

ORCHARD NETWORK

For Commercial Apple Producers

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Orchard Management

Response of Gala Apple Trees to ACC and Metamitron Applied at Different Fruitlet Diameters

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Introduction

Managing fruit load is a critical, yet challenging practice for growers involved in apple cultivation because setting more fruits than desired will directly affect fruit size and quality and may lead to biennial bearing. Chemical thinning is the preferred method to achieve this because fruit can be removed shortly after bloom, resulting in a greater impact on fruit size at harvest compared with hand-thinning later in the season.

In north America, carbaryl is a widely used chemical thinner, but because of potential negative impacts on human health and toxicity to bees, it is no registered as a fruitlet thinner in Europe. In Canada, carbaryl has recently undergone risk assessment by the PMRA, which has further restricted its use and re-entry periods.

Finding alternatives to carbaryl has led to interest in studying new thinning products and more predictable thinning strategies. Metamitron, formulated as Brevis (Adama Agricultural Solutions Canada Ltd) and 1-aminocyclopropane carboxylic acid (ACC), formulated as Accede ™ (Valent BioSciences) are two compounds that are currently being evaluated for thinning efficacy by our program. One aspect of our research is to investigate the optimal fruitlet size at which to apply these two new compounds because sensitivity to chemical thinner changes as fruits develop.

Experimental Details

A 4-year-old research orchard of Brookfield Gala / M.9 rootstock located at the University of Guelph Simcoe Research Station (42° 51' 40" Lat., -80° 16' 8" Long.) was used. Planted in 2018, trees were trickle irrigated and spaced 2.5 m x 4.5 m (889 trees / ha) and trained in a spindle system. This orchard was used for four experiments between 2021 and 2022.

In 2021, two experiments were conducted in a randomized complete block design with five replications and six fruitlet timing treatments applied to single tree plots.

- **Experiment 1:** Treatments consisted of an untreated control and 438 mg/L metamitron applied at 7 mm, 11 mm, 15 mm, 18.5 mm, and 22.5 mm fruitlet diameter.
- **Experiment 2:** Treatments consisted of an untreated control and 400 mg/L ACC applied at 7 mm, 11 mm, 15 mm, 18.5 mm, and 22.5 mm fruitlet diameter.

A non-ionic surfactant (Regulaid, Kalo, Oveland Park, KS) 0.05% (v/v) was included in treatments to improve product absorption. These experiments were repeated in 2022 at slightly different stages (diameters) of fruitlet development.

Treatments were applied using a commercial air blast sprayer (GB Irrorazione Diserbo, Model Laser P7, Italy) at 1379 kPa, 388 L/ha, which equated to tree row volume (TRV) pesticide dilute (Sutton and Unrath, 1988). The sprayer was equipped with five nozzles per boom (side) and 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.

Horticultural Measurements

Fruit set was determined on two main scaffold branches on both the east and west sides of each tree and averaged to calculate percent fruit set (number of fruit set divided by number of flower cluster). Total fruit weight and number of fruit per tree was recorded at harvest (Sept. 13, 2021 and Sept 12, 2022). The number of unmarketable fruits (undersize, poor colour, premature fruit drop) were also counted and weighed. Mean fruit size was estimated by dividing total fruit mass of marketable fruit by the number of fruits in the sample. All the apples from each were placed in cold storage (~2ºC) and subsequently graded on a commercial colour sorting and sizing line in Dec. 2021 and Nov. 2022. The trunk cross-sectional area (TCSA) was used to calculate crop load, which is expressed as the number of fruits per trunk cross sectional area. Tree trunk circumference at 30 cm above the graft union was measured at the beginning and end of each growing season.

Results

Fruit Set – Metamitron

In 2021 and 2022, there was a significant treatment effect on fruit set (P<0.0001) in the metamitron experiments (Fig. 1). The untreated control and the treatment with metamitron applied when fruitlet size was 22.5 mm in 2021 and 23.5 mm in 2022 had the highest fruit set. In 2021, metamitron applied at 11 mm followed by metamitron applied at 18.5 mm resulted in the lowest fruit set (Fig. 1A). Metamitron applied at 11 mm and 15 mm resulted in 79% and 40% reduced fruit compared to the untreated control, respectively. In 2022, metamitron reduced fruit set the greatest when applied at 14.5 mm (60% reduction) followed by 18.5 mm (47% reduction) fruitlet diameter (Fig. 1B) compared to the untreated control (P=0.001). Fruit set on trees treated with metamitron at 5 mm, 8 mm and 23.5 mm fruitlet diameter was similar to the untreated controls.

