Apple Crop Load Management: Enhancing Thinning Predictability and Tree Response Through Advancements in Modelling, New Precision Thinning Products and Strategies, and Technology




2024 Annual Report

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Project Sponsors

Enhancing Thinning Predictability and Tree Response Through Advancements in Modelling, New Precision Thinning Products and Strategies, and Technology

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1.0 Executive Summary

Managing the fruit load (crop load) of apples is one of the most important management decisions in the apple orchard because it affects fruit size, market returns and return flowering and cropping the following year. Yet it remains a significant challenge to producers, in part, because of the unpredictability of fruit set and fruitlet abscission.

This aims of this four-year project are to: 1) investigate new innovative chemical thinning compounds; 2) develop and implement decision support systems for producers to improve crop load management, and; 3) investigate advancements in artificial intelligence-based computer vision technology to measure key indicators of crop load to improve crop load management outcomes.

In the first objective, crop load was evaluated in response to various rates of metamitron (MET) and combinations with other chemical fruitlet thinners including 6-BA and carbaryl. In addition, later applications of metamitron and ACC were evaluated when fruitlets were 18- 20 mm diameter. MET and ACC are currently unregistered for commercial use in Canada. Trees that were hand-thinned and trees treated with MET at 18 mm, two applications of MET, and 400 mg/L 1-ACC had the greatest reduction in crop load 44%, 49 and 32%, respectively. Single applications of MET as high as 2.9 L/ha applied were less effective. There was no additive effect of 6-BA when mixed with MET on crop load.

In the second objective, the effectiveness of the BreviSmart thinning model, RIMPro thinning model, the Fruit Growth model (FGM) and Fruit Size Distribution (FSD) model were evaluated as predictors of final fruit set and improve thinning outcomes using chemical thinners. Overall, the RIMPro Apple Fruit Thinning Model is not well supported with documentation on how to use the model and interpret the output. It was not effective as a decision support tool to guide thinning in 2024. The BreviSmart model, although more straightforward to use, did not accurately predict thinning efficacy of MET based on the final number of fruit per tree or crop load at harvest.

Overall, the Malusim Fruit Growth Model was an effective tool for predicting fruit set and final crop load of Gala and Honeycrisp trees, but less so for Ambrosia. Overall, the FGM model predicted vs actual final crop loads within 58%, 0% (prediction was the same as actual) and 3% for Ambrosia, Gala and Honeycrisp, respectively. Its accuracy may be increased by measuring more trees or more fruit on a single tree. Also, the speed at which the voluminous amounts of fruit diameter measurements required to use the model can likely be increased by using Bluetooth calipers link to a tablet, rather than manually transcribing measurement and keying them into a spreadsheet.

We found that the Fruit Size Distribution model was generally no faster than the Fruit Growth model. Overall, the FSD model over estimated actual final crop loads at harvest by 3%, 265%, and 205%, respectively for the Ambrosia, Gala, and Honeycrisp trees in this experiment.

In the third objective, CropTracker - Crop Load Vision Module (CLVM) was the only commercial product we were able to evaluate in the first year of this project. The CLVM module can count and measure the diameters of fruit but does not count the number of flowers. The module has a minimum fruitlet size detection limit of approximately 15 mm, which is a major limitation when meaningful crop load intelligence is required during the chemical thinning window when fruit are 8-15 mm in diameter. Overall, the CLVM App was slow to use when scanning a single apple tree and not as advanced as effective as other commercial products in this technology space. Exploring and adopting nascent computer vision technologies, of which there are many, will be a goal in future years of this project.

2.0 Introduction

Apples are a predominate tree fruit crop grown world-wide with an estimated annual production of 124 million Mt produced over 4 million ha (FOA, 2019). To increase economic sustainability and compete globally, Canadian apple growers are improving returns by adopting new cultivars, rootstocks and orchard management practices that improve fruit quality. There is also an urgent need to reduce their dependency on labour because it accounts for over 60% of production costs (Ontario Apple Growers, 2018). Rapidly increasing wage rates and decreasing availability of skilled labourers to manage and harvest tree fruit is compounding this issue. Fortunately, apple producers have adopted next generation high-density orchard systems with very narrow, uniform canopies. This permits trees to be managed in ways that were never before possible. Growers can now determine the specific number of fruits per tree based on anticipated yield per hectare to target optimal fruit size at harvest.

Typically, fruit trees produce an overabundance of flowers and excessive number of fruit to be considered marketable size (Cline et al., 2018; Costa et al., 2018). Commercially, the extra fruits are removed using a number of crop-adjustment strategies (referred to as thinning), starting at bloom and ending with hand-thinning (Costa et al., 2018). Extra fruits must be removed by applying special foliar sprays, known as chemical thinners, to enhance the natural drop of fruits in June, and is one of the most impactful practices that determines profitability and influences fruit quality. The thinning process is currently a very inexact science and highly labour-intensive, accounting for up to 50 hrs/acre (110 hrs/ha) (35% of total labour costs), which is equal to $915/acre ($2020/ha) based on 2018 costs of production and labour rates (Ontario Apple Growers, 2018).

Many factors influence thinning outcomes, including cultivar, tree age and health, and the amount of bloom on the tree (Williams and Edgerton, 1981). Moreover, despite decades of experience, producers can not effectively predict how many fruit will be removed when special blossom and fruitlet chemical thinners are used. Over- or under-thinning can cause considerable economic loss to growers, making it crucial to be successful in early thinning. Repeat measurement of fruitlet diameters has been used to determine growth rates as an early predictor of the response to thinning (McArtney and Obermiller, 2010). Greene et al. (2013) proposed that fruit that are destined to drop will slow and stop growth well in advance of the actual time of drop. Others suggest that variability in chemical thinner efficacy is related both to stage of fruit development and carbohydrate availability to support fruit growth (Robinson et al., 2014).

Fruit Growth Model (Diametric Method)

The Fruit Growth Model (FGM) was developed by researchers in Massachusetts and New York (Greene et al., 2013; Schwallier and Brown, 2014) and is based on the concept that when the growth of fruitlets slows to less than 50% of the fastest growing fruitlet, they will abscise, while others will set and persist on the tree. To determine which and how many fruitlets are actively growing and which will abscise, fruitlet diameters are measured at approximately 3 and 8 days after thinning applications on pre-marked fruitlets using digital calipers. This model is available as an Excel

Spreadsheet at the following websites:

a. MSU Extension website: https://www.canr.msu.edu/uploads/files/PredictingFruitset1-21-14.xls
b. Malusim.org website https://malusim.org/ (a slightly modified version that is web-based and has built-in error checking)

This model tracks diameter measurements and calculated fruitlet growth and predicts set. The protocol suggested that between 20 to 100 representative flower clusters should be marked and diameter measured every three to four days. All fruit that slow to a growth rate of 50% or less of the growth rate of the fastest growing fruit are predicted to ultimately stop growth and abscise.

Abscising fruitlets will normally start slowing their growth rate approximately four days after a thinner application. Abscising slowly growing fruitlets at day seven stops growing altogether. The abscising fruitlets appear normal until a few days later when they start turning an off colour (dark green or yellow) with yellowing pedicels – this is the first visible evidence that fruitlets are going to abscise. Dropping fruitlets will have sepals that fold outward, and setting fruitlets will have sepals that fold inward over the calyx.

The FGM predicts fruit set based on the diameter growth disparity of fruitlets. The difference between these two measurements will be used by the FGM predict percentage set and thus determine if the target crop load is close. If not, additional chemical thinners can be applied if the fruit are within the thinning window.

Fruitlet size distribution Model (Fruitlet weight method)

Fruit set prediction models aim to produce timely estimates of fruitlet abscission after thinner applications to guide precision crop load management. The time to generate a prediction after an application is important to facilitate grower decisions to re-apply thinners while they are still efficacious, avoiding expensive hand thinning operations. The fruitlet growth model is a powerful tool that can accurately predict the percentage of fruitlets that will set in an orchard. Grower adoption has been limited because of the measurement-intensive procedure.

A new approach, termed the ‘Fruitlet Size Distribution (FSD) Model’, developed by

Hillman and Einhorn (2024), was developed to produce predictions of apple fruit set comparable to the FGM model but achievable with less time investment. The principle underlying both models is the same: the relative growth rate or size of a fruitlet is compared to the most rapidly growing or largest fruitlet within the sample date to determine if it will abscise. Most predictions can be made within eight days from thinner applications, though this depends on climatic, fruit development and physiological factors.

Digital Technologies using computer vision and AI Algorithms

There are several companies offer digital solutions for managing orchards. Products vary widely by camera systems, how images are captured, services offered and cost. This is a rapidly changing landscape with new companies entering the market (as some exiting) offering new and different products. Advanced camera systems and artificial intelligence learning models are making detection, counting and sizing fruit easy. It's likely that companies that translate data into actionable crop load solutions that are scalable and cost-effective will have the largest impact in the industry. Tree fruit physiologists are needed to understand fruit abscission and advance models that increase precision of estimating fruit drop in response to chemical thinning and weather conditions in the orchard.

Companies offering crop load management technologies for apples as of August 1 2025.														
Company	**App**	**Platform**	**Bud counting**	**Flower cluster Counting**	**Trunk diameter**	**Tree height, volume**	**Orchard mapping**	**Fruitlet counting**	**Fruitlet diameter**	**Crop load Fruit growth model**	**Yield forecasting**	**Bin scanning for size and colour**	**Website**	**Notes**
Vivid Machiesn, 360 Dufferin St. Unit 104, Toronto, ON M6K 1Z8 Canada		Vision's XV3 camera mounted on ATV or tractor, Camera is leased at $C 5000 per season. There are additional fees for scanning and data management		x			x	x	x	x	x	x	https://www.vivid-machines.co	Purported minimum fruit detect limit of ~8 mm
Addium Inc.1300 Henley Ct, Pullman, WA 99163, USA	POMViz (No longer supported)	iPhone (requires lidar)		x					x	x		x	https://app.pometa.io	Can detect fruitlet as small as 6 mm. App no longer available
CropTracker. PO Box 1084 Stn Main Kingston Ontario K7L 4Y5 Canada	Crop Load Vision Module (free for Ontario Apple Growers members)	iPhone						x	x		x	x	https://www.croptracker.com/	not able to detect fruitlets as small as 8 mm.
Fruit Scout 4001 Summit Ave, Suite 5-378 Yakima WA 98908 USA	FruitScout	iPhone (requires lidar)	x	x	x			x	x	x	x	x	https://fruitscout.ai/	
Orchard Robotics, 407 College Avenue, Suite 447, Ithaca, NY, USA	FruitScope Vision and FruitScope Vault	Camera mounted on tractor UTV or ATV. Grower can purchase camera system.	x	x	x		x	x	x	?	x		https://www.orchard.ai/	Can scan orchard at speeds up to 19 kph. It is unclear what the minimum fruit diameter detection limit is
Aurea Nijverheidsweg 16A, 3534 AM Utrecht, Netherlands	TreeScout	Camera mounted on tractor		x			x	x					https://aureaimaging.com/	
Green Atlas, Farmcloud, Syracuse NY Ph: +1 206 264 5500	Cartographer	Two carmera system to scan two rows at a time		x		x		x		?	x		https://greenatlas.com/; https://myfarmcloud.com/;	Scans up to 6 ha/hr
Outfield Technologies Ltd., 20-22 Wenlock Road, London, UK N1 7GU		Drone		x			x	x			x		https://outfield.xyz/	Blossom mapping, fruit counting > 35 mm

2.1 Project Objectives

This project will utilize a three-fold approach to focus on the knowledge gap: i) investigate new innovative chemical thinning compounds; ii) develop and implement decision support systems for producers to improve crop load management, and iii) investigate advancements in artificial intelligence-based computer vision technology to measure key indicators of crop load to improve crop load management outcomes.

Objective 1: Investigate new innovative chemical thinning compounds

To address this objective, crop load was evaluated in response to various rates of metamitron (MET) and combinations with other chemical fruitlet thinners, including 6-BA and carbaryl. In addition, later applications of MET and 1-aminocyclopropane-1-carboxylic acid (ACC) were evaluated when fruitlets were 18-20 mm diameter.

Objective 2: Develop and implement decision support systems for producers to improve crop load management

To address this objective, the effectiveness of the BreviSmart thinning model, RIMPro thinning model, the FGM and FSD model were evaluated as predictors of final fruit set and improved thinning outcomes using chemical thinners.

Objective 3. Investigate advancements in artificial intelligence (AI)-based computer vision technology to measure key indicators of crop load and improve crop load management outcomes.

This objective aimed to:

a) Investigate grower adoption of AI-driven vision-automation technology to advance the understanding of how these tools can collect and process flower and fruit numbers, and potentially fruit size to improve the precision and prediction of crop load management; and
b) Evaluate select digital technologies that use computer vision technology to count flower clusters and fruit during early development and measure the diameter of fruit as predictors of fruit set; and to understand the variation in bloom and crop load in the orchard and factors that influence annual bearing.

3.0 Materials and Methods

3.1.0 Experiment 1: Crop Load Management Studies with Fruitlet Applications of Metamitron (Brevis®) and ACC (Accede®) (Objective 1)

In 2024, a 6-year-old research orchard of Crimson Gala/M.9 T337 rootstock located at the University of Guelph, Ontario Crops Research Centre - Simcoe (42° 51' 40" Lat., -80° 16' 8" Long.), planted in 2019 at a spacing of 1 m x 3.6 m (2278 trees/ha), was used for this study. Trees were approximately 3 m tall with a canopy width of 1.1 m. Trees were trained using a super spindle training system. Trees were trickle-irrigated daily with an equivalent of ~2.5 cm of water weekly (adjusted for natural rainfall) on a schedule of 6 irrigation run-times per day every 4 h (20 min per event). Irrigation was supplied via 2 L h^{-1} pressure-compensating emitters spaced 45 cm apart. The irrigation system was activated in May 2024. Standard conventional cultural and pest management practices for Ontario were followed.

3.1.1 Treatments and application criteria

Treatments were applied using a commercial air blast sprayer (Slimline Manufacturing, Model MP3T19P with 19-60SS tower, Penticton, Canada) at 758 kPa (109 PSI), ~683 L ha^{-1}, which equated to 112% of tree row volume (TRV) pesticide dilute (Sutton and Unrath, 1988). The sprayer was equipped with 9 nozzles (Teejet TXR Conjet hollow cone, Springfield, PA) per boom (side) and a large axial fan to move the spray into the canopy. To minimize treatment interference caused by spray drift, experimental units were separated by at least one guard tree. Applications were made at a ground speed of 3 km/hr (2.5 km/h).

A randomized complete block with six replications and 11 treatments was used as the experimental design. Treatments were applied to two-tree plots and consisted of: i) untreated control; ii) hand-thinned control; iii) 1500 mg L^{-1} carbaryl tank mixed with 75 mg L^{-1} 6-benzyladenine (6-BA; MaxCel; Valent BioSciences, Libertyville, IL); iv) one application of a 'standard' rate of 441 mg L^{-1} (1.8 L ha^{-1}) MET (ADA 46701, Adama Canada) at a target king fruitlet size of 8-12 mm; v) one application of a 'high east' rate of 564 mg L^{-1} (2.3 L ha^{-1}) MET at 8-12 mm; vi) one application of a 'high west' rate of 711 mg L^{-1} (2.9 L ha^{-1}) MET at 8-12 mm; vii) one application of a 'standard' rate of 441 mg L^{-1} (1.8 L ha^{-1}) MET tanked mixed with 75 mg L^{-1} 6-BA (MaxCel) applied at a target king fruitlet size of 8-12 mm; viii) one application of a 'high east' rate of 441 mg L^{-1} (2.3 L ha^{-1}) MET tanked mixed with 75 mg L^{-1} 6-BA (MaxCel) applied at a target king fruitlet size of 8-12 mm; ix) one application of a 'high east' rate of 564 mg L^{-1} (2.3 L ha^{-1}) MET at a target king fruitlet size of 18 mm; x) application of a 'standard' rate of 441 mg L^{-1} (1.8 L ha^{-1}) MET applied at a target king fruitlet size of 8-12 mm followed by 441 mg L^{-1} (1.8 L ha^{-1}) MET at a target king fruitlet size of 14-15 mm (rates informed by the BreviSmart thinning model); and xi) 400 mg L^{-1} ACC (Accede™) applied at a target king fruitlet size of 18 mm. No surfactants were added to MET sprays when applied alone; however, 0.05% (v/v) Agral 90 (Syngenta Canada, Guelph, ON) was included with all the carbaryl, MET and ACC tank-mixed treatments (treatments iii, vii, iii, xi). The Gala trees were in full bloom on 6 May 2024. The 8-12 mm fruitlet diameter treatments were applied between 07:30 am and 1:30 pm on 20 May (14 days after full bloom; DAFB), the 14-15 mm treatment was applied on 30 May (24 DAFB) between 3:45 pm and 3:50 pm, and the 18 mm treatments were applied on 30 May (24 DAFB) between 3:15 pm and 4:15 pm with low wind conditions. The actual king and lateral fruitlet diameters on 21 May were 9.9/7.5 mm (n=75; n=300), and on 30 May were 16.4/10.4 mm (n=70; n=167), respectively.

The hand-thinned control trees were thinned on 21 June by removing all but one fruit per cluster and spacing fruit ~7 cm apart. Average number and weight of fruit removed by the hand-thinned trees (n=12) was 112 fruitlets. Municipal ground water with an average pH of 7.5 to 8.0 and hardness of 281 mg L^{-1} to 295 mg L^{-1} (Kristin Pressey, Personal Communications) was used as the source water for the spray mixture.

For treatment x) (which comprised two applications of MET), the timing of the first MET application was made shortly after petal fall, so a second application could take place at least eight days after the first application but before fruit exceeded 15mm fruitlet diameter. Based on the author's previous research, the greatest thinning response with MET has been achieved when applications are made between approximately 10-15 mm king fruitlet diameter. Since the protocol called for a second application of MET and a minimum of 8-10 days is required before a second application, an application at approximately 10 mm was necessary for the first MET application. The second MET application was made 10 days after the first. In Ontario, we consider Gala a "moderate to thin" cultivar, so the standard base rate of 1.8 L of Brevis/ha was selected. Consideration was then made to adjust the 'base rate' based on the output of the BreviSmart Model: when the output was green, a standard starting rate of 1.8 L/ha was applied, if the output was yellow, the rate was increased by 0.29 - 0.58 L/ha, and if the output was red, we waited to spray or reduce the rate by 0.5 - 1.2 L/ha but not below 1.2 L/ha. If daytime temperature exceeds 29°C on day of application, we reduced the rate as per 'red output' or waited until temperatures were less than 29°C. On 30-May, the BreviSmart output was 'green', signaling the need for a rate of 1.8 L/ha. Rate adjustments are summarized in the table below with more details in Appendix 2.

		Recommended Brevis rate adjustment based on BreviSmart output (L/ha)					
Cultivar thinning propensity	Eastern North America Recommended rate of application (L/ha)	Yellow		Green		Red	
Easy	1.2	1.49-1.78	+25-50%	1.2	(no change)	1	-17%
Medium	1.8	2.1-2.4	+16-32%	1.8	(no change)	1.1-1.3	-27-40%
Difficult	2.3	2.6-2.9	+12-24%	2.3	(no change)	1.1-1.8	-21-33%

Precautions:

[1] The first Brevis application should be made at or just following petal fall when 'king' fruitlets are 6-7 mm in diameter fruit.

[2] If daytime temperatures exceed 29°C on the day of application or 5 days after application, reduce the rate of application or consider waiting to spray until cooler temperatures are experienced. Primary concerns are the effect of high temperatures on leaf phytotoxicity and overthinning.

[3] If a second application in required, apply when king fruitlets are 12-15 mm diameter and no later than 10 days after the first application. Also, consider directing the spray to the top 50% of the canopy only.

3.2.0 Experiment 2: Validation of the RIMPro Malusim Carbohydrate Model to Improve Thinning Outcomes Using Chemical Thinners (Objective 2)

In 2024, an 8-year-old research orchard of Brookfield Gala/M.9 T337 rootstock located at the University of Guelph, Ontario Crops Research Centre - Simcoe (42° 51' 40" Lat., -80° 16' 8" Long.), planted in 2017 at a spacing of 0.9 m x 3.5 m (3175 trees/ha), was used for this study. Trees were approximately 3 m tall with a canopy width of 1 m. Trees were trained using a super spindle training system. Trees were trickle-irrigated daily with an equivalent of ~2.5 cm of water weekly (adjusted for natural rainfall) on a schedule of six irrigation run-times per day every 4 h (20 min per event). Irrigation was supplied via 2 L h^{-1} pressure-compensating emitters spaced 45 cm apart. The irrigation system was activated in May 2024. Standard conventional cultural and pest management practices for Ontario were followed.

3.2.1 RIMPro Weather Platform

RIMPro weather platform (www.rimpro.cloud; Amsterdam, The Netherlands) is a digital, subscription-based weather data platform that provides decision support systems (DSS) for the management of tree fruit and grape pests and diseases and also has a model for fruit thinning of apples. Environmental data can be collected from user-provided weather stations or from virtual weather data that is referenced via Meteoblue (Basel, Switzerland) based on longitude, latitude and elevation. Models incorporate both past and forecasted data. In January 2024, a virtual weather station for the Ontario Crops Research Station – Simcoe (42° 51' 40" Lat., -80° 16' 8" Long) was established. The annual subscription fee was € 300 ($C 450) for an account with one weather station which was a combination of €250 for access to the “RIMPro Cloud Service Grower account” and € 50 for the “Meteo Blue Weather Forecast” virtual weather station. Payment is made through PayPal, which added a €18 currency conversion fee to the total.

The primary purpose of testing RIMPro was to i) evaluate the fruit thinning model; and ii) compare daily actual versus virtual temperature, precipitation and solar radiation data. More details about the model can be found at this link. While this model is also available online at NEWA where it links to actual weather stations in several Midwestern and Northeastern states. There are no NEWA weather locations in Ontario, despite attempts by the author to add Ontario weather stations to the NEWA platform. RIMPro fails to indicate if their carbohydrate model is the same as the MaluSim model. RIMPro states that “within the period of susceptible fruit size, trees are easier to thin when there is a shortage of carbohydrates”. The DSS simulates photosynthesis and respiration and corrects the fruit-size based curve for thinning efficacy with the availability of carbohydrates in the days before and after application of the fruitlet chemical thinning agent. Weather data is forecasted for seven days and is simulated post-application to calculate carbon balance and heat sum. Photosynthesis and respiration are simulated in 30-min intervals based on radiation, temperature and humidity.

