Northern NY Agricultural Development Program
2018 Final Report

Precision Management and New Thinning Strategies to Optimize Profitability of NNY Apple Growers

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Cooperating Producers:

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- Tom Everett, Everett Orchards, Peru, NY

Background:

Pruning (33%), hand thinning (22%), and harvest (28%) are the major labor-intensive tasks performed annually in apple orchards that imply about 85% of the production cost. Many growers are making large investments in new tall spindle high-density orchards, but if they do not manage satisfactorily the payback on the huge investment will be jeopardized. There is a large need to develop sound management and performance data to know the right pruning mechanization procedure. On the other hand, management of crop load is a balancing act between reducing crop load (yield) sufficiently to achieve optimum fruit size and adequate return bloom without reducing yield excessively.

Managing crop load is one of most important management tasks faced by apple growers. For each variety and orchard there is an optimum number of fruits per tree where yield, fruit size, and fruit quality are optimized. Optimized crop loads for a given cultivar and production system in a particular environment can clearly give enhanced financial returns to growers.

In the Northeastern US, almost all apple orchards are chemically thinned early in the season each year using a combination of either naphthaleneacetic Acid (NAA, a synthetic auxin plant growth regulator) plus carbaryl (a carbamate insecticide), naphthalene acetamide (NAD) plus carbaryl or benzyl adenine (BA, a synthetic cytokinin plant growth regulator) plus carbaryl. carbaryl causes some thinning by itself but also enhances the thinning efficacy of either NAA, NAD or BA. Carbaryl has been an essential component of chemical thinning programs for more than 40 years. However, there is concern that carbaryl will be removed from the market by regulatory action either in the US or in Europe.

In the last couple of years, one retailer in the U.S. — Whole Foods Markets — prohibited carbaryl's use on produce sold in stores, creating several obstacles for growers to remain competitive in the apple industry. While growers have been using their own experiene to devise thinning strategies without carbaryl, there is still a need to develop new carbaryl-free thinning strategies for all of our commercial varieties of apples and various weather conditions. Therefore, in 2018, we added evaluation of carbaryl-free thinning strategies to this NNYADP-funded project.

If growers do not adopt strategies to grow high quality fruit in a more efficient way they will not be able to stay in business. Therefore, developing labor-saving management strategies, and yield and economic data as well as further refining and extending precision crop load management strategies will benefit the commercial apple growers in Northern New York.

Producing fruit of the appropriate size and high quality is one of the most important task growers must accomplish in order to ensure profitability. The decision over which thinning strategy to use to provide the best results is complex and will vary from orchard to orchard and season to season; furthermore, a combination of strategies will evolve each season.

Therefore, this project seeks to help apple growers to reduce production costs and optimize yield, fruit size, and fruit quality of the most important varieties recently grown in NY by implementing a suite of management practices we have named precision orchard management. One of the major outcomes of this project will be to facilitate the development of practical guidelines for NNY apple growers to optimize crop load and water management. We will do this through on-farm experiments, demonstration projects and workshops. The project will involve growers through the use of on-farm research plots. These grower-based plots will lead to broad grower involvement through field days and workshops and winter fruit schools.

Methods:

1. Precision Thinning

In 2018, we continued work with the NNY apple growers on how to achieve perfect fruit thinning by adopting the precision thinning program. We helped three growers in Northern New York (NNY), among 20 growers statewide, to manage chemical thinning of their Gala and Honeycrisp apple crops more precisely.

The precision chemical thinning protocol recommended to apple growers in 2018 was very similar to the 2017 protocol and incorporated two precision thinning models:

- the carbohydrate model developed by Alan Lasko, Cornell University, and
- the fruit growth rate model (FGR) developed by Duane Greene, University of Massachusetts.

The three growers in Northern New York's Champlain Valley region were advised to follow several simple steps to accomplish both models. The first step is to establish a target fruit number (target crop load). The target crop load was defined by each grower according to experience, variety, tree vigor and age, and desired fruit size.

The protocol includes a sequence of thinning sprays growers choose from to achieve desired target crop load, beginning with a spray at bloom, followed by a spray at petal fall, then, if needed, another spray at 10-12 mm fruit size and/or at 18 mm fruit size.

Before starting the thinning sprays, growers were instructed to use the apple carbohydrate model on the Cornell Network Environment and Weather Applications website to assist management decisions on whether or not to spray, how to adjust the application rate, and what days to avoid application.

The FGR model requires more effort from growers: to tag some spurs in the orchard, and measure the diameter of the little fruitlets in each spur twice: once exactly three days after application and again eight days after application. With those two measurements this model estimates how many of those fruitlets were still growing and how many were not growing. Those fruitlets not growing were categorized as ones that would fall off in approximately one week. Those still growing fast were categorized as ones that would persist and continue to grow. With this process the growers can have confidence they can get close to their target fruit number.

