PGR's and Thinning Strategies 2019
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Introduction

Thinning is the most difficult, most important, yet necessary practice a grower must perform each year. Making a mistake will compromise both this year's crop and next year's crop. Over-cropping and under-cropping will reduce income for a block for multiple years. But today with a more scientific approach to thinning we can achieve successful consistent annual croploads.

2018 Review

Last year Michigan experienced a moderate crop. 2018 was an on year for production and 2019 will be an off year in some blocks. Apple trees rested somewhat in 2017 and had only a moderate crop load in 2018. We expect a good return bloom in 2019 for most varieties and blocks.

A review of the thinning materials, thinning stages, the natural background sensitivity to thinning, Nibble Thinning, Precision Thinning, the Fruitset Model, the MaluSim Carbohydrate Model and 2018 thinning results will help achieve better thinning results in 2019 and beyond. These new models and approaches to thinning will help achieve a closer level of thinning to the target crop. New revisions to these models will strengthen decisions and increase thinning results.

Thinning Materials

Apples can be chemically thinned in all the thinning windows starting with bloom and continuing up to about 30 DAFB (days after full bloom). The major materials that could be considered include: Lime-Sulfur+Oil, ATS (ammonium thiosulfate), NAD (Naphthaleneaceatimide), NAA, 6-BA, Carbaryl, and Ethrel. Some experimental thinner's look promising but are not labeled at this time.

Natural Apple Background Sensitivity to Thinning

Thinning can be done during every growing stage starting at Full Bloom up to about 30 mm. There is a natural background sensitivity to thinning (Figure 1). To measure timing sensitivity to thinning, a thinning timing trial in a mature Gala block at CRC (Clarksville Research Center) was conducted each year from 2004 thru 2011. Every 3.5 days, a treatment of either S+N (Sevin+NAA) or S+M (Sevin+MaxCel) at aggressive rates (NAA @ 15 ppm or MaxCel @ 150 ppm combined with Sevin @ 1 qt/100) was applied. All treatments data points are plotted in Figure 1. There are four things that can be learned from the results, 1) at the 8 to 12 mm stage, fruitlets are at maximum sensitivity, 2) at PF (Petal Fall), the fruitlets are not very sensitive and over-thinning is a low risk, 3) there is a lot of variation in thinning at the early and at the late timings, and not as much at 10 mm stage

Figure 1. Natural Background Sensitivity of Gala

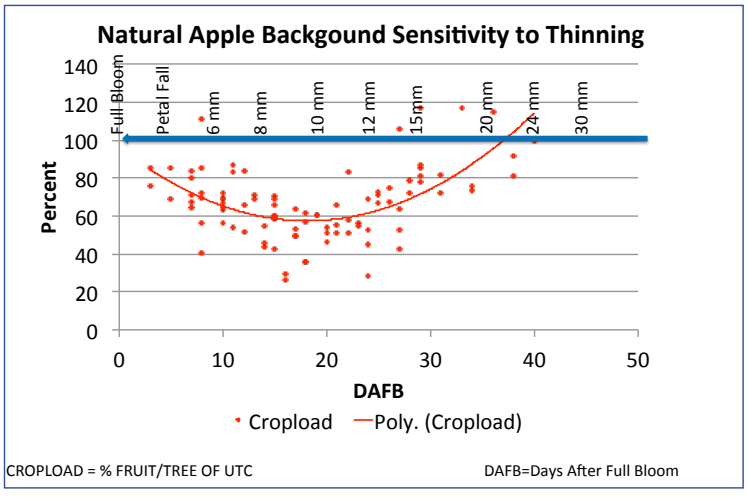
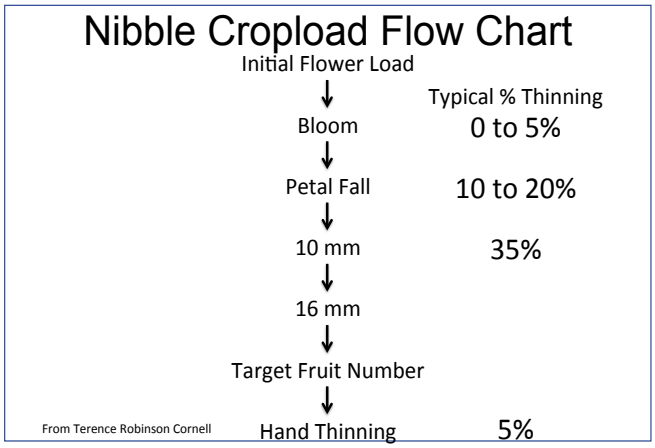