The MaluSim model on the NEWA website accesses temperature and sunlight data from the date of bud-break in the spring to calculate daily tree carbohydrate balance. The web version of the carbohydrate model also uses weather forecasts for prediction of carbohydrate balance seven days into the future. The website allows apple growers or consultants to run the model and receive predictions in real time of carbohydrate balance and suggested chemical thinner timing and rate adjustments based on carbon balance.

3.2.1 Treatments and Application Criteria

Treatments were applied using a commercial air blast sprayer (Slimline Manufacturing, Model MP3T19P with 19-60SS tower, Penticton, Canada) at 758 kPa (109 PSI), ~672 L ha^{-1}, which equated to 117% of tree row volume pesticide dilute (Sutton and Unrath, 1988). The sprayer was equipped with nine nozzles (Teejet TXR Conjet hollow cone, Springfield, PA) per boom (side) and a large axial fan to move the spray into the canopy. To minimize treatment interference caused by spray drift, experimental units were separated by at least one guard tree. Applications were made at a ground speed of 2.6 km/hr (1.59 miles/h).

A randomized complete block with seven replications and six treatments was used as an experimental design. Treatments were applied to two-tree plots and consisted of: i) untreated control; ii) hand-thinned control; iii) 1000 mg L-1 carbaryl (Sevin XLR Plus, Tessenderlo Kerley, Phoenix, Arizona) (-50% rate adjustment) ; iv) 1500 mg L-1 carbaryl tank-mixed with 50 mg L-1 6-BA (MaxCel; Valent BioSciences, Libertyville, IL) (-15% rate adjustment); v) 1500 mg L-1 carbaryl tank-mixed with 100 mg L-1 6-BA (0% - no rate adjustment), and; vi) 1500 mg L-1 carbaryl tank-mixed with 150 mg L-1 6-BA (+30% rate adjustment). All applications included a 0.05% (v/v) non-ionic surfactant (Agral 90, Syngenta Canada, Guelph, ON). Gala trees were in full bloom on 6 May 2024.

The 8-12 mm fruitlet diameter treatments were applied between 06:50 am and 9:45 am on 20 May (14 DAFB). Actual king and lateral fruitlet diameters on 21 May were 9.9/7.5 mm (n=75; n=300).

The hand-thinned control trees were thinned on 20 June by removing all but one fruit per cluster and spacing fruit ~7 cm apart. The average number of fruit removed by hand-thinning was 82 fruits/tree (n=14). Municipal ground water with average pH of 7.5 to 8.0 and hardness of 281 mg L^{-1} to 295 mg L^{-1} (Kristin Pressey, Personal

Communications) was used as the source water for the spray mixture.

3.3 Experiment 3: Predicting Fruit Set Based on Early Fruit Growth (Objective 2)

3.3.1 Fruit Growth Model (Diametric Method)

The equipment used in our study included digital calipers with 0.01 mm resolution, a Microsoft Excel software spreadsheet to record fruitlet diameter data (available for free at this link), flagging tape and markers, and hand click counters (helpful but not necessary). In our study, data were recorded to a custom excel spreadsheet (not shown) and then uploaded to www.malusim.org.

3.3.1.1 Pre-bloom Measurements

The first step in using the FGM was to evaluate the specific orchard block and set a target crop load. This can be challenging given that the target crop load can vary based on grower preference, which is largely dependent upon desire fruit size for their market. Trees often have five times this target bud load before pruning, so some dormant pruning in winter or early spring is a useful strategy to reduce bud load and crop load prior to bloom. The second step is to count the total number of flowering clusters on two to five representative trees for each cultivar of interest. Ideally, this is done when flower buds are at the first pink stage of development, which helps distinguish clusters from one another before the flowers fully open. The third step was to label 15 blossom clusters on five trees of Gala, Honeycrisp, and Ambrosia with flagging tape and to number clusters 1 to 15 on each tree (75 flower clusters total per cultivar). In our study, we intentionally did not label the individual fruit in the cluster so that repeat measurements on the same fruitlets could be taken; this approach has been described elsewhere (Greene et al., 2013; Schwallier and Brown, 2014).

3.3.1.2 Post-bloom Measurements

The FGM protocol recommends fruitlet diameter begin when king fruitlets are ~6 mm in diameter and measurements continue every 3-4 days to generate a complete picture of fruit growth, response to chemical thinners, and ultimately thinning efficacy vis-à-vis fruit set. Differences between measurements on two successive data are used by the FGM to predict the percentage set and estimate a target crop load. For research purposes, we took measurements on five dates (21-May, 24-May, 28-May, 31-May, 4-Jun) in 2024.

The first of these dates began one day after a tank mix of 1500 mg/L carbaryl and 75 mg/L 6-BA was applied on 20-May to Gala and Ambrosia trees and 1500 mg/L carbaryl and 10 mg/L NAA were applied to Honeycrisp trees. King and lateral fruitlets on 21-May were 9.9+-1.4 mm and 7.5+-1.9 mm, respectively. A repeat application of the tank mix of 1500 mg/L carbaryl and 75 mg/L 6-BA was applied again on 30-May to Gala and Ambrosia trees. All sprays included 0.05% Agral 90 non-ionic surfactant. Digital calipers were used to record fruitlet diameters, with two people measuring and one person recording.

There are at least three different sources that have developed FGM calculators in which data can be inputted to estimate fruit abscission using the primary principals of the FGM: a) the original Excel spreadsheet created by P. Schwallier; b) a website (Malus.org); and c) a more recent model developed by Tom and Joe Ferri. For the present study, Malus.org was used to predict fruit set using the FGM. While each source uses the principles of fruit growth between two measurement dates, they vary slightly by measuring protocol and data entry. The Malus.org model has particularly conservative error checking, which rejects values that have growth rates more than 1.5

mm/day or are greater than two standard deviations of all growth rates.

Source	Instruction	Link	Notes
Schwallier (2014)	https://www.canr.msu.edu/uploads/files/PredictingFruitset1-21-14.pdf	https://www.canr.msu.edu/uploads/files/PredictingFruitset1-21-14.xls	If you use the Schwallier spreadsheet, you need to mark and measure the same individual fruits in each cluster. Free of charge.
Malus.org	https://rvpadmin.cce.cornell.edu/uploads/doc_813.pdf https://jmcextman.blogspot.com/2019/05/how-to-use-malusim-app.html	www.malusim.org	Unsupported. Free of charge. Has built-in error checking that omits fruit that are growing faster than 1.5 mm/day and fruit with greater than 2 standard deviations of all growth rates. Error checking appears overly conservations rejecting valid data.
Ferri	https://jmcextman.blogspot.com/2023/01/the-fruit-growth-fg-app.html	https://ag.umass.edu/sites/ag.umass.edu/files/pdf%2Cdoc%2Cppt/2023masterrev2.1.2.xls or https://apps.apple.com/us/app/fruit-growth/id1604255929	Available on IOS or MacOS (Apple iPhone, iPad, or Max). $24.99. Current version 4.1.2

3.3.2 Fruitlet size distribution (FSD) Model (Fruitlet weight method) (Objective 2)

To optimize the FSD model, one should take measurements every three days beginning when the average fruitlet diameter is 6 mm. For example, if a prediction can be achieved by eight days, assuming an average growth of ~0.8 mm per day, then fruitlets will be ~ 12 mm by the time another application of chemical thinner is need if the first is made when the king fruitlet diameter is ~6 mm. When fruitlets are 12 mm fruitlets, they remain very sensitive to chemical thinners.

The equipment used in our study included: a) a laptop or desktop computer (with a USB port and Microsoft Excel software); b) a digital scale (Model NV2202, Ohaus Corp, Parsippany, NJ) that can accurately measure to 0.1 gram and is capable of connecting to the computer (USB Interface, Ohaus Part number 83032108) and exporting data directly into Excel, and; c) the Excel file to capture the data (freely available at this link).

Detailed instructions for using the model are made available by Hillman and Einhorn (2024). Briefly, some pre-bloom flower measurements and post-bloom fruitlet measurements are required.

3.3.2.1 Pre-Bloom Measurements

The first step is to count the total number of flowering clusters on two to five representative trees for each cultivar of interest. Ideally, this is done when flowers are at the first pink stage of bud development, which makes it easier to distinguish clusters before flowers fully open. The second step is to flag 40 flowering spurs per measurement day between pink and full bloom. Brightly coloured flagging is necessary so that the marked spurs can be easily found during the subsequent collection dates (typically 3, 6 and 9 days after thinner is applied).

The FSD does not indicate how many trees to use; however, in 2024, we marked eight representative flower clusters per tree (between 1 and 2 m from the ground) from 20 trees (160 flower clusters total). The third step is to collect 25 flower clusters randomly from representative trees at full bloom and count all flowers. When fruit reach 6-8 mm king fruitlet diameter and when weather permits, apply the chemical thinner(s) of choice.

3.3.2.2 Post-Bloom Measurements

The FSD protocol recommends three measurement dates taken at 3-day intervals (day 3, 6 and 9 from the last thinner application) to generate a complete picture of the thinning activity and response to chemical thinners. For research purposes, we took measurements on four dates (22-May, 27-May, 30-May, 3-Jun) in 2024.

The first of these dates was two days after a tank mix of 1500 mg/L carbaryl and 75 mg/L 6-BA was applied on 20-May to Gala and Ambrosia trees and 1500 mg/L carbaryl and 10 mg/L NAA to Honeycrisp trees. A repeat application of the tank mix of 1500 mg/L carbaryl and 75 mg/L 6-BA was applied again on 30-May to Gala and Ambrosia trees. All sprays included 0.05% Agral 90 non-ionic surfactant.

On each collection date, from the 20 previously flagged trees, two tagged fruiting clusters per tree were removed and placed in a small plastic labelled container. The 40 clusters were then transported to the lab. Data were tracked by tree number and cluster number in the FSD spreadsheet. Fruitlets from each cluster were individually detached from the spur with the pedicel intact. Each fruitlet was weighed on the scale, starting with the first tree. Data were transferred directly to the Excel spreadsheet as described in the protocol.

3.3.3 Harvest

Ambrosia, Gala, and Honeycrisp fruit were harvested on 4-Oct 2024, 19 Sep 2024, 26-Sep 2024. During harvest, the total number and weight of fruit per tree were recorded. The number of dropped and unmarketable fruit (undersize, poor colour) were also counted and weighed. Mean fruit weight was estimated by dividing the total mass of the marketable fruit by the number of fruit in the sample. Tree trunk circumference 30 cm above the graft union was measured in the fall of 2024 and used to calculate trunk cross-sectional area.

3.4 Orchard Management for Experiments 1, 2, 3

Standard conventional cultural and pest management practices for Ontario were used in this study. The orchard soil was classified as an Oakland sandy loam (brunisolic gray grown luvisol) with imperfect drainage and soil textures consisting of mainly gravelly sandy till. Weeds were controlled using 1% (v/v) glyphosate applications made mid-May, June, and July. A permanent sod culture was established the year of planting using a mixture of perennial rye, red fescue and Kentucky blue grass. There were strong bloom and good pollination conditions in this orchard block in 2024. To ensure uniformity of tree size and flowering, any trees that were smaller or had less bloom were excluded from the experiment.

3.5 Measurements for Experiments 1 and 2

On 1 May, prior to full bloom, a total of four main scaffold branches, two on each of the east and west sides of the tree, were selected and marked to determine fruit set by counting the number of flower clusters per branch. On 13 June (39 DAFB), after 'June drop' (but before applying the hand-thinned treatments), the number of fruit set per flower cluster was counted. These data were then used to calculate fruit set (number of fruit that set per 100 flower clusters) and fruit set per flower cluster derived from a spur. Approximately every 3-4 days between 21-May and 4-Jun (16-30 DAFB), 15 fruiting spurs were selected randomly from each of five untreated trees and the latitudinal diameter of the king and later fruits were measured using digital calipers. The number of king and lateral fruits per spur decreased over time with the progression of natural fruitlet abscission; these values were derived from a high of 75/269 king/lateral fruits on 21-May to a low of 68/56 king/later fruits on 4-Jun. Tree trunk circumference 30 cm above the graft union was measured in the fall of 2024 and used to calculate trunk cross-sectional area.

Leaf phytotoxicity was assessed on 27-May, 3-June, and 10-June using a nine-point leaf phytotoxicity scale, with: 1 = No symptoms; 2 = Light yellow discoloration between the veins; 3 = Yellow discoloration between the veins, beginning of necrosis on the edge and on the tip of the leaf; 4 = Strong yellow discoloration between the veins and beginning of necrosis on the edge of the leaf (1-2 mm) from the tip; 5 = Strong yellow discoloration between the veins and spread of necrosis from the edge (4-5 mm) to the base of the leaf; 6 = Reduction of leaf area by necrosis that spreads to the center and the base of the leaf; 7 = Reduction of leaf area by necrosis that spreads to the center and the base of the leaf, and leaf starts to curl (spoon shape); 8 = Only an area 1-cm wide remains green around the main vein, leaf is curled, and some leaves drop; and 9 = Leaf entirely necrosed and curled, sometimes a small green area may persist around the central vein and near the stem, and these leaves drop (Adama Canada, 2022; Appendix 2). An estimate of the percentage of leaves affected with phytotoxicity symptoms on the tree was also recorded.

Leaf chlorophyll fluorescence was measured *in situ* using a portable non-modulated light fluorimeter (Model Pocket PEA, Hansatech Instruments, King's Lynn, UK) to determine treatment effects on intrinsic (maximum) potential quantum efficiency of PSII (Fv/Fm). In addition, the performance index (PI) was calculated, which is an indicator of leaf vitality. It is an overall expression indicating a kind of internal force of the sample to resist constraints from outside (Strasser et al., 2000, 2004).

Approximately 20-30 min prior to taking measurements, manufacturer-provided proprietary leaf clips were placed on four randomly selected new and fully expanded leaves on extension shoots (not spur leaves) per tree located between 1.25 m and 2 m from the ground. The clips were placed on either side of the leaf midrib, approximately halfway between the apex and base. Different leaves were selected on each measurement date. The leaf clips served two purposes: i) to shield the fluorescence detector from ambient light, and; ii) to pre-condition or dark-adjust a section of the leaf prior to measurement. The clips had a 4-mm diameter measurement orifice.

After dark adjustment, fluorescence measurements were made between 09:00 and 11:00 on select treatments on the day of treatments but prior to application, day 1- , 4-, 7-, and 10 days after treatments were applied (on 20 May). Further measurements were taken on trees that received MET treatments 30 May. The instrument provided illumination of 3500 mmol$\cdot$m$^{-2}\cdot$s^{-1} with a peak wavelength of 627 nm using LEDs. Data were recorded for a duration of 3 s and five pre-configured fluorescence levels [F1 (t=50ms), F2 (t=100ms), F3 (t=300ms), F4 (t=2ms), F5 (t=30ms)].

The Pocket PEA instrument measures several parameters and calculates an array of others. Herein we report Fv/Fm, which is the parameter of the maximum photochemical efficiency of PSII. Fv/Fm is the ratio of the difference between the maximum and minimum fluorescence to maximum fluorescence, $(F_m – F_0)/F_m$. The F_m parameter defines the maximum fluorescence when exposed to high-intensity light and all PSII reaction centres are closed (Maxwell and Johnson, 2000).

Fruit was harvested on 10 Sep 2024. During harvest, the total number and weight of fruit were recorded. The number of dropped and unmarketable fruit (undersize, poor colour) were also counted and weighed. Mean fruit weight was estimated by dividing the total mass of the marketable fruit by the number of fruit in the sample.

Sixty randomly selected, sound fruit (minus fruit with rot) from each two-tree experimental unit (30/tree) were placed in cold storage (~2°C) for subsequent grading on 14 Dec 24 using a commercial colour sorting and sizing grading line. Fruit were graded at the Norfolk Fruit Growers in Simcoe, which utilizes cameras and sensors to weigh and size each fruit and to determine colour intensity and percent of the surface with red colour. Fruit length and diameter (L:D) ratios were also determined by image analyses from the grading line. Fruit were then separated according to their weight into 15 size categories expressed as an average count size category, which was the number of apples needed to fill a 20 kg box (Canadian Food Inspection Agency, 2011). The weight of fruit in each of the following count size category was calculated for each tree: 1) < 91 (count size 216); 2) 91-102 g (count size 198); 3) 103-110 g (count size 175); 4) 111-120 g (count size 163); 5) 121-130 g (count size 150); 6) 131-144 g (count size 138); 7) 145-159 g (count size 125); 8) 160-180 g (count size 113); 9) 181-205 g (count size 100); 10) 206-225 g (count size 88); 11) 226-250 g (count size 80); 12) 251-282 g (count size 72); 13) 283-322 g (count size 64); 14) 323-376 g (count size 56); and 15) ≥ 377 g (count size 48).

Gross returns per tree were calculated based on the weight of marketable fruit in each category and the wholesale market price of fruit in each size category (count sizes 56 to 216). The wholesale prices of Ambrosia apples were obtained from a commercial packing house in Ontario who provided the following prices based on an 18-kg (40 lb) box of fruit (count size in parentheses): $1.16/kg (56), $1.16/kg (64), $1.35/kg (72), $1.35/kg (80), $1.35/kg (88), $1.16/kg (100), $1.16/kg (113), $0.73/kg (125), $0.73/kg (138), $0.73/kg (150), $0.44/kg (163), $0.44/kg (175), $-0.34/kg (198), and $-0.34/kg (216).

Return bloom was measured in the spring of 2025 (when flower clusters were evident but prior to full bloom). Percentage of flower spurs was determined by counting the number of spurs with and without flowers on four limbs per tree between 1.5 m and 2 m aboveground.

Environmental conditions were recorded ~500 m away from the orchard using the research weather station located at the Ontario Crops Research Centre – Simcoe.

3.6 Data Management and Statistical Analysis

Data were curated and managed in Excel and subjected to analysis of variance using the mixed model PROC GLIMMIX procedure of SAS (SAS 9.4, SAS Institute, Cary, NC) with treatments as fixed effects, and blocks as random effects. A Type I error rate of P= 0.05 was used to report statistical significance. Mean fruit weight was adjusted by using crop load as a covariate. Mean separation using Tukey's HSD was used to separate treatment means (*P*=0.05). Single degree of freedom orthogonal comparisons were performed in Experiment 1 to evaluate the rate effect of MET, MET with and without 6-BA, and one versus two applications of MET; and in Experiment 2, the rate of 6-BA. A Shapiro-Wilk test was used to test normality of residuals. Scatterplots of studentized residuals were visually observed to test the assumption that errors were not heterogeneous. In cases where there were large deviations from the assumptions, data were transformed using log- or square root-transformation prior to analysis. All graphs were created using SigmaPlot version 13 (Inpixon Inc., Palo Alto, USA) and Excel.

4.0 Results

4.1 Experiment 1: Crop Load Management Studies with Fruitlet Applications of Metamitron (Brevis®) and ACC (Accede®) (Objective 1)

4.1.1 Environmental conditions

Air temperatures were favorable for applying the chemical fruitlet thinners on 20-May and 30-May 2024 with good drying conditions, low wind conditions and maximum/minimum air temperatures reaching 29.5/21.8 and 19.8/13.6^{o}C, respectively (Figure 1; Appendix 3). Solar radiation levels and air temperatures remained high following the first and second treatment applications. Maximum daytime air temperatures ranged from 21.0^{o}C to 29.0^{o}C seven days following the first application while minimum nighttime temperature lows ranged from 12.0 – 19.4^{o}C for the same time. Maximum air temperatures following the second application on 30-May ranged from 18.0-28.5^{o}C while nighttime lows ranged from 6.6-18.2^{o}C seven days following 7-June. Solar radiation levels were variable between 20-May and 30-May. The Brevis model was run during these dates and the outputs are indicated in Appendix 3.

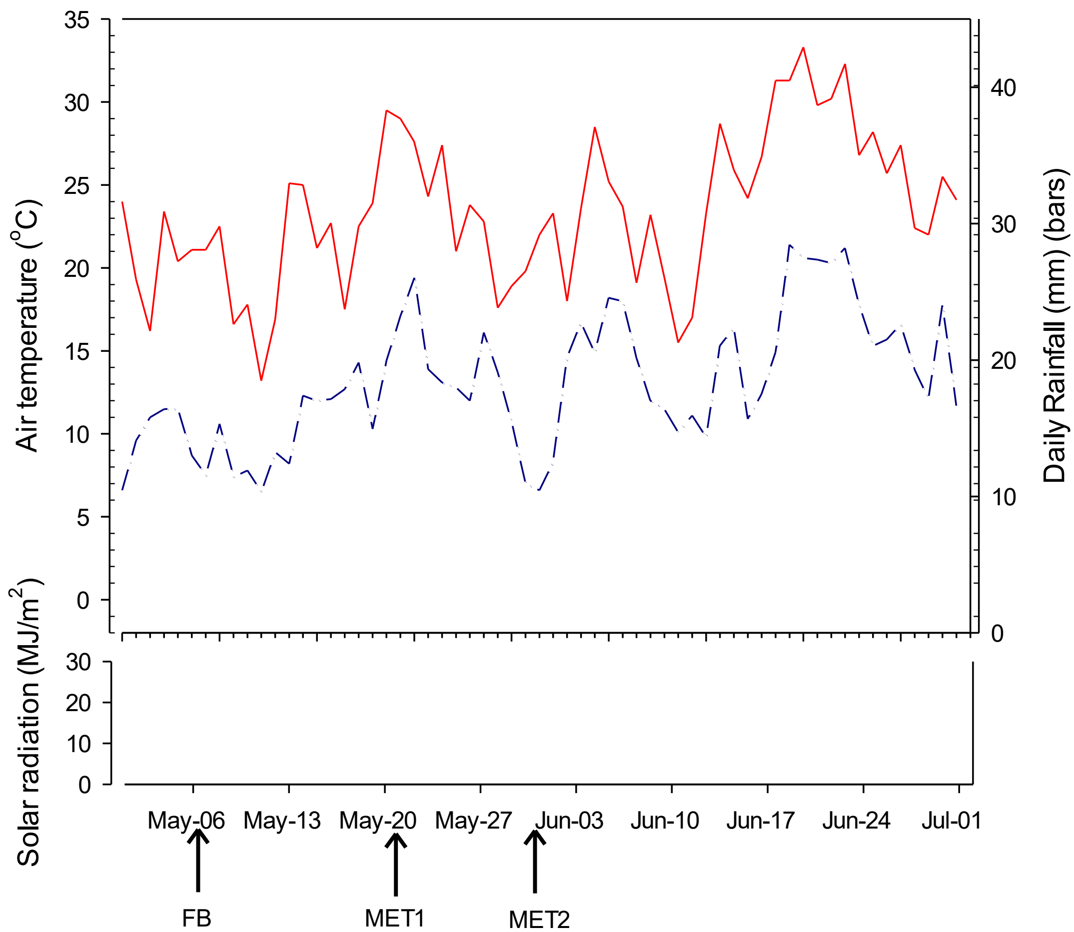


Figure 1. 2024 minimum and maximum air temperature, precipitation and solar radiation at the University of Guelph, Simcoe (1 May - 30 June). Arrows indicate the dates of full bloom (FB) (6 May) and application of metamitron treatments (MET1 - 20 May; MET2- 30 May) and (grower standard carbaryl and 6-BA 20-May).

