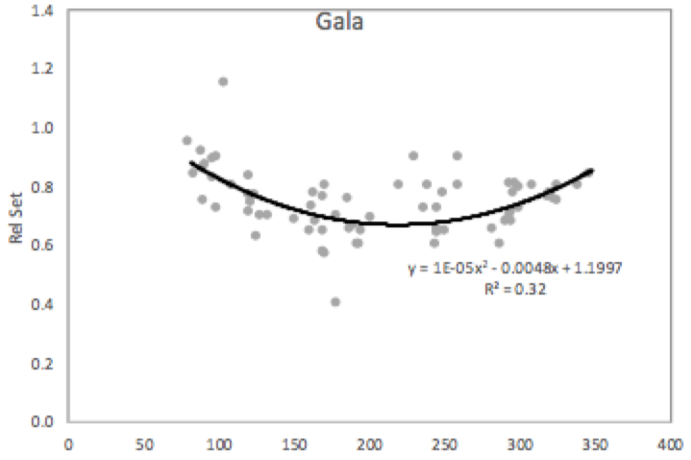


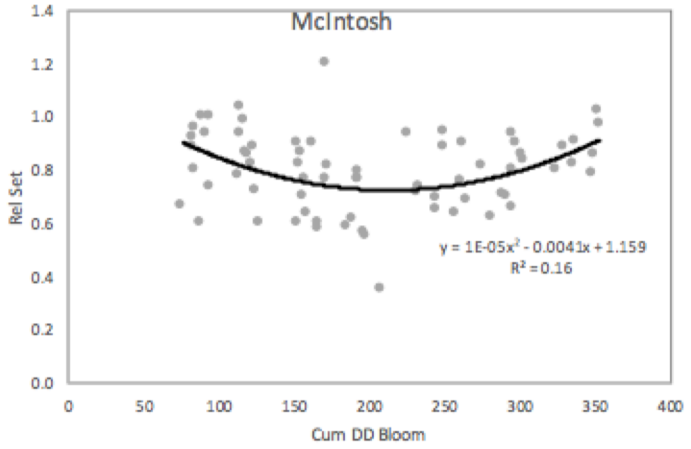
Results – Chemical Thinning

Fruit set of Delicious, Gala and McIntosh was lowest when chemical thinners were applied at 200-250 degree days after full bloom

