Northern NY Agricultural Development Program
2020 Project Report

Utilizing the Pollen Tube Growth Model and the Fruit Growth Rate Model for Bloom Thinning in Northern New York Apple Orchards

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Grower Collaborators:

- Northern Orchard, Peru, NY
- Everett Orchards, Peru, NY
- Forrence Orchards, Peru, NY

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 to achieve optimum fruit size and return bloom without reducing crop yield excessively. For each variety, there is an optimum number of fruit per tree where yield, fruit size, and fruit quality are well-balanced to bring the greatest economic return to the grower.

In Northern New York most commercial apple crop load management is performed by thinning trees when fruit are between 10-12 mm as fruit begin to set on the trees following bloom. Thinning at this 10-12 mm timing relies primarily on the use of hormone-based plant growth regulator materials, such as NAA and 6-BA, and carbaryl, an insecticide that also causes mild fruit thinning. While NAA and 6-BA are industry standards for thinning, their efficacies are very temperature-dependent. The optimal temperature for the application of these materials is generally in the mid 70s Fahrenheit (F). Below 70 degrees F, efficacy is greatly reduced to where trees may be under-thinned, leaving too heavy of a crop on the tree, resulting in poor fruit quality and poor return bloom the following year. On the other end the spectrum, temperatures at and above the mid-80s F can remove all the fruit from a tree. In Northern New York, these narrow temperature ranges are sometimes difficult to achieve during cool springs, making crop load management with these hormone-based materials relatively ineffective in some years.

An alternative method that can be used for crop load management is bloom thinning. This method uses different materials, like fertilizers and biofungicide products, to inhibit flower fertilization during bloom. Trees thinned earlier at bloom often produce larger fruit at harvest, have greater return bloom the following spring, and have reduced biennial bearing (many fruit on the tree one year, few fruit the following) (Kon et al, 2018). 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 and 2019. This resulted in poor return bloom in 2019 on their Honeycrisp trees (Honeycrisp is 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 currently remains difficult to perform in New York, as it requires precise timing of the thinning material applications to inhibit fertilization of the correct number of flowers. When materials are applied at the incorrect timing, it is very easy to over-thin or under-thin the trees. To better time these applications, some Northern New York 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 (Yoder et al., 2013).

By beginning the thinning process at bloom, growers also have the opportunity to gauge how well the trees are responding to the thinner applications. This response can be quantified using the fruit growth rate model, developed by pomologists at Cornell University, the University of Massachusetts, and Michigan State University. In this model, the growth of fruitlets is monitored after each thinning application to determine how many fruit will be removed by the previous thinning spray (Greene et al., 2013). We have used this model in Northern New York with growers in previous projects, and have found the tool useful in estimating the amount of crop still on the tree to determine if additional thinning applications should be made.

Combining the fruit growth rate model with an effective bloom thinning protocol will bolster the profitability of Northern New York 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 orchard blocks.

Methods:

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

Northern Orchard: Gala Variety Trial

Our Gala experiment at Northern Orchard in Peru consisted of a mature block of Brookfield Gala, planted at 4x12-foot spacing. We selected 15 trees in April (five replications of three trees) within the orchard to receive the experimental ammonium thiosulfate (ATS) applications

(Treatment 1), and 15 trees to receive the grower's standard thinning applications (Treatment 2), giving us 30 trees total within the experiment.

Working with the grower, we determined the target crop load for the block was 90 fruit per tree. At the pink bud growth stage, the number of flower buds were counted on all the trees within the experiment, and trees were subsequently pruned to reduce some of the crop load. Following pruning, 15 flower clusters on 5 representative trees (75 clusters total) within Treatment 1 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).

As bloom began, 30 king flowers were collected from trees within the experiment block at random. Flower styles were measured, and the average style length from these flowers was added to the pollen tube growth model (Figure 2). As more flowers opened, we monitored the block closely to estimate that the targeted 90 king flowers per tree opened in the block on May 21, 2020, allowing us to begin running the pollen tube growth model. The first application of 2.5% ATS was made to Treatment 1 on May 23, when the PTGM reached 60%. On the same day, trees in Treatment 2 received an application of Fruitone (an NAA product) at the rate of 4 oz. per 100 gallons dilute tree row volume (TRV). A second application of 2.5% ATS was made to Treatment 1 on May 25, when the model once again reached 60%.