4.1.2 Fruitlet growth

Growth of king and lateral fruitlets increased linearly over time between 21-May and 4-Jun 2024 at approximately 0.83- and 0.58-mm/day for the average king and lateral fruits, respectively (Figure 2). Note that the lateral fruit growth rate is skewed lower than actual because the lateral fruit growth values represent actively growing and abscising fruitlets.

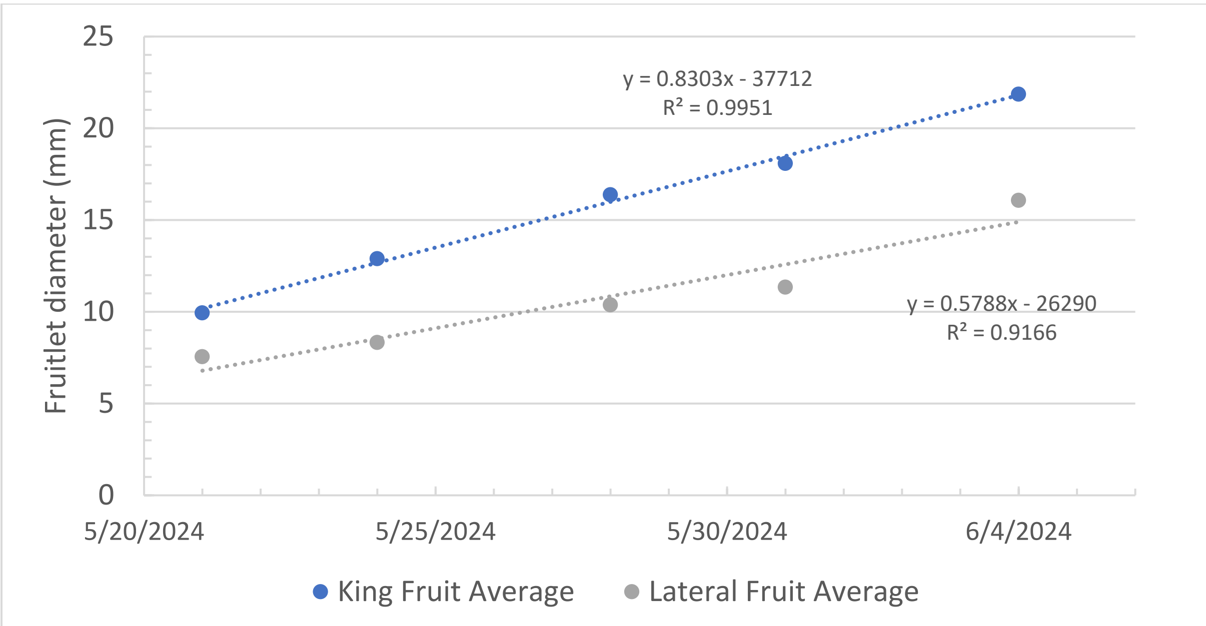
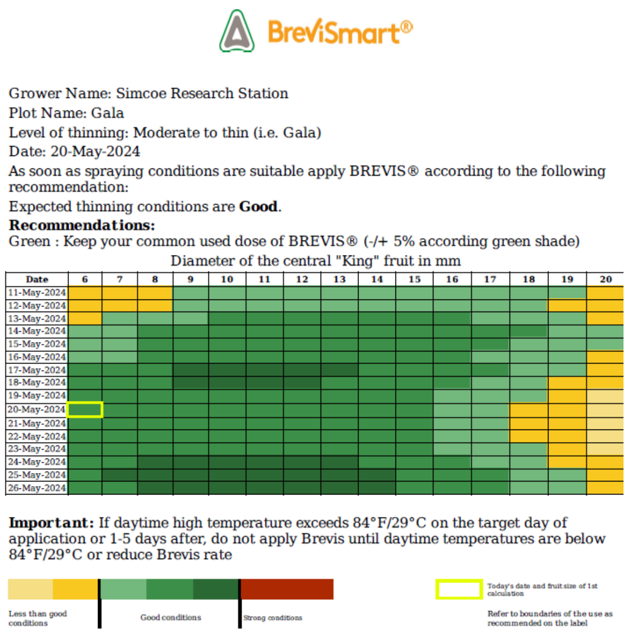


Figure 2. Fruitlet growth of Gala king (blue circle) and lateral fruitlets (grey circle) between 21-May and 6-Jun in 2024 (15 and 29 days after full bloom) with associated linear regression lines.

4.1.3 BreviSmart Online Computer Model

As per the experimental protocol, the BreviSmart online thinning model (https://brevismart.adama.com/) was run just prior to the first application and toward the end of the application dates. The assumption we made that Gala is a ‘moderate’ to thin cultivar. The model outputs are shown in Figure 3. Further details about the model are note in Appendix 2.



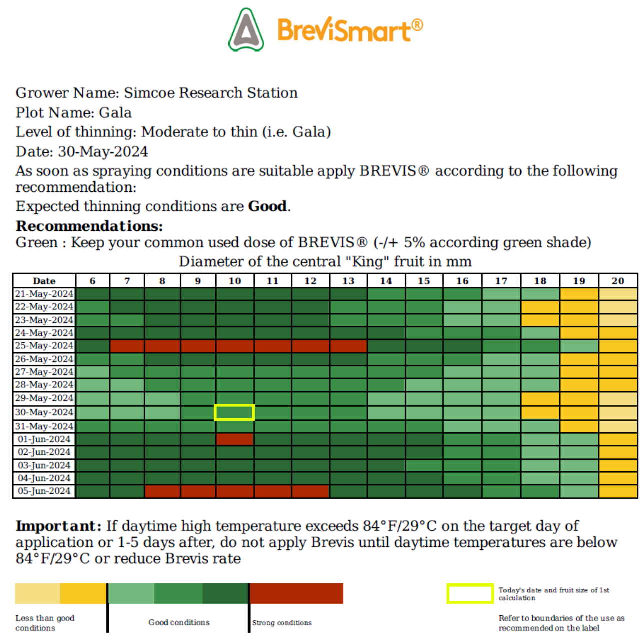


Figure 3. BreviSmart output for 20-May and 30-May 2024 for the Simcoe, Research Station, Simcoe. Both application dates based on fruit diameter suggested "good" conditions for MET thinning efficacy, indicating that a 'standard' rate of Brevis should be applied.

4.1.4 Fruit Set

There was a high number of flowering spurs in the Gala block and environmental and bee pollination conditions for fruit set were ideal. Consequently, fruit set was very high. There was a significant treatment effect on fruit set (P<0.0001) (Table 1). Trees that received combined sprays of carbaryl and 6-BA, a single spray of MET at 1.8 L/ha or higher concentration, or two sprays of 1.80 L/ha MET had significantly lower fruit set compared to the untreated and hand-thinned control treatments. Trees that received a single application of 1.8 or 2.3 L/ha MET tank-mixed with 75 mg/L 6-BA had similar fruit set as the untreated and hand-thinned control treatments. Orthogonal contrasts indicated that there was a highly significant (P=0.001) linear decrease in fruit set with increasing rate of MET, but no difference between sprays of MET alone or MET tank-mixed with 6-BA, and no difference in fruit set between a single and two applications of MET. Note that the fruit set of the hand thinned control treatments was measured prior to hand thinning, which is why it was similar to the untreated control treatment.

There was also a significant treatment effect on the number of fruit set per flowering cluster (Table 1; Figure 4). Trees that were left untreated had 32% flower clusters that set zero fruit/cluster and 57.7% of spurs that set one fruit/cluster. The combined sprays of carbaryl and 6-BA, a single spray of MET at 1.8 L/ha or higher concentration, or two sprays of 1.80 L/ha MET resulted in a higher percentage of flowering spurs that set zero fruit, ranging from 49.8 to 62.0%, and a lower percentage of flowering spurs that set one or more fruit. Only trees that were left unthinned or hand thinned had a significantly higher percentage of clusters with two fruit (P=0.01). Overall, all treatments had a higher numerical percentage of fruit with zero fruit/cluster, which should conceivably increase return bloom in the spring of 2025.

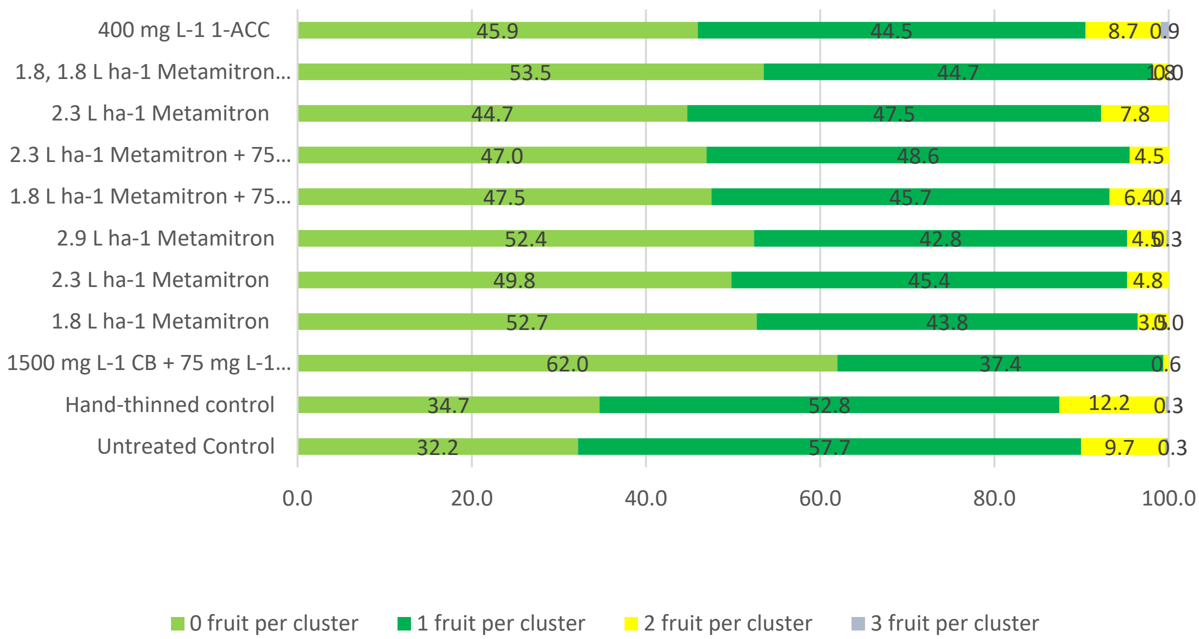


Figure 4. Influence of thinning treatments on the number of Gala fruit set per flowering spur (actual data shown in Table 1). Note: data were collected before trees were hand thinned.

4.1.5 Yield parameters and economic value of fruit

There was a significant treatment effect on total fruit yield per tree (P=0.0004), total number of fruit per tree (P<0.0001), percent marketable yield per tree (p=0.0039), mean weight of marketable fruit (P<0.0001), mean fruit weight (P<0.0001), crop-load adjusted mean fruit weight (P=0.0381) and crop load (P<0.0001), but no effect on gross economic returns per tree (P=0.81621) (Table 2). Trees that were hand-thinned, treated with 2.3 L/ha MET at 18 mm, and trees treated with two applications of 1.8L/Ha MET had significantly lower yields compared to the untreated control; there was no yield suppression for all the other chemical thinning treatments compared to the untreated control except for trees treated with two applications of MET. Trees that were hand-thinned and trees treated with MET at 18 mm, two applications of MET, and 400 mg/L 1-ACC had the greatest reduction in total fruit per tree, 37%, 42 and 45%, respectively. The tank-mixed carbaryl and 6-BA treatment and single MET application treatments applied at 18-12 mm had similar numbers of fruit per tree as the hand thinning and untreated control treatments. Untreated trees had the lowest percentage of fruit that were marketable. In general, thinning treatments increased mean weight of marketable fruit and all fruit per tree, with the greatest improvement observed for the hand-thinned, tank-mixed carbaryl and 6-BA and two applications of MET. There was a significant positive response with mean marketable fruit weight and well as one versus two applications of MET. However, including 6-BA in the tank mix with MET did not lead to larger fruit weight when adjusted for treatment differences in crop load. Crop load of untreated trees was very high with 11.3 fruit per cm^2 TCSA. The hand-thinned treatment 2.3 L/ha MET and two applications of MET were most efficacious at reducing crop load to an ideal level of ~6 fruit per cm^2 TCSA. Orthogonal contrasts indicated that crop load declined with increasing rates of MET, and that two applications of MET were more effective than a single application. However, there was no additive effect of 6-BA on crop load when tank-mixed with MET. All the thinning treatments had similar gross returns per tree.

4.1.6 Fruit Size Distribution

Thinning treatments had a marked effect on the size distribution of fruit (Table 3; Figure 5), except for fruit in the 64-, 72-, 80-, 88-, 175- and higher box size categories. For the untreated control treatment, most fruit (by weight) peaked in the 113-box size category while for the hand thinned control, most fruit peaked in the 100-box size category. Trees receiving chemical thinners had most fruit by weight in the 113-box size category, except trees receiving 2.3 L/ha MET at 18 mm and trees receiving two sprays of 1.8 L/ha MET, which had most fruit in the 100-box size category. There was no difference in the amount of fruit that were undersized (box sizes 175-216). Based on orthogonal contrasts, MET with and without 6-BA had no effect on fruit size distribution.

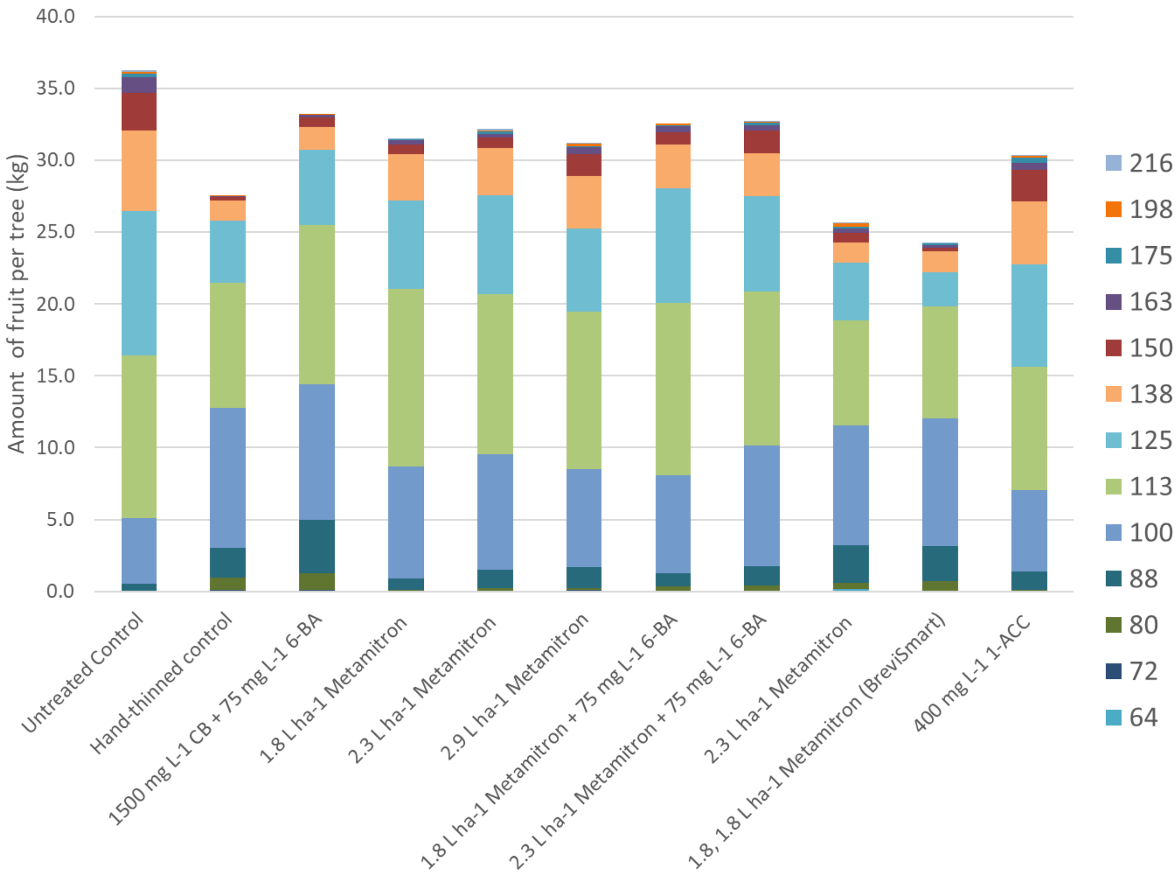


Figure 5. Influence of the various thinning treatment carbaryl (CB), metamitron, 6-benzyl adenine (6-BA), and ACC on size distribution of Gala fruit based on count/box size fruit categories (data taken from Table 3).

4.1.7 Leaf Phytotoxicity

Overall, treatment effects on severity and incidence of leaf phytotoxicity on Gala trees were very low (<1.5 and <0.5%, respectively). On 27-May (seven days after the first sprays were applied), there was no treatment effect on leaf phytotoxicity (rating) but a slight increase (P=0.0395) in incidence that appeared to be largely attributable to the inclusion of 6-BA with MET as opposed to the rate of MET applied. However, there were no treatment effects on severity or incidence of leaf phytotoxicity on 3-Jun (14 days after first treatment) and 10-June (21 days after first treatment).

4.1.8 Leaf Photosynthesis

There was a significant treatment effect on Fv/Fm values, measured by the Pocket PEA fluorescence instrument beginning one day after thinner applications (Fig. 6B). The Fv/Fm values fell to a minimum seven days after application and did not recover to the pre-treatment or untreated control levels by 10 days post-treatment, the date at which trees treated with a single application were last monitored. There were few differences in Fv/Fm levels between trees treated with 1.8, 2.3 or 2.9 L/ha MET. Trees which received two applications 1.8 L/ha MET had the lowest Fv/Fm values of any treatment, as measured one day after the second application (31 May). Fv/Fm values for this treatment did not recover to untreated control values by 21 days after the first treatment application; however, there was some variation in values over time.

There was also a significant treatment effect on the photosynthetic performance index (PI_{abs}) values, beginning one day after thinner applications (Fig. 6A). The PI_{abs} values reached a minimum 4 days after application and did not recover to the pre-treatment or untreated control levels by 10 days after treatment. There was little difference in PI_{abs} levels between trees treated with 1.8, 2.3 or 2.9 L/ha MET. Minimum PI_{abs} on trees which received two applications 1.8 L/ha MET were similar to trees that received one application of 1.8L/ha MET. PI_{abs} for this treatment did not recover to untreated control values by 21 days after the first treatment application.

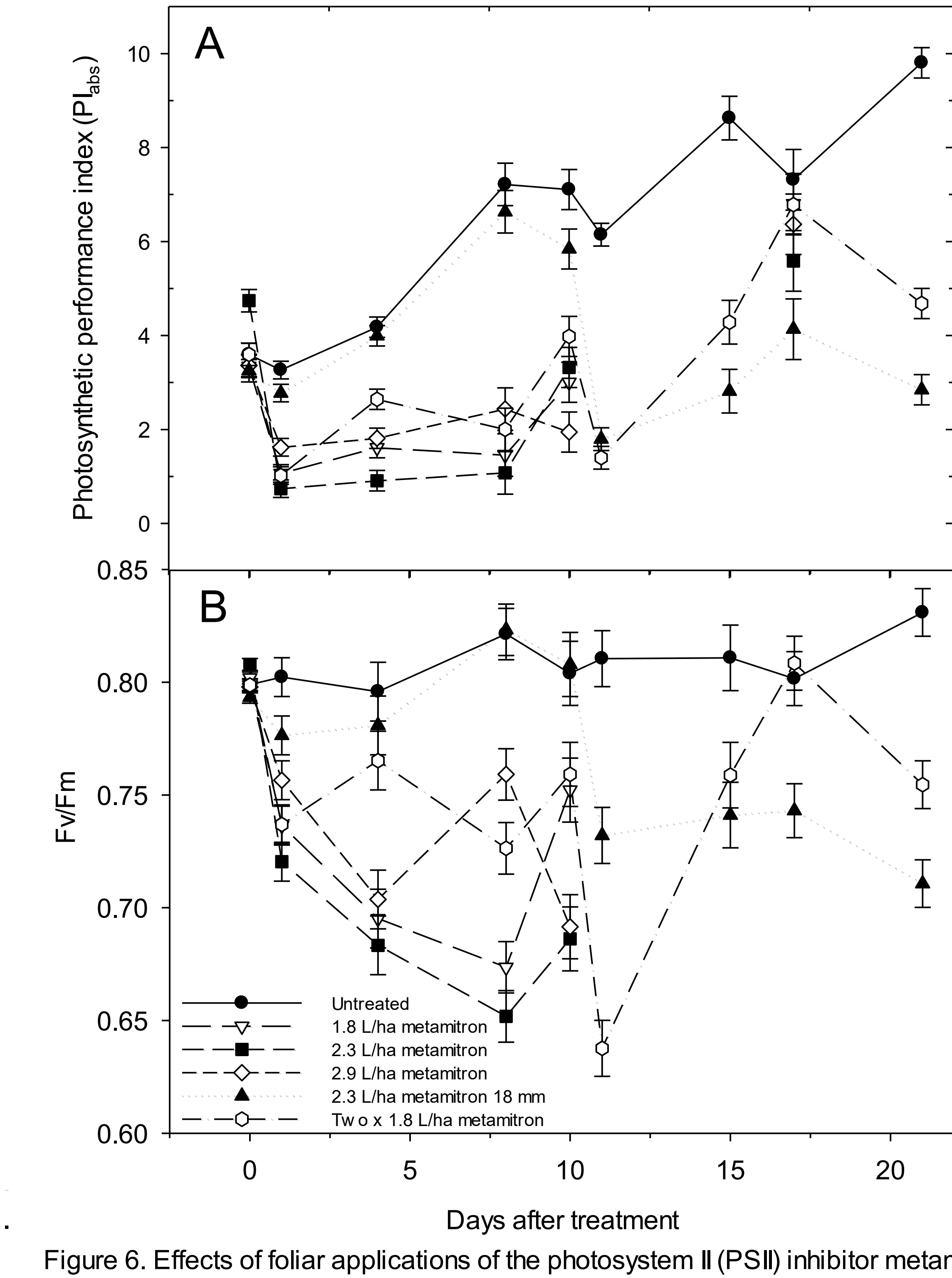


Figure 6. Effects of foliar applications of the photosystem II (PSII) inhibitor metamitron on the photosynthetic performance index (A) and dark-adapted chlorophyll fluorescence (Fv/Fm) (B) measured *in situ* in newly fully expanded Gala leaves. Metamitron was first applied applied on 20 May [14 d after bloom] and 30 May (10 days after the first application). Vertical bars indicate standard error of the means; n = 24.