Bottom Line: Apply thinners for maximum effect at 200-250 DD after bloom





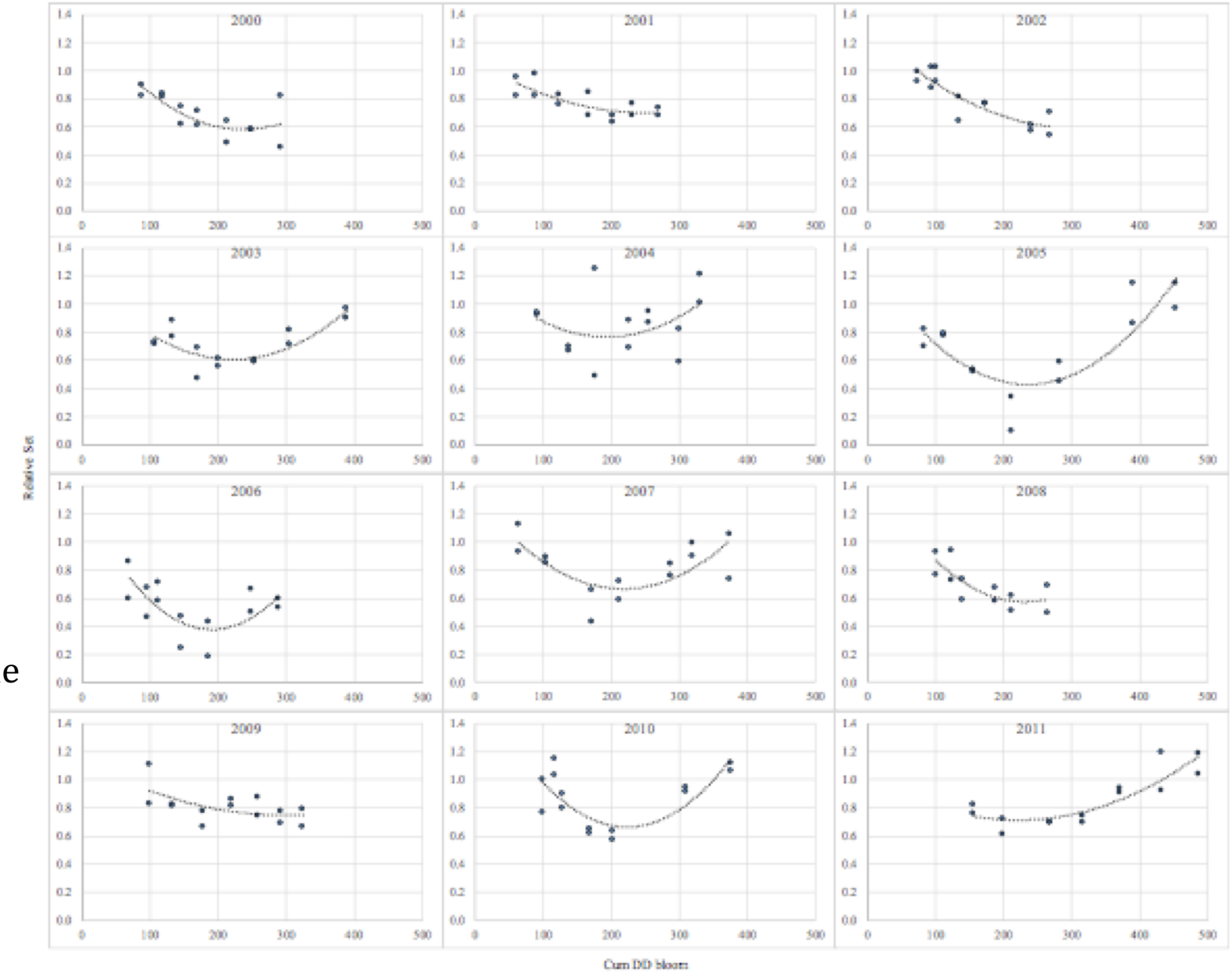


Results – by year

Year to Year Variability in results at petal fall and 18 mm