At each location the cooperating grower counted the number of flower buds on 5 representative trees at pink and calculated the target number of fruits per tree needed to achieve a desired high yield. The cooperators then targeted 15 representative spurs per tree on the 5 test trees. After the petal fall spray, the fruit diameter of each fruit in the 15 tagged clusters on each of the 5 trees (375 fruits) were measured 3 days after spraying and again 7 or 8 days after spraying to clearly differentiate abscising versus retained fruit.

The diameter data were sent electronically to the Cornell University Horticulture Department for analysis by post-doctoral research associate Poliana Francescatto using the FGR model. Within 24 hours the results were sent to growers with the

recommendation for the next spray. The cooperators then had to, or not, depending on the number of fruit on the trees, spray the test blocks sequentially with one of two spray protocols (bloom + PT +12mm +18mm sprays or PF +12mm+18mm sprays).

After each spray, the cooperators had to measure fruit diameters as mentioned above at 3 and 7 days after spraying and data was again analyzed and a new recommendation sent back to the cooperators.

Michael Basedow with the Cornell Cooperative Extension ENY Commercial Horticulture Program assisted growers on how to set up the protocol on their farm, how to use the models, how to take the measurements, and how to interpret the results.

A parallel trial was conducted at the Cornell Agricultural Experimental Station in Geneva, NY, as a reference test model for comparison with orchard-hosted trials in NNY.

In 2018, we tested a smartphone app we recently developed to help growers take the data more efficiently and, moreover, more accurately achieve better profit and orchard productivity through precision chemical thinning.

2. <u>Precision Irrigation</u>

In 2018 we continued our irrigation management trial that started in 2015 on three apple farms: one each in Clinton County (NNY), Ulster County (eastern NY), and Orleans County (Lake Ontario region), and one at the experimental station in Geneva by using the Cornell Apple Irrigation Model.

The orchards are composed as follows:

- Clinton: NY1/B9 orchard, planted in 2010 at 1,037 trees/acre;
- Ulster County: Hudson, Gala/M9 orchard, planted in 2011, 1,117 trees/acre;
- Orleans County: Plumac/B9 orchard, planted in 2015, 1,980 trees/acre, used for 2015-16 trial; Gala/M9 orchard planted in 2010, 1,210trees/acre, 2017 trial;
- Geneva, NY: Empire/B9 orchard, planted in 2011, 1,156 trees/acre.

At each site, we managed soil water level according to the irrigation model to minimize water stress while other trees were left unirrigated. We assessed tree growth and tree stress, and crop yield, fruit size, and fruit quality (flesh firmness and sugars) with irrigation and no irrigation.

3. <u>Carbaryl-free Thinning Strategies</u>

In 2018, we evaluated several carbaryl-free thinning strategies. The trial was done at Forrence Orchards and included the evaluation of the timing of thinning, single vs. multiple sprays of BA, NAA, NAD (naphthalene acetamide), and combinations of these products as well as the use of some of the caustic thinners at bloom, petal fall and 12 mm fruit size on thinning efficacy of Honeycrisp apple. In order to find the best program that provides growers the best crop value, several evaluations were done from bloom to harvest including fruit set, yield, fruit size, color and fruit quality.

Results:

1. Precision Thinning

The 2018 season brought an intense apple bloom. Sunny and warm weather was experienced during bloom. Bee activity was intense and fruit set was visually considered very heavy. Temperatures were much higher around the 8-10 mm sprays than when applications were done at 14-16 mm. The carbohydrate balance at Geneva showed there was no carbohydrate surplus from green tip to about 14 mm fruit size. There was a considerable carbon deficit around 8-10 mm fruit size (+/- 3 days) and an increased thinning response was expected. Whereas, when apples were at 14-16 mm the model indicated a constant increase in carbohydrate production by the tree and the opposite was expected to happen (Fig. 1).

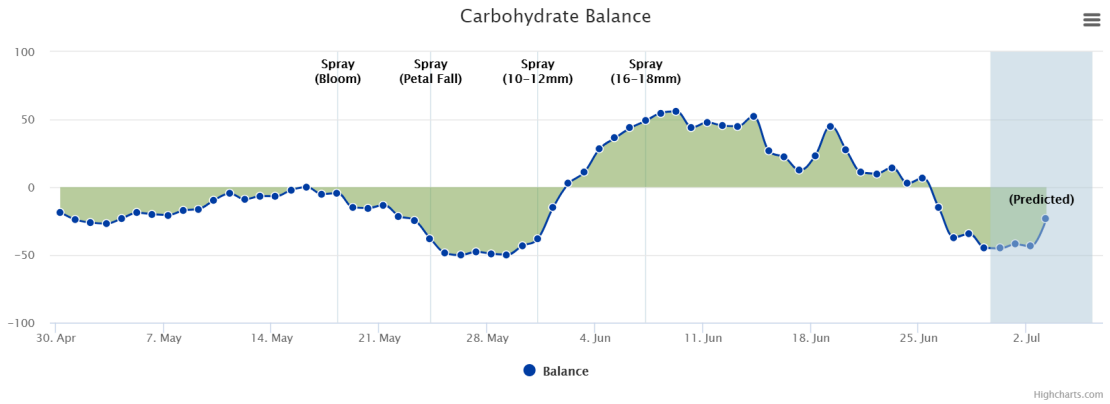

Figure 1. Predicted daily carbohydrate balance during spray applications in Geneva, NY, according to weather data and the MaluSim model, 2018.