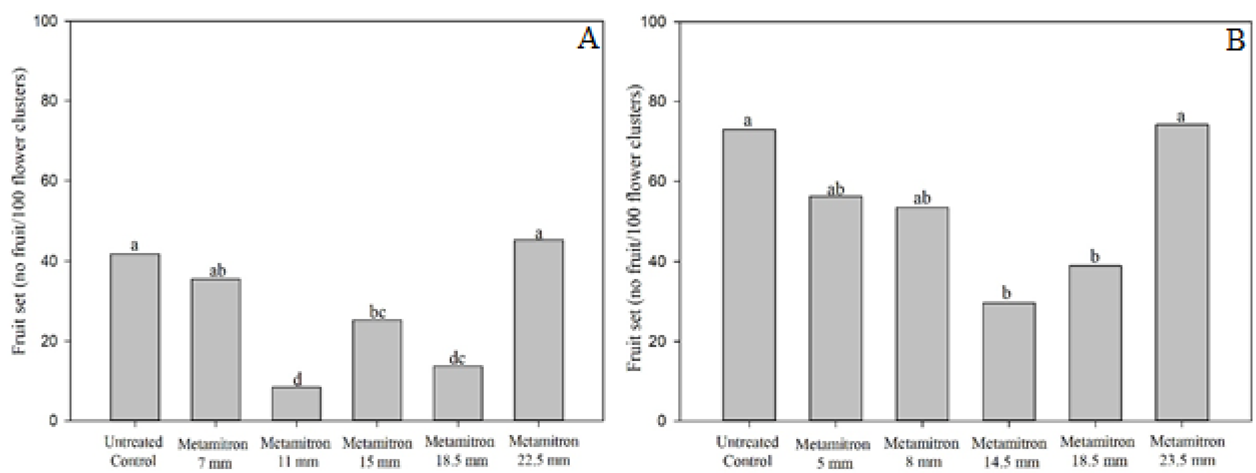

Figure 1. Fruit set of Gala trees in response to metamitron applications at different fruitlet sizes in 2021(A) and 2022 (B). Mean values with the same letter within a given year are not significantly different according to Tukey's HSD test a P=0.05.

Fruit Set - ACC

In 2021 and 2022, there was no significant treatment effect on fruit set (P<0.0001) in the ACC experiments (Fig. 2).

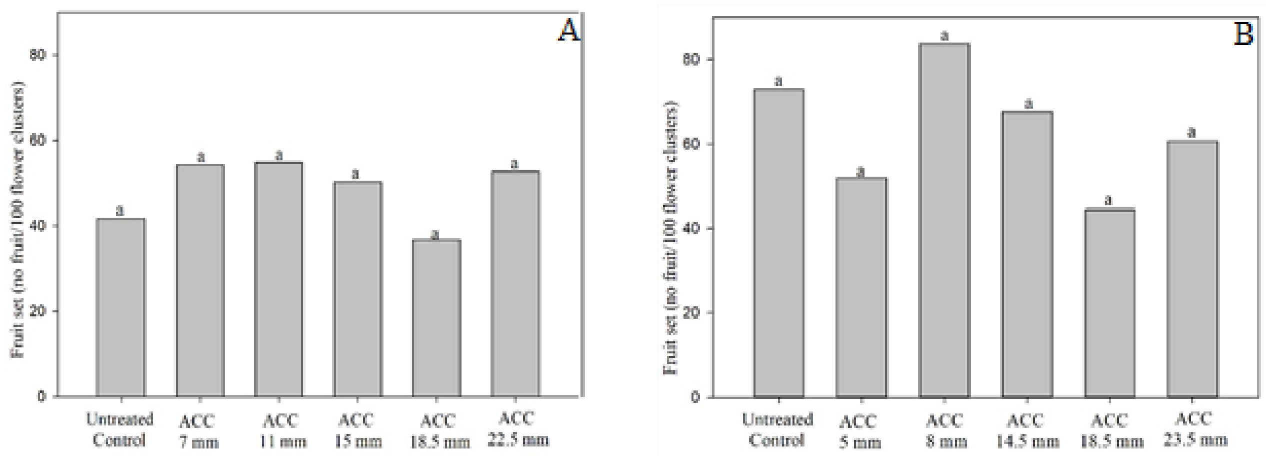

Figure 2. Fruit set of Gala trees in response to ACC applications at different fruitlet sizes in 2021(A) and 2022 (B). Mean values with the same letter within a given year are not significantly different according to Tukey's HSD test a P=0.05.

Yield Parameters - Metamitron

In 2021, metamitron treatments significantly influenced the number of fruits per tree (P<0.0001), total yield per tree (P<0.0001), mean weight of marketable fruit (P<0.0092), and crop load (P<0.0001). The number of fruits per tree (Fig. 3A) followed a similar trend as the total yield (Fig. 3B) with the highest number of fruit and total fruit yield observed on the untreated control trees, followed by metamitron applied at 22.5 mm and 7 mm. The number of fruit per tree when metamitron was applied at 11 mm, 15 mm and 18.5 mm was 75%, 57% and 67% lower than the untreated trees, respectively (Fig. 3A). There was also a significant treatment effect on marketable fruit weight (P=0.0092); metamitron applied at 11 mm resulted in the greatest fruit weight (181g) but when applied at 18.5 mm resulted in the lowest fruit weight (135g) (Fig. 3B). Applications of metamitron between 11 mm and 18.5 mm resulted in significantly lower yields compared to the untreated control (Fig. 3B). Crop load was reduced with metamitron applied between 11 mm and 18.5 mm in comparison to the untreated control (Fig. 5A).

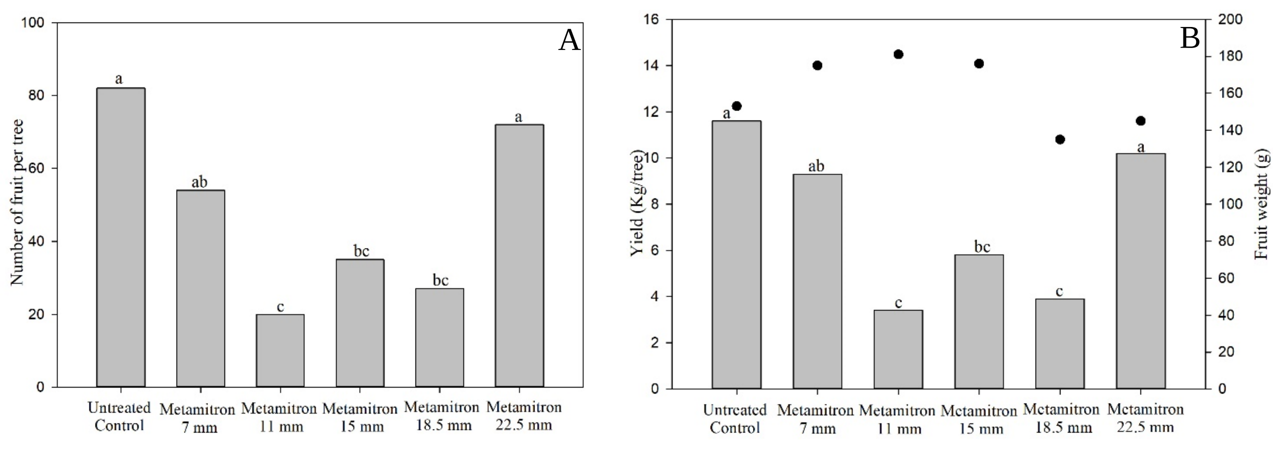

Figure 3. Number of fruit per tree (A), total yield per tree (bars) and average fruit weight (dots) (B) of Gala in response to metamitron applications at different fruitlet sizes in 2021. Mean values with the same letter within a given year are not significantly different according to Tukey's HSD test at P=0.05