Best thinning was always between 200-250 DD

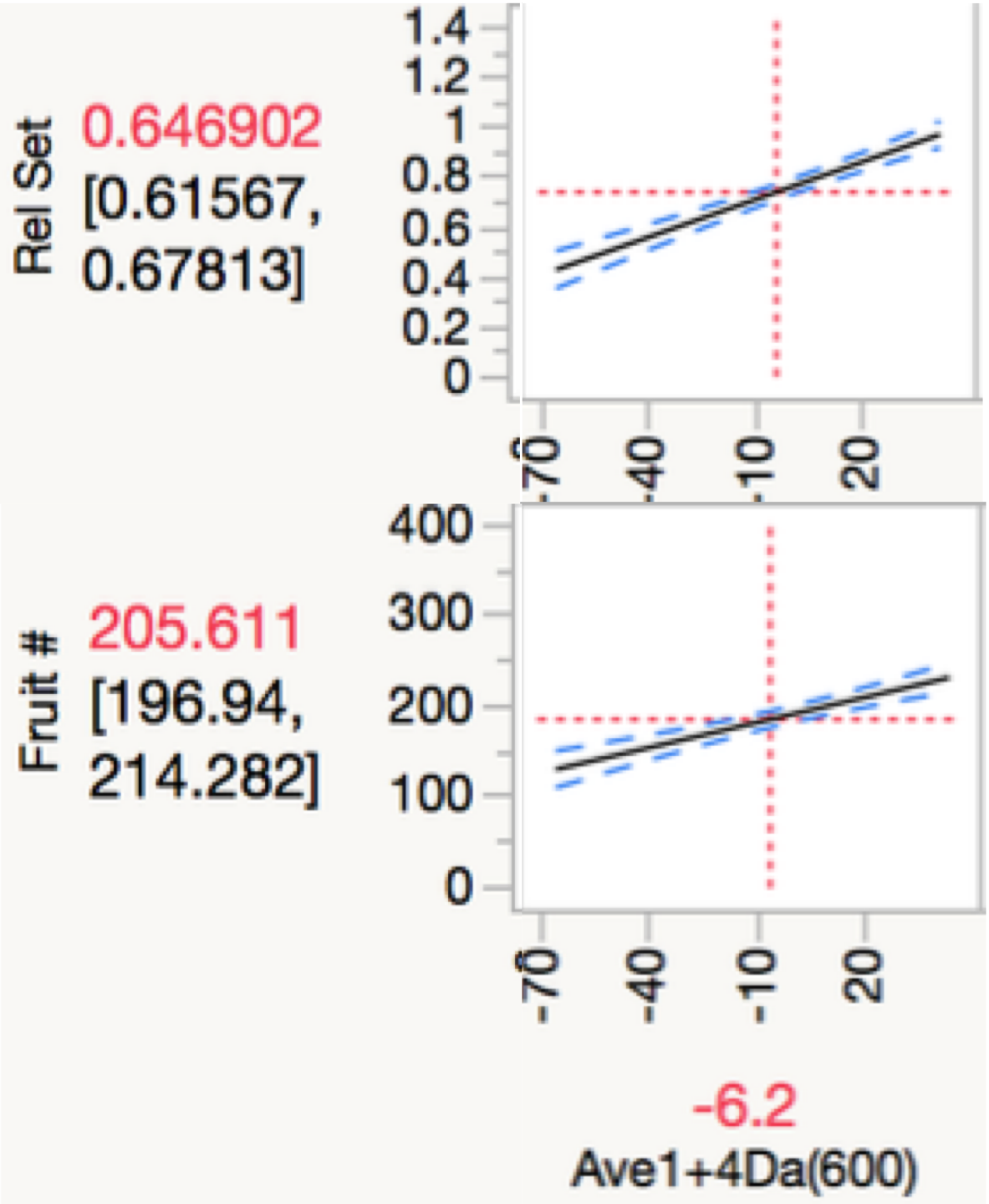
Take home message: Time thinning sprays by DD and target 200-250DD