The carbohydrate balance at Plattsburgh or Chazy in Northern New York showed there was no carbohydrate surplus from green tip to about 7 mm fruit size. Thereafter, there was a considerable carbon all the way through the thinning period (Figs. 2+3+4).

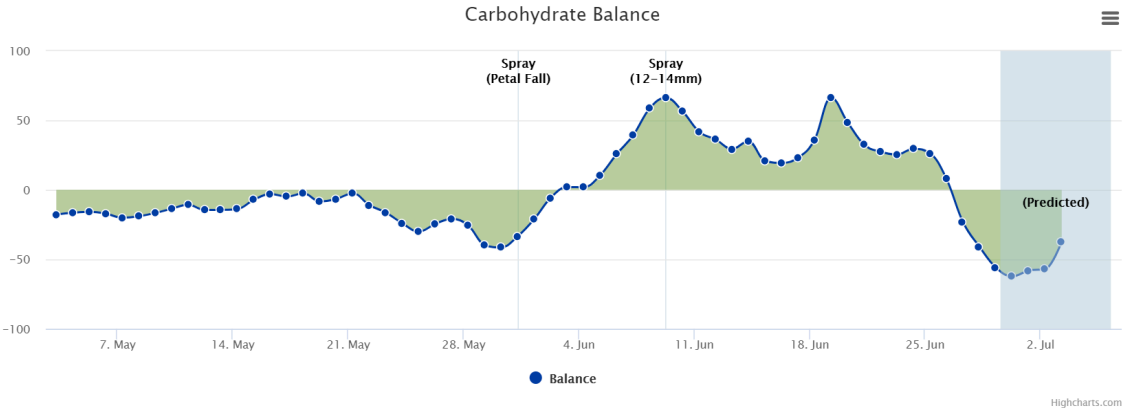

Figure 2. Predicted daily carbohydrate balance during spray applications in Plattsburgh, NY, according to weather data and the MaluSim model, 2018, NNYADP.

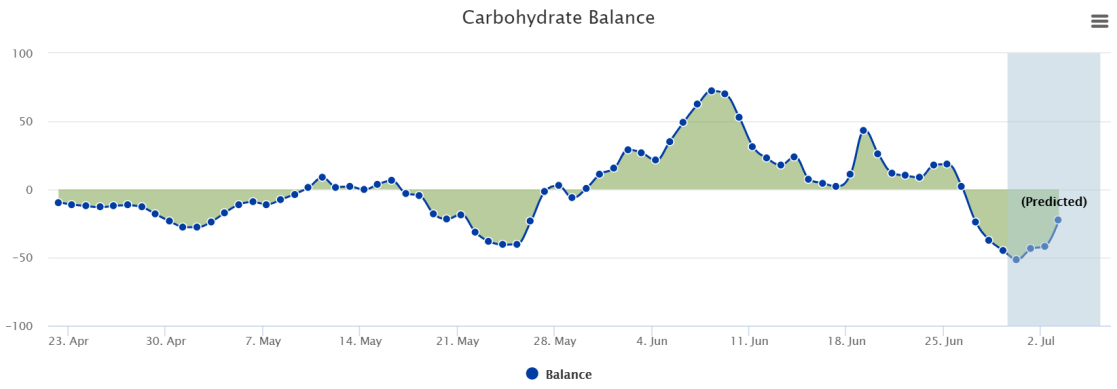

Figure 3. Predicted daily carbohydrate balance during spray applications in Chazy, NY (Honeycrisp), according to weather data and the MaluSim model, 2018, NNYADP.

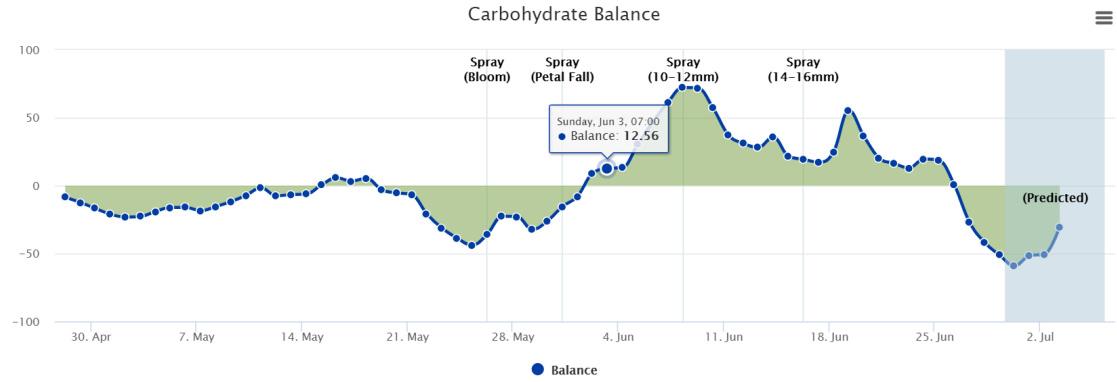

Figure 4. Predicted daily carbohydrate balance during spray applications in Chazy (Gala), NY, according to weather data and the MaluSim model, 2018, NNYADP.

