Northern NY Agricultural Development Program
2022 Project Report

Utilizing Computer Models and Additional Thinning Materials for Precise Crop Load Management in Northern New York Apple Orchards

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Background

Apple crop load management is the single most important management practice affecting an orchard's crop value. Growers must balance reducing crop load (yield) sufficiently in order to achieve optimum fruit size and obtain good levels of return bloom in the following season. For each variety of apple, there is an optimum number of fruit per tree where yield, fruit size, and fruit quality are balanced to bring the greatest economic return to the grower.

In Northern New York, most crop load management is performed by thinning trees when fruit are between 10-12mm in size following the petal fall period. Thinning at this timing relies on the use of hormone-based plant growth regulator materials, such as NAA and 6-BA, and carbaryl, an insecticide that also acts as a mild fruit thinner. While NAA and 6-BA materials are currently industry standards, their efficacies are highly temperature-sensitive. The optimal temperature for the application of these hormone-based materials is generally in the mid-70°F's. Below 70°F efficacy is greatly reduced, leaving too many fruit on the tree. At the same time, temperatures in the mid-80°F's can remove all the fruit from a tree. In Northern New York, these narrow temperature windows are sometimes difficult to achieve, making crop load management with these hormone-based materials relatively ineffective in some years.

An alternative method for crop load management is to begin thinning earlier at bloom. This method uses different materials, like ammonium thiosulfate (ATS, a common row crop fertilizer) and lime sulfur (LS, an organic fungicide product) to inhibit flower fertilization. These materials have the potential to take more fruit off the trees beginning at bloom. Trees thinned earlier at bloom may produce larger fruit at harvest, and have greater return bloom the following spring, reducing orchard biennial bearing (many fruit on the trees one year, few the following year). This would be particularly valuable in Northern New York apple production, as growers across the region had poor thinning results with some hormone-based thinners in 2018, 2019, and 2020, and had poor return bloom in 2019 and 2021 on their Honeycrisp crop, one of Northern New York's most valuable apple varieties.

While bloom thinning is a promising approach for crop load management, and is being used extensively in Washington State, it remains difficult to perform locally, as it requires precise timing of the thinning applications to inhibit the correct number of blossoms. When materials are applied at the incorrect timing, trees are likely to be over-thinned or under-thinned. To better time these applications, some Northern NY growers have begun to use the pollen tube growth model (PTGM).

The pollen tube growth model was developed through a decade of research at Virginia Tech. This model estimates the amount of time between pollination and fertilization of the apple flowers, allowing growers to better time their bloom thinning materials. Growth rate models have been developed for the Honeycrisp, Gala, Golden Delicious, Fuji, Cripps Pink (Pink Lady), Granny Smith, and Red Delicious varieties.

By beginning the thinning process at bloom, growers have multiple opportunities to thin their trees, and can gauge how trees are responding to each thinner application. This response can be quantified using the fruit growth rate model, developed by researchers at the University of Massachusetts and Cornell University. In this model, fruitlet growth is monitored after each thinning application to determine how many fruitlets will be removed by the previous thinning spray, allowing growers to more precisely reach their target crop load.

In this 2022 NNYADP project, our primary objective was to further test and validate the efficacy of alternative bloom thinning materials, at their currently recommended spray rates, precisely timed with the pollen tube growth model.

Our secondary objective was to utilize the fruit growth rate model on the same orchard blocks to precisely reduce the crop load to the growers' target crop density through additional thinner applications, and to further validate the utility of the fruit growth rate model.

We anticipate that combining the fruit growth rate model with an effective bloom thinning protocol with applications of ATS or LS will bolster the profitability of Northern NY apple growers by making thinning applications in our region more reliable, allowing fruit growers to achieve optimum crop loads to maximize their fruit yield and quality, while reducing biennial bearing in Honeycrisp.

Methods

We established two field trials in commercial orchards in Northern New York in 2022, one in Gala (Northern Orchard), and one in Honeycrisp (Forrence Orchards).

Northern Orchard: Gala Variety Trial

Our Gala experiment at Northern Orchard in Peru consisted of a block of Buckeye Gala, initially planted in 2012 at 4x12-foot spacing. We selected 15 trees in April 2022 (five replications of three trees) within the orchard to receive one of four thinning treatments at bloom (Table 1).