4.1.8 Fruit Quality

Thinning treatments had a significant effect on fruit length:width ratio (P=0.0274) and percentage of the surface skin with red colour (P=0.0474), but no effect on fruit density, skin ground or blush hue colour determined from the optical sensor on the grading line (Table 5). Orthogonal contrasts indicated that increasing rates of MET increased the percentage of surface with red colour on fruit and that two sprays of 1.8 L/ha MET also had fruit with a higher percentage of surface with red colour.

4.1.9 Return Bloom

Thinning treatments had a significant effect on return bloom as expressed as the percentage of flowering spurs (P=<0.0001). Treatments that the reduced the crop load the greatest, had higher return bloom, however only the HTC, grower standard treatment of carbaryl tank mixed with 6-BA, single spray of 2.3 L/ha MET applied at 8-10 mm or 18 mm, or two sprays of 1.8 L/ha MET (8-12 and 14-16 mm), and 400 mg/L ACC applied at 18 mm had the highest return bloom. The two sprays of MET stood out with comparable return bloom as the HTC and grower standard treatment.

4.2. Experiment 2. Validation of the RIMPro Malusim Carbohydrate Model to Improve Thinning Outcomes Using Chemical Thinners (Objective 2)

4.2.1 Environmental conditions

Air temperatures were favourable for applying the chemical fruitlet thinners on 20-May with good drying conditions, low wind conditions and maximum/minimum air temperatures reaching 29.5/21.8^{o}C (Figure 1; Appendix 3). Solar radiation levels and air temperatures remained high following the first and second treatment applications. Maximum daytime air temperatures ranged from 21.0^{o}C to 29.0^{o}C seven days following the first application, while minimum nighttime temperature lows ranged from 12.0 to 19.4^{o}C for the same time period.

4.2.2 RIMPro Apple Thinning Model

The Apple Thinning model provided within RIMPro was evaluated on the day of application of the thinners, 20-May 2024. The model output is shown in Figure 7a and is based on forecasted weather data between 3:00 pm 20-May and 11:59 pm 27-May. Fruitlet chemical thinners were applied on 20-May when the predicted thinning effect was slightly above optimal (red area in top graph), and the carbohydrate balance was slightly negative (grey line in the bottom graph), and the predicted fruit diameter was 10 mm (area of pink partially obscured by the red area on the top graph). The blue vertical line on May 20 indicates the time the model was run in RIMPro (20 May 3:00 pm). All data after this date is predicted and based on forecasted weather data.

The Apple Thinning model provided was also evaluated *after* the day of application of thinners based on actual environmental conditions. Model output is shown in Figure 7b. The only distinctions between Figures 7a and 7b are the dates the model was run and that Figure 7b is based on data used in the model that is very close to actual environmental conditions in the orchard.

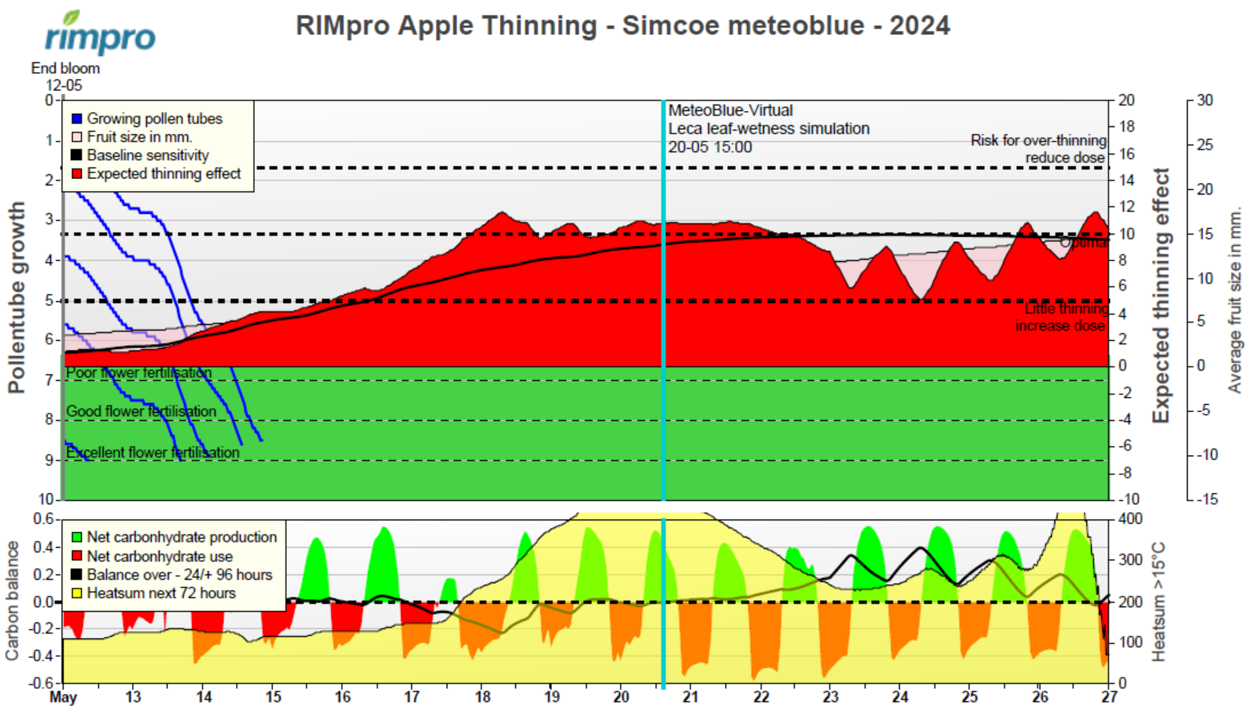


Figure 7a. RIMPro Apple Thinning model output for the period 11-27 May 2024 for the Ontario Crops Research Center – Simcoe (42.86°N 80.27°W), based on a virtual weather station (Meteoblue). Fruitlet chemical thinners were applied on 20-May when there was the predicted thinning effect was slightly above optimal, and the carbohydrate balance was slightly negative, and the predicted fruit diameter was 10 mm. The blue vertical line on May 20 indicates the time the model was calculated (20 May 3:00 pm). All data after this date is predicted and based on forecasted weather data.

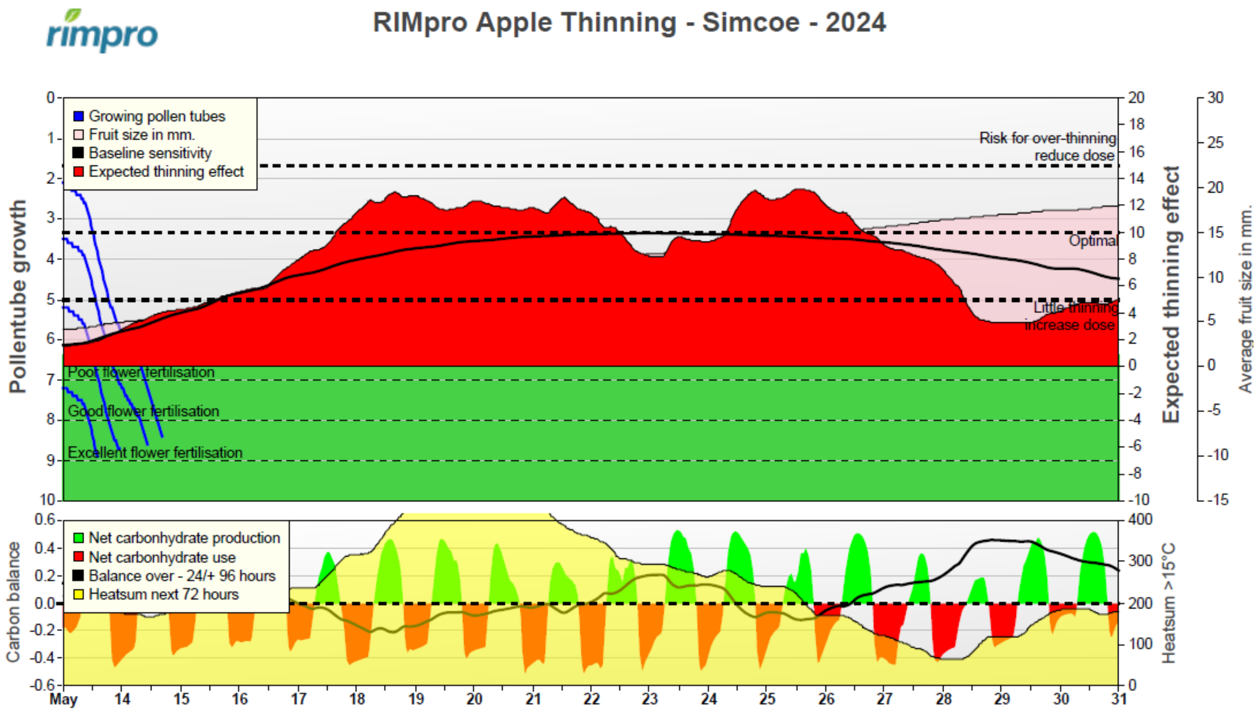


Figure 7b. RIMPro Apple Thinning model output for the period 12-31 May 2024 for the Ontario Crops Research Center – Simcoe (42.86°N 80.27°W) based on a virtual weather station (Meteoblue). Fruitlet chemical thinners were applied on 20-May when the predicted thinning effect was slightly above optimal, and the carbohydrate balance was slightly negative and the predicted fruit diameter was 10 mm. Note that this model was run after the thinning season and is based on actual (predicted) Meteoblue data and is not based on forecasted weather data.

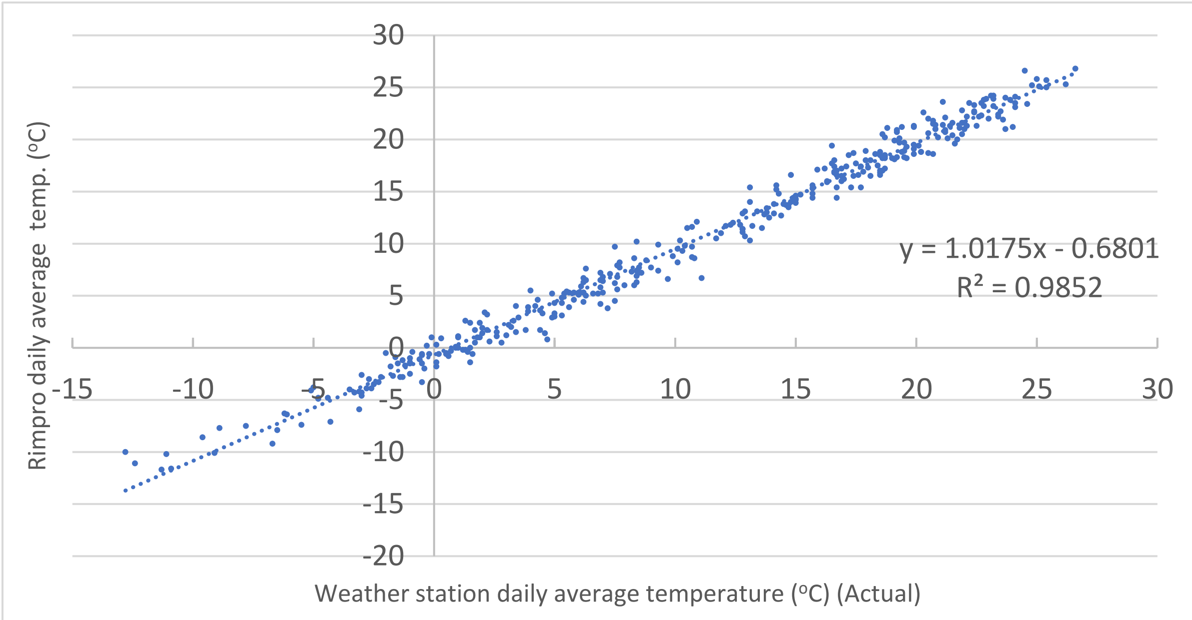
4.2.3 Verification of RIMPro Weather Data

Computer model projections are only as good as their data inputs. The best weather data is derived from calibrated weather stations with high-quality sensors and instrumentation. However, the initial hardware purchase, ongoing cellular communication charges, and maintenance can make weather stations expensive to operate. Given that the Ontario Crop Research Centre- Simcoe has an existing weather station, one project objective was to evaluate RIMPro using a virtual weather station that relies on weather data provided by a third-party provider called Meteoblue. Meteoblue uses several proprietary and commonly available predictive climate models, combined with a large measurement database and machine learning algorithms, to produce best-fit weather data. In addition, Meteoblue uses the most recent measurements from local public weather stations to fine-tune their data.

Through the RIMPro website, past, current, and forecasted daily maximum air temperature, daily minimum air temperature, daily average air temperature, daily average relative humidity, precipitation, number of hours of rainfall, hours of rainfall greater than 0.2 mm, crop wet hours, and evapotranspiration (Eto) is available for download. Because the parameters used in the Apple Thinning algorithm within RIMPro are not publicly available, we cannot be sure which weather variables are being input into models, or how the expected thinning effect is calculated. For comparison purposes using linear regression, we chose to compare daily average, minimum, and maximum air temperature and daily rainfall from 1-Jan to 31-Dec 2024 with the same actual recorded measurements.

Meteoblue estimated measurements were plotted against actual measurements to determine their relationship and how well they fit a 1:1 line. The correlation coefficient and root mean square error (RMSE) were used to evaluate this relationship. Overall, there were highly significant linear relationships between actual and estimated minimum, maximum, and average daily air temperature. Average daily air temperature had the best fit with a R^2 value of 0.98 and RMSE = 1.16 (Figure 8). Thirty-two percent of estimated measurements were within 0.5°C of actual, 59% of estimated measurements were within 1.0°C of actual, and 90% of estimated measurements were within 2.0°C of actual. Estimated average daily minimum and maximum air temperatures were less accurate with R^2 values of 0.94 and 0.97, respectively and RMSE values of 2.11 and 1.66, respectively.

To evaluate the cumulative error in the estimated average daily air temperature over the growing season, cumulative degree days (DD) base 5°C was calculated from 1-Jan to 31-Dec 2023 for the virtual and actual weather stations. The cumulative DD for the virtual and actual weather stations were 2597- and 2687-degree days, respectively, representing a 3.3% error rate (data not shown).


Rimpro daily average temp. (°C)
Weather station daily average temperature (°C) (Actual)
y = 1.0175x - 0.6801
R² = 0.9852
30
25
20
15
10
5
0
-5
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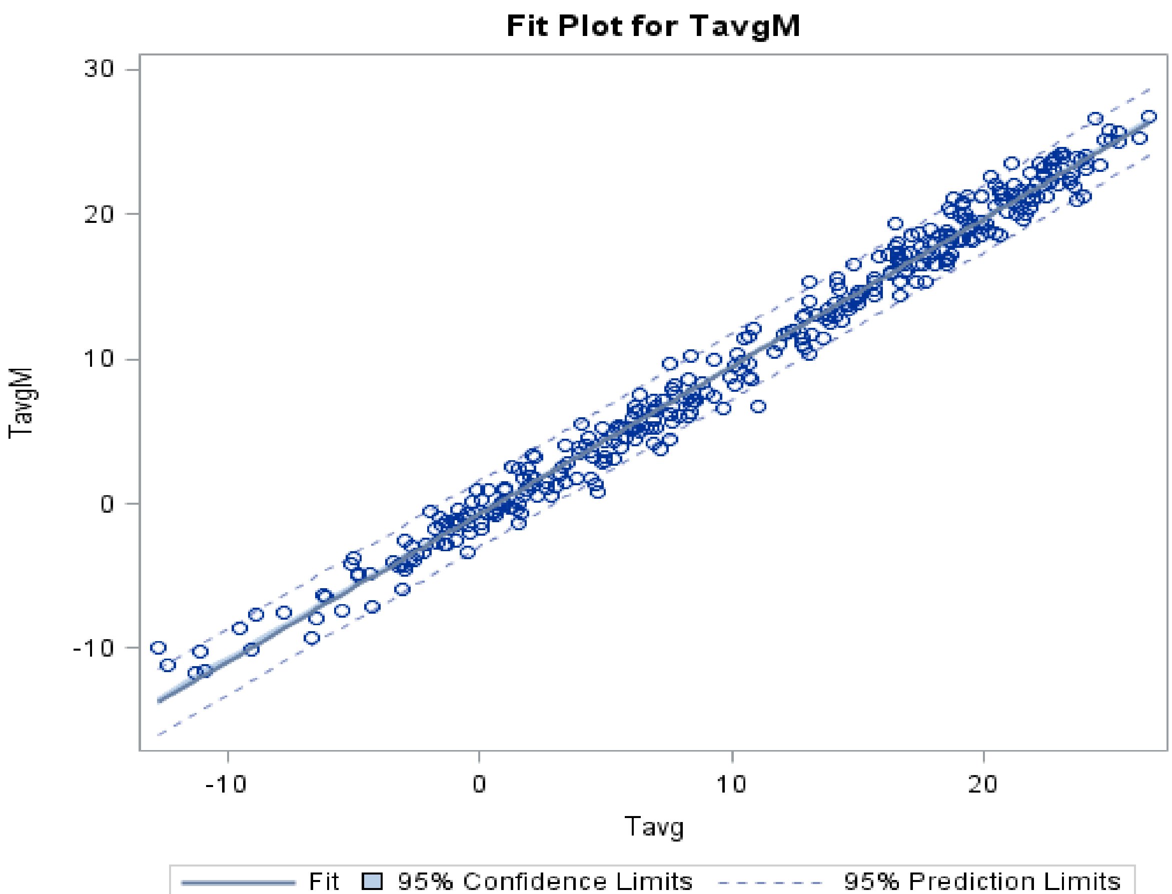
Fit Plot for TavgM
TavgM
Tavg
30
20
10
0
-10
-10
0
10
20
Fit
95% Confidence Limits
95% Prediction Limits

Figure 8. Relationship between average daily air temperature (2 m above ground) recorded at the Ontario Crops Research Centre – Simcoe (42.86°N 80.27°W) (Tavg**)** and the average daily air temperature (TavgM) provided by RIMPro via their virtual weather station (Meteoblue).

4.2.4 Fruit Set

There was a high number of flowering spurs in the Gala block and environmental and bee pollination conditions for fruit set were ideal. Consequently, fruit set was high in the block in which fruit were not thinned. There was a significant treatment effect on fruit set (P<0.0001) (Table 7). Statistically, there was no difference in fruit set among treatments that contained different rates of 6-BA combined with 1500 mg/L carbaryl. Note that the fruit set of the hand-thinned control treatments was measured prior to hand thinning; in other words, fruit set in this treatment was similar to the untreated control treatment.

There was also a significant treatment effect on the number of fruit set per flowering cluster (Table 7; Figure 8). Trees that were left untreated had 46.0% of flower clusters that set zero fruit/cluster and 48.5% of spurs that set one fruit/cluster while the hand-thinned control had 42.6%. Compared to the controls, all fruitlet thinners had higher percentages of flowering spurs with zero fruit, ranging from 57.4-68.8%. There was no effect of 6-BA or increasing rates of 6-BA on this metric. The untreated and hand-thinned control trees also had a higher percentage of flower clusters with one or two fruits. Overall, all chemical thinning treatments had a higher percentage of fruit with zero fruit per cluster, which should conceivably increase return bloom in spring 2025.

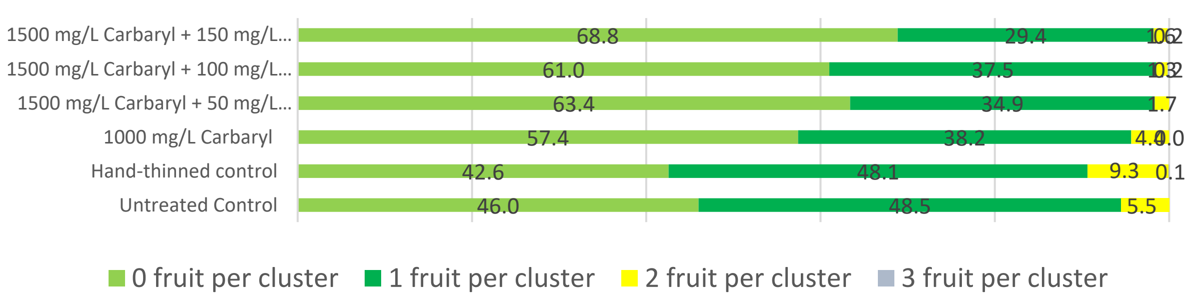

Figure 8. Influence of thinning treatments on the number of Gala fruit set per flowering spur (actual data shown in Table 1) Note: data were collected before trees were hand thinned.