Bloom treatments were then followed with a petal fall thinning application of 3 oz. Fruitone per 100 Gallon gallon dilute TRV + 1 pt Sevin on May 30.

Following the petal fall application, fruitlet growth was measured on the clusters we had flagged at the pink bud stage (Figure 3). Measurements were made on June 2, and again on June 6. Following the petal fall application, the fruit growth rate model predicted there were still 723 fruit per tree remaining, so a 12 mm thinning application of 80 oz Maxcel + 1.25 pts Sevin per 100 gallon dilute TRV was made on June 8. We measured fruitlet growth again on June 11, and the model predicted 282 fruit per tree remained. On June 14, we made a final thinning application of 48 oz Maxcel + 1 pt Sevin per 100 gallons dilute TRV. For this application, the bottom 4 nozzles were shut off on each side of the sprayer, so more of the thinner could be directed to the upper portion of the tree canopy. Fruitlets were measured again on June 17 and 23, at which point the model predicted 184 fruit per tree remained.

Fruit were harvested on September 22, 2020. 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. Fruit were then shipped to Terence Robinson at Cornell AgriTech in Geneva, New York, and were sorted over a color and size grader. These data were then used to tabulate total crop value per acre of each treatment.

Everett Orchards: Honeycrisp Variety Trial
Our Honeycrisp trial at Everett Orchards in Peru, New York, consisted of a mature Honeycrisp orchard, planted at a 3x11-foot spacing. We selected 15 trees in April (three replications of five trees) within the orchard to receive the experimental bloom thinning ATS applications (Treatment 1), and 15 trees to receive the grower's standard thinning applications (Treatment 2), giving us 30 trees total within the experiment.

Working with the grower, we determined the target crop load for the block was 40 fruit per tree. At the pink bud growth stage, the number of flower buds were counted on all the trees within the experiment, and 15 flower clusters on 5 representative trees (75 clusters total) within Treatment 1 were also flagged and numbered, so we could run the fruit growth rate model on the trees to track the 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 pollen tube growth model. However, upon inspection of the flowers, we determined some of the king blooms had been injured by frost events that occurred in the orchard in the weeks leading up to bloom. Since bloom thinning with the PTGM depends on having healthy king flowers, we decided not to treat this orchard with any bloom thinners this season.

Instead, all 30 trees received 3 oz. Fruitone + 1 pt Sevin per 100 gallons dilute TRV at petal fall on May 30. Following this petal fall application, fruitlets on the 75 clusters were measured on June 2 and June 6, and were entered into the fruit growth rate model. At this point, the model predicted there were still 282 fruit remaining per tree. An additional application of 3 oz. Fruitone + 1 pt Sevin per 100 gallons dilute TRV was applied on June 8. Fruitlets were measured again on June 11 and on June 16 following this application, and at this point the model predicted there were 34 fruits per tree remaining, so no additional thinning applications were made.

Fruit were harvested on September 22 and September 28. As fruit were harvested, total fruit count and weight were recorded per tree. From these measurements, average fruit size per tree was also tabulated. Fruit were then shipped to Terence Robinson at Cornell AgriTech in Geneva, New York, and were sorted over a color and size grader. These data were then used to tabulate total crop value per acre.

Forrence Orchards: Honeycrisp Trial

Due to the cold-injured flowers we saw at Everett Orchards, we initiated an additional Honeycrisp trial at Forrence Orchards in May. This site consisted of five-year-old Honeycrisp trees, planted at a 4x16-foot spacing. We selected 15 trees (3 replications of 5 trees) to receive the experimental bloom thinning ATS applications (Treatment 1), and 15 trees to receive the grower's standard thinning applications (Treatment 2), giving us 30 trees total within the experiment. Working with the grower, we determined the target crop load for the block was 45 fruit per tree.

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 pollen tube growth model. As more flowers opened, we monitored the block closely to estimate that the targeted 45 king flowers per tree had opened in the block on May 23, allowing us to begin running the pollen tube growth model. The first application of 2.4% ATS was made to Treatment 1 on May 24, when the pollen tube model was at 20%, earlier than we had intended it to. Because this application was applied early, we decided not to apply a second ATS application. On May 25, the 15 trees in Treatment 2 received an application of 3 oz. Fruitone per 100 gallons dilute TRV.