Trt No.	Bloom Whole tree
1.	10ppm NAA
2.	PTG model using ATS at 2.5%
3.	PTG model using ATS at 3%
4.	PTG model using LS at 2% and mineral oil at 1%

Table 1. Bloom thinning treatments, Gala trial, Northern Orchard, Peru NY; NNYADP Utilizing Computer Models and Additional Thinning Materials for Precise Crop Load Management in Northern New York Apple Orchards, 2022.

Working with the grower, we determined the target crop load for the block was 100 fruit per tree. At the pink bud growth stage, the number of flower buds were counted on 10 trees within the experiment, and trees were subsequently pruned to reduce some of the crop load. Following pruning, 15 flower clusters on five representative trees (75 clusters total) within Treatment 3 were flagged and numbered, so we could run the fruit growth rate model on the trees to track the estimated crop load following each thinning application (Figure 1: Photos section).

As bloom began, 30 king flowers were collected from trees within the experiment block at random (Figure 2). Flower styles were measured in the field (Figure 3), and the average style length from these flowers was added to the pollen tube growth model (PTGM; freely available to growers at ptgm.newa.cornell.edu.) As more flowers opened, we monitored the block closely to estimate that the targeted 100 king flowers per tree opened in the block on May 13, 2022, allowing us to "start" the PTGM.

Treatment 1 received an application of Fruitone (an NAA product) at the rate of 4 oz. per 100 gallons dilute tree row volume (TRV) on May 14. The first applications of ATS and LS were applied to Treatments 2-4 on May 14 when the PTGM estimated that pollen tube length reached 53% of the style length. The second applications of ATS and LS were applied on May 15, when the model reached 31%, and the third applications of ATS and LS were applied on May 17, when the model reached 85%. We were unable to apply at the ideal timings this season due to rainy weather conditions.

All of the bloom treatments were then followed with a petal fall thinning application of 3 oz. Fruitone per 100 gallon dilute TRV + 1 pt Sevin per 100 gallons on May 25.

Following the petal fall application, fruitlet growth was measured on the clusters we had flagged at the pink bud stage (Figure 4). Measurements were made on May 26, and again on May 31. Following the petal fall application, the fruit growth rate model predicted there were still 284 fruit per tree remaining, so a 12 mm thinning application of 64 oz Maxcel per 100 gallon dilute TRV + 1 pt Sevin per 100 gallon was made on June 2. We measured fruitlet growth again on June 3 and June 7, and the model predicted 185 fruit per tree remained. Given that we were now relatively close to our desired crop load, we decided to stop thinning. Fruitlets were measured again on June 14, at which point the model predicted 86 fruit per tree remained.

A first pick of fruit was conducted on September 16, 2022. A second pick was conducted on October 5, 2022. As fruit were harvested, we recorded the total fruit count and fruit weight per tree. From these measurements, average fruit size per tree was also tabulated. A subsample of 50 fruit per treatment was shipped to Dr. Terence Robinson at Cornell AgriTech in Geneva, New York, and were sorted over a color and size grader. Fruit were also examined for their level of fruit russeting. These data were then used to tabulate total crop value per acre of each treatment.

Return bloom data from our 2021 trial was collected in May 2022 by assessing the number of flowering spurs on three limbs on five trees in each treatment of our 2021 field trial.

Forrence Orchards: Honeycrisp Trial

This site consisted of Honeycrisp trees, initially planted in 2012 at a 3x14-foot spacing. We selected 15 trees (5 replications of 3 trees) to receive one of four bloom thinning treatments (Table 2.).

Trt No.	Bloom Whole tree
1.	10ppm NAA
2.	PTG model using ATS at 2.5%
3.	PTG model using ATS at 3%
4.	PTG model using LS at 2% and mineral oil at 1%

Table 2. Bloom thinning treatments at our Honeycrisp trial at Forrence Orchards in Peru NY; NNYADP Utilizing Computer Models and Additional Thinning Materials for Precise Crop Load Management in Northern New York Apple Orchards, 2022.

Working with the grower, we determined the target crop load for the block was 85 fruit per tree. At the pink bud growth stage, the number of flower buds were counted on five trees within the experiment to help us determine our starting bud load. We flagged and numbered 15 flower clusters on five representative trees (75 clusters total) within Treatment 3, so we could run the fruit growth rate model on the trees to track the estimated crop load following each thinning application.