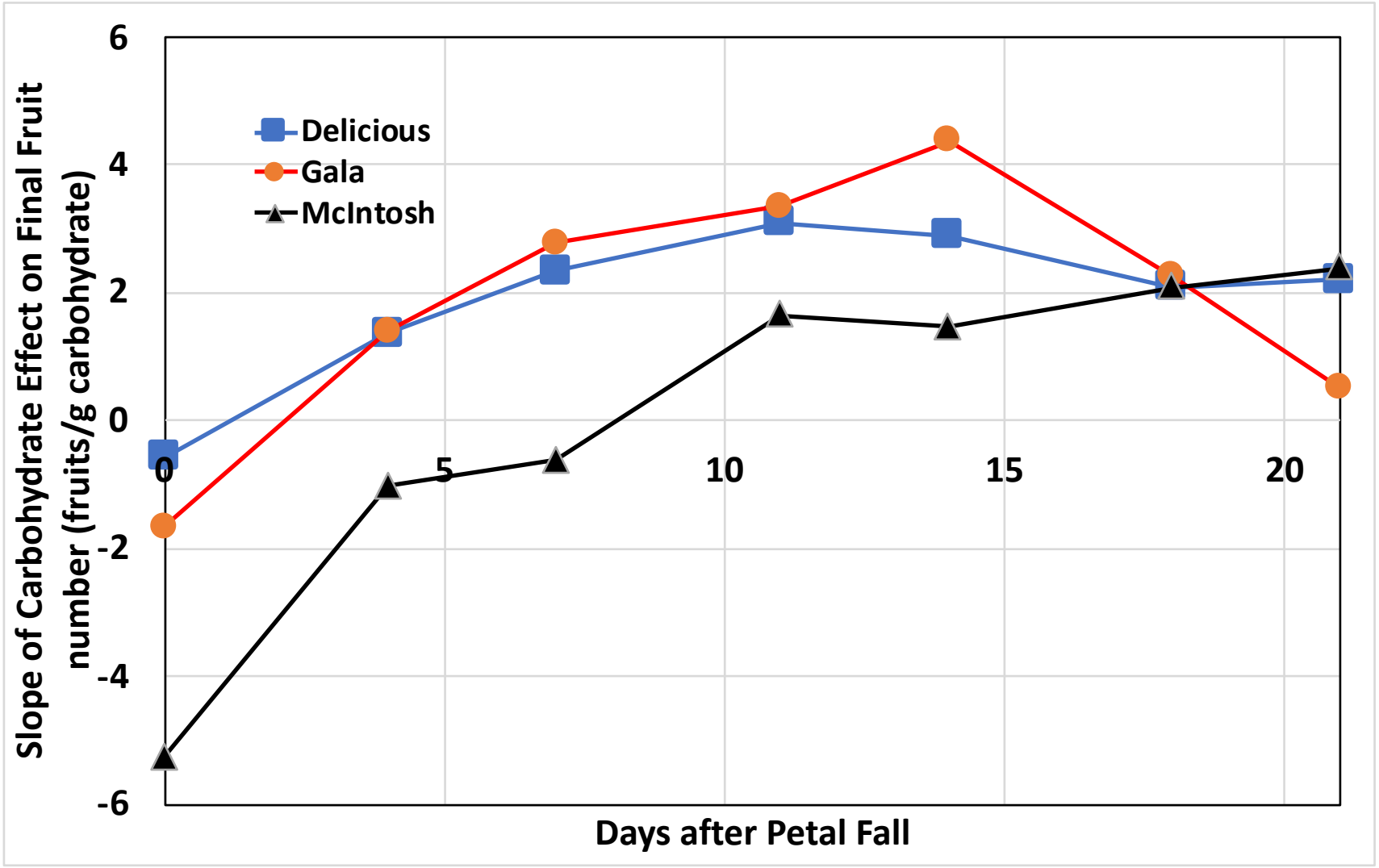
Results – Chemical Thinning

Fruit set positively correlated to carbohydrate balance over the period of 2 days before chemical application and 4 days after chemical application.

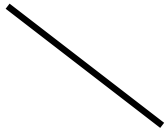
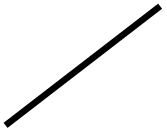
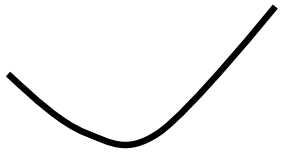
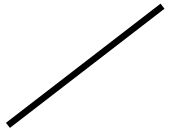
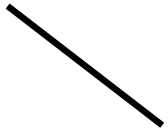
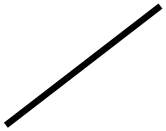
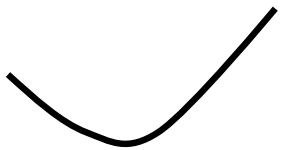
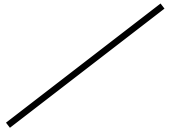
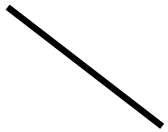
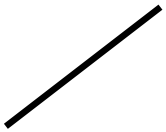
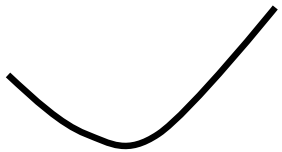
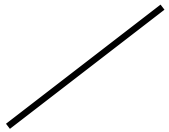
Bottom Line: Consider carbohydrate balance when making decisions about thinning