In 2022, metamitron treatments also significantly affected the number of fruit per tree (P<0.0001), total fruit yield per tree (P<0.0001) and crop load (P<0.0001). Trees treated with metamitron at 14.5 mm and 18.5 mm resulted in the fewest number of fruit per tree (Fig. 4A), lowest total yield (Fig. 4B), greatest fruit weight (Fig. 4B) and lowest crop load (Fig. 5B). In contrast, trees treated with metamitron at 5 mm, 8 mm, and 23.5 mm fruitlet size had similar number of fruits per tree

(Fig 4A) and crop load (Fig 5B) as the untreated control, indicating the poor response of Gala to metamitron when applied at these fruitlet stages.

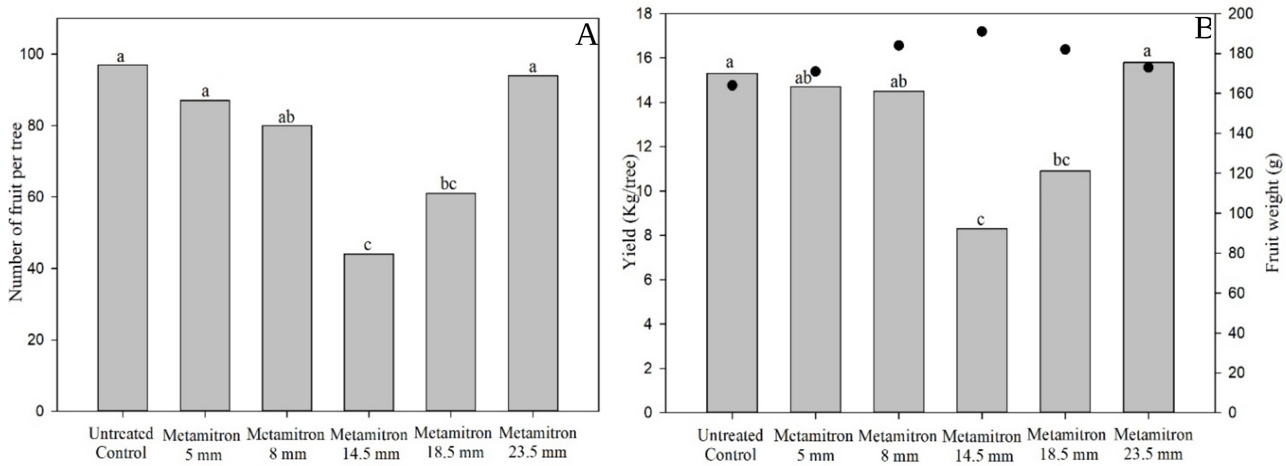

Figure 4. Number of fruit per tree (A), total yield per tree (bars) and average fruit weight (dots) (B) of Gala in response to metamitron applications at different fruitlet sizes in 2022. Mean values with the same letter within a given year are not significantly different according to Tukey's HSD test at P=0.05

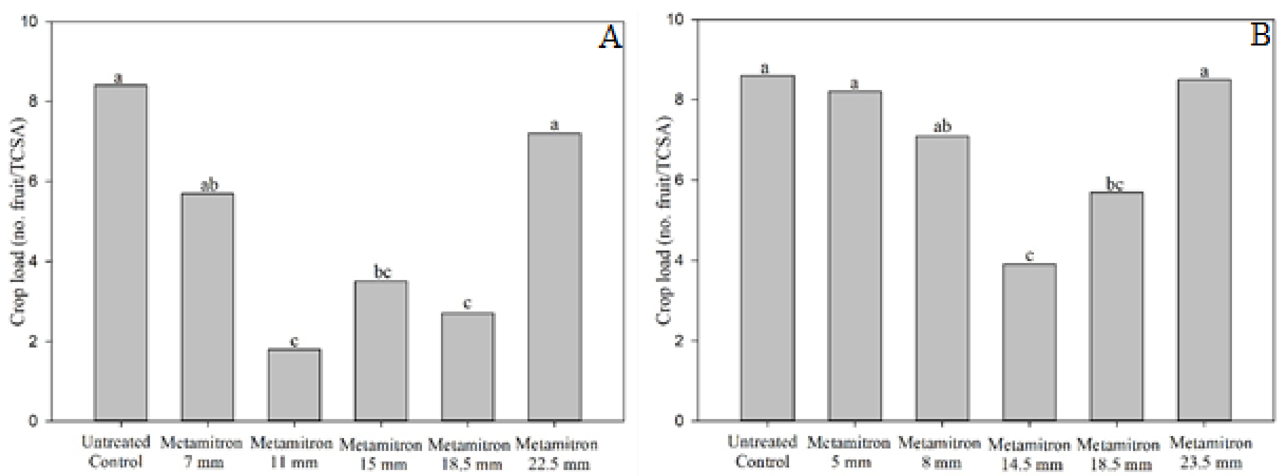

Figure 5. Crop load of Gala trees in response to Metamitron applications at different fruitlet sizes in 2021(A) and 2022 (B). Mean values with the same letter within a given year are not significantly different according to Tukey's HSD test a P=0.05.