Figure 2. Nibble or Precision Cropload Flow Chart.

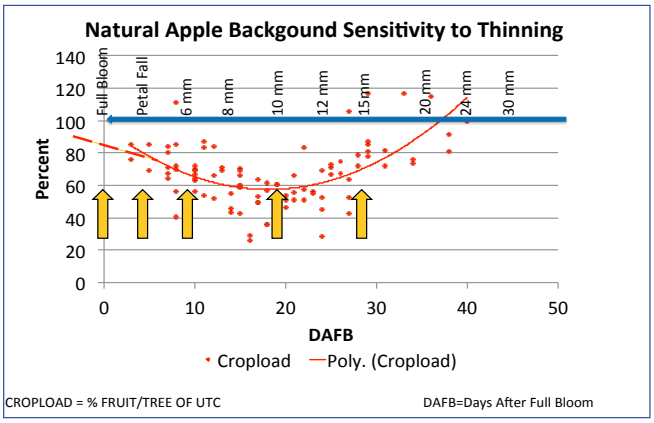


and 4) the thinning window closes rather quickly after 15 mm. Of course, the thinning response is driven by the weather at the time of thinning. Hot cloudy conditions at any of these stages will promote thinning and cold sunny weather will decrease thinning.

Nibble Thinning

The concept of "Nibble Thinning" is to thin a little of the crop at every opportunity until the cropload has been reduce to the desired target level. This means to thin starting early and planning multiple applications. Start thinning early at FB, then at PF, then again at 6 mm and 10 mm and more if needed (Figure 2 & 3). Nibble the crop down to the perfect cropload. Often, we let the early thinning windows (FB, PF, and 6 mm) pass by because we are unsure of bud health or fruit set. A frost event or some other early trauma makes us want to wait and see what fruitset will be before thinning. But, apple trees are resilient; they will set crops almost every year even when conditions look bleak. As time goes on, more information of frost injury, bee activity, pollination, fertilization becomes known and this allows a better judgment of fruitset and thinning needs. However, delaying first thinning action until late in the thinning window may allow only one chance to thin and then results may be unsatisfactory. Start early when over-thinning risk is low.

Figure 3. Precision Multiple Thinning Timing.



Initial flower load is the best early indicator of cropload. The initial flower numbers on a tree follows with corresponding number of fruit on the tree following fruitset. Heavy bloom or "Snowball" bloom will set heavy crops. Get started with early thinning during "Snowball" years. The natural background sensitivity to thinning predicts typical success in thinning. The sensitivity is low at PF and greatest at 10 mm and then quickly becomes insensitive as 25 mm stage is approached.

Nibble and Precision thinning is to thin at every time there is an opportunity such as FB, PF, 6 mm, 10 mm, etc. until the target cropload is reached. This method achieves success yet reduces risk of over and under thinning. Figure 2 indicate the typical percent thinning expected if thinning is performed at the corresponding stage with moderate thinning rates. Aggressive rates will have a greater response. Typically about 50% thinning is the target level in the vast majority of years on most blocks.

Table 1. Chemical Apple Thinning Materials and Comments.