Following the bloom applications, both treatments received a petal fall thinning application of 3.75 oz. Fruitone + 1 pt Sevin per 100 gallons dilute TRV on June 1.

We were unable to perform the fruit growth rate model at the Forrence Orchard site this year, since this block was added late due to the freeze event at the Everett Orchard site. However, we still observed fruitlet growth with the grower and determined to not apply any additional thinning treatments following the petal fall application.

Fruit were harvested on September 16, September 25, and October 5. As fruit were harvested, total fruit count and weight were recorded per tree. From these measurements, average fruit size per tree was also tabulated. Fruit were then shipped to Terence Robinson at Cornell AgriTech in Geneva, New York, and were sorted over a color and size grader. These data were then used to tabulate total crop value per acre for each treatment.

Statistical Analysis:
From the Northern and Forrence orchards' field trials, treatment differences in number of fruit per tree, yield per tree (kg), yield per acre, fruit size (oz.), and crop value were analyzed using the GLM (general linear model) feature in SAS statistical software.

Results:

Northern Orchard: Gala

Trees in both the experimental bloom thinning and the grower standard thinning treatments did not achieve the desired level of thinning in 2020. While our target crop load for this block was 90 fruit per tree, our bloom ATS treatment (Treatment 1) averaged 167 fruit per tree, and the bloom NAA treatment (Treatment 2) averaged 161 fruit per tree. Yield per tree averaged 28.34 kg in Treatment 1, and 28.00 kg in Treatment 2. This would equate to an average yield of approximately 1382 bushels per acre, and 1437 bushels per acre, respectively. Average fruit size averaged 6.1 oz. in Treatment 1, and 6.2 oz. in Treatment 2, representing fruit sizes of about 113 fruit per bushel. Taking into account the yield and fruit quality data, we estimated the value of the crop in Treatment 1 as $11,608per acre, whereas the value for Treatment 2 as $10699 per acre. None of the differences in any values were statistically significant between the two bloom thinning treatments (Table 1).

Northern Orchard Gala						
Bloom Thinning Material	**Fruit Per Tree**	**Yield Per Tree (kg)**	**Bushels Per Acre**	**Fruit Size (oz)**	**Fruit Tray Pack**	**Crop Value Per Acre**
ATS	167	28.34	1382	6.06	113	11608
NAA	161	28.00	1437	6.19	113	10699
P-value	**0.588**	**0.858**	**0.858**	**0.295**		**0.860**

Table 1. Harvest and crop value data from the Northern Orchard Gala trial.

The fruit growth rate model predicted that trees started with an initial crop load of 1225 fruit per tree. Following the bloom and petal fall applications, the model predicted there were 723 fruit remaining per tree. This prediction suggests that two applications of 2.5% ATS alone at bloom would have been inadequate for reaching the target crop load.

The fruit growth rate model predicted a final crop load of 184 fruit per tree. Our actual average fruit per tree at harvest was 167 in the ATS treatment, suggesting that the fruit growth rate model was quite accurate in this block, over-predicting by only 17 fruit (about 10%).

Everett Orchards: Honeycrisp

Although we were unable to compare our experimental bloom thinning treatment to the NAA standard at this site this year, we were still able to estimate the final crop value of the block from thinning with the recommendations of the fruit growth rate model. Trees in this trial were over-thinned this season. While the target crop load had been 40 fruit per tree, the final average fruit per tree was only 13. The average yield per tree was 2.20 kg, which would equate to an average yield of 159 bushels per acre. Average fruit size was 5.7 oz., representing a fruit size of about 125 fruit per bushel. This correlates to an average crop value of $2,599 per acre (Table 2).

Everett Orchards Honeycrisp						
Bloom Thinning Material	Fruit Per Tree	Yield Per Tree (kg)	Bushels Per Acre	Fruit Size (oz)	Fruit Tray Pack	Crop Value Per Acre
NAA	13	2.20	159	5.7	125	2599

Table 2. Harvest and crop value data from the Everett Orchards Honeycrisp trial.