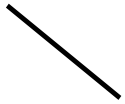
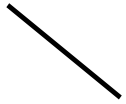
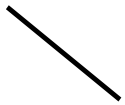
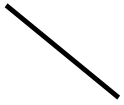
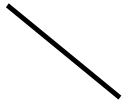


Results – Chemical Thinning



At petal fall there is a very small effect of carbohydrate balance on thinning results
At later times the effect varied from 1 fruit to 4 fruits per g of carbon

Cultivar	Cluster #		DD Bloom		CHO	
	Set	F#	Set	F#	Set	F#
Delicious						
Gala						
McIntosh						

Cultivar	DD Nov-Dec		DD Jan-Bud Break		DD Bud Break - Bloom		DD Bloom - Petal Fall	
	Set	F#	Set	F#	Set	F#	Set	F#
Delicious		NS	NS		NS			NS
Gala	NS	NS			NS		NS	NS
McIntosh	NS	NS			NS			NS

Results

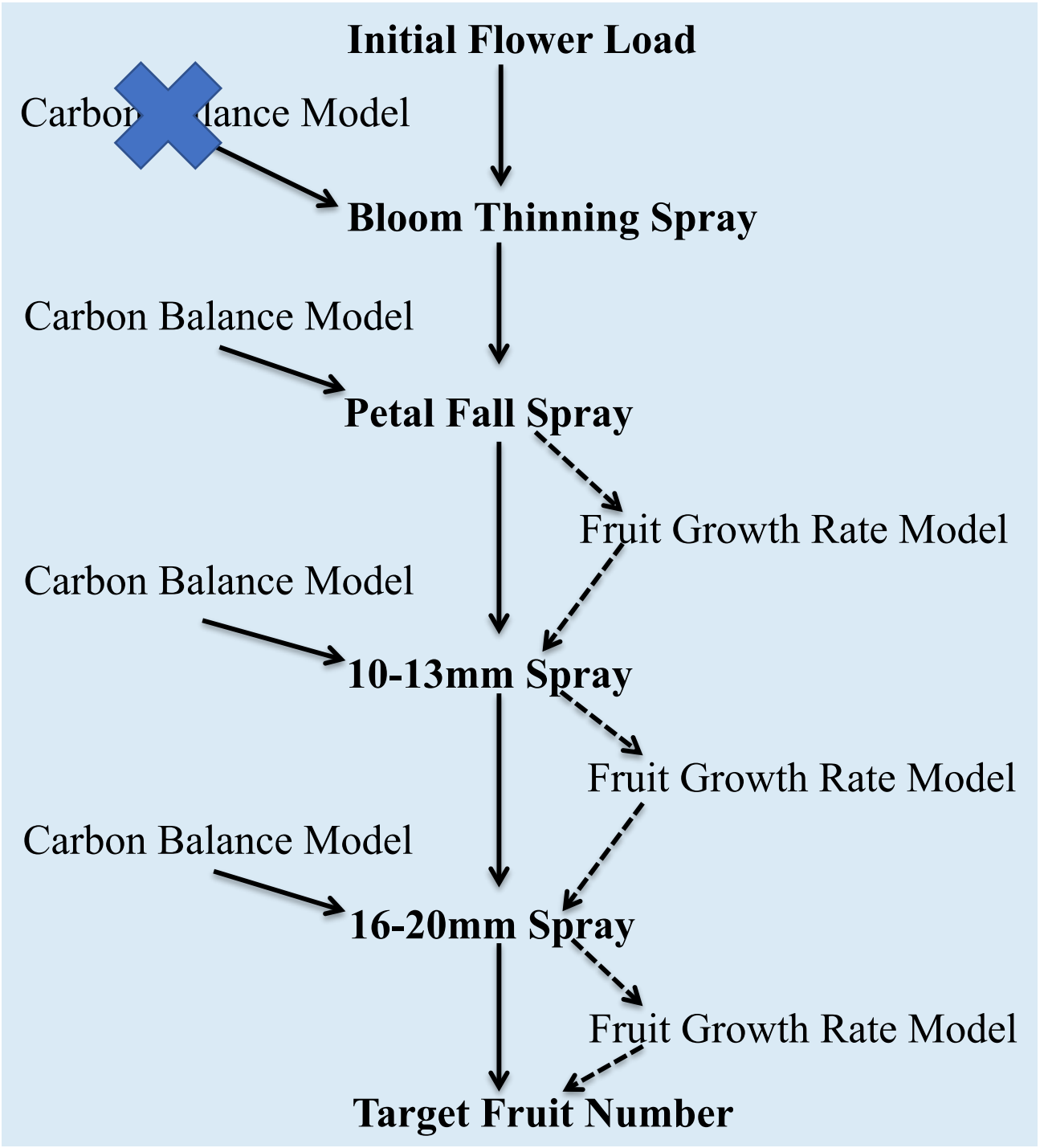
Year	Bud break	Bloom	Petal fall	Bloom length (days)	DD previous fall (Sep1-Dec31)	DD previous fall (Nov1-Dec31)	DD Jan1 - BB	DD BB-B	DD B-PF	DD B-PF+21d	DD B+41d
2000	10-Apr	7-May	13-May	6	.	.	133	172	88	293	479
2001	14-Apr	10-May	16-May	6	.	.	68	140	61	270	492
2002	14-Apr	6-May	16-May	10	812	192	126	179	75	268	414
2003	16-Apr	16-May	27-May	11	683	51	90	220	108	348	478
2004	18-Apr	11-May	17-May	6	649	91	105	205	91	331	540
2005	18-Apr	12-May	23-May	11	702	75	104	154	84	391	528
2006	11-Apr	10-May	17-May	7	774	122	106	215	70	313	493
2007	19-Apr	14-May	21-May	7	651	136	93	218	65	361	567
2008	17-Apr	5-May	17-May	12	786	39	111	184	101	313	474
2009	14-Apr	7-May	18-May	11	638	77	79	193	100	325	450
2010	31-Mar	30-Apr	7-May	7	618	81	66	226	99	309	509
2011	18-Apr	12-May	25-May	13	648	53	86	171	156	487	590
2013	14-Apr	15-May	20-May	5	694	72	66	258	52	328	543
2014	14-Apr	20-May	26-May	6	662	63	71	284	70	369	594
2015	16-Apr	12-May	19-May	7	669	61	61	249	77	309	503
2016	21-Mar	15-May	23-May	8	818	185	70	231	60	377	548
2017	30-Mar	7-May	19-May	12	760	94	89	255	79	315	453