Material	Description	Comment
Lime Sulfur & Oil	Depresses Photosynthesis. Burns Pistils. Reduces Fertilization. Prevents Pollen Germination Good for Organic Growers.	Use LS @ 2.5 gal/100 + Oil @ 2 gal/100. Apply @ 100/acre. Target 80% FB (just after KB). Follow every 3 to 4 days as needed.
ATS **(Ammonium Thiosulfate)** **Fertilizer**	Burns Pistils. Nitrogen and Sulfur fertilizer.	Use ATS @ 2 to 3 gal/100. Apply @ 100/acre. Target 80% FB (just after KB). Follow 2 days later if needed.
NAD **(Naphthaleneaceatimide)** **Amid-Thin**	Mild to little thinning. Use only at Petal Fall. NAD treated trees should be more difficult to thin at the 10 mm stage.	Use @ 50 ppm. Mostly on early summer varieties (Spy, Mac, Empire).
NAA **(Naphthaleneacetic Acid)** **Fruitone N** **Fruitone L** **PoMaxa**	Workhorse thinner. Moderate harsh thinner. Dose dependent. Use throughout thinning window. Can be damaging (defoliation). Promotes return bloom. Stunts fruit growth temporarily, but fewer fruits then grow larger. Aggressive with Sevin.	Use @ 5 to 20 ppm. Red Delicious and Fuji are sensitive to NAA. Stunted leaves and pygmy fruits can result if applied with or close to Promalin or 6-BA applications.
6-BA (6 Benzyadenine) **MaxCel** **Exilis**	Mild to moderate, gentle, thinning. Dose dependent. Improves fruit size, increases cell division. Not compatible with NAA. (needs more research) Aggressive with Sevin.	Use @ 50 to 150 ppm. Standard rate = 100 ppm (64 oz/100 or /acre). Labeled up to 200 ppm.
Carbaryl **Sevin**	Workhorse thinner. Mild to moderate thinning. Relatively safe gentle thinner. Tends to promote large fruit size. Not dose dependent. Use throughout window, but generally used late. Can be damaging (russet). Selective, thins weak laterals, leaving one fruit/cluster (singulates fruit). Will also thin out whole clusters. Can be used from PF to 30 mm. Harsh on beneficials and bees.	Use at 1# to 2#/acre (1 pt to 1 qt/100 or /acre). Combinations with NAA or 6-BA are aggressive thinners.
Ethrel	Mild to excessive thinning. Dose dependent. Will thin very late (20mm +). Generally used late for emergency thinning. Somewhat unpredictable. Can over-thin.	
Other Thinners	ACC ABA Metamitron	

Table 2. Apple Thinning Windows Considerations.

Stage	Description	Choices and Comments
Bloom	Set unknown. Early timing, start of "Nibble" or "Precision" thinning. Generally, too early for growers to feel comfortable. Helps difficult to thin varieties. Helps small fruited varieties. Fruits drop early. Maximizes fruit size & return bloom. Allows additional steps in reducing a heavy crop. Generally, weather is not best.	Lime Sulfur & Oil (maybe not preferred). ATS (possible with experience). MaxCel (preferred choice). NAA (good choice).
Petal Fall	Generally early time to thin. Best 1st thinning for return bloom. 1st thinning which allows 2nd and 3rd chance. Fruitset is unknown, generally under-thins. Bloom climate and bee activity is known.	NAD on early summer varieties. Sevin alone on all varieties across the board. NAA alone. Sevin+NAA or Sevin+MaxCel for more aggressive thinning.
6 mm	Get started early. Can get some thinning, but generally under-thins. Moderate risk thinning. Excellent return bloom. Still will have more chances to thin. Good for "Nibble" or "Precision" thinning.	Dose/rate dependent for thinners, choose rates to get target thinning: 6-BA or NAA or combinations of: Sevin+NAA or Sevin+6-BA.
10 mm	8 mm to 12 mm diameter fruit. **Traditional best timing and results for one-time application thinning.** Choose thinning level. Fruitset somewhat unknown, but fruitlets showing strength. Good return bloom. Still will have a last chance in 7 days.	Dose/rate dependent for thinners, choose rates to get target thinning: 6-BA or NAA or combinations of: Sevin+NAA or Sevin+6-BA.
15 mm	12 mm to 18 mm diameter fruit. Still receptive to thinning. Should use full or higher rates. Combinations best. **Last chance** thinning. Thinning window closing fast.	Dose/rate dependent for thinners, choose rates to get target thinning: Probably need combinations of: Sevin+NAA or Sevin+6-BA.
25+	Very late, probably no or low response. Use aggressive combinations. Perhaps **Ethrel** is only good choice. Dangerous and unpredictable. Ethrel at 300 to 600 ppm (1 pt-1 qt). Can use **Ethrel + other thinners and oil.**	Use: Ethrel +Sevin +Oil All @ 1 qt/100 or /acre.