The precision thinning protocol when implemented at Geneva with Gala resulted in significant thinning, but after 4 sprays the trees still had too many fruits (400 fruits) (Fig. 5). This required significant hand thinning to reach the target of 130 fruits.

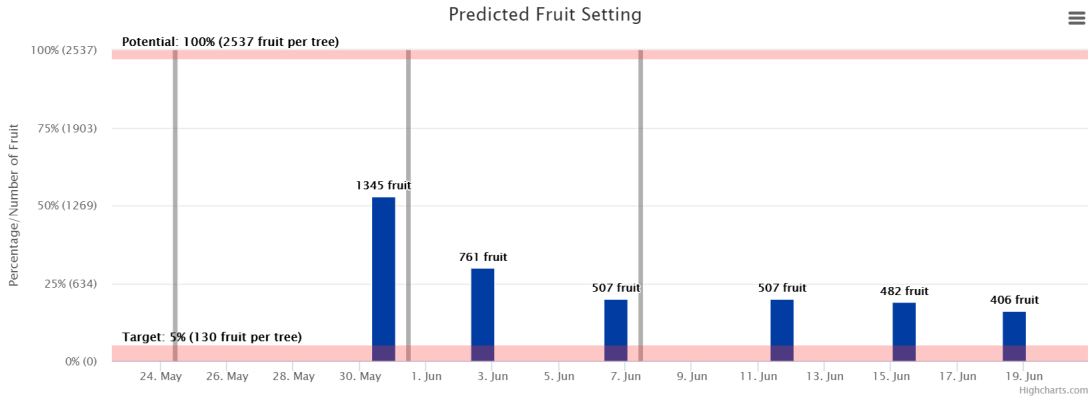

Figure 5. Number of fruit/tree (blue bars) predicted by Fruit Growth Rate Model and target fruit number (red horizontal bar) of precision-thinned Gala apple trees after 4 thinning sprays (bloom, petal fall, 10-12 mm fruit size and 16-18mm fruit size) at the Cornell Experimental Station, Geneva, NY, 2018.

However, the precision thinning protocol when applied at Everett Orchards (NNY) with Honeycrisp resulted in a perfect thinning job with 180 fruits compared to the target of 130 fruits (Fig. 6). This required a very small hand thinning adjustment to remove only 20 fruits.

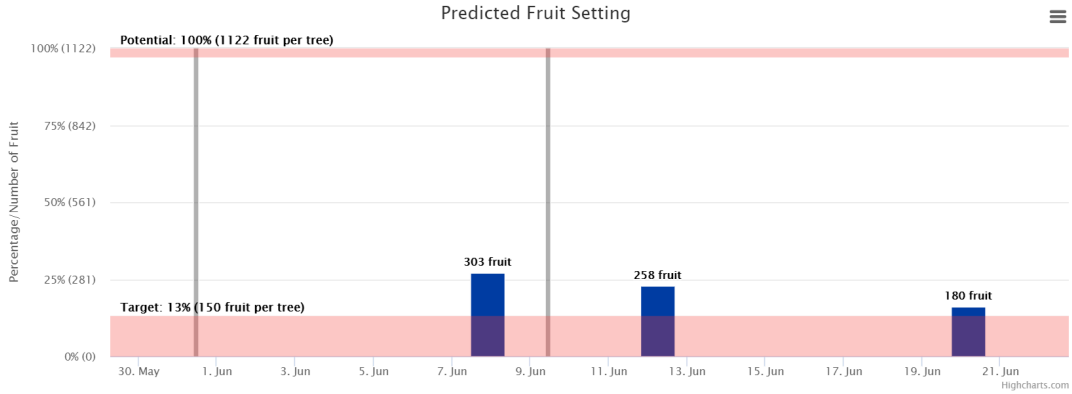

Figure 6. Number of fruit/tree (blue bars) predicted by Fruit Growth Rate Model and target fruit number (red horizontal bar) of precision-thinned Honeycrisp apple trees after 2 thinning sprays (petal fall and 13 mm fruit size) at Everett Orchards, Plattsburgh, NY, 2018, NNYADP. Target was achieved.

Use of the precision thinning protocol with Gala at Everett Orchards resulted in greater thinning than desired indicating the last spray should have been skipped (Fig. 7).