Degree days each year were not consistent. This suggests that the DD model we used is not an optimal model. Nevertheless, the variation in DD did explain a significant portion of the variation in natural fruit set.

Status of Carbohydrate Model for 2019:

- Both a new Web-based version and a new mobile phone version will be available in May 2019
- Users will be required to provide:
  - green tip date
  - full bloom date
  - relative bloom density (% of spurs flowering)
- The model will use relative bloom density to adjust predicted thinning efficacy for any given spray.
- The model will use bloom date to calculate degree days and adjust predicted thinning efficacy according to the number of DD from full bloom for any given spray.
- The model will predict thinning efficacy (thinning index) using a running 7-day carbon balance (2 days before spraying plus 4 days after spraying)

Steps in Precision Chemical Thinning



Conclusions

- Since thinning efficacy is related to the number of flower clusters on the tree, pruning to the optimum bud number is essential to successful chemical thinning. (Prune to 1.5-2 buds per final target fruit number)

- The best thinning is achieved at 200-250 DD after bloom. Thus earlier or later timings give less thinning

- Carbohydrate balance 2 days before thinning and 4 days after thinning have a big influence on thinning effectiveness

- Take home message:
  - Use precision pruning (count buds)
  - Use the carbohydrate model to time sprays and adjust rate
  - Use the fruit growth rate model to determine when to stop thinning