Table 3. Precision Thinning, Timing, Materials and Predicted Percent Thinning Most Years.

Stage	Material Choices (red = preferred choice)	Predicted % Thinning (red = expected result)			
Bloom	Lime & Sulfur Oil	0 to 20%			
	ATS (2 to 3 gal/100)	0 to 20%			
	MaxCel (100 ppm, 64 oz/100)	5 to 10%			
	NAA (10 to 15 ppm, 8 to 16 oz/acre)	5 to 10%			
Petal Fall	Sevin (1 qt/100 or /acre)	10 to 20%			
	NAA (10-15 ppm, 8-16 oz/acre)	10 to 20%			
6 to 20 mm		6 mm	10 mm	15 mm	20 mm
	Sevin (1# to 2#, 1 pt to 1 qt /acre) NAA (10-20 ppm, 8-20 oz/acre)	10 to 25% 15%	15 to 30% 20%	15 to 30% 20%	10 to 25% 15%
	Sevin+NAA (standard rates) Sevin+MaxCel (standard rates)	15 to 35% 30%	25 to 50% 40%	25 to 50% 40%	15 to 35% 25%

Theory of Fruitset

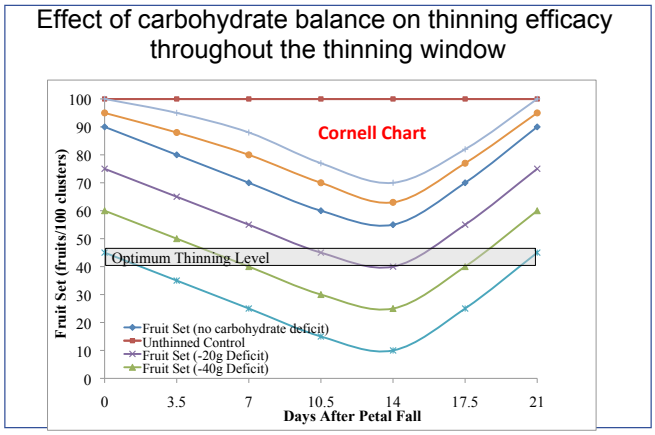
Fruitlets are living respiring organs; they need energy (carbohydrates) to grow and set. When fruitlets demand for energy is greater than supply, fruitlets will be shorted energy, and the weakest ones will drop. When energy is abundant, fruitlets set and resist thinning. Fruitlet stress, both environmental and chemical stress, has a big impact on sensitivity and response to thinning actions. Temperature and sunlight affect the supply and demand of energy (carbon) available for the fruit and leaves. Energy is supplied to fruitlets from two sources, 1) last years overwintering reserves in the wood and 2) this years photosynthesis. It is thought that photosynthesis is the most important fruitlet energy source. A supply/demand crisis occurs after bloom when reserves are depleted and photosynthesis is picking up. This energy crisis on average occurs at the 10 mm stage, which is why fruit are so responsive to thinning at that time.