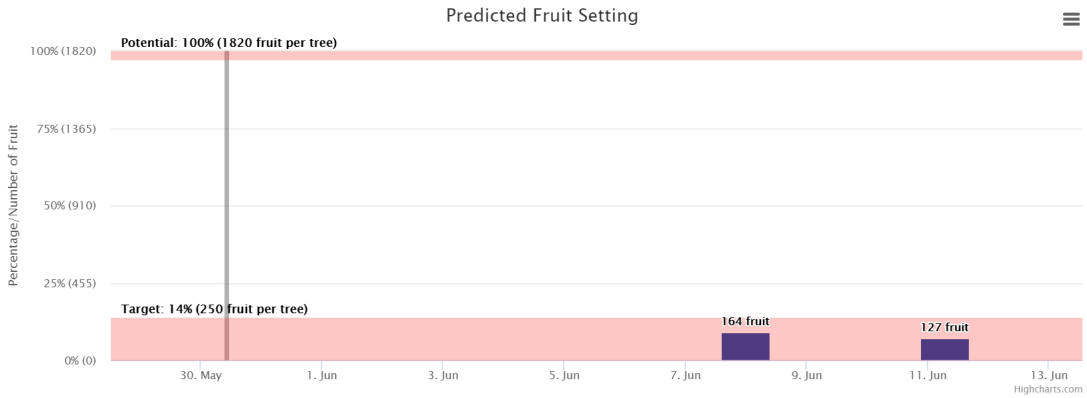

Figure 7. Number of fruit/tree (blue bars) predicted by Fruit Growth Rate Model and target fruit number (red horizontal bar) of precision-thinned Gala apple trees after 2 thinning sprays (petal fall and 13 mm fruit size) at Everett Orchards, Plattsburgh, NY, 2018, NNYADP. Trees were overthinned.

The precision thinning protocol when implemented at Chazy Orchards (NNY) with Honeycrisp with only 2 sprays (bloom and petal fall) resulted in too little thinning and the trees had too many fruits (460 fruits). This required significant hand thinning to reach the target of 130 fruits. This indicates that additional thinning sprays were required (Fig. 8).

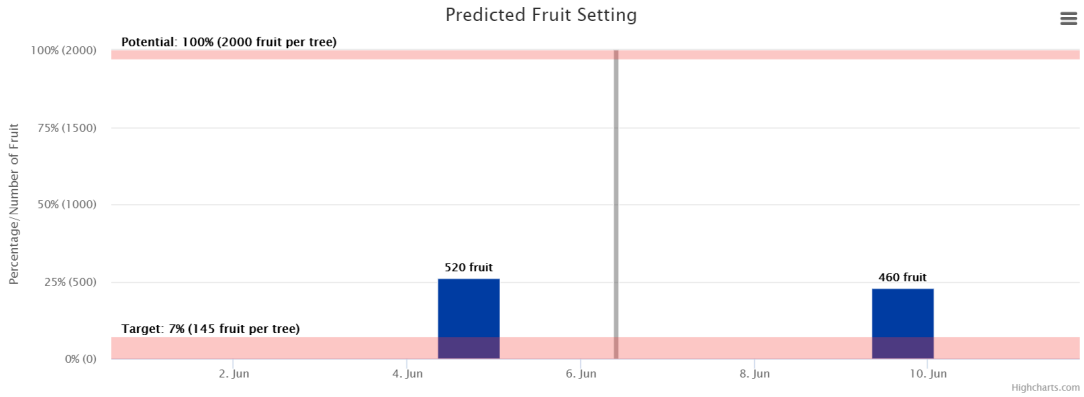

Figure 8. Number of fruit/tree (blue bars) predicted by Fruit Growth Rate Model and target fruit number (red horizontal bar) of precision-thinned Honeycrisp apple trees after 2 thinning sprays bloom and petal fall) at Chazy Orchards, Chazy, NY, 2018, NNYADP.

The precision thinning protocol when implemented at Chazy Orchards with Gala with the full 4 sprays program (bloom, petal fall, 10mm and 16mm) resulted perfect thinning with a final fruit number of 82 compared to a target of 65 fruits (Fig. 9). This required a very small hand thinning adjustment to remove only 18 fruits.

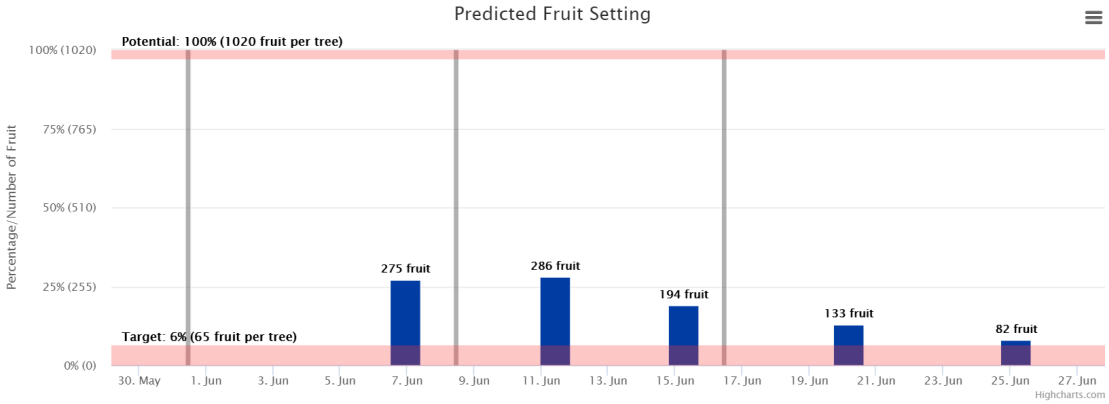

Figure 9. Number of fruit/tree (blue bars) predicted by Fruit Growth Rate Model and target fruit number (red horizontal bar) of precision-thinned Gala apple trees after 4 thinning sprays bloom, petal fall, 10-12mm and 14-16mm) at Chazy Orchards, Chazy, NY, 2018, NNYADP.