Yield Parameters - ACC

In 2021, there was no significant treatment effect of ACC on the number of fruits per tree (Fig. 6A), total yield per tree and fruit weight (Fig. 6B), or crop load (Fig. 8A).

However, in 2022, there was a significant treatment effect of ACC on the number of fruits per tree (P=0.0044), total fruit yield (P=0.0174), mean weight of marketable fruit (P=0.0234) and crop load (P<0.0034). ACC applied at 18.5 mm resulted in the fewest number of fruits per tree (Fig. 7A), lowest total yield (Fig. 7B) and crop load (Fig. 8B). There was no treatment effect of ACC on fruit weight at any of the application timings when compared to the untreated control. Trees treated with ACC at 18.5 mm decreased the total number of fruits per tree by 29% (Fig. 7A) and crop load by 28% (Fig. 8B) compared to the untreated control.

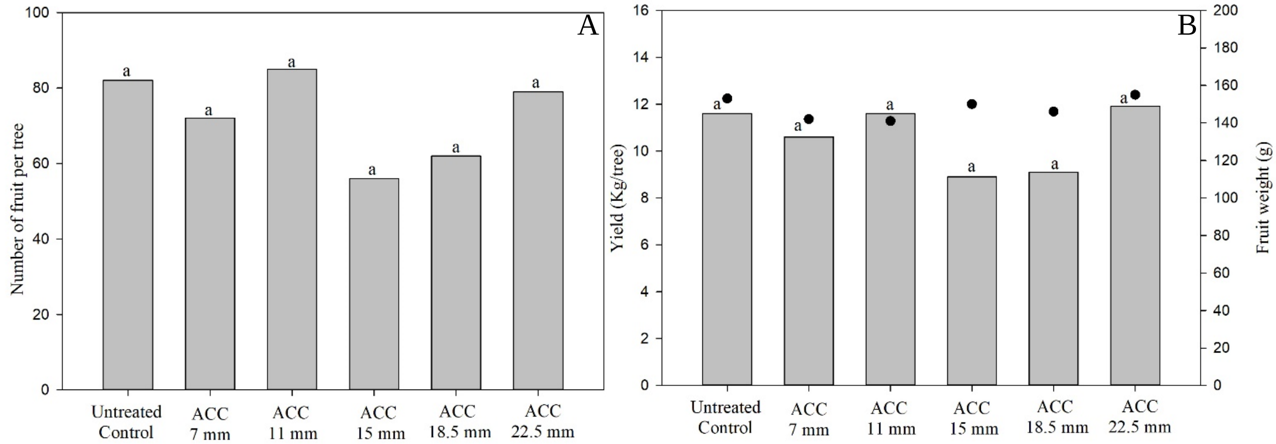

Figure 6. Number of fruit per tree (A), total yield per tree (bars) and average fruit weight (dots) (B) of Gala in response to ACC applications at different fruitlet sizes in 2021. Mean values with the same letter within a given year are not significantly different according to Tukey's HSD test at P=0.05

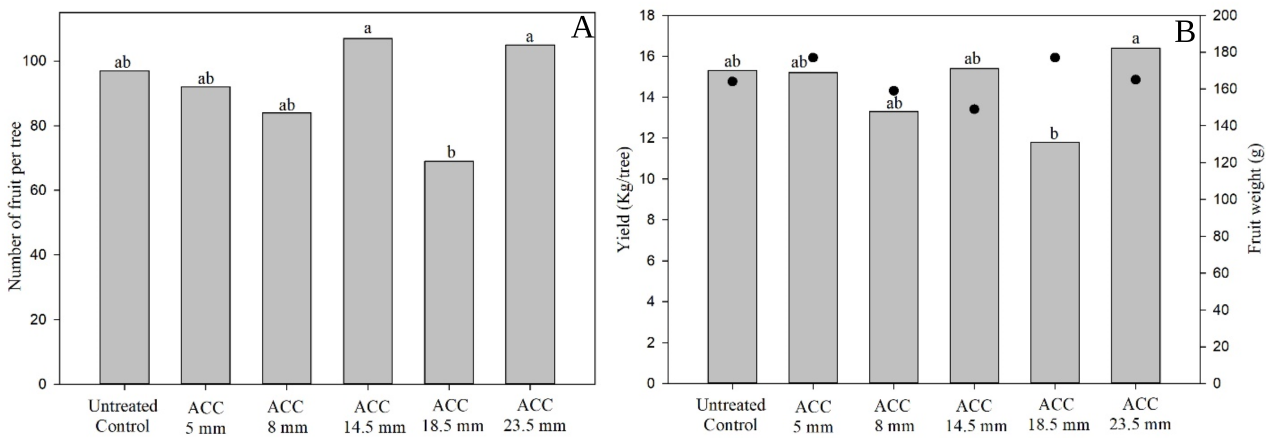

Figure 7. Number of fruit per tree (A), total yield per tree (bars) and average fruit weight (dots) (B) of Gala in response to ACC applications at different fruitlet sizes in 2022. Mean values with the same letter within a given year are not significantly different according to Tukey's HSD test at P=0.05