As bloom started, 30 king flowers were collected from trees within the experiment at random. Flower styles were measured, and the average style length from these flowers was added to the PTGM. As more flowers opened, we monitored the block closely to estimate that the targeted 85 king flowers per tree had opened in the block on May 13, allowing us to "start" the PTGM. The bloom NAA application of 4 oz NAA per 100 gallons dilute TRV was applied to Treatment 1 on May 14. The first applications of ATS and LS were made to Treatment 2-4 on May 14, when the pollen tube model was at 60%. The second applications were made at 36% on May 15. We were unable to apply at the ideal timings this season due to rainy weather conditions.

Due to concern of overthinning, no petal fall thinner applications were made after the bloom thinners on our Honeycrisp trial.

Following the petal fall time period, fruitlet growth was measured on the clusters we had flagged at the pink bud stage. Measurements were made on May 26, and again on May 31. At this timing, the fruit growth rate model predicted there were 152 fruit per tree remaining, so we did not apply a 12mm application. We measured fruitlet growth again on June 7, and the model predicted only 22 fruit per tree remained.

Fruit were harvested on September 16, September 23, September 30, October 6, and October 12. As fruit were harvested, total fruit count and weight were recorded per tree. From these measurements, average fruit size per tree was also tabulated. A subsample of 50 fruit per treatment was shipped to Dr. Terence Robinson at Cornell AgriTech in Geneva, New York, and were sorted over a color and size grader. Fruit were also examined for their level of fruit russeting. These data were then used to tabulate total crop value per acre for each treatment.

Return bloom data from our 2021 trial was collected in May of 2022 by assessing the number of flowering spurs on three limbs on five trees in each treatment of our 2021 field trial.

Statistical Analysis:
From the Northern and Forrence orchards' field trials, treatment differences in number of fruit per tree, yield per tree (kg), fruit size (oz.), and russeting were analyzed in SAS statistical software using the Generalized Linear Model (GLM) procedure. Where the model determined significant treatment differences, differences between individual treatments were assessed using Duncan's Multiple Range Test in SAS statistical software. Return bloom differences were assessed using the Fit Model function on JMP statistical software. Treatment differences were then evaluated using Tukey's Honestly Significant Differences test.

Results

Northern Orchard: Gala
None of the treatments achieved the desired level of thinning in 2022 (Table 3). Significant differences in thinning in terms of total fruit per tree at harvest were observed (p=.0025). While our target crop load for this block was 100 fruit per tree:

- bloom NAA treatment (Treatment 1) averaged 236 fruit per tree,
- 2.5% ATS at bloom treatment (Treatment 2) averaged 194 fruit per tree,
- 3% ATS at bloom treatment (Treatment 3) averaged 170 fruit per tree, and
- 2% LS + 1% mineral oil at bloom treatment (Treatment 4) averaged 144 fruit per tree.

Yield per tree also differed significantly between treatments (p=.0022). Yield per tree averaged:

- 35.97 kg in Treatment 1,
- 31.37 kg in Treatment 2,
- 27.71 kg in Treatment 3, and
- 23.74 kg in Treatment 4.

This would equate to an average yield of approximately 1800, 1570, 1386, and 1188 bushels per acre, respectively.

Fruit size did not differ between treatments. Fruit size averaged:

- 0.15 kg in Treatment 1, and
- 0.16 kg in Treatment 2, 3, and 4, representing fruit sizes of about 126 and 118 fruit per bushel, respectively.

Fruit percent red color did not differ significantly between treatments. Fruit percent red color averaged:

- 63.5% in Treatment 1,
- 69.0% in Treatment 2,
- 70.9% in treatment 3, and
- 75.5% in Treatment 4.

Russeting did not significantly differ between treatments. The 2% LS + 1% mineral oil had the most fruit free from russeting (100% russet free), followed by NAA (99.6%), 2.5% ATS (99.1%), and 3% ATS (99.1%).

Crop values did not significantly differ between bloom thinning treatments. Taking into account the yield, fruit quality, and russeting data, we estimated the value of the crop in:

- Treatment 1 as $15,347 per acre,
- Treatment 2 as $16,886,
- Treatment 3 as $15,559 per acre, and
- Treatment 4 as $14,320 per acre.