4.2.5 Yield parameters and crop value

There was a significant treatment effect on total fruit yield per tree (P=0.0003), total number of fruit per tree (P<0.0001), mean weight of marketable fruit (P<0.0001), mean fruit weight (P<0.0001), crop-load adjusted mean fruit weight (P=0.0003) and crop load (P=0.0019). However, there was no effect on percent marketable yield per tree (P=0.1188) (Table 8). Trees that were hand-thinned, treated with 1500 mg/L carbaryl combined with 100 mg/L 6-BA or 1500 mg/L carbaryl combined with 150 mg/L 6-BA had the lowest yields compared to the untreated control. Increasing rates of 6-BA resulted in a linear reduction in total yield (P=0.01). Trees that were hand-thinned and trees treated with 1500 mg/L carbaryl combined with 150 mg/L 6-BA had the greatest reduction in total fruit per tree, 31% and 28%, respectively compared to the untreated control trees. The hand thinning treatment and all chemical thinning treatments increased mean weight of marketable fruit comparably, with mean weight ranging from 184 to 195 g, compared to 166 g for the untreated control. Mean weight of all harvested fruit followed a similar trend. Crop-load adjusted mean fruit weight was greatest from trees that were hand thinned and those receiving 1500 mg/L carbaryl combined with 100 or 150 mg/L 6-BA; however, there was no effect of 6-BA based on orthogonal contrasts. Both trees that were hand thinned and those treated with 1500 mg/L carbaryl combined with 150 mg/L 6-BA had lower crop loads than the untreated control trees; all other chemical thinning treatments had intermediate crop loads that were statistically similar to the untreated control trees. All treatments had similar gross crop value.

4.2.6 Fruit Size Distribution

Thinning treatments had a marked effect on the size distribution of fruit in the following box sizes: 80 (P=0.0002), 88 (P<0.0001), 113 (P=0.0014), 125 (P<0.0001) and 138 (P-0.0108) (Table 9; Figure 9). For the untreated control treatment, most fruit (by weight) peaked in the 113-box size category while for the hand thinned control, most fruit peaked in the 100-box size category. Trees receiving chemical thinners had most falling within the 100-box size category. There were no treatment differences in the quantity of fruit in box size 150 or smaller.

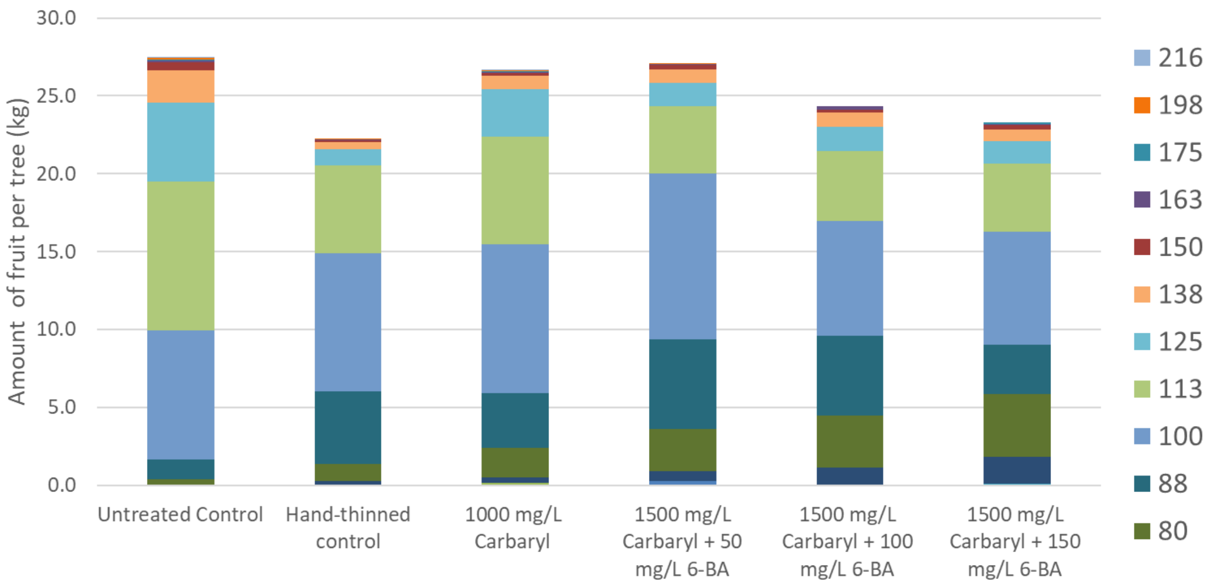

Figure 9. Influence of thinning treatments on size distribution of Gala fruit based on count/box size fruit categories (data taken from Table 9).

4.2.7 Fruit Quality

Thinning treatments had a significant effect on fruit length:width ratio (P<0.0001) and skin ground hue colour, but no effect on fruit density, percent of fruit skin with red blush, or skin blush hue colour determined from the optical sensor on the grading line (Table 10). Orthogonal contrasts indicated that increasing rates of 6-BA increased the fruit length: width in a linear fashion. All trees treated with 1500 mg/L carbaryl combined with 50-150 mg/L 6-BA had higher fruit length:width ratios. While trees that were hand-thinned had the lowest skin ground colour hue, there was no difference in this metric compared to the other treatments or the untreated control treatment. Overall, fruit had excellent blush colour with over 92% of the skin surface having red blush.

4.2.8 Return Bloom

Thinning treatments had a significant effect on return bloom, expressed as the percentage of flower spurs in 2025 (P=0.0006) and (Table 11). The untreated control trees had 56% spurs that were flowering, which was similar to the HTC and 1000 mg/L carbaryl (-50% thinning rate). Trees treated with the sprays of carbaryl tank mixed with 6-BA, all had highest percentage of spurs that were flowering - ranging from 79-80%.

Increasing rates of 6-BA combined with 1500 mg/L carbaryl failed to increase return bloom. It is noteworthy that the HTC had the lowest crop loads (Table 7) but this did not translate into the highest return bloom.

4.3 Experiment 3: Predicting Fruit Set Based on Early Fruit Growth (Objective 2)

4.3.1 Fruit Growth Model (FGM)

Fruitlet diameters were measured five different times at approximately 3-day intervals one day after the first application of chemical thinners. Average king and lateral fruitlet diameters varied by cultivar on each day (Table 12). Ambrosia fruitlets were smaller than Gala and Honeycrisp on each day. By the last measurement date, the number of king and lateral fruitlets that persisted in the fruiting cluster was reduced markedly from the first measurement date, particularly for Ambrosia. Overall, the Malusim FGM model predicted that 20, 203, and 78 Ambrosia, Gala, and Honeycrisp fruit, on average (n=5), would remain per tree at harvest, respectively, whereas actual numbers of fruit per tree were 52, 203, and 76, respectively (n=5) (Figure 10). This represents an accuracy of 158%, 0%, and -3% of actual measurements (Figure 11).

The number of flower clusters per tree ranged among the six trees used for the FGM. On average, Ambrosia, Gala and Honeycrisp trees had 265, 328, and 279 flower clusters, but the numbers varied among trees for each cultivar. The variation was greatest for Honeycrisp trees, indicated by a coefficient of variation (CV) of 29% compared to lower CV values for Ambrosia (17%) and Gala (19%). Average numbers of flowers per cluster were 3.8, 4.8 and 4.7 for Ambrosia, Gala, and Honeycrisp, respectively. Again, Honeycrisp had the greatest variation in the number of flowers per cluster among the 50-cluster sample.

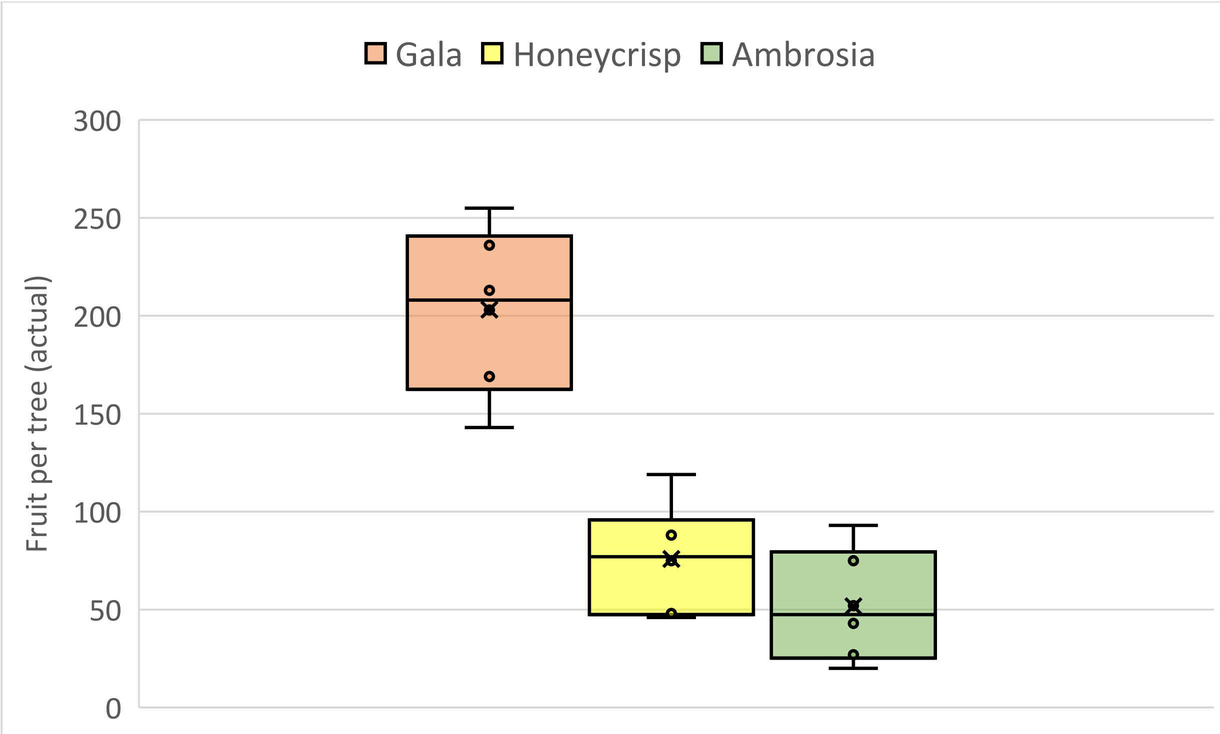

Figure 10. The actual number of fruit per tree measured at harvest on five Ambrosia, Gala, Honeycrisp trees using the fruit growth model (n=5 for each cultivar).

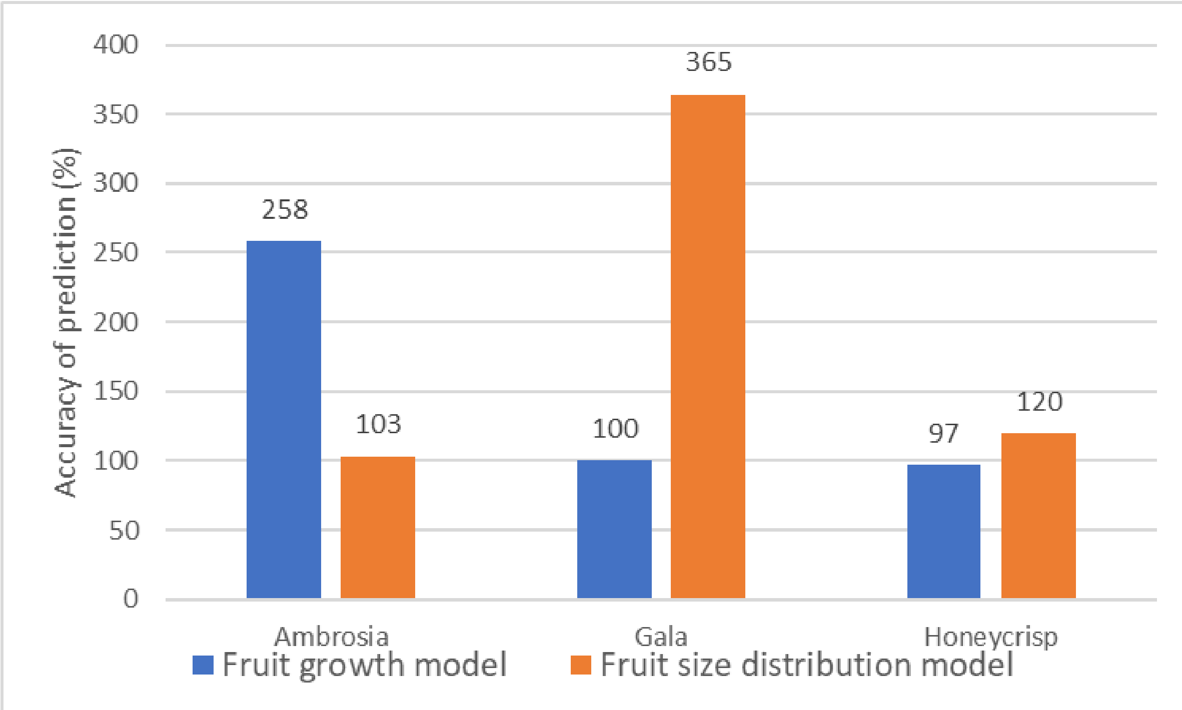

Figure 11. Accuracy of the fruit growth model (FGM) and fruit size distribution (FSD) model in predicting the number of Ambrosia, Gala, Honeycrisp fruit per tree at harvest (n=5 for the FGM, n=20 for the FSD). An accuracy of 100% indicates the model prediction was the same as the actual measurement.

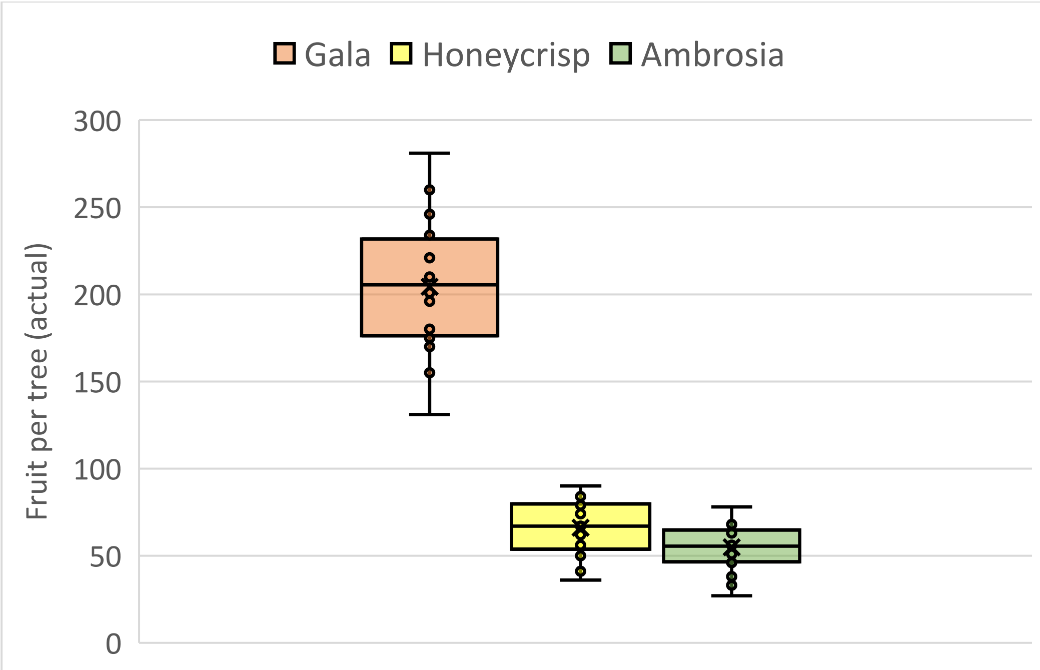

Figure 12. The actual number of fruit per tree measured at harvest on 20 Ambrosia, Gala, Honeycrisp trees using the fruit distribution model (n=20 for each cultivar).

4.3.2 Fruitlet size distribution model (Fruitlet weight method)

Fruitlet weights were measured four different times at 3- to 4-day intervals beginning two days after the first application of chemical thinners (Table 13). Generally, Ambrosia fruitlets were smaller than Gala and Honeycrisp on each day. By the last measurement date, the number fruitlets that persisted in the fruiting cluster was reduced markedly from the first measurement day, particularly for Ambrosia. Overall, the FSD model predicted that on average 27, 44, and 30 Ambrosia, Gala, and Honeycrisp fruit would remain per tree at harvest (n=5 trees), respectively, whereas actual numbers of fruit per tree were 55, 204, and 66, respectively (n=20) (Figure 12). These values represent overestimates of actual measurements by 3%, 265%, and 205%, respectively (Figure 11).

The number of flower clusters per tree ranged among the six trees used for the FSD (Table 11). On average, Ambrosia, Gala and Honeycrisp trees had 253, 406, and 265 flower clusters, but numbers varied among trees for each cultivar. The variation was greatest among Honeycrisp trees, indicated by a CV of 23% compared to lower CV values for Ambrosia (10%) and Gala (14%). Average numbers of flowers per cluster were 3.8, 4.8 and 4.7 for Ambrosia, Gala, and Honeycrisp, respectively. Again, Honeycrisp had the greatest variation in the number of flowers per cluster among the 50-cluster sample.

4.4 Investigate advancements in artificial intelligence-based computer vision technology to measure key indicators of crop load and improve crop load management outcomes.

4.4.1 Investigate grower adoption of AI-driven vision-automation technology to advance understanding of how these tools can collect and process flower and fruit numbers, and potentially fruit size to improve the precision and prediction of crop load management

In 2024, there appeared to be limited adoption of AI-driven computer vision technology by apple producers in Canada to assist with crop load management of apples. A few Ontario growers were using Vivid Machine's crop load management system, but cost may be an impediment for many growers. The business model for many of these start-up companies is to charge a minimum annual subscription or onboarding fee (e.g., an annual lease if a specialized camera is required) plus additional charges for software, scanning, mapping, and data analytics, usually based on the area (i.e., acres) scanned.

Larger growers appear to be early adopters of this technology. Because of their larger acreage and greater complexity in orchard management decisions, having insight into bloom levels and initial fruit set helps to inform crop load decisions. Decision support tools are particularly helpful when growers have several orchard blocks that may differ by age, cultivar, geographical location and phenological development. Moreover, the cost of these new digital technologies can be an impediment for smaller growers. For larger growers, the investment can be spread over greater acres, making the cost easier to justify. Additional challenges are the set-up time required for orchard scanning, as well as learning how to access the information and deciphering output to make informed orchard-management decisions.

4.4.2 Evaluate select digital technologies that use computer vision technology to count flower clusters and fruit during early development and measure the diameter of fruit as predictors of fruit set and to understand the variation in bloom and crop load in the orchard and factors that influence annual bearing.

The key indicators required to fully understand crop load are: i) number of flower clusters per tree; ii) number of developing fruitlets; iii) rate of diametric fruitlet growth (with a resolution of 1 mm and minimum fruit diameter of 8 mm); iv) number of developing fruit per cluster; v) trunk diameter/circumference to estimate a target crop load per tree, and; vi) final fruit number after natural abscission (‘June’ drop). To fully understand the impact of crop load on flower initiation and bearing the following year, repeat flower cluster counts at the single tree level are necessary.

For crop load management and physiology experiments, such as those being investigated in this project, having these metrics for each experimental tree in the research block is necessary. Some of these can be measured manually, where others such as whole tree flower and fruit counts are excessively time-consuming when several hundred trees are being investigated. For computer vision technologies, geospatial data is required to obtain repeat measurements at the single tree level, and as such requires submeter (cm) GPS accuracy and triangulation algorithms to detect where the tree is in reference to the camera.

4.4.2.1 Pometa - POMViz App

Prior to the start of this project, in 2023, a pilot study was conducted using the POMviz App (Pometa) to count flowers and fruit per tree and measure fruitlet size to determine its utility as a crop load management tool. Many features of this system were very useful as a research tool and for decision support (i.e., to inform decisions regarding chemical thinning of crop loads). In particular, the scans would provide a count of the number of fruitlets per tree, their size distribution and average fruitlet diameter (with a detection limit of approximately 4 mm), and the percentage of single, double or triple fruitlets per cluster (Figure 13). Unfortunately, as of 2024, the Pometa App is no longer commercially. Reasons for this were not given; Pometa simply stated that it was pursing digital technologies for other crops such as berries.

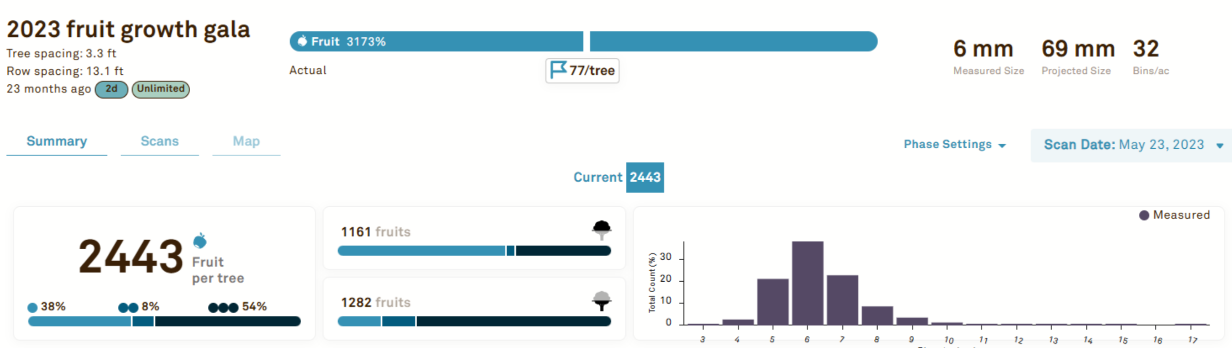

Figure 13. Visual output of the POMviz crop load App (Pometa) for a scan of a single Gala tree on May 23, 2023. The target crop load was set at 77 fruit per tree for the given

age and size of the trees in this orchard block.