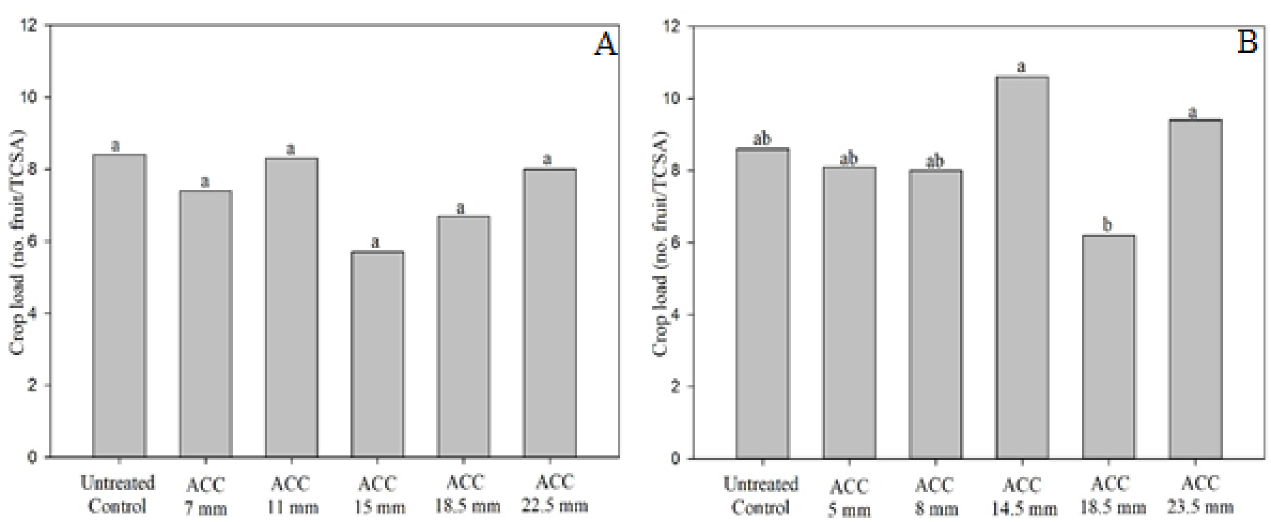

Figure 8. Crop load of Gala trees in response to ACC applications at different fruitlet sizes in 2021(A) and 2022 (B). Mean values with the same letter within a given year are not significantly different according to Tukey's HSD test a P=0.05.

Key Conclusions

Metamitron

- Metamitron applied at 438 mg/L when fruitlets were between 11 mm and 18.5 mm reduced fruit set, number of fruit per tree and crop load of Gala trees in both years. Application made at 5 mm, 8 mm and 23.5 mm fruitlet diameter were ineffective at thinning in this two-year study.
- In 2021, fruit weight was 14%, 18%, and 15% higher compared with the untreated control when 438 mg/L metamitron was applied at 7 mm, 11 mm and 15 mm, respectively. Metamitron applied at 18.5 mm and 22.5 mm decreased fruit weight by 12% and 5% compared to the untreated control, respectively.
- In 2022, when metamitron was applied at 5 mm, 8 mm, 14.5 mm, 18.5 mm and 23.5 mm, fruit weight increased 4%, 12%, 17%, 11% and 6% compared to the untreated control, respectively.
- A high rate of 438 mg/L metamitron was used to ensure adequate treatment response at the various fruitlet stages in this study. However, lower rates should be considered commercially when less thinning is required (subject to Brevis registration in Canada).
- **Metamitron is an effective thinner when used alone (and not combined with other thinning compounds such as 6-BA, NAA or carbaryl).**

1-aminocyclopropane carboxylic acid (ACC)

- **In one of two years, ACC demonstrated mild effectiveness as a thinner for Gala trees.**
- ACC was most effective in 2022 when applied at 18.5 mm fruitlet diameter but had little effect when applied between 5 mm and 18.5 mm, and at 23.5 mm fruitlet diameter.

Please note that apple cultivars may respond differently to the fruitlet thinner compounds used in this study. Furthermore, environmental conditions during and following metamitron and ACC applications at the various fruitlet stages used in this study are very likely influencing the thinning response.

Acknowledgements

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AgRobotics in Ontario

Kristen Obeid, Weed Management Specialist – Horticulture, OMAFRA

What a challenging few years the agriculture sector and the world has had. But challenges pave the way for opportunities. And there are opportunities abound in the AgRobotics space. What is the problem you are trying to solve? Likely, there is a company somewhere in the world trying to solve it.

Since 2021, an AgRobotics Working Group comprised of more than 80 people (OMAFRA staff, Haggerty Creek AgRobotics, growers, grower associations, agri-business, universities and colleges, federal and municipal governments and technology companies) have been meeting weekly. The group brainstorms about available and future technologies, builds networks and collaborations, conducts on-farm demonstrations, and builds cross-functional teams to apply for funding opportunities in hopes of ground truthing these technologies in Ontario production systems. The technology companies are impressed with the diversity of production, government support and research capabilities in Ontario.

In 2021, Haggerty Creek AgRobotics Company along with OMAFRA and grower associations conducted six demonstrations with 3 different robots in Brussels sprouts, cauliflower, peppers, onions, carrots, celery, strawberries and haskaps. The robots included:

- **Naïo Oz** is an inter-row weeding robot. Capable of weeding through standing crops in row widths of 30" or more. Guided by RTK GPS. It can attach any implement, such as a 1-row seeder, hooded sprayer, wagon to haul loads, etc. The following video link shows two robots in a celery field (https://twitter.com/weedprofesh/status/1405223208530419716?s=12).
- **Naïo Dino** is an inter-row weeding robot. Capable of weeding in any row spacing (adjustable tool bar) of a standing crop. Guided by RTK GPS.
- **Korechi RoamIO** is an autonomous platform for soil sensing, mowing, cultivating. The limit is your imagination.

Projects conducted in 2022 include five different robots in various crops and locations performing numerous tasks: seeding, weeding (active and passive), mowing, soil sampling and analysis. The following summarizes features and capabilities of each robot:

FarmDroid

Website: https://farmdroid.dk/en/welcome

Seeding and inter and intra-row weeding robot. It knows exactly where the seed is planted enabling it to weed as close to the plant as possible. Guided by RTK GPS. Developed on sugar beets, canola, onions and spinach in Denmark. Tested in sugar beets and rutabagas in Ontario. There are over 150 active units in Europe. It is solar-powered with a backup battery and can cover 12 – 15 acres/day.