2022 Gala									
Treatment	Bloom Thinning Material	Fruit Per Tree	Yield Per Tree (kg)	Estimated Bushels Per Acre	Fruit Size (kg)	Fruit Count Per Bushel	Fruit Color (% Red)	% Russet Free Fruit	Crop Value Per Acre
1	NAA	236 A	35.97 A	1800	0.15	126	63.5	99.6	$15,347
2	2.5% ATS	194 BC	31.37 AB	1570	0.16	118	69.0	99.1	$16,886
3	3% ATS	170 BC	27.71 BC	1386	0.16	118	70.9	99.1	$15,559
4	2% LS + Oil	144 C	23.74 C	1188	0.16	118	75.5	100	$14,320
P-value		**0.0025**	**0.0022**		0.0820		0.2138	0.7886	0.0896

Table 3. Harvest and crop value data from the Northern Orchard Gala trial. Differing letters show statistically significant differences between treatments at p value < .05; NNYADP Utilizing Computer Models and Additional Thinning Materials for Precise Crop Load Management in Northern New York Apple Orchards, 2022.

The fruit growth rate model predicted that the Gala trees in our 3% ATS treatment started with an initial crop load of 1,234 fruit per tree. Following the bloom and petal fall applications, the model predicted there were 284 fruit remaining per tree. This prediction suggests that three applications of 3% ATS alone at bloom would have been inadequate for reaching the target crop load.

The fruit growth rate model had predicted a final crop load of 86 fruit per tree (49% less than what was on the trees at harvest). Our actual average fruit per tree at harvest was 170 in the 3% ATS treatment, suggesting that the fruit growth rate model was very inaccurate in this block in this research year.

Forrence Orchards: Honeycrisp

None of the treatments achieved the desired level of thinning in 2022 (Table 4). Fruit per tree at harvest differed significantly in our trial (p=.0015). While our target crop load for this block was 85 fruit per tree:

- bloom NAA treatment (Treatment 1) averaged 135 fruit per tree,
- 2.5% ATS at bloom treatment (Treatment 2) averaged 137 fruit per tree,
- 3% ATS at bloom treatment (Treatment 3) averaged 208 fruit per tree, and
- 2% LS + 1% mineral oil at bloom treatment (Treatment 4) averaged 236 fruit per tree.

Yield per tree was significantly different in our trial (p=.0485). Yield per tree averaged:

- 30.06 kg in Treatment 1,
- 30.36 kg in Treatment 2,
- 34.91 kg in Treatment 3, and
- 36.14 kg in Treatment 4.

This would equate to an average yield of approximately 1718, 1735, 1995, and 2066 bushels per acre, respectively.

Average fruit size differed significantly (p=.0051), and was .23 kg, .23 kg, .17 kg, and .16 kg, respectively. Percent red color differed significantly between treatments (p=.0236). Red color was 49.6%, 45.1%, 40.4%, and 38.4% respectively.

Russeting did not differ significantly between treatments. The 3% ATS treatment had the most fruit free from russet (100%), followed by the Lime Sulfur (99.6%), 2.5% ATS (98.6%) and NAA treatment (97.4%).

Taking into account the yields and fruit quality data, crop value per acre differed significantly between treatments (p=.0229). We estimated the value of the crop in:

- Treatment 1 as $41,154 per acre,
- Treatment 2 as $38,690 per acre,
- Treatment 3 as $28,909 per acre, and
- Treatment 4 as $26,740 per acre.

2022 Honeycrisp Bloom Thinning Trial									
Treatment	**Bloom Thinning Material**	**Fruit Per Tree**	**Yield Per Tree (kg)**	**Estimated Bushels Per Acre**	**Fruit Size (kg)**	**Fruit Count Per Bushel**	**Fruit Color (% Red)**	**% Russet-Free Fruit**	**Crop Value Per Acre**
1	NAA	135 B	30.06 B	1718	0.23 A	83	49.6 A	97.4	$41,154 A
2	2.5% ATS	137 B	30.36 B	1735	0.23 A	82	45.1 AB	98.6	$38,690 AB
3	3% ATS	208 A	34.91 AB	1995	0.17 B	111	40.4 B	100.0	$28,909 BC
4	2 % LS + Oil	226 A	36.14 A	2066	0.16 B	118	38.4 B	99.6	$26,740 C
P-Value		**0.0015**	**0.0485**		**0.0051**		**0.0236**	0.1136	**0.0229**

Table 4. Harvest and crop value data from the Forrence Orchards Honeycrisp trial. Differing letters show statistically significant differences between treatments at p value < .05; NNYADP Utilizing Computer Models and Additional Thinning Materials for Precise Crop Load Management in Northern New York Apple Orchards, 2022.