2. Irrigation Trials

Water stress in a high-density orchard planted on dwarfing rootstocks can significantly reduce fruit yield, size, and quality in a dry year. In terms of crop value, the lack of irrigation has shown losses in fruit size of 20 grams, in yield of more than 500 bushels per acre, and in economic terms of several thousand dollars across an approximate acreage of a hectare (~2.471 acres in U.S. Customary measure) depending on orchard density. Losses due to tree water stress can be even greater for full production orchards and late season varieties, e.g., Fuji, with a longer growing season. Irrigation is also critical for improving and maximizing tree growth of newly planted or young apple trees.

With more precise water management, assisted by the Cornell University evapotranspiration model, apple growers are better able to monitor crop water status and reduce tree stress to consistently achieve optimum production. In 2018, rainfall in the Champlain valley was slightly below the long-term average. This reduced water availability was reflected in the irrigation model, which recommended irrigation throughout much of the summer, though the non-irrigated trees never reached a severe water deficit. Irrigated trees in participating orchards in the Champlain valley had more apples per tree and higher fruit yields at harvest time compared to the non-irrigated control trees. Complete data is currently in analysis and will be available at a future date. This information will be shared with participating growers and at fruit extension meetings.

3. Carbaryl-free Thinning Strategies

This experiment was conducted only at Forrence Orchards in Peru, NY. Temperatures during the thinning period were moderate during bloom, relatively high at petal fall and cool at the 10mm stage (Fig. 10.)

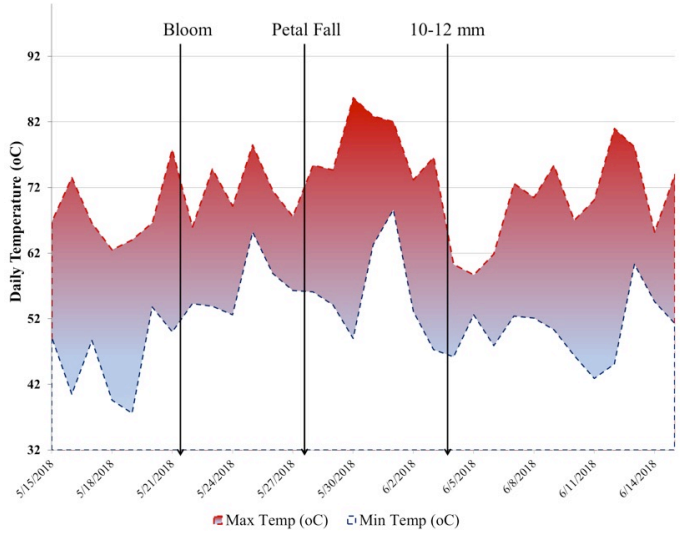

Figure 10. Weather conditions (maximum and minimum temperatures) during spray applications at Forrence Orchards, Peru, NY, according to weather data and the MaluSim model, 2018.

All thinning treatments except Ammonium Thiosulfate (ATS) at bloom caused fruit thinning compared to the unthinned control (Table 1 and Fig. 11).

The most effective treatments were the 3-spray program with NAA+carbaryl (standard treatment) and the 2-spray program of NAA at bloom and BA+NAA at the 12 mm stage.

All of the thinning treatments except the bloom ATS treatment had similar crop loads and fruit number per tree and yield but fruit size was largest for the treatment with carbaryl.

Crop value was also highest for the treatment with carbaryl but the treatment with NAD at bloom and petal fall followed by BA+NAA at 12mm had slightly lower but not significantly different crop value.

The thinning treatments did not affect fruit color, fruit shape, fruit soluble solids or seed number but fruit firmness was lower with all thinning treatments compared to the unthinned control (Table 2). This was probably due to the larger fruit size of the thinning treatments.

Table 1: Effects of different thinners alone or in combination applied at different timings on fruit yield of Honeycrisp apples at Forrence Orchards, Peru, NY, 2018, NNYADP.