The fruit growth rate model predicted that trees started with an initial crop load of 688 fruit per tree. Following the petal fall application, 282 fruit were predicted to remain, and, following the 12 mm application, 34 fruit were predicted to be remaining.

While the model predicted 34 fruit remaining on the trees, we only harvested an average of 13 fruit/tree. While the model only over-predicted by 21 fruit (usually corresponding to about a 10-20% difference), at these low crop levels this is a nearly 3x overestimation of the final crop load.

Forrence Orchards: Honeycrisp

Trees in both the experimental bloom thinning and the grower standard thinning practices were close to the grower's targeted crop load. The target crop load for this block was 45 fruit per tree. Average fruit per tree in the ATS bloom treatment (Treatment 1) was 45, and 37 fruit per tree in the NAA bloom treatment (Treatment 2). The average yield per tree was 8.82 kg in Treatment 1, and 6.28 kg in Treatment 2. This equates to an average per acre yield of approximately 331 bushels per acre, and 235 bushels per acre, respectively. Fruit size was 6.8 oz. in Treatment 1, and 6.1 oz. in treatment 2. This corresponds to fruit sizes of 100 fruit per bushel, and 113 fruit per bushel, respectively. Taking into account the yields and fruit quality data, we estimate the value of the crop in Treatment 1 was $7,104 per acre, whereas the value for Treatment 2 was $4,173 per acre. None of these differences were statistically significant between treatments (Table 3).

Forrence Orchards Honeycrisp						
Bloom Thinning Material	Fruit Per Tree	Yield Per Tree (kg)	Bushels Per Acre	Fruit Size (oz)	Fruit Tray Pack	Crop Value Per Acre
ATS	45	8.82	331	6.80	100	7104
NAA	37	6.28	235	6.10	113	4173
P-value	**0.343**	**0.252**	**0.252**	**0.299**		**0.277**

Table 3. Harvest and crop value data from the Forrence Orchards Honeycrisp trial.

Discussion:

At the two orchard sites where we were able to compare ATS vs. NAA bloom thinning materials, we found both treatments, when applied with similar follow up applications post-bloom, led to very similar levels of fruit thinning, as we found no statistically significant differences in the total number of fruit per tree, yield per tree, fruit size per tree, or crop value per acre between the two treatments.

Weather was very conducive to good hormonal thinning in 2020. ATS applications were made when the weather was very warm and dry this year, which likely led to fast drying times on the trees. Previous experiments have found that ATS efficacy is reduced under fast drying times (Janoudi and Flore, 2005), which may partially account for why we saw similar levels of thinning between our treatments.

When comparing the costs between the two bloom treatments, we estimate two applications of ATS cost our cooperators approximately $29.60 per acre in materials and spray labor. The cost of one bloom application of NAA was estimated at $24.63 per acre. These numbers do not account for the added labor expense associated with using the PTGM, so in these particular situations this year, it appeared more economical to use NAA at bloom on the basis of input costs and crop value alone.

Other accounts have suggested an additional benefit of treating trees with ATS at bloom may be improved return bloom in biennial varieties such as Honeycrisp (Robinson, 2020). We will be evaluating return bloom at the Forrence Orchards' Honeycrisp trial site in May 2021 to determine if there is a significant difference in return bloom between the two treatments. These results should also be considered when comparing overall value to the orchard operation, as poor return bloom is detrimental to orchard profitability.

Our fruit growth rate model results from the Northern Orchard Gala trial site suggests that two applications of 2.5% 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. We may contribute some of this reduced efficacy to quick drying times in the orchard this season due to the hot, dry weather prevalent at bloom during the applications. Given our results, bloom applications of ATS may require additional thinner applications at later fruit growth stages, or may necessitate using a higher concentration of ATS at bloom when quick drying conditions are prevalent. Commercial recommendations suggest concentrations of ATS between 2% and 4% for bloom thinning. In our estimation, a higher concentration may be necessary in Northern New York in hot and dry years to achieve more effective early crop load reduction. However, higher concentrations may cause unacceptable levels of leaf damage and fruit finish, so further research on the most appropriate concentration relative to weather conditions during the application window is warranted.