The fruit growth rate model predicted that Honeycrisp trees in our 3% ATS treatment started with an initial crop load of 2,174 fruit per tree. Following the bloom application, the model predicted there were 152 fruit remaining per tree. The fruit growth rate model predicted a final crop load of 22 fruit per tree (89% less than what was on the trees at harvest). Our actual average fruit per tree at harvest was 208 in the 3% ATS treatment, suggesting that the fruit growth rate model was very inaccurate in this block this year.

Return Bloom from 2021 Trials
The 2022 return bloom in our 2021 Gala trial block was not affected by our bloom thinning treatments (Table 5).

The 2022 Honeycrisp return bloom was affected by thinning treatment in our 2021 Honeycrisp trial ($p<.0001$). Trees treated with 2% LS + 1% mineral oil in 2021 had significantly more return bloom in 2022 than trees treated with 2.5% ATS or with NAA (Table 6).

2021 Gala Bloom Thinning Trial	
Bloom Thinning Material	**Return Bloom (%)**
NAA	80.8
2.5 % ATS	84.7
P-value	0.2073

Table 5. 2021 Gala Thinning Trial return bloom.

2021 Honeycrisp Bloom Thinning Trial	
Bloom Thinning Material	**Return Bloom (%)**
NAA	34.4 B
2.5 % ATS	46.6 B
2% LS + Oil	70.1 A
P-Value	**<.0001**

Table 6. 2021 Honeycrisp Thinning Trial return bloom.

Discussion

In our Gala trial, the 2.5% ATS rate yielded fewer fruit per tree than the industry standard NAA application. This contrasts to our previous two years of results, which found no significant difference in thinning efficacy between these two treatments. 3% ATS at bloom and 2% LS + 1% mineral oil also yielded fewer fruit per tree than the standard NAA treatment, and yielded similar levels of fruit per tree as the 2.5% ATS treatment. Unfortunately, this extra thinning did not lead to significantly improved fruit size and color relative to the NAA treatment. The different bloom treatments had no effect on fruit russeting of Gala.

2.5% ATS bloom treatment returned the highest crop value per acre, followed by 3% ATS, NAA, and LS. However, none of these values differed significantly from each other. Please note that these crop values do not incorporate the amount of labor time it takes to harvest more or less fruit from each tree.

In our Honeycrisp trial, the 2.5% ATS rate gave similar levels of thinning as the NAA treatment, with no significant differences in fruit per tree or yield per tree. Contrary to our expectations, the 3% ATS and 2% LS + 1% mineral oil treatments thinned off fewer fruit per tree than the NAA and 2.5% ATS treatments. We expected to see a positive rate response from ATS, where increasing concentrations would lead to increased thinning. Our findings are also in disagreement with our previous year's results, where LS + mineral oil gave similar levels of thinning as 2.5% ATS.

Honeycrisp fruit size was smallest in our 3% ATS and 2% LS + 1% mineral oil treatments. Red color was also negatively affected by crop load, as 2% LS + 1% mineral oil had significantly less red fruit than trees treated with NAA. Russeting was worse in the NAA treatment and lowest in the 3% ATS treatment, but did not significantly differ.

The NAA-thinned blocks returned the highest crop value per acre, followed by 2.5% ATS, 3% ATS, and then LS. In these blocks, the Honeycrisp that had the most thinning had the best fruit quality in terms of size and color, which helped to significantly increase the fruits' value despite the yield reductions. Again, please note that these crop values do not incorporate the amount of labor time it takes to harvest more or less fruit from each tree.

Our results suggest that 2.5% ATS timed with the PTGM can provide comparable levels of thinning as traditional NAA bloom thinning in Honeycrisp when used in a traditional thinning program, followed up with additional hormone thinner applications at petal fall, 12mm, and beyond. In Gala, we found 2.5% ATS, 3% ATS, and 2% LS + 1% mineral oil can thin significantly more fruit, but this additional thinning had limited effects on fruit quality and crop value this year. In Honeycrisp, fruit thinned with 3% ATS and 2% LS + 1% mineral oil thinned substantially fewer fruit than NAA and 2.5% ATS, resulting in higher yields of poor quality fruit, resulting in lower crop values.