MaluSim Carbohydrate Model

Dr. Alan Lakso and Dr. Terence Robinson of Cornell University have developed a MaluSim Carbohydrate Model to predict in current real time the energy levels of a fully bearing mature moderately cropped Empire tree. This model is useful to assist thinning decisions. That is, it predicts the daily stress small young setting fruitlets might be experiencing and therefore, help growers adjust their chemical thinning applications. MaluSim predicts the daily carbohydrate balance of a tree. This assists growers in the prediction of fruitlets sensitivity to drop, set and thinning. A surplus of energy at thinning time will set fruitlets and growers will need to thin more aggressively. A serious energy deficit will drop fruitlets and growers may want to delay thinning or reduce rates. The model starts at green tip and will predict the tree daily supply and demand of carbon (energy) based on three daily inputs, 1) daily max, 2) min temperature and 3) daily solar radiation. It also adjusts predictions for the earth latitude of the weather station to estimate day length. Sparta is at latitude 43°, Benton Harbor 42°, and Suttons Bay 45°. The four days following a thinning application is the most important carb model stress prediction to estimate thinning results. A four-day average carb balance of the predicted carb levels is used to help make a thinning decision. In real time this four-day average is using the results of the weather forecast to predict the future. This is risky, in that rarely are the forecast predictions correct, but it is the best information in real time during the thinning time. A decision guide has been developed by Cornell (Figure 3) and adjusted for Michigan conditions (Figure 4 & 5), which include a suggested rate at various stress levels for difficult to thin varieties (Table 4 and 5).

Figure 3. Cornell Carb Balance Predicted Thinning.

Figure 4. Michigan Carb Balance Predicted Thinning.



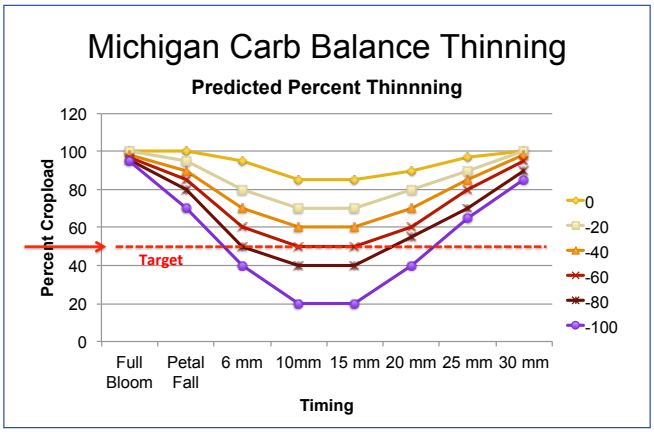


Figure 5. Michigan Predicted Percent Thinning.

Table 4. Carb Model Thinning Decision Guide.

Stress Level	4 Day Ave Carb Balance	Thinning Rate Recommendation
No	> 0	Increase Rate by 30%
Slight	-20 to 0	Use Standard Rate
Mild	-40 to -20	Reduce Rate by 15%
Moderate	-60 to -40	Reduce Rate by 30%
Severe	-80 to -60	Reduce Rate by 50%
Extreme	<-80	Do not thin, many fruits will fall off

Michigan Predicted % Thinning

Target

	4 Day Ave Carb. Balance					
	0	**-20**	**-40**	**-60**	**-80**	**-100**
Full Bloom	0	0	2	3	4	5
Petal Fall	0	5	10	20	30	40
6 mm	5	20	30	40	50	60
10 mm	15	30	40	50	60	80
15 mm	15	30	40	50	60	80
20 mm	10	20	30	40	45	60
25 mm	3	10	15	20	30	35
30 mm	0	0	2	5	10	15

Table 5. Thinning Combination Rates Levels, 100 gal/acre for difficult to thin varieties.

Level	Sevin + MaxCel (1 qt + ppm)	Sevin + NAA (1 qt + ppm)
30% Increase	1 + 150 + 1 qt Oil	1 + 15 + 1 qt Oil
Aggressive	1 + 150	1 + 15
Standard	1 + 100	1 + 10
10% Reduction	1 + 75	1 + 7
20% Reduction	1 + 50	1 + 5
30% Reduction	1 qt Sevin	1 qt Sevin
Sevin rate = 1 qt/100 = 1 qt/acre.		

Figure 6. Nibble or Precision Cropload Flow Chart.