Naïo Dino

Website: https://www.naio-technologies.com/en/dino

The Naïo Dino is capable of weeding in any row spacing. The adjustable tool bar allows it to weed as close to the crop as possible. Guided by RTK GPS. Tested in carrots and celery in Ontario. There are over 150 active units worldwide. It is battery-powered with autonomy of 8-10 hours and can cover approximately 10 acres/day.

Nexus Goat

Website: https://nexusrobotics.ca

The Nexus Goat navigates and removes weeds autonomously (picks the weeds out). It uses cameras and a neural network to differentiate between weeds and crops. Guided by RTK GPS. Tested in onions and carrots in Ontario. It is a hybrid model (battery and diesel fuel) with 24-hour autonomy. The speed depends on how weedy the field is.

Korechi RoamIO HCT

Website: https://korechi.com

The Korechi RoamIO HCT is a custom autonomous platform made in Ontario with multiple uses. It integrates soil scanning and sensing equipment with numerous tools such as cultivators, seeders and mowers. Used for soil optics sensing and a cover crop row mower project.

Raven OMNiPOWER

Website: https://ravenprecision.com

OMNiPOWER is an autonomous power platform that easily interchanges farm implements. It is controlled remotely from a tablet. No driver necessary. Currently being use for custom fertilizer applications.

Future of AgRobotics in Apples

The AgRobotics Working Group continues to submit funding applications to test other technologies in many different production systems. Recently, an AgRobotics Apple Sub-Committee was formed with plans to have their first meeting in early 2023. This group hopes to investigate the possibility of bringing various technologies and expertise to Ontario in the coming year, such as:

1. **Advanced Farm Robotics** (https://advanced.farm) – Autonomous apple harvester
2. **Naïo Ted Robot** (https://www.naio-technologies.com/) - Currently used in grapes for hilling, de-hilling, vine hedging, cultivating and yield estimation. Could be used in any trellised system. Haggerty AgRobotics Company (https://www.haggertyagrobotics.com) will be bringing one to Ontario in 2023.
3. **UV-C technology** for fire blight and other disease / insect control.
4. **AgXeed Agbot 2.055W3 and H.S.S. CF2000AB (**https://holsprayingsystems.com) – Autonomous sprayer**.** Provide Agro (www.provideag.ca) has sold 3 of these units in ON that will be operational Spring 2023.

We're a long way off from widespread use of robotics in field and horticulture crops because there's so much to learn. But we are learning together and are asking the tough questions with our current projects:

- Does the robot do what it is supposed to do?
- How much does it cost? What is the return on investment?
- What are the benefits? Labour savings? Environmental? Carbon footprint? Reduced inputs?
- Can the robot(s) be integrated into our current production systems?
- What is the technical skill set required to operate the robotics?

As you can see, there are a lot of questions to be answered before widespread adoption on Ontario farms. But this is the start of something big. Much bigger than anyone can predict. It is the future and holds promise to enhance food security, environmental sustainability and solve the critical problems faced by agriculture today and those of tomorrow.

Crop Protection

Apple Alternaria – Another Annoyance?

Katie Goldenhar, Plant Pathologist - Horticulture, OMAFRA

I know what you're thinking – do we really have ANOTHER disease to worry about in apples?! To put your mind at ease, likely not. However, in 2022, there were several odd leaf spots in apples that were perplexing to consultants, growers and extension specialists alike so I wanted to take a deeper give into what might be going on. One thing these leaf spots had in common when diagnosed at a lab were *Alternaria* species.

Fungi within the *Alternaria* genus are numerous and abundant in our environment. In fact, many are not pathogenic and are endophytic, meaning they can live within a plant but do not cause disease. However, some *Alternaria* species are known to infect crops and cause disease, including leaf spots in crops such as potato, ginseng, carrot, Brassica vegetables and fruit rot in crops such as blueberries. Some species such as *A. solani* in potatoes and tomatoes or *A. panax* in ginseng are crop specific and do not cause disease outside of their host. Some species have an incredibly wide host range including *A. alternata* which has been noted as a pathogen on 1519+ different hosts!

In 2013, Glomerella leaf spot (caused by *Colletotrichum* spp.) was a concern due to the increase in bitter rot across the province. A survey done at that time included 28 leaf samples, 57% (16/28) were diagnosed as *Alternaria* sp. In all cases, symptom severity was noted as low to moderate. Were these leaf spots truly Alternaria leaf blotch? Without proving that those species could re-infect apple leaves, we can't know for sure. *Alternaria* species are common secondary pathogens, meaning they infect only after something else (insect, other pathogen, chemical burn, etc.) damages the tissue.

Alternaria mali is the species reported in most US literature on Alternaria leaf blotch. Reports from Michigan, Pennsylvania and North Carolina all state *A. mali* as the cause of Alternaria leaf blotch. However, in a recent review of *Alternaria* species (DeMers 2022), *A. mali* may now be classified as *A. alternata*. This leads to further questions on what is really going on!

In 2022, an Ontario orchard had unidentifiable leaf spots on a cultivar with Delicious and Gala parentage spread evenly throughout the foliage (Figure 1). In September, samples were sent to the diagnostic lab, and the results came back as *A. arborescens*. My first instinct was that the *Alternaria* sp. detected is secondary, only infecting the plant once something else has caused the injury / lesion such as necrotic leaf blotch (NLB). NLB is an abiotic phenomenon in apples, specifically impacting 'Golden Delicious' and 'Gala' lineages. However, leaf blotch caused by *A. arborescens* has been reported in the Netherlands, France, Italy, Chile, Australia, and New Zealand (see references). In Australia, the main *Alternaria* species associated with 60% of leaf samples was *A. arborescens*, followed by *A. alternata* (16%), *A. tenuissima* (16%) and *A. longipes* (8%).