Fruit Russeting

Excessive fruit russeting can decrease the value of fruit. Previous studies have found an increased risk of russeting from using lime sulfur and ammonium thiosulfate for bloom thinning (*Peck et al., 2017; Marchioretto et al., 2018*). While the exact reasoning for this russeting is not always clear (*Allen et al., 2021*), the standard guidance has been to use reduced rates of the materials or to avoid using these materials under slow drying conditions.

Fruit treated at 2.5 and 3% ATS had the most russeting in our Gala trial in 2022, followed by NAA, followed by 2% LS + 1% mineral oil, not significantly different. Russeting was minimal on all the 2021 Gala treatments, and, therefore, had a negligible impact on fruit quality.

The NAA treatment had the most russeting in our 2022 Honeycrisp trial, followed by the 2.5% ATS treatment, the 3% ATS, and 2% LS + 1% mineral oil treatment, not significantly different.

In our 2021 Honeycrisp trial, the 2% LS + 1% mineral oil treatment produced significant russeting, ATS at 2.5% moderate russeting, and NAA very little russeting on Honeycrisp. In that trial, the extra size and color gain from the lime sulfur led to similar overall returns to the grower with either the lime sulfur or NAA treatment. Russeting was less severe in the ATS-treated fruits and with the extra color gain made the ATS treatment the most profitable.

Economics

In Table 6 we estimate the cost of each bloom thinning treatment per acre per season, along with the final crop value obtained from that treatment. With costs considered, the 2.5% ATS treatment was the most profitable bloom thinner in our Gala trial, while the NAA treatment was our most profitable thinner in the Honeycrisp trial.

2022 Economics Per Acre			
Gala Trial			
Bloom Thinning Material	Crop Value	Per Acre Costs	Total Returns
NAA	$15,347	$24.65	$15,322.35
2.5% ATS	$16,886	$44.40	$16,841.60
3% ATS	$15,559	$47.28	$15,511.72
2% LS	$14,320	$143.11	$14,176.89
Honeycrisp Trial			
Bloom Thinning Material	Crop Value	Per Acre Costs	Total Returns
NAA	$41,154	$24.65	$41,129.35
2.5% ATS	$38,690	$29.60	$38,660.40
3% ATS	$28,909	$31.52	$28,877.48
2% LS	$26,740	$107.60	$26,632.40

Table 6. Crop value data and per-acre costs of each bloom thinning treatment from Gala and Honeycrisp trials. These returns do not account for all other expenses occurred by the grower to produce the fruit, this is simply the costs associated with each bloom thinning treatment; NNYADP Utilizing Computer Models and Additional Thinning Materials for Precise Crop Load Management in Northern New York Apple Orchards, 2022.

Weather Impacts

Weather was not very conducive to good hormonal thinning during our petal fall application for Gala in 2022, nor was it particularly conducive to good thinning at our 12mm application. This may help to explain why we did not reach our target crops at either site.

The weather in 2022 during bloom was not conducive to bloom thinning with the PTGM. Rain showers were predicted for each day we wanted to make applications, which required us to get applications on earlier than we would have liked for the second ATS application and both of the LS applications. The first applications also went on under very warm conditions, when it was approximately 82°F. These hot temperatures likely led to increased leaf burn on the trees. Trees grew out of this damage, though, and we feel it prevents little risk to grower profitability. Applications made the next day probably

gave good efficacy, as conditions were warm and humid, and we expect higher levels of thinning efficacy when these materials are applied under slow drying conditions (*Janoudi and Flore, 2005*). However, even under these strong thinning conditions, timing issues due to rain likely impacted overall efficacy this season in the Honeycrisp trial. Our third Gala application was made when the daily temperature was a high of 61°F, so we expect this likely did some mild additional thinning of the remaining fruit buds. Since applications were made early at both sites, it is very likely that the Honeycrisp site would have benefited from a third application of bloom materials, but we were unable to get a third application on due to time and weather constraints.

Thinning at Bloom Alone?

Our fruit growth rate model results from the Northern Orchard Gala trial site suggest that three applications of 3% ATS alone would have been insufficient to adequately reduce crop load. Kon et al. (2018) found that two applications of 2.0% ATS at bloom did not reduce final crop load sufficiently. Given our results, Gala treated with three bloom applications of 3% ATS may require additional thinner applications at later fruit growth stages. Commercial recommendations suggest concentrations of ATS between 2% and 4% for bloom thinning. Given the limited amount of russet we saw at 3% in our Gala study, we feel comfortable recommending up to 3% ATS at this timing when conditions are favorable, following up with additional hormone materials as needed.