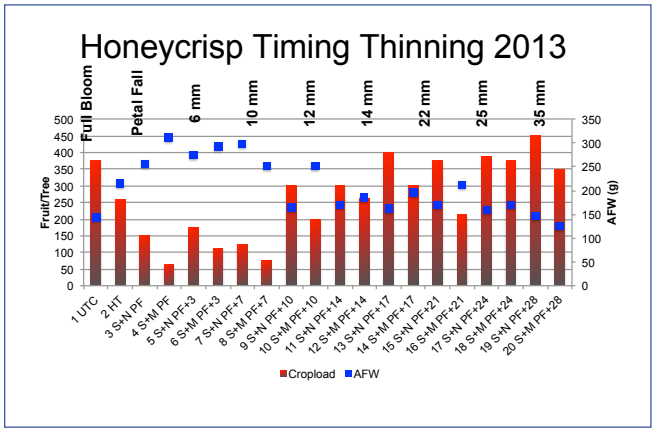
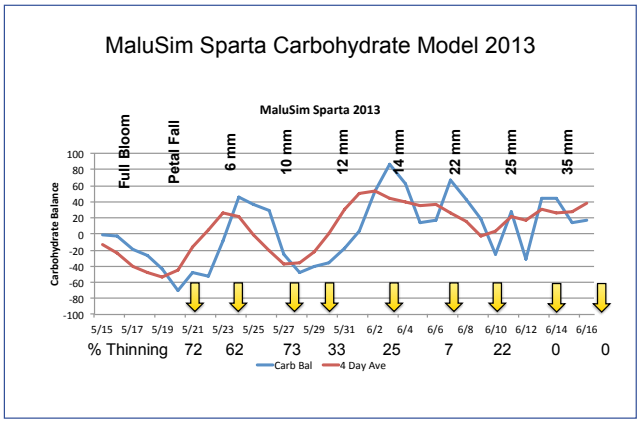


Figure 7. MaluSim Sparta Model 2013.



Honeycrisp Timing Thinning 2013

A thinning trial was conducted in 2013 on Honeycrisp with S+N (1 qt/100+10 ppm) and S+M (1 qt/100+150 ppm) as the thinning materials combinations. The applications were made every 3.5 days throughout the thinning window starting at PF and continuing to about 28 DAFB (Figure 6). The results are expressed as fruit/tree and AFW and should be compared to the prediction output of the MaluSim Model (Figure 7). Significant stress occurred on three occasions, 1) Petal Fall, 2) 10 mm and 3) the 25 mm stage. The amount of thinning is indicated in Figure 7. The down arrows indicate average percent thinning for each timing. More aggressive thinning than expected occurred in the early stages but the significant thinning at 25 mm was not expected. Good thinning occurred at the 25 mm stage with S+M. The resultant thinning followed the MaluSim Model predictions quite well. The model is good, but not precise.

Precision Thinning

The Precision Thinning concept uses all information available to achieve a target cropload. The concept of Precision Thinning takes the nibble thinning concept and adds the use of the Fruitset Model to help verify or indicate how the thinning process is proceeding. Duane Green of UMASS developed the Fruitset Model. Precision Thinning uses the MaluSim Model to help guide thinning choices or predictions at each stage and measure ongoing fruitset with the Fruitset Model during fruitlet growth (Figure 8 & 9). It starts with an evaluation of initial flower load on a typical tree. It is suggested to dormant prune trees to a level of two to three times the bud load of the desired cropload. For example, if 100 fruits/tree is the target cropload, then reduce the flower clusters/tree to a level of 200 to 300 with dormant pruning. The initial flower load is a good indicated of final cropload most years. Start at FB with the MaluSim Model indicating stress. Then step right through the stages, adding the Fruitset Model at 6 mm to get a prediction of crop set.

Fruitset Model

This model is available as an Excel Spreadsheet downloadable at:

Apples.msu.edu

http://extension.umass.edu/fruitadvisor/resources/clements-corner

This model keeps track of measurements of fruitlet growth and predicts set. We suggested that between 20 to 100 (40 is probably adequate) representative flower clusters should be marked (Figure 10) and diameter measured every three to four days. The diameter growth will be used to predict fruitlet abscission

(Table 6). All fruit that slow to a growth rate of 50% or less of the growth rate of the fastest growing fruit, will ultimately stop growth and abscise.