4.4.2.2 Vivid Machines

We were unsuccessful at collaborating with Vivid Machines to evaluate their computer vision system for crop load management in 2024. In September 2024, we contacted Vivid Machines to reserve a camera for the 2025 growing season. However, the University of Guelph expressed concerns about assuming liability wherein the MSO agreement requests the lessor "…indemnify and defend Vivid Machines Inc in the event that any of our data that Vivid Machines Inc uses infringes someone else's rights." Consequently, we were unable to research a camera for 2025 and reach an agreement to test this system in this project. There are some characteristics of the Vivid system that may be a concern: i) only one side of the tree is scanned; ii) not all the raw metadata for each scan are available; iii) GPS positioning is +/-20cm; therefore, it may not work in high density orchards where single tree data are required; and iv) the systems provide the following data: latitude and longitude, timestamp, blossom or fruit count, average fruit size (per tree) and tree volume classification (currently L, M, H). For research purposes, we require access to all the raw data for each tree, not just the average fruit size. The minimum size and resolution of fruitlets for their camera are also unknown.

4.4.2.2 CropTracker – Crop Load Vision Module

CropTracker has a crop load vision fruit size and fruit count module that is included for members of the Ontario Apple Growers. We tested this briefly in late June 2024 to measure the number and size of apples on a single tree. The module does not measure flower clusters and has a minimum fruitlet size detection limit of approximately 15 mm. These are major limitations in providing meaningful information for managing crop load and adjusting spray recommendations during the chemical thinning window (8-15 mm fruitlet diameter). Notwithstanding, we found the App cumbersome and slow to use when scanning a single apple tree; one needs to watch the phone screen while scanning to avoid duplicate counts and it was clear that some fruitlet were missed while scanning – because they were occluded or simply were not detected by the algorithm. Further, the iPhone tended to overheat when doing multiple scans and it was not easy to input identification for each tree when scanning (e.g. a tree row and number) – which is necessary to collate information for repeat scan and overlay it with experimental treatments. In addition, the raw metadata for each fruitlet for the scan is not available to the user. We found the computer dashboard slow to respond when loading scan data. Also, there are errors with the size distribution data; the data is not normal in its distribution and the system is overestimating the size of fruits (for example on June 24, the system detected fruit between 3.25-3.5 inches – which is clearly not possible this early in the season). Because of these limitations, we will not be evaluation this system in the future.

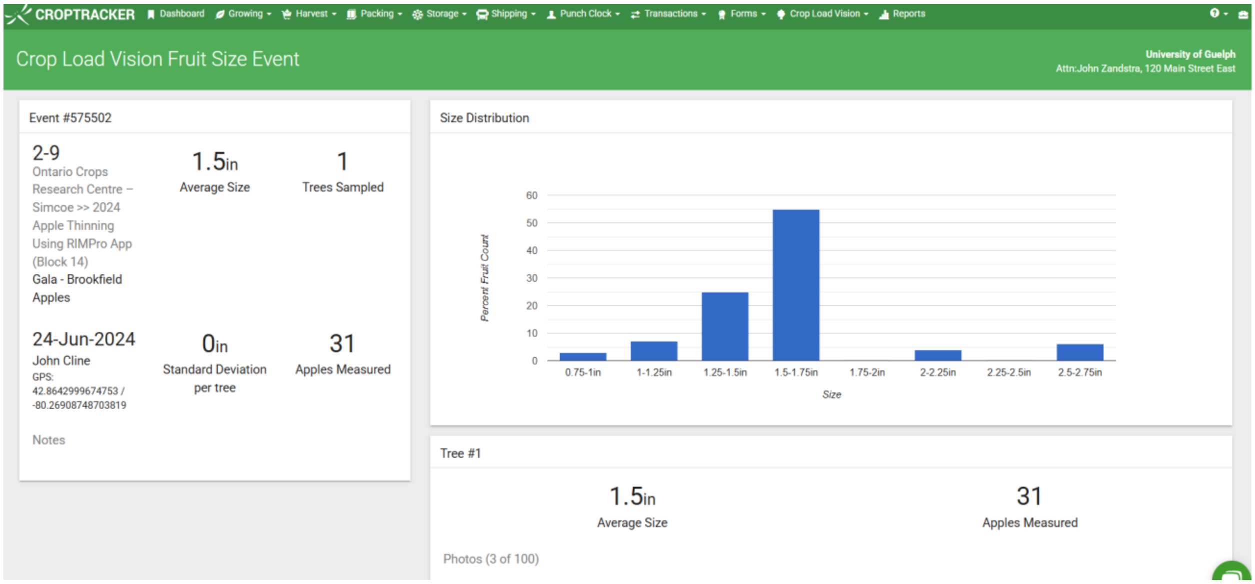

Figure 14. Computer dashboard output of the Crop Load Vision Fruit Size module within CropTracker on July 24, 2024. The output displays the average size of fruit and fruit size distribution (based on %).

5.0 Discussion

5.1 Objective 1: Investigate new innovative chemical thinning compounds

For this objective, crop load was evaluated in response to various rates of MET and combinations of MET with other chemical fruitlet thinners including 6-BA and carbaryl. In addition, later applications of MET and ACC were evaluated when fruitlets were 18- 20 mm diameter.

MET induced a mild level of thinning of Gala trees base on the slight to moderate reduction in fruit set, number of fruit per tree, and crop load. Further, treatment responses did not vary markedly between MET rates of 1.2, 1.8 and 2.4 L/ha. Despite this, MET treated trees had larger fruit, shifting the peak box-size count of the untreated control trees from 138 to 113 (an average 8% increase in fruit weight across all MET treatments). Moreover, the gross economic returns were markedly increased with MET applications compared with the untreated controls.

Fruit set and crop load of untreated trees was very high in this block. Further, the tank mix application of carbaryl and 6-BA, normally a very efficacious thinning combination, did not thin satisfactorily. Treatment and thinning response are invariably linked to weather conditions during and following spray applications. Trees were sprayed on 29-May (14 days after bloom), when the actual king and lateral fruit diameters were 10.1 mm and 7.4 mm, respectively. The second application of MET was made on 7 June when king and lateral fruit diameters were estimated to be 17.2 mm and 13.3 mm, respectively. Solar radiation levels and air temperatures remained high following the first treatment applications with no measurable rainfall between May 21 and June 7th. Maximum daytime air temperatures ranged from 22.3^{o}C to 33.3^{o}C seven days following the first application while minimum nighttime daily low temperature ranged from 8.6 – 17.1^{o}C for the same time period. With the high light levels, warm temperatures, combined with relatively low night-time air temperatures, fruit may have been more difficult to thin', even though the BreviSmart predicted 'good' thinning.

Overall, the effect of the MET treatments were comparable with the grower standard treatment of carbaryl combined with 6-BA. There was no clear additional thinning with the second application of MET.

5.2 Objective 2: Develop and implement decision support systems for producers to improve crop load management

In this objective, the effectiveness of the BreviSmart thinning model, RIMPro thinning model, the Fruit Growth model (FGM) and Fruit Size Distribution (FSD) model were evaluated as predictors of final fruit set and to improve thinning outcomes using chemical thinners.

5.2.1 BreviSmart Model

When MET was applied on 29-May-2204, the model predicted "Good" thinning conditions and to "keep your commonly used dose of Brevis® (-/+ 5%) – which Adama indicates is 1.8 L/ha for Ontario. Fruit set for trees that received a single spray of MET at 1.8 L/ha or higher concentration had lower fruit set compared to the untreated, with results comparable among the three rates (1.8, 2.3 and 2.9 L MET/ha). However, there was no effect of MET on reduction of total number of fruit per tree or crop load in comparison with the untreated control treatment. Furthermore, number of fruit per tree and crop load were comparable among the three rates of MET applied (1.8, 2.3 and 2.9 L MET/ha). Overall, the BreviSmart model did not accurately predict thinning efficacy of MET based on the final number of fruit per tree or crop load at harvest. Even if thinning conditions were considered, increasing rates above those recommended for (>2.3 L/ha) Ontario did not prove to be efficacious when applied as a single application at 8-10 mm fruitlet diameter stage of fruit development.

5.2.2 RIMPro Apple Fruit Thinning Model

Meteoblue sourced average daily temperatures were highly correlated with actual daily temperatures while the estimated average daily min and maximum air temperatures were less accurate. The cumulative error in the estimated average daily air temperature over the growing season, determined by calculating the cumulative degree days base 5^{o}C was withing 3.3% of the actual cumulative degree days measured. The RIMPro thinning model apparently relies on temperature and solar radiation inputs, but since solar radiation is not provided in RIMPro, it was not possible to compare its accuracy with actual measurements.

The Apple Fruit Thinning model provided within RIMPro was evaluated on the day of application of the thinners, 20-May 2024. Based on forecast weather data (assessed via Meteoblue within the model), the predicted thinning effect was slightly above “optimal” and the carbohydrate balance was slightly negative and the predicted fruit diameter was 10 mm. Unlike the Carbohydrate model available within NEWA, the RIMPro Apple Fruit Thinning Model does not specify how to adjust rates of chemical thinners or how to interpret the graphical output; it simply displays the current status relative to “risk for overthinning – lower dose”, “optimal thinning” and “little thinning – increase dose”. For example, the model fails to indicate how to adjust the amount of chemical thinner based on environmental conditions and consequently it is not particularly helpful as a decision support tool.

If we assume that the model in 2024 was indicating not to adjust the chemical thinner rates or at most reduce them by 15%, based on the experimental treatments, both scenarios reduced fruit set by 36 and 32% compared to the untreated control trees, respectively while number per tree was reduced by 14 and 25%, respectively. However, there was no difference in crop load of these two treatments compared to the untreated control.

Another complication of the Apple Fruit Thinning Model is a feature within the model that provides three radio buttons referred to as “Carbon balance (MET)”, “Chemistry update (hormones)", and "Combined effect". There is no explanation of how these options differ, or the algorithm used to distinguish them. Another potential problem is that when using the Apple Fruit Thinning Model, it relies on forecasted weather data after the chemical thinner is applied to predict what is termed "expected thinning effect". However, when the model is computed post-hoc after the thinners are applied, the results can differ widely because the model uses actual rather than forecasted (Meteoblue) data. Commercial practice requires growers to use the model in real time to guide chemically thinner application rates and timing, so having accurate forecast weather data would presumably make the output more reliable.

Another concern is that the model is based on predicted apple fruitlet diameter. There is no option for the user to input actual fruitlet diameters into the model interface, and it has been well established that when fruitlet diameters range between 8 and 15 mm, they are most sensitive to chemical thinning. We did not evaluate predicted verse actual fruitlet diameter in this study, but if the model is off by even a few millimeters, it could affect the accuracy of Apple Fruit Thinning Model.

Lastly, and most problematic is there is no documentation on the actual algorithm used in the Apple Fruit Thinning Model and how it differs or is similar to the Carbohydrate Model used in NEWA. We were unable to compare the two because the NEWA Carbohydrate Model is not available in Canada, but without clear documentation of the algorithm, one is left seriously wondering about the accuracy of the output and the RIMPro Apple Fruit Thinning Model.

Overall, the RIMPro Apple Fruit Thinning Model is not well supported; there is sparse documentation to explain the scientific basis and model inputs or discern how to interpret its output. For example, it is unclear if the RIMPro Apple Fruit Thinning Model uses the same algorithm as the NEWA carbohydrate model. Without some understanding of the algorithm, it is analogous to a 'black box" that theoretically RIMPro software engineers could change at anytime with the user knowing. This would complicate comparing data from one year to the next.

Predicting Fruit Set Based on Early Fruit Growth

Overall, the Malusim Fruit Growth Model was an effective tool for predicting fruit set and final crop load of Gala and Honeycrisp trees, but less effective for Ambrosia. Overall, the FGM model predicted estimated actual final crop loads at harvest within 58%, 0% (prediction was the same as actual) and 3% for Ambrosia, Gala and Honeycrisp. Its accuracy may be increased by measuring more trees or more fruit on a single tree. Also, efficiency of taking measurements can likely improved with Bluetooth calipers link to a tablet, which will be used in future years.

We found that the Fruit Size Distribution model was not more efficient (faster) than the Fruit Growth model. Overall, the FSD model over estimated actual final crop loads at harvest by 3%, 265%, and 205%, respectively for the Ambrosia, Gala, and Honeycrisp trees in this experiment.

5.3 Objective 3. Investigate advancements in artificial intelligent based computer vision technology to measure key indicators of crop load to improve crop load management outcomes.

There are two primary aims of this objective

a) Investigate grower adoption of AI-driven vision-automation technology to advance the understanding of how these tools can collect and processes flower and fruit numbers, and potentially fruit size to improve the precision and prediction of crop load management
b) Evaluate select digital technologies that use computer vision technology to count flower clusters, fruit during early development and measure the diameter of fruit as predictors of fruit set and to understand the variation in bloom and crop load in the orchard and factors that influence annual bearing.

In 2024, CropTracker - Crop Load Vision Module (CLVM) was the only commercial product available to evaluate. The CLVM module can count and measure the diameters of fruit but does not count the number of flowers. The module has a minimum fruitlet size detection limit of approximately 15 mm, which is a major limitation in providing meaningful information for managing crop load and adjusting spray recommendations during the chemical thinning window (8- 15 mm fruitlet diameter). Overall, the CLVM App was slow to use when scanning a single apple tree and subpar in comparison with the now defunct Pometa App we evaluated in 2023. Also, the iPhone tended to overheat when doing multiple scans and it was cumbersome and time consumer to input individual tree identification information when scanning (e.g., a tree row and number) – which is necessary to collate information for repeat scans and overlay it with experimental treatments. We also found the web-based desktop computer dashboard slow to respond when loading previously scanned data, and there were errors with the size distribution data; the data was often not normally distributed because the system would sometime over-estimate the size of fruits. For example, on June 24, the system detected fruit between 3.25-3.5 inches – which is clearly not possible this early in the season when fruit are 25–30 mm in diameter. Because of these limitations, we found this App has limited commercial potential in its current state for managing the crop load of apples.

6.0 Acknowledgements

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7.0 Literature Cited

Appenroth, K.J., J. Stockel, A. Srivastava, and R.J. Strasser. 2001. Multiple effects of chromate on the photosynthetic apparatus of *Spirodela polyrhiza* as probed by OJIP chlorophyll a fluorescence measurements. Environmental Pollution 115:49-64.

Castro, F.A., Campostrini, E., Torres Netto, A. and Viana, L.H., 2011. Relationship between photochemical efficiency (JIP-Test Parameters) and portable chlorophyll meter readings in papaya plants. Brazilian Journal of Plant Physiology 23:295-304.

Clements, J. 2025. Predicting fruit set using the fruitlet growth rate model [Online] https://ag.umass.edu/fruit/fact-sheets/hrt-recipe-predicting-fruit-set-using-fruitlet-growth-rate-model (accessed 14 Feb 2025)

Cline, J.A., Bakker, C.J. and Beneff, A., 2022. Multi-year investigation on the rate, timing, and use of surfactants for thinning apples with post-bloom applications of metamitron. Canadian Journal of Plant Science 102:1-28.

Greene, D.W., Lakso, A.N., Robinson, T.L. and Schwallier, P. 2013. Development of a fruitlet growth model to predict thinner response on apples. HortScience 48(5):584-

587DOI: https://doi.org/10.21273/HORTSCI.48.5.584.
Gonzalez Nieto, L., Wallis, A., Clements, J., Miranda Sazo, M., Kahlke, C., Kon, T.M. and Robinson, T.L., 2023. Evaluation of computer vision systems and applications to estimate trunk cross-sectional area, flower cluster number, thinning efficacy and yield of apple. Horticulturae 9(8), p.880.
Gonzalez Nieto, L., Wallis, A., Clements, J., Miranda Sazo, M., Kahlke, C., Kon, T.M. and Robinson, T.L. 2024. Predicting fruit set based on the fruit growth rate model with vision systems. Acta Hortic. 1395, 409-416 DOI: https://doi.org/10.17660/ActaHortic.2024.1395.54
Hillman, L, Einhorn. T. 2024. The fruit size distribution (FSD) model: A how-to guide. [Online]. https://pacman.extension.org/wp-content/uploads/2023/03/FS-Predict-Instructions.pdf (accessed 14 Feb 2025)
Hillmann, L., L. Gonzalez Nieto, T. Kon, S. Musacchi, T. Robinson, S. Serra, and T. Einhorn. 2022. A modified apple fruit set prediction model to guide repeat thinner applications. Fruit Quarterly 30(2):4-6 https://nyshs.org/wp-content/uploads/2022/08/NYFQ-BOOK-Summer-2022_PRINT.pdf
Lakso, A.N., and Robinson, T.L. 2015. Decision support for apple thinning based on carbon balance modeling. Acta Hortic. 1068: 235–242 https://doi.org/10.17660/ActaHortic.2015.1068.29.
Maxwell, K. and G.N. Johnson. 2000. Chlorophyll fluorescence—A practical guide. J. Expt. Bot. 51:659–668.
Ontario Apple Growers, 2022. Annual Report of the Ontario Apple Growers.
Ontario Ministry of Agriculture, Food and Rural Affairs. 2021. Fruit crop production guide 2018-2019. Publication 360. 2 March 2020.
Robinson, T., Lakso, A., Greene, D., and Hoying, S. 2013. Precision crop load management part 1. New York Fruit Quarterly *21*, 3–9.
Robinson, T.L., Gonzalez, L., Cheng, L., Ziang, Y., Peck, G., Arnoldussen, B., Gomez, M., Guerra, M., Miranda Sazo, M., Kahlke, C., et al. (2023). Studies in precision crop load management of apple. Acta Hortic. *1366*, 219–226 https://doi.org/10.17660/ActaHortic.2023.1366.25.
Schwallier, P., and Irish-Brown, 2014. Predicting Fruitset Model [Online]. https://www.canr.msu.edu/uploads/files/predictingfruitset1-21-14.pdf (assessed 14 Feb 2025).
Solomakhin, A.A. and Blanke, M.M. 2010. Mechanical flower thinning improves the fruit quality of apples. J. Science of Food and Agr., 90:735-741.
Strasser, R.J., Srivastava, A. and Tsimilli-Michael, M., 2000. The fluorescence transient as a tool to characterize and screen photosynthetic samples. In Probing

photosynthesis: mechanisms, regulation and adaptation, 25, pp.445-483.
Strasser, R.J., Tsimilli-Michael, M. and Srivastava, A., 2004. Analysis of chlorophyll fluorescence transient. In: Chlorophyll a fluorescence: a signature of photosynthesis (pp. 321-362). Dordrecht: Springer, Netherlands.
Sutton, T.B. and Unrath, C.R., 1988. Evaluation of the tree-row-volume model for full-season pesticide application on apples. Plant Disease, 72(7):629-632.
Wallis, A., J. Clements, M. M. Sazo, C. Kahlke, K. Lewis, T. Kon, L. Gonzalez, Y. Jiang, and T. Robinson. 2023. Digital Technologies for Precision Apple Crop Load Management (PACMAN) Part I: Experiences with Tools for Predicting Fruit Set Based on the Fruit Growth Rate Model. Fruit Quarterly, Volume 31, Number 1, Spring 2023. https://nyshs.org/spring-2023/

Table 1. Influence of carbaryl (CB), 6-benzyladenine (6-BA), metamitron and 1-ACC applied at various rates and timings, and use of BreviSmart decision making support system on fruit set in 2024 of 'Crimson Gala'/M.9 T337 apple trees.[a]

Treatment	Application timing[b]	Mean fruit set (no fruit/100 flower clusters)		Reduction in fruit set compared to the untreated control (%)	Percentage of flowering spurs with indicated number of fruit							
					0		1		2		3	
Untreated Control		79.3	a		32.2	d	57.7	a	9.7	ab	0.3	a
Hand-thinned control	June Drop	78.2	ab	1	34.7	cd	52.8	ab	12.2	a	0.3	a
1500 mg L^{-1} CB + 75 mg L^{-1} 6-BA	9 mm	38.7	d	41	62.0	a	37.4	b	0.6	e	0.0	a
1.8 L ha^{-1} Metamitron	9 mm	52.0	cd	27	52.7	ab	43.8	ab	3.5	cde	0.0	a
2.3 L ha^{-1} Metamitron	9 mm	58.9	bcd	20	49.8	abc	45.4	ab	4.8	bcde	0.0	a
2.9 L ha^{-1} Metamitron	9 mm	52.6	cd	27	52.4	ab	42.8	ab	4.5	bcde	0.3	a
1.8 L ha^{-1} Metamitron + 75 mg L^{-1} 6-BA	9 mm	59.6	abc	20	47.5	abcd	45.7	ab	6.4	bcd	0.4	a
2.3 L ha^{-1} Metamitron + 75 mg L^{-1} 6-BA	9 mm	60.6	abc	19	47.0	abcd	48.6	ab	4.5	bcde	0.0	a
2.3 L ha^{-1} Metamitron	9 mm	63.0	abc	16	44.7	bcd	47.5	ab	7.8	abc	0.0	a
1.8, 1.8 L ha^{-1} Metamitron (BreviSmart)	9 mm, 16 mm	50.6	cd	29	53.5	ab	44.7	ab	1.8	de	0.0	a
400 mg L^{-1} 1-ACC	16 mm	64.5	abc	15	45.9	bcd	44.5	ab	8.7	abc	0.9	a
P value		<0.0001			<0.0001		0.0096		<0.0001		0.0360	
Contrasts[c]												
Metamitron Rate		L***			L***		L**		L**		ns	
Metamitron vs Metamitron + 6-BA		ns			ns		ns		ns		ns	
Metamitron 1 vs 2 applications		ns			ns		ns		ns		ns	

[a] Mean values with the same letter within a given column are not significantly different according to Tukey's HSD test at P=0.05.

[b] CB + 6-BA applied on 20 May (8-12 mm); metamitron applied on 20 May (8-12 mm), 30 May (14-16 mm); 1-ACC applied 30 May (18 mm).

[c] Contrasts include different confidence levels at *=0.05, **=0.01 and ***=<0.0001, where L represents linear contrast, Q represents quadratic contrast, and ns represents nonsignificant differences.