Our harvest results from the Forrence Orchard Honeycrisp trial site shows two applications of 3% ATS alone was insufficient to adequately reduce crop load. Given the limited amount of russet we saw at 3% in our Honeycrisp study, we feel comfortable recommending up to 3% ATS at this timing when conditions are favorable, following up with additional hormone materials as needed.

Return Bloom Considerations

Other researchers have suggested an additional benefit of treating trees with ATS at bloom may be an improved return bloom in biennial varieties such as Honeycrisp (*Robinson, 2020*). In 2022 we evaluated return bloom in our 2021 trial blocks. In our Honeycrisp trial, bloom thinning had a significant impact on return bloom the following season ($p<.0001$). We found 2.5% ATS at bloom increased return bloom by 12% relative to bloom NAA treatments, and LS at bloom significantly increased return bloom by 36%.

We only saw a 4% return bloom increase in our 2021 Gala trial block. In our 2020 trials, we found no significant increase in return bloom in either Honeycrisp or Gala. We note that return bloom was very low in many Northern NY Honeycrisp blocks in 2021, which could have contributed to ATS being less effective at improving return bloom in that year. We plan to evaluate return bloom for our 2022 trials in spring 2023 to better understand the effects of thinning with 3% ATS and 2% LS + 1% mineral oil on return bloom.

Under- and Over-Prediction Variability

The fruit growth rate model under-predicted the amount of fruit remaining on the trees in 2022 at both orchard sites. The model under-predicted final fruit per tree by 49% at our

Gala site, and by 89% at our Honeycrisp site. The Gala trees we tagged had many additional fruits at the tops of the trees at harvest, whereas the clusters we had tagged were more uniformly distributed throughout the canopy. This might explain the under-prediction we observed in Gala this season.
We found excessive king bloom damage in our Honeycrisp trial this season. Conversations with the model developers (*Robinson, 2022*) suggest the model likely greatly underestimated in 2022 due to the lack of king fruits growing. In years with excessive king damage, the model may not be able to determine if lateral blossoms are going to abscise or not. In our Honeycrisp trial, the model likely thought more laterals were going to thin off than actually did.

In our 2021 trial, the model under-predicted remaining fruit by 44% in our Gala experiment, and by 16% in our Honeycrisp experiment. Earlier experiments have found that the model tends to slightly overestimate in trials by about 10% (*Robinson, 2020*).

The three years of data results indicate that the fruit growth rate model can be a valuable tool in roughly estimating the amount of fruit left on the tree to help growers to determine when to stop thinning, but it is unlikely to be exact, and may be inaccurate in years where excessive king damage is present.

Moving Forward into 2023
Our target crop loads were not met at either of our trial sites this season. However, given the increased risk of leaf damage and russet above 3% with ATS, we currently recommend growers use ATS rates between 2.5 and 3% when conditions are favorable on Honeycrisp blocks that struggle with biennial bearing. Since we had poor weather conditions in 2022, we believe further research is required to refine the use of these models in commercial settings to incorporate them into an integrated thinning program in Northern New York. Updated bloom thinning models are currently in development at Cornell University, and we plan to partner with the developers on a small trial basis in 2023 to support their implementation in northern New York.

Conclusions

The bloom thinning of apples has great potential to increase early thinning to improve fruit quality, and to promote return bloom the following season in biennial varieties like Honeycrisp.

In our 2022 Gala trial, bloom thinning with 2.5% ATS, 3% ATS, or 2% LS + 1% mineral oil with the PTGM thinned more fruit at bloom than NAA, but this additional thinning did not provide additional benefits in fruit quality or crop value when followed with the same thinning protocols at petal fall and 12mm. While not statistically significant, fruit thinned with two applications of 2.5% ATS at bloom was the most profitable option. However, the labor costs of setting up the PTGM should also be strongly considered. Since Gala does not tend to have an issue with return bloom, we generally recommend growers continue to thin with NAA at bloom, and to complement this with additional thinners at petal fall, 12mm, and 18mm as needed.