Table 6. Fruitset Model Growth Prediction.

Fruitlet Fate	Prediction
Persist	A fruit is predicted to persist if the growth rate over the measurement period was at least 50% or greater of the fastest growing fruit.
Abscise	A fruit is predicted to abscise if the growth rate of the fruit slowed to 50% or less of the growth rate of the fastest growing fruit.

Figure 8. Cornell Precision Flow Chart.

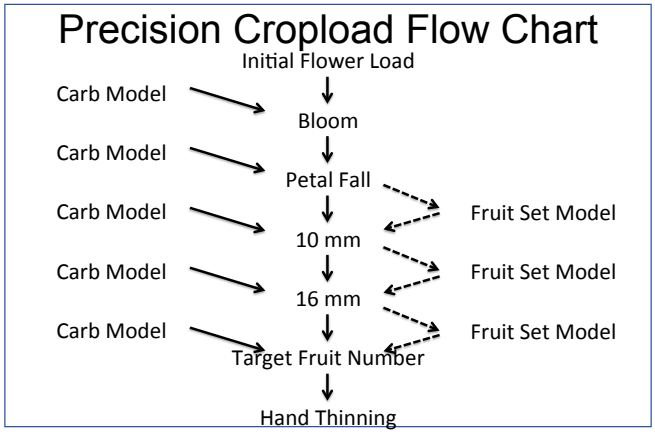


Figure 9. Persisting and Abscising Fruitlet Growth.

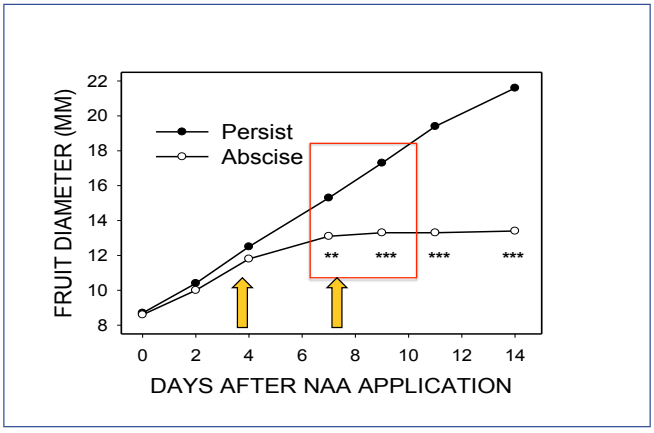
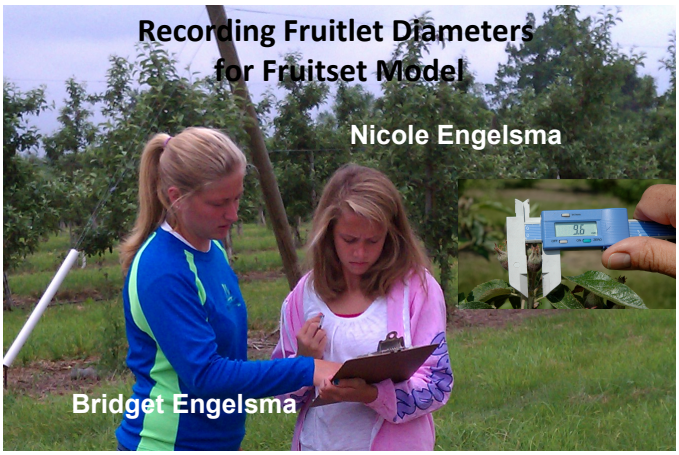


Figure 10. Fruitset Model Numbering Fruits.

Figure 11. Record Fruitlet Diameters.



A summary of the data collected is shown in Figure 11 collected by Bridget and Nicole Engelsma. The first step is to determine the target cropload. In this block, the target crop load was 15% (20 apples) of the 130 original fruit measured. On June 1st, three days after the first measurement, the model predicts only 30 (23.1%) apples are growing fast and thus very close to the predict target of 20 apples. On June 11th, 13 days after the first measurement, the model predicts 28 (21.5%) are setting and thus the cropload will be about 6% heavy. The model predicted early (after 3 days) that the setting crops was close to the target cropload.