Table 2. Influence of carbaryl (CB), 6-benzyladenine (6-BA), metamitron and 1-ACC applied at various rates and timings, and use of BreviSmart decision making support system on harvest parameters of 'Crimson Gala'/ M.9 T337 apple in 2024.[a]

Treatment	Application timing[b]	Total fruit yield (kg/tree)	Total number of fruit (no/tree)	Reduction in fruit per tree compared with the untreated control (%)	Percent marketable fruit (%)	Mean weight of marketable fruit (g)	Mean weight of all harvested fruit (g)	Adjusted mean weight of all harvested fruit (g)[c]	Crop load (no. fruit /TCSA[d])	Economic return ($/tree)	Economic return ($/ha)
Untreated Control		36.3 a	251 a		76 a	151 c	145 d	155 b	11.3 a	25.53	70,926
Hand-thinned control	June Drop	27.5 bc	158 bcd	37	91 a	177 ab	175 ab	166 ab	6.1 c	27.18	75,494
1500 mg L^{-1} CB + 75 mg L^{-1} 6-BA	8-12 mm	33.3 ab	195 abcd	22	78 a	170 ab	171 abc	172 a	8.9 abc	28.63	79,521
1.8 L ha^{-1} Metamitron	8-12 mm	31.5 abc	202 abc	19	77 a	162 abc	157 bcd	165 ab	10.9 ab	24.29	67,478
2.3 L ha^{-1} Metamitron	8-12 mm	32.2 abc	203 abc	19	85 a	165 abc	160 abcd	161 ab	8.7 abc	27.68	76,904
2.9 L ha^{-1} Metamitron	8-12 mm	31.2 abc	199 abc	21	83 a	166 abc	160 abcd	159 ab	8.2 abc	25.51	70,866
1.8 L ha^{-1} Metamitron + 75 mg L^{-1} 6-BA	8-12 mm	32.5 abc	212 ab	15	77 a	159 bc	154 cd	160 ab	10.3 ab	24.64	68,440
2.3 L ha^{-1} Metamitron + 75 mg L^{-1} 6-BA	8-12 mm	32.7 abc	208 ab	17	80 a	163 abc	158 abcd	160 ab	9.3 abc	26.12	72,559
2.3 L ha^{-1} Metamitron	18 mm	25.4 bc	144 cd	42	92 a	180 a	177 a	169 ab	6.3 c	24.96	69,325
1.8, 1.8 L ha^{-1} Metamitron (BreviSmart)	8-12 mm, 14-16 mm	24.5 c	139 d	45	90 a	181 a	177 a	167 ab	5.8 c	24.41	67,812
400 mg L^{-1} 1-ACC	18 mm	30.4 abc	189 bcd	25	89 a	164 abc	162 abcd	158 ab	7.6 bc	25.24	70,130
P value		0.0004	<0.0001		0.0039	<0.0001	<0.0001	0.0381	<0.0001	0.8162	0.8162
Contrasts[e]											
Metamitron Rate		L*	L**		ns	L**	L**	ns	L**	ns	ns
Metamitron vs Metamitron + 6-BA		ns	ns		ns	ns	ns	ns	ns	ns	ns
Metamitron 1 vs 2 applications		**	**		*	**	**	ns	***	ns	ns

[a] Mean values with the same letter within a given column are not significantly different according to Tukey's HSD test at $P = 0.05$.

[b] CB + 6-BA applied on 20 May (8-12 mm); metamitron applied on 20 May (8-12 mm), 30 May (14-16 mm); 1-ACC applied 30 May (18 mm).

[c] Mean weight of marketable fruit and mean weight of all harvested fruit adjusted using Crop Load as a covariate.

[d] Trunk cross-sectional area. Crop load determined by dividing the total number of fruit harvested by the TCSA measured.

[e] Contrasts include different confidence levels at *=0.05, **=0.01 and ***=<0.0001, where L represents linear contrast, Q represents quadratic contrast, and ns represents nonsignificant differences.

Table 3.Influence of carbaryl (CB), 6-benzyladenine (6-BA), metamitron and 1-ACC applied at various rates and timings, and use of BreviSmart decision making support system on the weight of fruit per count size of 'Crimson Gala'/ M.9 T337 apples in 2024.[a]

		kg fruit per tree in each size category[c]																			
Treatment	Application timing[b]	64[d]		72	80	88		100	113		125		138		150		163		175	198	216
Untreated Control		0.00	a	0.00	0.00	0.56	b	4.52	11.37	a	10.02	a	5.59	a	2.64	a	1.09	a	0.23	0.14	0.10
Hand-thinned control	June Drop	0.00	a	0.10	0.88	2.05	ab	9.74	8.67	a	4.37	bc	1.37	b	0.25	b	0.04	b	0.04	0.04	0.00
1500 mg L^{-1} CB + 75 mg L^{-1} 6-BA	8-12 mm	0.00	a	0.13	1.12	3.72	a	9.46	11.07	a	5.22	bc	1.58	ab	0.68	ab	0.17	ab	0.00	0.00	0.00
1.8 L ha^{-1} Metamitron	8-12 mm	0.00	a	0.00	0.13	0.79	ab	7.76	12.38	a	6.11	abc	3.25	ab	0.67	ab	0.29	ab	0.06	0.05	0.03
2.3 L ha^{-1} Metamitron	8-12 mm	0.00	a	0.00	0.22	1.27	ab	8.05	11.14	a	6.86	abc	3.33	ab	0.70	ab	0.28	ab	0.13	0.06	0.16
2.9 L ha^{-1} Metamitron	8-12 mm	0.00	a	0.11	0.11	1.44	ab	6.87	10.95	a	5.74	abc	3.69	ab	1.49	ab	0.48	ab	0.11	0.15	0.06
1.8 L ha^{-1} Metamitron + 75 mg L^{-1} 6-BA	8-12 mm	0.00	a	0.00	0.38	0.87	ab	6.81	11.98	a	8.00	ab	3.06	ab	0.83	ab	0.44	ab	0.06	0.11	0.00
2.3 L ha^{-1} Metamitron + 75 mg L^{-1} 6-BA	8-12 mm	0.00	a	0.00	0.42	1.32	ab	8.39	10.74	a	6.64	abc	3.01	ab	1.57	ab	0.37	ab	0.18	0.06	0.04
2.3 L ha^{-1} Metamitron	18 mm	0.16	a	0.00	0.45	2.59	ab	8.33	7.35	a	3.98	bc	1.42	b	0.65	ab	0.28	ab	0.12	0.27	0.03
1.8, 1.8 L ha^{-1} Metamitron (BreviSmart)	8-12 mm, 14-16 mm	0.00	a	0.00	0.73	2.45	ab	8.83	7.80	a	2.41	c	1.46	ab	0.21	b	0.22	ab	0.09	0.00	0.07
400 mg L^{-1} 1-ACC	18 mm	0.00	a	0.00	0.11	1.28	ab	5.67	8.60	a	7.10	ab	4.41	ab	2.15	ab	0.54	ab	0.33	0.11	0.08
P value		0.0357		0.6438	0.2530	0.0281		0.1908	0.0300		0.0001		0.0135		0.0073		0.1259		0.7828	0.7947	0.5064
Contrasts[e]																					
Metamitron Rate		ns		ns	ns	ns		ns	ns		L**		ns		L*, Q*		L*		ns	ns	ns
Metamitron vs Metamitron + 6-BA		ns		ns	ns	ns		ns	ns		ns		ns		ns		ns		ns	ns	ns
Metamitron 1 vs 2 applications		ns		ns	ns	ns		ns	**		*		ns		ns		ns		ns	ns	ns

[a] Mean values with the same letter within a given column are not significantly different according to Tukey's HSD test at *P*=0.05.

[b] CB + 6-BA applied on 20 May (8-12 mm); metamitron applied on 20 May (8-12 mm), 30 May (14-16 mm); 1-ACC applied 30 May (18 mm).

[c] Fruit diameter equivalents for each count size: 48 = >98, 56 = 95-98 mm, 64 = 92-95 mm, 72 = 89-92 mm, 80 = 84.5-89 mm, 88 = 83-84.5 mm, 100 = 79-83 mm, 113 = 76-79 mm, 125 = 73-76 mm, 138 = 70-73 mm, 150 = 67-70 mm, 163 = 64-67 mm, 175 = 60-64 mm, 198 = 57-60 mm, 216 = <57 mm.

[d] The mean separation does not reflect all significant comparisons. The 2.3 L ha^{-1} Metamitron (18 mm) treatment is significantly different from the following treatments: 400 mg L^{-1} ACC, CB + 6-BA, 1.8 L ha^{-1} Metamitron (8-12 mm), 2.3 L ha^{-1} Metamitron + 6-BA, 1.8 L ha^{-1} Metamitron + 6-BA, Hand-thinned control, Untreated control, 2.3 L ha^{-1} Metamitron (8-12 mm), 2.9 L ha^{-1} Metamitron.

[e] Contrasts include different confidence levels at *=0.05, **=0.01 and ***=<0.0001, where L represents linear contrast, Q represents quadratic contrast, and ns represents nonsignificant differences.

Table 4. Severity of phytotoxicity following applications of carbaryl (CB), 6-benzyladenine (6-BA), metamitron and 1-ACC applied at various rates and timings, and use of BreviSmart decision making support system on 'Crimson Gala'/M.9 T337 apple trees.[a]

Treatment	Application timing[b]	27-May Rating (Brevis Scale 1 [uneffected] -9 [entire leaf necrosis])[c]	27-May % of leaves affected		3-Jun Rating (Brevis Scale 1 [uneffected] -9 [entire leaf necrosis])	3-Jun % of leaves affected	10-Jun Rating (Brevis Scale 1 [uneffected] -9 [entire leaf necrosis])	10-Jun % of leaves affected
Untreated Control		1.0	0.0	a	1.2	0.2	1.0	0.0
Hand-thinned control	June Drop	1.0	0.0	a	1.2	0.3	1.1	0.1
1500 mg L^{-1} CB + 75 mg L^{-1} 6-BA	8-12 mm	1.0	0.0	a	1.1	0.1	1.0	0.0
1.8 L ha^{-1} Metamitron	8-12 mm	1.2	0.2	a	1.1	0.1	1.1	0.1
2.3 L ha^{-1} Metamitron	8-12 mm	1.1	0.1	a	1.2	0.3	1.2	0.2
2.9 L ha^{-1} Metamitron	8-12 mm	1.3	0.3	a	1.5	0.5	1.1	0.1
1.8 L ha^{-1} Metamitron + 75 mg L^{-1} 6-BA	8-12 mm	1.4	0.4	a	1.3	0.2	1.1	0.1
2.3 L ha^{-1} Metamitron + 75 mg L^{-1} 6-BA	8-12 mm	1.3	0.4	a	1.2	0.2	1.1	0.1
2.3 L ha^{-1} Metamitron	18 mm	1.1	0.1	a	1.0	0.0	1.1	0.1
1.8, 1.8 L ha^{-1} Metamitron (BreviSmart)	8-12 mm, 14-16 mm	1.2	0.2	a	1.2	0.2	1.3	0.3
400 mg L^{-1} 1-ACC	18 mm	1.0	0.0	a	1.2	0.2	1.2	0.2
P value		0.0754	0.0395		0.5219	0.7228	0.7756	0.7756
Contrasts[d]								
Metamitron Rate		ns	ns		ns	ns	ns	ns
Metamitron vs Metamitron + 6-BA		ns	*		ns	ns	ns	ns
Metamitron 1 vs 2 applications		ns	ns		ns	ns	ns	ns

[a] Mean values with the same letter within a given column are not significantly different according to Tukey's HSD test at *P* =0.05.

[b] CB + 6-BA applied on 20 May (8-12 mm); metamitron applied on 20 May (8-12 mm), 30 May (14-16 mm); 1-ACC applied 30 May (18 mm).

[c] 1 = No symptoms, 2 = Light yellow discoloration between the veins, 3 = Yellow discoloration between the veins, beginning of necrosis on the edge and on the tip of the leaf, 4 = Strong yellow discoloration between the veins and beginning of necrosis on the edge of the leaf (1-2 mm) from the tip, 5 = Strong yellow discoloration between the veins and spread of necrosis from the edge (4-5 mm) to the base of the leaf, 6 = Reduction of leaf area by necrosis that spreads to the center and the base of the leaf, 7 = Reduction of leaf area by necrosis that spreads to the center and the base of the leaf, leaf starts to curl (spoon shape), 8 = Only an area of 1 cm wide remains green around the main vein, leaf curled, some leaves drop, 9 = Leaf entirely necrosed and curled,

[d] Contrasts include different confidence levels at *=0.05, **=0.01 and ***=<0.0001, where L represents linear contrast, Q represents quadratic contrast, and ns represents nonsignificant differences.

Table 5. Influence of carbaryl (CB), 6-benzyladenine (6-BA), metamitron and 1-ACC applied at various rates and timings, and use of BreviSmart decision making support system on fruit quality in 2024 of 'Crimson Gala'/ M.9 T337 apple trees. [a]

Treatment	Application timing[b]	Fruit density (g/cm^3)	Length to width ratio		Skin percent red (%)		Skin ground hue	Skin blush hue
Untreated Control		0.732	1.040	a	80.5	a	143.8	182.7
Hand-thinned control	June Drop	0.722	1.044	a	89.7	a	139.7	183.3
1500 mg L^{-1} CB + 75 mg L^{-1} 6-BA	8-12 mm	0.727	1.042	a	81.0	a	141.9	182.5
1.8 L ha^{-1} Metamitron	8-12 mm	0.727	1.041	a	80.2	a	141.1	182.3
2.3 L ha^{-1} Metamitron	8-12 mm	0.727	1.041	a	88.2	a	144.8	183.3
2.9 L ha^{-1} Metamitron	8-12 mm	0.729	1.041	a	87.3	a	140.3	183.0
1.8 L ha^{-1} Metamitron + 75 mg L^{-1} 6-BA	8-12 mm	0.732	1.040	a	85.3	a	144.1	182.7
2.3 L ha^{-1} Metamitron + 75 mg L^{-1} 6-BA	8-12 mm	0.731	1.042	a	87.6	a	140.8	183.4
2.3 L ha^{-1} Metamitron	18 mm	0.728	1.043	a	91.2	a	140.1	184.0
1.8, 1.8 L ha^{-1} Metamitron (BreviSmart)	8-12 mm, 14-16 mm	0.725	1.043	a	88.9	a	140.4	183.4
400 mg L^{-1} 1-ACC	18 mm	0.731	1.041	a	85.8	a	140.3	183.8
P value		0.1826	0.0274		0.0474		0.6888	0.8295
Contrasts[c]								
Metamitron Rate		ns	ns		L*		ns	ns
Metamitron vs Metamitron + 6-BA		ns	ns		ns		ns	ns
Metamitron 1 vs 2 applications		ns	ns		*		ns	ns

[a] Mean values with the same letter within a given column are not significantly different according to Tukey's HSD test at *P* =0.05.

[b] CB + 6-BA applied on 20 May (8-12 mm); metamitron applied on 20 May (8-12 mm), 30 May (14-16 mm); 1-ACC applied 30 May (18 mm).

[c] Contrasts include different confidence levels at *=0.05, **=0.01 and ***=<0.0001, where L represents linear contrast, Q represents quadratic contrast, and ns represents nonsignificant differences.

Table 6. Influence of carbaryl (CB), 6-benzyladenine (6-BA), metamitron and 1-ACC applied at various rates and timings, and use of BreviSmart decision making support system on return bloom in 2025 for treatments applied in 2024 on 'Crimson Gala'/ M.9 T337 apple trees.[a]

Treatment	Application timing[b]	Percent of flowering spurs	
Untreated Control		42	d
Hand-thinned control	June Drop	74	ab
1500 mg L^{-1} CB + 75 mg L^{-1} 6-BA	8-12 mm	74	ab
1.8 L ha^{-1} Metamitron	8-12 mm	55	bcd
2.3 L ha^{-1} Metamitron	8-12 mm	68	abc
2.9 L ha^{-1} Metamitron	8-12 mm	55	bcd
1.8 L ha^{-1} Metamitron + 75 mg L^{-1} 6-BA	8-12 mm	53	bcd
2.3 L ha^{-1} Metamitron + 75 mg L^{-1} 6-BA	8-12 mm	48	cd
2.3 L ha^{-1} Metamitron	18 mm	70	abc
1.8, 1.8 L ha^{-1} Metamitron (BreviSmart)	8-12 mm, 14-16 mm	78	a
400 mg L^{-1} 1-ACC	18 mm	68	abc
P value		<0.001	
Contrasts[c]			
Metamitron Rate		L*, C*	
Metamitron vs Metamitron + 6-BA		*	
Metamitron 1 vs 2 applications		0.0010	

[a] Mean values with the same letter within a given column are not significantly different according to Tukey's HSD test at *P* =0.05.

[b] CB + 6-BA applied on 20 May (8-12 mm); metamitron applied on 20 May (8-12 mm), 30 May (14-16 mm); 1-ACC applied 30 May (18 mm).

[c] Contrasts include different confidence levels at *=0.05, **=0.01 and ***=<0.0001, where L represents linear contrast, Q represents quadratic contrast, and ns represents nonsignificant differences.

Table 7. Influence of carbaryl and 6-benzyladenine (6-BA) applied at various rates adjusted according to the RIMPro decision support system on fruit set in 2024 of 'Crimson Gala'/M.9 T337 apple trees.[a]

Treatment	Adjusted rate of thinner	Application timing[b]	Mean fruit set (no. fruit/100 flower clusters)		Reduction in fruit set compared to the untreated control (%)	Percentage of flowering spurs with indicated number of fruit						
						0		1		2		3
Untreated Control	-		59.5	ab		46.0	bc	48.5	a	5.5	ab	0.0
Hand-thinned control	-	June Drop	66.6	a	-12	42.6	c	48.1	ab	9.3	a	0.1
1000 mg/L Carbaryl	-50%	8 mm	46.9	bc	21	57.4	ab	38.2	abc	4.4	b	0.0
1500 mg/L Carbaryl + 50 mg/L 6-BA	-15%	8 mm	38.3	c	36	63.4	a	34.9	c	1.7	b	0.0
1500 mg/L Carbaryl + 100 mg/L 6-BA	0%	8 mm	40.6	c	32	61.0	a	37.5	bc	1.3	b	0.2
1500 mg/L Carbaryl + 150 mg/L 6-BA	30%	8 mm	33.1	c	44	68.8	a	29.4	c	1.6	b	0.2
P value			<0.0001			<0.0001		<0.0001		<0.0001		0.6878
Contrasts[c]												
Rate of 6-BA			ns			ns		ns		ns		ns

[a] Mean values with the same letter within a given column are not significantly different according to Tukey's HSD test at *P* =0.05.

[b] Chemical thinner treatments applied on 20 May 2024 (8 mm); Trees were hand thinned on 20 June 2024.

[c] Contrasts include different confidence levels at *=0.05, **=0.01 and ***=<0.0001, where L represents linear contrast, Q represents quadratic contrast, and ns represents nonsignificant differences.

Table 8. Influence of carbaryl and 6-benzyladenine (6-BA) applied at various rates adjusted according to the RIMPro decision support system on harvest parameters of 'Crimson Gala'/ M.9 T337 apple in 2024.[a]

Treatment	Adjusted rate of thinner	Application timing[b]	Total fruit yield (kg/tree)		Total number of fruit (no/tree)		Reduction in fruit per tree compared with the untreated control (%)	Percent marketable fruit (%)	Mean weight of marketable fruit (g)		Mean weight of all harvested fruit (g)		Adjusted mean weight of all harvested fruit (g)[c]		Crop load (no. fruit /TCSA[d])		Estimated gross crop value ($/tree)	Estimated gross crop value ($/ha)
Untreated Control	-		27.4	a	171	a		85	166	b	161	b	173	c	10.2	a	24.99	79,354
Hand-thinned control	-	June Drop	22.3	c	118	c	31	90	193	a	190	a	182	abc	6.3	b	23.94	76,020
1000 mg/L Carbaryl	-50%	8 mm	26.6	ab	150	ab	12	85	184	a	179	a	179	bc	7.8	ab	26.21	83,224
1500 mg/L Carbaryl + 50 mg/L 6-BA	-15%	8 mm	27.1	a	147	ab	14	86	191	a	187	a	191	a	8.8	ab	28.07	89,125
1500 mg/L Carbaryl + 100 mg/L 6-BA	0%	8 mm	24.3	abc	128	bc	25	86	195	a	192	a	190	a	7.7	ab	25.28	80,257
1500 mg/L Carbaryl + 150 mg/L 6-BA	30%	8 mm	23.3	bc	124	bc	28	91	195	a	192	a	188	ab	7.0	b	25.39	80,619
P value			0.0003		<0.0001			0.1260	<0.0001		<0.0001		0.0003		0.0019		0.1188	0.1188
Contrasts[e]																		
Rate of 6-BA			L**		L*			ns	ns		ns		ns		L*		ns	ns

[a] Mean values with the same letter within a given column are not significantly different according to Tukey's HSD test at P=0.05.

[b] Chemical thinner treatments applied on 20 May 2024 (8 mm); Trees were hand thinned on 20 June 2024. x`

[c] Mean weight of marketable fruit and mean weight of all harvested fruit adjusted using Crop Load as a covariate.

[d] Trunk cross-sectional area. Crop load determined by dividing the total number of fruit harvested by the TCSA measured.

[e] Contrasts include different confidence levels at *=0.05, **=0.01 and ***=<0.0001, where L represents linear contrast, Q represents quadratic contrast, and ns represents nonsignificant differences.

Table 9. Influence of carbaryl and 6-benzyladenine (6-BA) applied at various rates adjusted according to the RIMPro decision support system on the weight of fruit per count size of 'Crimson Gala'/ M.9 T337 apples in 2024.[a]

Treatment	Adjusted rate of thinner	Application timing[b]	kg fruit per tree in each size category[c]														
			48	56	64	72	80	88	100	113	125	138	150	163	175	198	216
Untreated Control	-		0.00	0.00	0.00	0.00 b	0.37 c	1.29 c	8.30	9.56 a	5.06 a	2.05 a	0.54	0.10	0.05	0.10	0.04
Hand-thinned control	-	June Drop	0.00	0.00	0.00	0.28 ab	1.08 bc	4.69 ab	8.87	5.59 b	1.07 c	0.46 b	0.12	0.04	0.00	0.03	0.00
1000 mg/L Carbaryl	-50%	8 mm	0.00	0.13	0.00	0.38 ab	1.85 abc	3.52 abc	9.58	6.89 ab	3.06 b	0.88 ab	0.15	0.05	0.09	0.04	0.01
1500 mg/L Carbaryl + 50 mg/L 6-BA	-15%	8 mm	0.29	0.00	0.00	0.62 ab	2.68 ab	5.77 a	10.68	4.30 b	1.49 bc	0.86 ab	0.30	0.05	0.00	0.04	0.00
1500 mg/L Carbaryl + 100 mg/L 6-BA	0%	8 mm	0.00	0.00	0.07	1.07 ab	3.33 a	5.13 ab	7.35	4.51 b	1.55 bc	0.93 ab	0.18	0.21	0.00	0.00	0.00
1500 mg/L Carbaryl + 150 mg/L 6-BA	30%	8 mm	0.00	0.00	0.11	1.70 a	4.03 a	3.17 bc	7.25	4.40 b	1.40 bc	0.79 ab	0.26	0.08	0.11	0.00	0.00
P value			0.4346	0.4346	0.5451	0.0349	0.0002	<0.0001	0.1079	0.0014	<0.0001	0.0108	0.2408	0.1999	0.3610	0.3441	0.4904
Contrasts[d]																	
Rate of 6-BA			ns	ns	ns	L*	ns	L**	L*	ns	ns	ns	ns	Q*	ns	ns	ns

[a] Mean values with the same letter within a given column are not significantly different according to Tukey's HSD test at *P* =0.05.