Figure 1. Leaf lesions on apple caused by *A. arborescens*

Given all that, the question remains - are *Alternaria* species currently a threat for Ontario apples? Incidence levels of leaf spots suspected to be solely from *Alternaria* species are low and seem to only be severe in certain varieties. Reports in other regions suggest leaf blotch caused by *A. aborescens* is usually minimal and may not cause economic damage. More research is needed to determine if the *Alternaria* species we are detecting can re-infect apple leaves. For now, just something else to keep in the back of your mind. With the reduction of group M fungicides (captan, mancozeb), pathogens that might have been suppressed may be more predominate if you aren't considering them in your disease management plan.

If you have concerns or questions about Alternaria leaf blotch in apples, contact Katie Goldenhar (519-835-5792, katie.golenhar@ontario.ca) or Kristy Grigg-McGuffin (519-420-9422, kristy.grigg-mcguffin@ontario.ca).

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Species of Bitter Rot in Ontario Orchards

Asifa Munawar, Department of Plant Agriculture, University of Guelph

Project Team

Asifa Munawar, Mary Ruth MacDonald and Katerina Jordan, University of Guelph
Kristy Grigg-McGuffin, OMAFRA

Bitter rot is found frequently in Ontario orchards. In the disease survey carried out by our pathology team in 2019-2020, we found a 92-93% prevalence of the disease in study orchards. For more information on this survey and preliminary infection timing findings, see the December 2021 Orchard Network article, *Post-harvest incidence and timing of infection of bitter rot on apple* (https://onfruit.ca/wp-content/uploads/2021/12/ONNL-Dec-10-2021_kgm.ed-edits-12152021.pdf).

During this survey, we also isolated the pathogen from symptomatic apple fruit. The molecular identification of the selected isolates showed that *Colletotrichum fioriniae* is not the only pathogen species causing bitter rot in Ontario. We identified two species, *Colletotrichum godetiae* in orchards in Districts 2 and 3 and *C. nympheae* from an orchard in District 5. Previous reports of these species include, *C. godetiae* in the United Kingdom and Slovenia and *C. nympheae* in the USA and many other countries. The predominant pathogen in Ontario orchards is *C. fioriniae* and only a small percentage of the disease is caused by other species. Our team will be testing the sensitivity of these species against pyraclostrobin (active ingredient in Pristine and Merivon, FRAC 11) and captan. The results will be available in 2023 to apple growers.

Air Monitoring for Apple Scab

Kristine White, CEO, Spornado Inc. and Kristy Grigg-McGuffin, Horticulture IPM Specialist, OMAFRA

For the past two seasons, OMAFRA and Spornado (https://spornadosampler.com/), an Ontario-based company which conducts air monitoring for crop diseases, have been working on an Ontario Agri-Food Research Initiative (OAFRI) funded project in apple with the support of the Ontario Apple Growers Association. The focus of this project was air monitoring for *Venturia inaequalis*, the fungal pathogen that causes apple scab to develop molecular tests for rapid detection and the molecular identification of fungicide resistance in the airborne spores. This is particularly important as the availability of effective scab fungicides has become limited in recent years due to Health Canada re-evaluations. These tests could provide information that would allow growers to better choose and time fungicide applications. This could reduce unnecessary sprays, allowing growers to save fungicides for when they are truly needed and also promote environmental stewardship by reducing pesticide load.

To sample the air for apple scab spores, inexpensive wind-powered air samplers (Figure 1) were installed in three orchards in Norfolk County with historically high scab pressure. Disposable sample collection cassettes were placed in the samplers and changed out at 3-4 day intervals during the summer, and once a week in September and October. The cassettes were then couriered overnight to a laboratory, and results were emailed within 24 hours.

Figure 1. Passive wind-powered Spornado air sampler placed at the end of a row of Ambrosia within an orchard with a history of apple scab. Spores carried by wind are collected from the air through the orange funnel onto sample cassettes which are then shipped to a laboratory for analysis.

In 2021, a total of 136 samples were analysed by molecular analysis, and 4 positive results were identified. The first positive result was identified the first week of sampling (June 21). Positive samples were identified in 3 of the 4 following sample submissions. No positive samples were identified after July 5, 2021. It was hypothesized that the limited number of positives may have been influenced by low levels of wind in the orchard due to it being blocked by the trees when the canopy was full. Each of the three sites monitored had positive results during the season.

This season, the research team switched from using passive wind-only samplers to samplers that comprise of a solar-powered fan (Figure 2) to increase air passage through the collection cassette, in particular when the tree canopy is full. A total of 98 samples were collected over 3 different sites, with 2 samplers installed at each site. The first positive result was identified on May 17, and there were positive samples periodically throughout the season, corresponding to rain events. A total of 13 positive samples were identified throughout the season; each site had positive results.

Figure 2. Enhancements to the Spornado air sampler includes the addition of a solar-powered fan to increase air passage through the collection cassette which improves spore detection in an orchard setting.

The comparison of dates corresponding to scab infection events and/or onset of observed symptoms to dates of *V. inaequalis* spore detection is on-going to assess the capacity of the Spornado traps in orchards. Optimal height placement for traps throughout the season needs further investigation as well. All confirmed *V. inaequalis* samples are currently being assessed for the detection of the cytb gene point mutation (G143A) that confers high QoI fungicide (FRAC 11) resistance level.

Integrating spore trapping into a scab management program has the potential to offer a number of benefits. Current guidelines recommend beginning a protectant fungicide program at bud break to protect green tissue from early ascospore release. However, if scab pressure is known in an orchard by doing Potential Ascospore Dose assessments in the previous fall or – as this project investigates – the use of spore traps, there is a possibility of delaying the first scab sprays of the season. In other words, spore traps could be used as an early indicator of ascospore release, or the start of primary scab period. This could also be applied to the end of primary scab period, which is typically estimated using the ascospore maturation degree day model combined with scab infection event estimations (eg. Mills table). Detecting spore release – or lack of spore activity – could be used to determine the point in the season where spray intervals could be relaxed if no scab lesions are present. Determining the start and end of the primary scab period would allow for more precise fungicide timing, avoiding unnecessary sprays and saving money on pesticide use over the season.