Bloom	*PF*	*10-12mm*	*Fruit set (no.f ruit/ cluster)*	Crop load (no/cm2 TCA)	Fruit number per tree	Yield (kg/tree)	Yield (bu/acre)	Fruit Size (g)	Crop value ($/acre)
UTC	UTC	UTC	0.77 a	11.6 a	369 a	37 a	1060 a	101 c	$ 2,906 c
10 ppm NAA	7.5 ppm NAA + 500 ppm Carbaryl	5 ppm NAA + 500 ppm Carbaryl	0.28 c	4.8 c	169 b	29 b	826 b	173 a	$ 11,124 a
10 ppm NAA	50 ppm 6-BA + 7.5 ppm NAA	50 ppm 6-BA + 7.5 ppm NAA	0.47 b	5.5 c	182 b	27 b	772 b	149 b	$ 7,902 b
10 ppm NAA	-	50 ppm 6-BA + 7.5 ppm NAA	0.29 c	5.1 c	165 b	24 b	683 b	151 b	$ 6,685 b
10 ppm NAA	50 ppm 6-BA + 7.5 ppm NAA	-	0.48 b	5.7 c	191 b	27 b	770 b	141 b	$ 6,960 b
50 ppm NAD + 0.125% Regulaid	50 ppm NAD + 0.125% Regulaid	50 ppm 6-BA + 50 ppm NAD	0.44 b	5.5 c	189 b	28 b	807 b	153 ab	$ 8,582 ab
2.5% ATS + 2% ATS	-	-	0.76 a	10.1 b	345 a	39 a	1129 a	116 c	$ 5,954 b
Signif icance Duncan P≤0.05			**	**	**	**	**	**	**

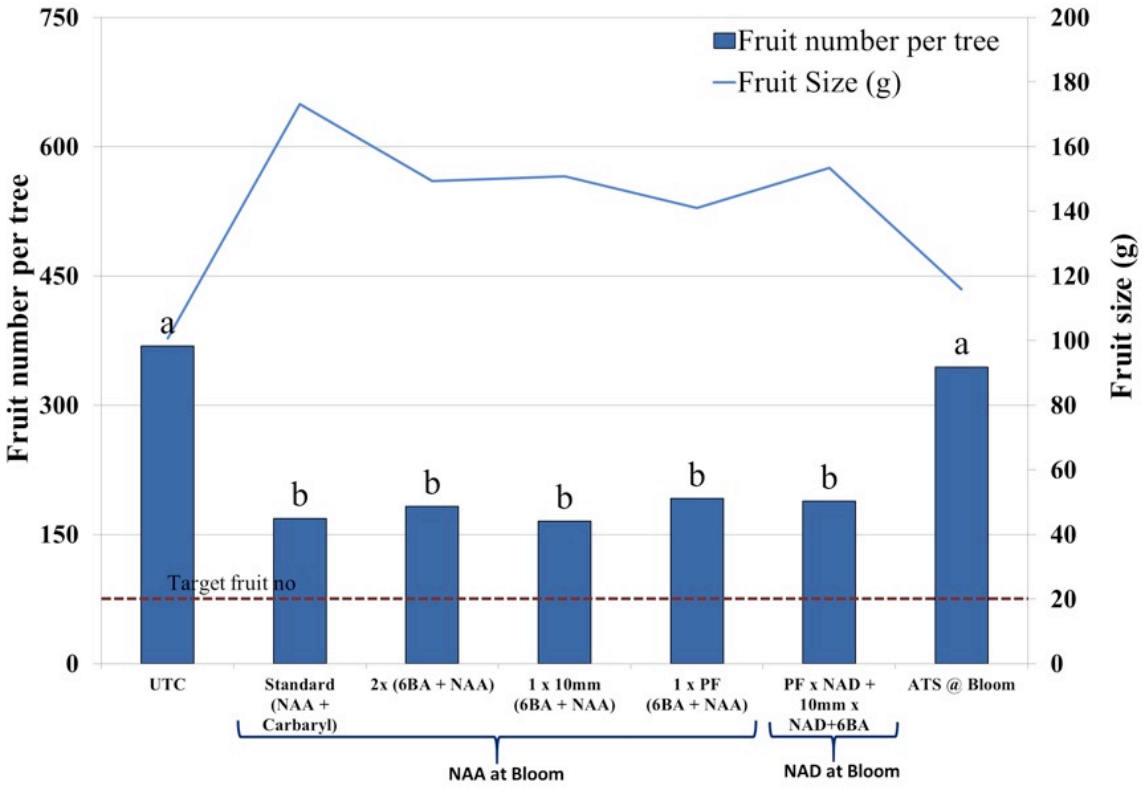

Figure 11: Effects of different thinners alone or in combination applied at different timings on fruit number per tree and fruit size of Honeycrisp apples at Forrence Orchards, Peru, NY, 2018, NNYADP.

Table 2: Effects of different thinners alone or in combination applied at different timings on fruit quality of Honeycrisp apples at Forrence Orchards, Peru, NY, 2018, NNYADP.