The fruit growth rate model over-predicted the amount of fruit remaining on the trees. The model over-predicted by 10% at our Gala site, but by 160% at our Honeycrisp site where the final crop was greatly reduced. This indicates that the fruit growth rate model can be a valuable tool in predicting the amount of fruit left on the tree, but it may overestimate the amount of fruit remaining on the trees, particularly when the final crop load is low. Earlier experiments have also found that the model tends to slightly overestimate in trials by about 10% (Robinson, 2020). We believe part of this overestimation may be related to fruit drop in the orchard in June and just prior to harvest. Additional drop is particularly likely in years of high heat and drought stress, as was observed in 2020. At the Everett Orchards' trial site, the model may not have fully accounted for cold-damaged buds, which we believe may have thinned off easier than they would have in an average year.

Given that our target crop loads were met at only one of our three trial sites, we believe further research is required to refine these models, and fully understand how to best implement these models into an integrated thinning program in Northern New York.

Conclusions

The bloom thinning of apples has the greatest potential to increase fruit size and promote return bloom the following season. In our trials, bloom thinning with 2.5% ATS with the PTGM did not provide additional benefits compared to the standard practice of using NAA at bloom in terms of yield, fruit size, fruit quality, or crop value at either our Gala or Honeycrisp orchard field sites when followed with the same thinning protocols at petal fall, 12mm, and 15mm+. We will still need to evaluate the return bloom in our Honeycrisp field site in the spring of 2021 to determine if the ATS treatment reduced biennial bearing. Two applications of 2.5% ATS at bloom were not effective in reducing crop load to acceptable levels alone in Gala, as documented by the fruit growth rate model results, and would necessitate follow up applications of hormone based thinners to achieve the targeted crop load.

The fruit growth rate model provided a reasonable estimate of the amount of fruit remaining on the trees in our trials; however, the model slightly over-predicted the number of fruit at both sites.

Before we can confidently make recommendations for growers to implement bloom thinning based on use of the PTGM and the fruit growth rate model on a commercial orchard level under Northern New York conditions, we will need to repeat these trials to evaluate additional ATS rates and materials,.

Education and Outreach:

2020 Champlain Valley Pruning and Thinning Meeting, January 30, 2020, Plattsburgh, NY
We reviewed the principles of pruning and thinning to achieve desired crop loads with 16 Northern New York apple growers.

2020 Eastern New York Fruit and Vegetable Conference, February 18-19, 2020, Albany, NY. Multiple talks were presented, including information on precision pruning and thinning by Dr. Terence Robinson. This meeting was attended by more than 350 fruit growers.

2020 Pollen Tube Growth Model Webinar, March 30, 2020.
Speakers included Dr. Greg Peck and Dan Olmstead. This meeting had over 60 attendees. A recording of the meeting is online on the Eastern New York Commercial Horticulture Program (ENYCHP) YouTube page (422 views as of January 6, 2021).

Virtual Thinning Meetings, May-June 2020
Three weekly thinning meetings were held online for Northern New York growers. Dr. Robinson and Mike Basedow discussed thinning conditions and their recommendations for thinning each week. Weekly attendance fluctuated between 10 and 20 growers. Recordings of these meetings are posted on the ENYCHP YouTube page (37, 21, and 20 views, respectively, as of January 6, 2021).

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 our test sites in Peru, reaching an audience of 678 Eastern/Northeastern New York 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 were well received and will continue through 2021, including a panel discussion of the pollen tube growth model at the virtual New York Tree Fruit Conference, scheduled for February 3, 2021. More than 250 fruit growers regularly attend this event.

In spring 2021, we will evaluate the return bloom at the Forrence Honeycrisp orchard site by counting the amount of floral and vegetative buds on three limbs of each tree within the trial to determine if the ATS bloom treatments significantly increased return bloom.

Given the variation in final crop load relative to the target numbers for two of the three orchards in our 2020 study, we believe additional research is necessary to fully understand how to best incorporate the use of these two models into an integrated thinning program in Northern New York. We intend to continue running bloom thinning experiments in 2021. Northern New York apple producers were optimistic about the continued use of ATS in their thinning programs; however, we believe additional work needs to be done to find the most effective concentration of ATS to use at bloom, and we would also like to trial the use of lime sulfur as an additional bloom thinning material.

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Photos:


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

Figure 3. Measuring apple fruitlets to enter into the Fruit Growth Rate Model, NNYADP. Photo by Michael Basedow.