At the Honeycrisp field site, 2.5% ATS provided similar levels of thinning and crop value as NAA applied at bloom. 3% ATS and 2% LS + 1% mineral oil provided less thinning efficacy, and was met with reduced fruit quality and crop value. At this site, the NAA bloom treatment was the most profitable bloom thinner. While we haven't assessed the 2022 season's return bloom yet, our 2021 trial data shows that return bloom is slightly increased with 2.5% ATS over NAA at bloom. Therefore, where growers have a particularly biennial block of Honeycrisp that is going to be in a high bloom year, they might consider treating the block with 2.5-3% ATS if conditions for the application are favorable on a limited trial basis.

Lime sulfur remains unlabeled for bloom thinning in New York. Companies have shown little interest in adding this use to their labels. New York growers should not use lime sulfur for bloom thinning.

The fruit growth rate model under-predicted the number of fruit at our Gala site, and greatly underestimated the number of fruit at our Honeycrisp fruit site. The fruit growth rate model might be of limited utility in orchards that have sustained winter damage to the king blooms.

Additional work is required to further evaluate the most appropriate rates of these materials under various weather scenarios. Updated versions of the PTGM being developed at Cornell might make implementing it on commercial orchards easier in the following years.

Education and Outreach

- What's New in Crop Load Management? Webinar, March 18, 2022, virtual; presentations by Dr. Greg Peck on bloom thinning with the pollen tube growth model and by Mike Basedow on results from the 2021 NNYADP-funded trial. Participants: 85 fruit growers. Video posted on Eastern NY Commercial Horticulture Program (ENYCHP) YouTube page, 111 views as of January 5, 2023.

- 2022 Statewide Pre-Bloom Thinning Webinar, April 28, 2022, virtual; Dr. Terence Robinson discussed bloom thinning with the pollen tube growth model. Participants: 78. Video on Lake Ontario Fruit Program YouTube page, 294 views as of January 5 2023.

- 2022 Bloom Thinning Orchard Walk and Talk, May 12, 2022, Peru, NY; Mike Basedow provided an overview of bloom thinning with the PTGM, and showed growers in-person the return bloom results of 2021 bloom thinning trials. Attended by 15 growers.

- Virtual Thinning Meetings, May-June 2022. Three weekly thinning meetings were held online for Northern New York growers. Dr. Robinson and project leader Mike Basedow discussed thinning conditions and recommendations for

thinning each week. Weekly attendance:12-14 growers. Video posted on ENYCHP YouTube page.

- E-mail Alerts: following each virtual thinning meeting, growers were emailed a recap of the discussed thinning recommendations, along with additional details from model outputs from test sites in Peru, NY, reaching 678 Eastern/Northeastern NY fruit growers.

- One-on-One Outreach: growers participating in the thinning projects received frequent personalized emails, text messages, phone calls, and farm visits to discuss the models, and were given thinning advice based on these model recommendations.

Next Steps

Grower outreach events in 2022 were well received and will continue through 2023. In spring 2023, we will evaluate return bloom at our orchard sites by counting the amount of floral and vegetative buds on three limbs of each tree within the trial to determine if the experimental bloom thinning treatments significantly increased return bloom.

From our three years of trials, we will recommend growers continue to thin with either NAA or 2.5% ATS in Gala in northern NY. Given the additional labor expenses with setting up the PTGM, NAA may still be the best option for Gala growers, particularly since return bloom is much less of a concern. Our three years of studies with bloom thinning with the PTGM in Champlain Valley Honeycrisp suggest 2.5% ATS provides similar levels of thinning as NAA at bloom, and similar levels of return bloom. Unfortunately, we did not see additional benefits on fruit quality from thinning with 3% ATS in 2022, or 2% LS + 1% mineral oil in either 2021 or 2022. We did see an increase in return bloom in Honeycrisp with 2% LS + 1% mineral oil in our 2021 trial, but we will need to see if this trend is consistent in 2023.

We believe additional research is needed to find the most effective concentration of ATS to use at bloom on these varieties relative to the weather conditions on the day of application.

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For More Information

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NNYADP Apple/Precision Orchard Research Reports (2013-2021):
https://nnyagdev.org/index.php/horticulture/nny-horticultural-research

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Photos:

Left: Figure 1. A tree at Northern Orchard pruned, counted, and with clusters tagged for Fruit Growth Rate Model measurements. Photo by Michael Basedow
Right: Figure 2. Collecting king flower blossoms to measure flower style length. Photo by Andy Galimberti

Left: Figure 3. Measuring flower style lengths in the field. Photo by Andy Galimberti
Right: Figure 4. Measuring apple fruitlets to enter into the Fruit Growth Rate Model. Photo by Andy Galimberti