Bloom	*PF*	*10-12mm*	Fruit Color (%)	Fruit L/D ratio	Fruit Firmness (lb)	Fruit Soluble Solids (%)	Seed number
UTC	UTC	UTC	20	0.86	15.4	10.9	7.4
10 ppm NAA	7.5 ppm NAA + 500 ppm Carbaryl	5 ppm NAA + 500 ppm Carbaryl	32	0.87	14.2	10.9	7.3
10 ppm NAA	50 ppm 6-BA + 7.5 ppm NAA	50 ppm 6-BA + 7.5 ppm NAA	19	0.85	13.8	10.6	7.1
10 ppm NAA	-	50 ppm 6-BA + 7.5 ppm NAA	32	0.86	14.1	11.6	6.9
10 ppm NAA	50 ppm 6-BA + 7.5 ppm NAA	-	27	0.84	13.9	11.3	7.1
50 ppm NAD + 0.125% Regulaid	50 ppm NAD + 0.125% Regulaid	50 ppm 6-BA + 50 ppm NAD	24	0.85	13.7	11.0	7.7
2.5% ATS + 2% ATS	-	-	25	0.88	15.1	11.6	7.1
Signif icance Duncan P≤0.05			*NS*	*NS*	**	*NS*	*NS*

4. Adjunct: Smartphone App-Assisted Management

In 2018, we worked with four NNY apple growers in the Champlain valley to test a beta-version of a new smartphone app we recently developed (*NYFVI funding*). We tested the app during the thinning season and sought input on improvements. The app worked well and allowed participating growers to take the data more efficiently and view the results more easily in the field rather than going to their office to run the models. The app has been updated for full release in May 2019.

Conclusions/Outcomes/Impacts:

The precision thinning protocol was very successful in achieving near perfect thinning in the Champlain valley when 3 or 4 sprays were applied. However, if only the first 2 sprays were applied, then too little thinning was achieved, resulting in a large hand thinning job. The impact of applying this precision orchard management technology is that apple growers in the Champlain valley will be able to more consistently achieve the optimum crop load, resulting in greater crop value ($2,000-5,000 more per acre) with less hand thinning resulting in time saving and less labor cost.

The quest to develop carbaryl-free thinning programs was a partial success. We were successful in achieving good thinning without using carbaryl, but crop value was not as high as when we used carbaryl. Also, we will not be able to evaluate the impact on return bloom on the test trees until May 2019.

Outreach:

The results of this project were reported at the Eastern NY fruit and vegetable school in February 2019, and in an article on precision pruning in the April 2019 Fruit Quarterly published by the New York State Horticultural Society .

Next Steps:

We have proposed to further evaluate the precision crop load management strategy with precision pruning and precision thinning trials in the Champlain valley in 2019, and to continue carbaryl-free thinning evaluation.

Acknowledgments:

We acknowledge the help of Peter Herzelle and Jose Ochoa in conducting the field trials at Geneva and the Champlain valley.

Reports and/or articles in which results of this project have been published:

Journal articles

Fazio, G., J. Lordan, P. Francescatto, L. Cheng, A. Wallis, M.A. Grusak, and T.L. Robinson. 2018. 'Honeycrisp' apple fruit nutrient concentration affected by apple rootstocks. *Acta Hortic.* 1228:223-228.

Lordan, J., G. Fazio, P. Francescatto and T.L. Robinson. 2018. Effects of apple (Malus × domestica) rootstocks on vigor and yield response on 'Honeycrisp'. *Acta Hortic.* 1228:149-152.

Lordan, J., P. Francescatto,, L.I. Dominguez and T.L. Robinson. 2018. Long-term effects of training systems and rootstocks on 'McIntosh' and 'Honeycrisp' performance, a 15-year study in a northern cold climate: Part 1 Agronomic Analysis. *HortScience* 53:968-977.

Lordan, J., A. Wallis, P. Francescatto, and T.L. Robinson. 2018. Long-term effects of training systems and rootstocks on 'McIntosh' and 'Honeycrisp' performance, a 20-year study in a northern cold climate- Part 2: Economic analysis. *HortScience* 53:978-992.

Non-Refereed Technical

Francescatto, P., T. Robinson, J. Jordan and P. Herzeelle. 2018. The use of plant growth regulators for crop load management in apples. I. Fruit thinning and flower formation. *Fruit Quarterly* 26:(1):5-10.

Robinson, T.L., P. Francescatto and J. Lordan. 2019. Precision pruning of Gala apples. *Fruit Quarterly* 27:(1):5-8.

Book Chapters

Agnello, A.M., A. Landers, D.A. Rosenberger, T.L. Robinson, J.E. Carroll, L. Cheng, P.D. Curtis, D.I. Breth, and S. Hoying. 2018. Pest management guidelines for commercial tree-fruit production 2018, p. 252. Cornell University, Ithaca, NY, USA.

Conference Proceedings

Francescatto, P., Lordan, J. and Robinson, T.L. 2018. Precision crop load management in apples. International Horticulture. Congress Istanbul, Turkey. Abstracts.

Lordan, J., T.L. Robinson, P. Francescatto, P. Herzeelle, and G. Fazio. 2018. Effects of apple rootstocks on nutrient concentration in 'Honeycrisp' scions. International Horticulture. Congress Istanbul, Turkey. Abstracts.

Extension articles
Robinson T.L. and Francescatto P. 2018 Recommendations for fruit drop control in WNY in 2018. *Lake Ontario Fruit Newsletter* 2018(13):1-2.

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