[b] Chemical thinner treatments applied on 20 May 2024 (8 mm); Trees were hand thinned on 20 June 2024

[c] Fruit diameter equivalents for each count size: 48 = >98, 56 = 95-98 mm, 64 = 92-95 mm, 72 = 89-92 mm, 80 = 84.5-89 mm, 88 = 83-84.5 mm, 100 = 79-83 mm, 113 = 76-79 mm, 125 = 73-76 mm, 138 = 70-73 mm, 150 = 67-70 mm, 163 = 64-67 mm, 175 = 60-64 mm, 198 = 57-60 mm, 216 = <57 mm.

[d] Contrasts include different confidence levels at *=0.05, **=0.01 and ***=<0.0001, where L represents linear contrast, Q represents quadratic contrast, and ns represents nonsignificant differences.

Table 10. Influence of carbaryl and 6-benzyladenine (6-BA) applied at various rates adjusted according to the RIMPro decision support system on fruit quality in 2024 of 'Crimson Gala'/ M.9 T337 apple trees.[a]

Treatment	Adjusted rate of thinner	Application timing[b]	Fruit density (g/cm^3)	Length to width ratio		Skin percent red (%)	Skin ground hue		Skin blush hue
Untreated Control	-		0.743	1.0389	c	95.4	136.3	ab	185.7
Hand-thinned control	-	June Drop	0.733	1.0432	ab	97.4	123.3	b	187.2
1000 mg/L Carbaryl	-50%	8 mm	0.733	1.0422	bc	92.8	140.2	a	184.4
1500 mg/L Carbaryl + 50 mg/L 6-BA	-15%	8 mm	0.737	1.0438	ab	95.0	135.6	ab	185.7
1500 mg/L Carbaryl + 100 mg/L 6-BA	0%	8 mm	0.729	1.0445	ab	95.9	132.5	ab	186.1
1500 mg/L Carbaryl + 150 mg/L 6-BA	30%	8 mm	0.729	1.0462	a	96.7	132.3	ab	185.7
P value			0.2087	<0.0001		0.1307	0.0244		0.3040
Contrasts[c]									
Rate of 6-BA			ns	L*		ns	ns		ns

[a] Mean values with the same letter within a given column are not significantly different according to Tukey's HSD test at *P* =0.05.

[b] Chemical thinner treatments applied on 20 May 2024 (8 mm); Trees were hand thinned on 20 June 2024

[d] Contrasts include different confidence levels at *=0.05, **=0.01 and ***=<0.0001, where L represents linear contrast, Q represents quadratic contrast, and ns represents nonsignificant differences.

Table 11. Influence of carbaryl and 6-benzyladenine (6-BA) applied at various rates adjusted according to the RIMPro decision support system on return bloom in 2025 for treatments applied in 2024 on 'Crimson Gala'/ M.9 T337 apple trees.[a]

Treatment	Adjusted rate of thinner	Application timing[b]	Percent of flowering spurs	
Untreated Control	-		56	b
Hand-thinned control	-	June Drop	66	ab
1000 mg/L Carbaryl	-50%	8 mm	72	ab
1500 mg/L Carbaryl + 50 mg/L 6-BA	-15%	8 mm	80	a
1500 mg/L Carbaryl + 100 mg/L 6-BA	0%	8 mm	78	a
1500 mg/L Carbaryl + 150 mg/L 6-BA	30%	8 mm	79	a
P value			0.0006	
Contrasts[c]				
Rate of 6-BA			ns	

[a] Mean values with the same letter within a given column are not significantly different according to Tukey's HSD test at $P = 0.05$.

[b] Chemical thinner treatments applied on 20 May 2024 (8 mm); Trees were hand thinned on 20 June 2024.

Table 12. Average Ambrosia, Gala, and Honeycrisp king and lateral fruit diameters and number of fruit measured on each measurement date, and calculated average fruit diameter and predicted final fruit set using the Malusim fruit growth model

	King fruitlets		Lateral fruitlets			
Date	Average diamter (mm)	No fruitlets measured	Average diamter (mm)	No fruitlets measured	Malusim calculated average fruitlet diameter (mm)[1]	Predicted fruit set/tree
			Ambrosia			
5/21/2024	8.4	75	6.4	194	6.95	-
5/24/2024	10.0	75	7.5	175	8.14	246
5/28/2024	10.5	75	7.9	138	8.62	98
5/31/2024	10.9	69	8.4	75	9.21	98
6/4/2025	13.8	24	9.0	1	10.82	20
			Gala			
5/21/2024	9.9	75	7.5	269	8.07	-
5/24/2024	12.9	70	8.3	240	9.17	514
5/28/2024	16.4	70	10.4	167	11.34	359
5/31/2024	18.1	70	11.3	127	12.96	171
6/4/2025	21.9	68	16.1	56	17.03	203
			Honeycrisp			
5/21/2024	9.5	75	5.8	235	6.72	
5/24/2024	11.6	75	6.7	193	7.79	274
5/28/2024	13.7	75	7.8	128	9.32	156
5/31/2024	14.4	75	8.0	75	10.46	156
6/4/2025	20.7	42	7.5	7	17.14	78

[1] - Malusim.org evalutes data for excessive growth rate (E) for that measurement (greater than 1.5 mm/day) and measurements considered outliers (O) determined if the values is greater than two standard deviations of all growth rates. The model detected and rejected a total of 32(E) and 74(O)values for Ambrosia, 150(E) and 96(O)values for Gala, and 105(E) and 80(O)values for Honeycrisp.

Table 13. Average Ambrosia, Gala, and Honeycrisp fruitlet weights (king and lateral combined) and predicted final fruit set using the fruit distribution model.

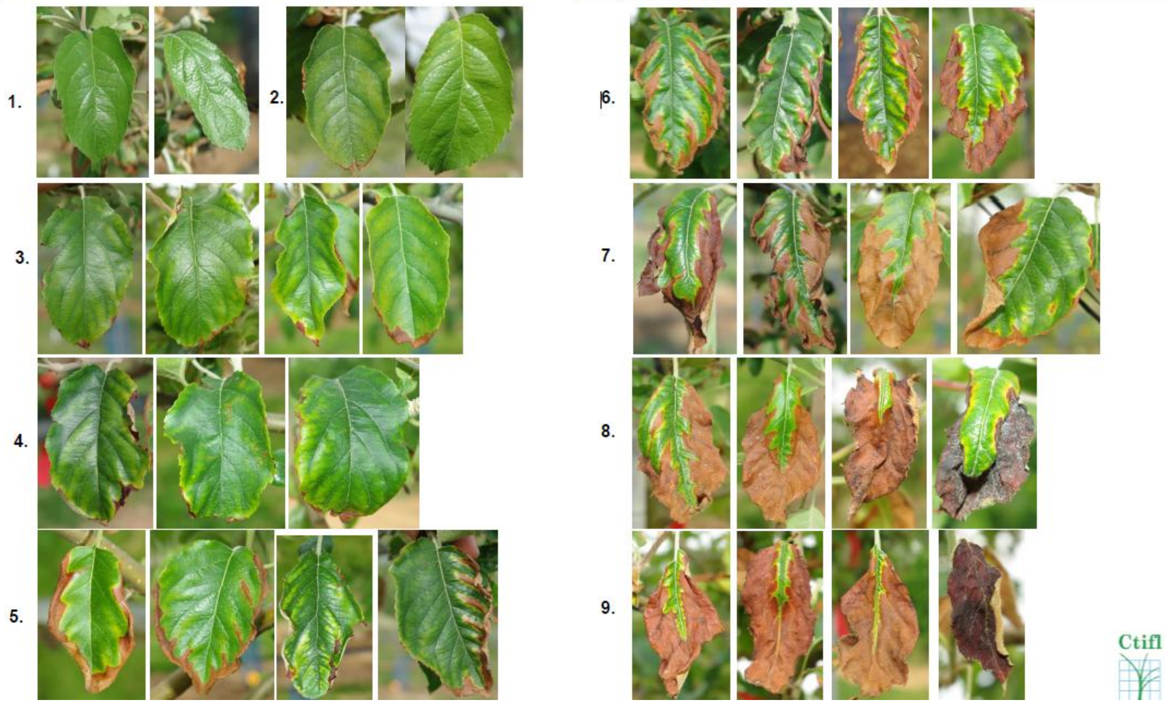
Date	Fruitlets: Average fruitlet weight (g)	Fruitlets: No fruit measured	Predicted fruit set/tree	Actual fruit set/tree (average, n=20)	Accuracy of Prediction (%)
		Ambrosia		Ambrosia	
5/22/2024	0.8	200	82		
5/27/2024	1.1	200	54		
5/30/2024	1.3	138	47		
6/3/2025	2.6	1	27	55	103
		Gala		Gala	
5/22/2024	0.7	269	89		
5/27/2024	1.3	240	55		
5/30/2024	1.9	167	48		
6/3/2025	3.6	127	44	204	365
		Honeycrisp		Honeycrisp	
5/22/2024	0.5	200	70		
5/27/2024	1.1	200	44		
5/30/2024	1.5	95	32		
6/3/2025	4.8	82	30	66	120

8.0 Appendices

8.1 Phytotoxicity Scale (link)

APPLE – Scale of phytotoxicity assessment: BREVIS

1	No symptoms	6	Reduction of leaf area by necrosis that spreads to the center and the base of the leaf. This stage is very typical.
2	Light yellow discoloration between the veins	7	Reduction of leaf area by necrosis that spreads to the center and the base of the leaf. Leaf starts to curl (spoon shape)
3	Yellow discoloration between the veins, beginning of necrosis on the edge and on the tip of the leaf	8	Only an area of 1 cm wide remains green around the main vein. Leaf curled. Some of them drop.
4	Strong yellow discoloration between the veins and beginning of necrosis on the edge of the leaf (1-2 mm) from the tip	9	Leaf entirely necrosed and curled, sometimes a small green area may persist around the central vein and near the stem. These leaves drop
5	Strong yellow discoloration between the veins and spread of necrosis from the edge (4-5 mm) to the base of the leaf		



8.2 BreviSmart Instructions

Site: https://brevismart.adama.com/user-guide/user-guide_BreviSmart.pdf
https://brevismart.adama.com/

- On the login in page, you can see 10 days of forecasted
- Label will recommend not applying Brevis when air temperatures at or following application are <55 F and >84 F
- The model predicts thinning response based on nighttime temperatures from 8 pm to 7 am and solar radiation 5 days before and after application
- The model also incorporates easy of thinning based on fruit size. When fruit are between 10-15 mm, they are greater sinks compared to when fruit are < 10 mm smaller

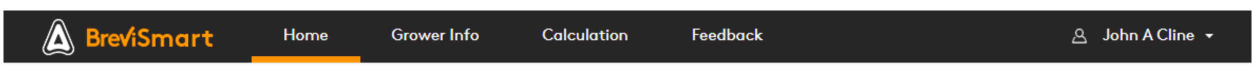
Tuesday, 12-May-2020

Your current location 8°C 1.43 MJ/m² C F

Tuesday 12-May-2020	Wednesday 13-May-2020	Thursday 14-May-2020	Friday 15-May-2020	Saturday 16-May-2020	Sunday 17-May-2020	Monday 18-May-2020	Tuesday 19-May-2020	Wednesday 20-May-2020	Thursday 21-May-2020

HOUR	TEMPERATURE	RADIATION	HOUR	TEMPERATURE	RADIATION
00:00	2°C	0.00MJ/m²	12:00	9°C	3.21MJ/m²
01:00	1°C	0.00MJ/m²	13:00	9°C	3.48MJ/m²
02:00	1°C	0.00MJ/m²	14:00	10°C	3.51MJ/m²
03:00	0°C	0.00MJ/m²	15:00	10°C	3.35MJ/m²
04:00	-1°C	0.00MJ/m²	16:00	11°C	3.00MJ/m²
05:00	-2°C	0.00MJ/m²	17:00	10°C	2.47MJ/m²
06:00	-2°C	0.00MJ/m²	18:00	10°C	1.85MJ/m²
07:00	-1°C	0.13MJ/m²	19:00	9°C	1.12MJ/m²
08:00	2°C	0.81MJ/m²	20:00	8°C	0.49MJ/m²
09:00	5°C	1.52MJ/m²	21:00	6°C	0.03MJ/m²
10:00	7°C	2.20MJ/m²	22:00	5°C	0.00MJ/m²
11:00	8°C	2.78MJ/m²	23:00	4°C	0.00MJ/m²

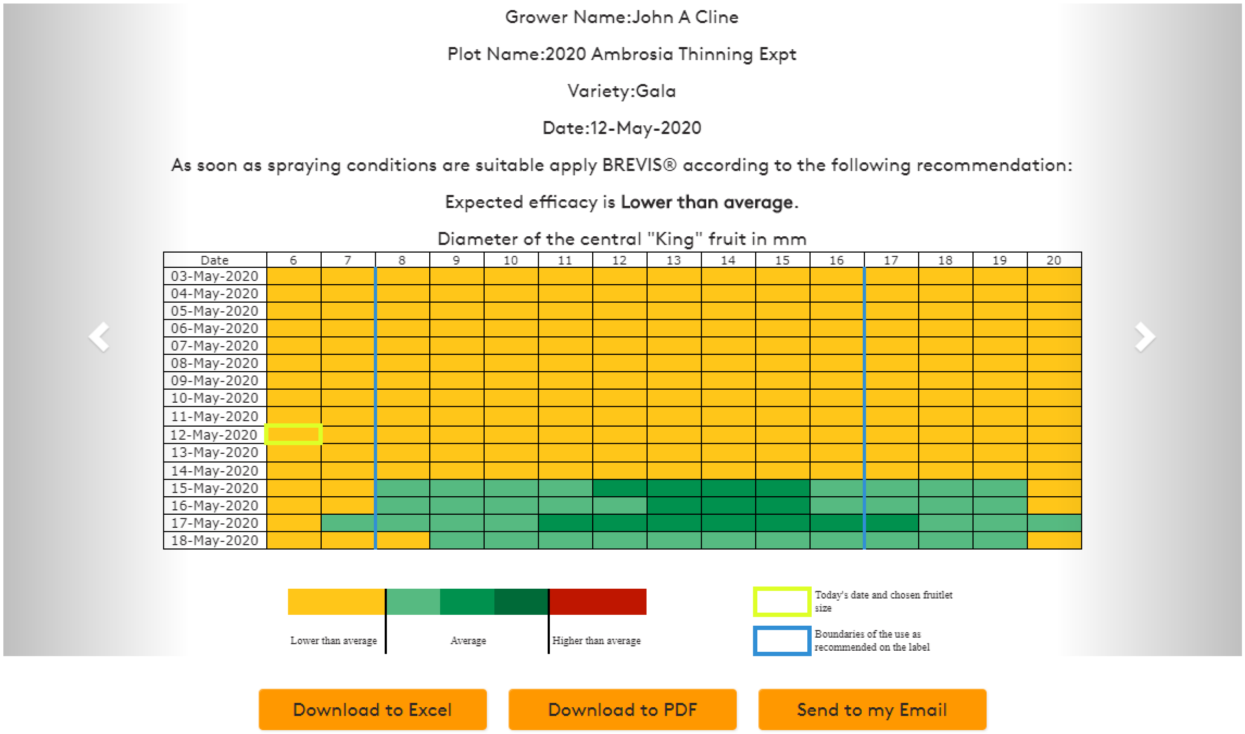
- On the top bar (use the Grower Information for orchard details)



- When running calculations, go to the calculation button
- You can also schedule calculations to be delivered by email for 5 days
- You can also look at historical calculations

Interpretation of Output

Green = Average - apply at a standard rate for the cultivar (moderate or difficult to thin)
Yellow = Lower than average thinning response. Need to increase the rate or Metamitron
Red = Higher than average thinning response. Need to lower the rate or Metamitron



	Easy to thin cultivar	Moderate to thin cultivar	Difficult to thin cultivar
Cultivar	McIntosh	Gala	Fuji Golden Delicious
Recommended rate of Brevis (kg/ha)	1.1	1.67	2.2
Lower the Rate (Red)	0.94 - 0.77 (-15 to -30 %)	1.42 – 1.17 (-15 to -30 %)	1.85 – 1.54 (-15 to -30 %)
Maintain recommended rate (Green)	1.1	1.67	2.2
Increase the Rate (Yellow)	1.27 – 1.43 (+15-30%)	1.92 – 2.17 (+15-30%)	2.53 – 2.86 (+15-30%)

8.3 Weather Data at the Simcoe Research Station (1-May to 30-Jun 2024)

Date	Min Air Temp (°C)	Max Air Temp (°C)	Avg Air Temp (°C)	Rain (mm)	Avg. RH (%)	Solar Rad (kJ/m²)
5/1/2024	6.6	24.0	15.7	0.0	75.8	19785
5/2/2024	9.6	19.3	14.7	0.0	70.9	22027
5/3/2024	11.0	16.2	13.1	4.8	86.2	5715
5/4/2024	11.5	23.4	16.3	0.0	84.6	13556
5/5/2024	11.5	20.4	15.0	6.2	95.3	8294.6
5/6/2024	8.7	21.1	14.1	0.0	59.3	19234
5/7/2024	7.5	21.1	14.9	1.4	57.9	21624
5/8/2024	10.6	22.5	16.6	2.6	72.4	18934
5/9/2024	7.4	16.6	12.1	0.0	69.8	13482
5/10/2024	7.8	17.8	12.7	0.0	64.4	12178
5/11/2024	6.5	13.2	10.1	1.6	89.5	8636.5
5/12/2024	8.9	16.9	12.3	1.0	79.9	14672
5/13/2024	8.2	25.1	16.9	2.6	69.2	16117
5/14/2024	12.3	25.0	18.4	0.0	71.7	20431
5/15/2024	12.0	21.2	16.6	0.0	75.5	20910
5/16/2024	12.1	22.7	17.0	0.0	82.6	17133
5/17/2024	12.7	17.5	15.9	11.6	97.5	4060.6
5/18/2024	14.3	22.5	17.5	0.2	88.6	14257
5/19/2024	10.3	23.9	17.4	0.0	86.4	21176
5/20/2024	14.4	29.5	21.8	0.0	72.2	21109
5/21/2024	17.1	29.0	23.5	0.0	69.9	22048
5/22/2024	19.4	27.6	24.0	0.6	69.5	17147
5/23/2024	13.9	24.3	19.9	1.8	61.5	23729
5/24/2024	13.1	27.4	20.5	0.0	52.9	23719
5/25/2024	12.8	21.0	16.2	16.4	85.5	11267
5/26/2024	12.0	23.8	17.4	13.0	87	18780
5/27/2024	16.1	22.8	18.5	27.0	90.3	12250
5/28/2024	13.7	17.6	15.2	3.4	94.3	7362.2
5/29/2024	10.7	18.9	15.0	0.0	78.1	14052
5/30/2024	7.0	19.8	13.6	0.0	58.1	25277
5/31/2024	6.6	22.0	15.0	0.0	59.7	25189
6/1/2024	8.3	23.3	16.7	0.0	66.6	21218

6/2/2024	14.6	18.0	16.3	3.0	91.1	3579.4
6/3/2024	16.7	23.6	19.1	0.0	92	14734
6/4/2024	14.9	28.5	22.0	0.0	76.6	21295
6/5/2024	18.2	25.2	21.5	12.2	87.1	14074
6/6/2024	18.0	23.7	20.7	4.2	78.4	19535
6/7/2024	14.6	19.1	16.7	1.0	73.7	11648
6/8/2024	12.0	23.2	16.7	10.2	73.1	17100
6/9/2024	11.5	19.4	14.8	7.4	87.1	17310
6/10/2024	10.1	15.5	12.8	0.0	80.6	9066.3
6/11/2024	11.1	17.0	13.8	0.0	76.5	14411
6/12/2024	9.8	23.3	16.6	0.0	80.9	23034
6/13/2024	15.3	28.7	23.7	0.0	61.6	22356
6/14/2024	16.4	25.9	21.6	0.0	59.8	24598
6/15/2024	10.9	24.2	17.7	0.0	68.7	23043
6/16/2024	12.4	26.7	19.5	0.0	69.1	21925
6/17/2024	14.9	31.3	24.1	0.4	72.8	15622
6/18/2024	21.4	31.3	25.1	0.8	79.3	17743
6/19/2024	20.6	33.3	26.6	0.0	78.6	18065
6/20/2024	20.5	29.8	25.0	6.2	85.5	16838
6/21/2024	20.3	30.2	25.4	0.0	86.1	19294
6/22/2024	21.2	32.3	26.2	0.0	81.5	19697
6/23/2024	17.8	26.8	23.4	2.2	79.7	11271
6/24/2024	15.3	28.2	21.9	0.0	63.8	21697
6/25/2024	15.7	25.7	21.4	0.0	76.4	12675
6/26/2024	16.6	27.4	21.5	36.6	86.8	9041.2
6/27/2024	13.9	22.4	18.1	0.2	76.7	20868
6/28/2024	12.1	22.0	17.7	0.0	72.2	12019
6/29/2024	17.8	25.5	22.1	29.4	94.9	5778.6
6/30/2024	11.7	24.1	17.8	0.0	83.7	16090