Figure 12. Fruitset Model Summary Sheet.

Thinning Factors

Thinners work best when temperatures are warm especially for four days following the thinning application. Slow drying conditions when the thinners are applied will increase uptake and response. Cloudy, hot conditions will increase stress and thus, increase thinning. Young trees (under 4 or 5) will thin easier. Nighttime temperatures are important, warm nights increase respiration thus stress.

Summary Sheet Engelsma Gala

Sampling			Diameter (mm)		Diameter Growth (mm)		Number of Fruit			Predicted % Setting	
Number	Date	Days between sample dates	Mean of 20 largest fruitlets	Mean of all fruitlets	Mean of up to 20 fastest growing fruitlets	50% fastest growing fruitlets	>50% fastest	<50% fastest	Measured	Based on Original # of Fruit	Based on Current # of Fruit
1	5/29	0	9.52	9.29					130		
2	6/1	3	10.08	10.58	3.61	1.80	30	86	116	23.1	25.9
3	6/11	10	21.26	22.00	8.83	4.41	28	0	28	21.5	100.0

5/10 100ppm MaxCell (Full Bloom)
5/21 1 qt Sevin (Petal Fall)
6/1 50 ppm MaxCell and 1 pint of Sevin

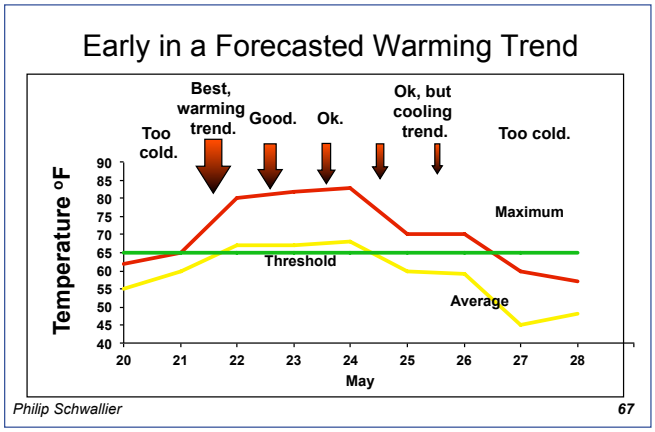
Table 7. Summary of Thinner Effectiveness and Climate Conditions (adapted from Cornell information).

Climate Condition	Prediction
Warm Conditions >65°F.	All thinners work best.
Dark Cloudy Weather.	Greater stress, greater thinning response, greater drop.
High night temperatures (>65°F).	Greater stress, high demand and use of energy for night respiration, greater drop.
Very High day-time temperatures (>85°F).	Greater stress, high energy demand, greater drop.
Very cool temperatures (<65°F), greater set.	Reduced stress, reduced energy demand, greater set.
High light.	Increased supply: harder to thin.
Low light.	Reduced supply: easier to thin.
Low temps.	Low demand: harder to thin.
High temps.	High demand: easy to thin.
Worst.	Low light and warm temps.

Thinning Timing

For best thinning response, pick climate conditions that favor a response. Apply thinners early in a forecasted warming trend when maximum temperature reaches 80 to 85°F (>65°F). If temperatures are cool, either increase the rate or delay treatment until warm conditions return. Avoid applying thinners during a cooling trend where maximum temperatures will drop <65°F. Cloudy warm conditions will increase drop and may cause mild thinning. Cut back on rates.

Figure 13. Best Timing for thinning.



2019 Thinning Considerations

- Consider last years cropload, mostly reduced crop
- Heavy crop 2018, easier thinning 2019, use normal rates.
- Light crop 2018, more difficult to thin 2019, be more aggressive.
- 2018 Winter weather, any extreme temperature drops that might damage buds.
- Evaluate 2019 bloom quality and density; higher numbers of bloom= greater fruitset.
- Evaluate bee activity, pollination, and fertilization conditions; most years these are not a factor.
- We expect heavy crop in 2018 in North America.