In addition to early detection of disease activity in an orchard, gathering more information on the efficacy of fungicide groups in an orchard would allow for appropriate fungicide selection throughout a season. As mentioned earlier, the changes to the availability and use of broad-spectrum fungicides has left limited options for a protectant fungicide program. This puts strain on the remaining single-site – and high resistance risk – products. Getting real-time updates on the resistance status in an orchard creates the opportunity for fast response to prevent control failures.

A final report summarizing all results will be generated this winter. If you would like a copy of the report or more information, please contact info@spornadosampler.com.

Automated Fire Blight Detection in Apple and Tender Fruit Orchards

Cole Tarry, Matthew Veres, Medhat Moussa, The Robotics Institute, University of Guelph

Overview

The objective of this project is to develop automated systems for the detection of fire blight. This system will be part of an automated farm digital library (AFDL) that will include precise information on every tree in an orchard. The proposed system will enable inspecting every tree at a frequency of 1 – 2 times / week or even higher. The results will be digitized in the AFDL, enabling comparison over time with IPM strategies and labour utilization.

Data Collection System

Following the data collection strategy used during the summer of 2021, a revised system was developed to improve the quality and quantity of the collected data. The system consists of a computer, power source, RTK-GPS, mast, and three imaging sensors. While the system was initially developed to be pulled along the rows with a wagon, it was further improved to be mounted on the back of a truck, allowing us to drive along the rows of the orchard in a more controlled manner.

The setup of the data collection system can be seen in Figure 1 and Figure 2.

Figure 1. Data collection cart

Figure 2. Data collection system mounted on a truck

The three imaging sensors are mounted on the vertical mast, and all capture different images of the same tree. A description of these sensors can be seen in Table 1.

Software was developed to synchronise data capturing from all sensors in the system, and both (a) images, and (b) RTK-GPS location data was saved into a database on the computer.

Figure 3 to Figure 7 show a sample image set from the system during the early Spring 2022 growing season, where one branch on a tree has been flagged with fire blight (depth image not shown).

Table 1: Cameras used during collection of fire blight data

Camera	Description
20-megapixel colour camera	Captures a large image of the tree in high resolution
RGB-D camera	Captures a colour and depth image of the base of the tree to identify canker on the trunk and to assist in locating the tree in space relative to the RTK-GPS on the mast. Accurately geo-locating the tree in the field gives the ability of tracking images over time of the same tree as the season (and disease) progresses.
RGB-NIR Camera	Captures 3 identical images in different wavelengths: • A visible colour channel from 400-670 nm • A near infrared (NIR) channel from 700-800 nm • A second NIR channel from 820-1000 nm

Figure 3. 20 Megapixel colour image of tree

Figure 4. Colour image from RGB-D camera of base of tree

Figure 5. (400-670 nm) Image from Colour/NIR camera of part of tree

Figure 6. (700-800 nm) Image from Colour/NIR camera of part of tree

Figure 7. (830-1000 nm) Image from Colour/NIR camera of part of tree

Data Collection System

Early Season – Spring 2022

Tree cankers are a primary source of infection for fire blight within orchards. To collect this data, the orchard was scanned in early Spring of 2022, prior to any foliage developing on the trees. Once the foliage has developed, identifying these cankers becomes much more difficult to the obstructive nature of the leaves.

A total of 5040 images were captured and consists of 840 sets of images taken from all cameras. 3 sets of images were collected of both sides of each tree as the data collection system moved past, gathering data on a total 140 trees.

Mid-Late Season Collection – Spring / Summer 2022

Data collection further continued into the late spring and summer months. Image sets were collected on a bi-weekly basis of specific rows in the orchard, and every tree in the row was imaged, regardless of whether it had visible fire blight or not. This imaging strategy allows us to look back in time once fire blight has appeared on a tree, in order to attempt to identify it before it was visibly apparent to the OMAFRA specialists.

An additional 4500 image sets (27,000 images) have been collected of the trees with foliage on them.

Sample Tree Images Across the Winter, Spring & Summer 2022 Growing Season

Leveraging the GPS and depth data collected from the trees, fire blight can be monitored across the growing season. Figures 8 and 9 show the progression of fire blight across the 2022 growing season.

Data Processing

Following the distinction of the Early and Mid-Late season fire blight, it can be noted that the features of fire blight (or symptoms of fire blight) can differ significantly. While in the early season cankers may be visible, these become much more difficult to observe during the later stages of the year once the tree begins to bear fruit and leaves.

Two approaches are being investigated: one that focuses on detecting cankers in an image (or similarly, regions of the image that were labeled by OMAFRA specialists), and a second approach that tries to quantify the severity of fire blight symptoms, by counting the number of diseased leaves in an image. Both approaches require different labeling strategies, which in turn require different degrees of labeling efforts.

Early Season Canker Identification

This approach is based on work that leverages deep learning for object detection, as well as work that investigates pixel-level class prediction ("semantic segmentation"). While these approaches differ in their overall objectives, they can both make use of the same labelled data representations.

Following the ground-truth labelling provided by OMAFRA specialists, we have devised a set of label classes based on their relationship with the annotated region. A total of 133 images have been labelled, and the distribution of labelled instances can be seen according to Table 2.

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Table 2. Distribution of labels in early-blight collected dataset

Class Description	Labelled # Instances (across 133 images)
Tree support	99
Healthy region	88
Region inside flagged area	107
Region outside flagged area	79
Branch inside flagged area	143
Branch outside flagged area	96
Possible canker (not flagged)	127

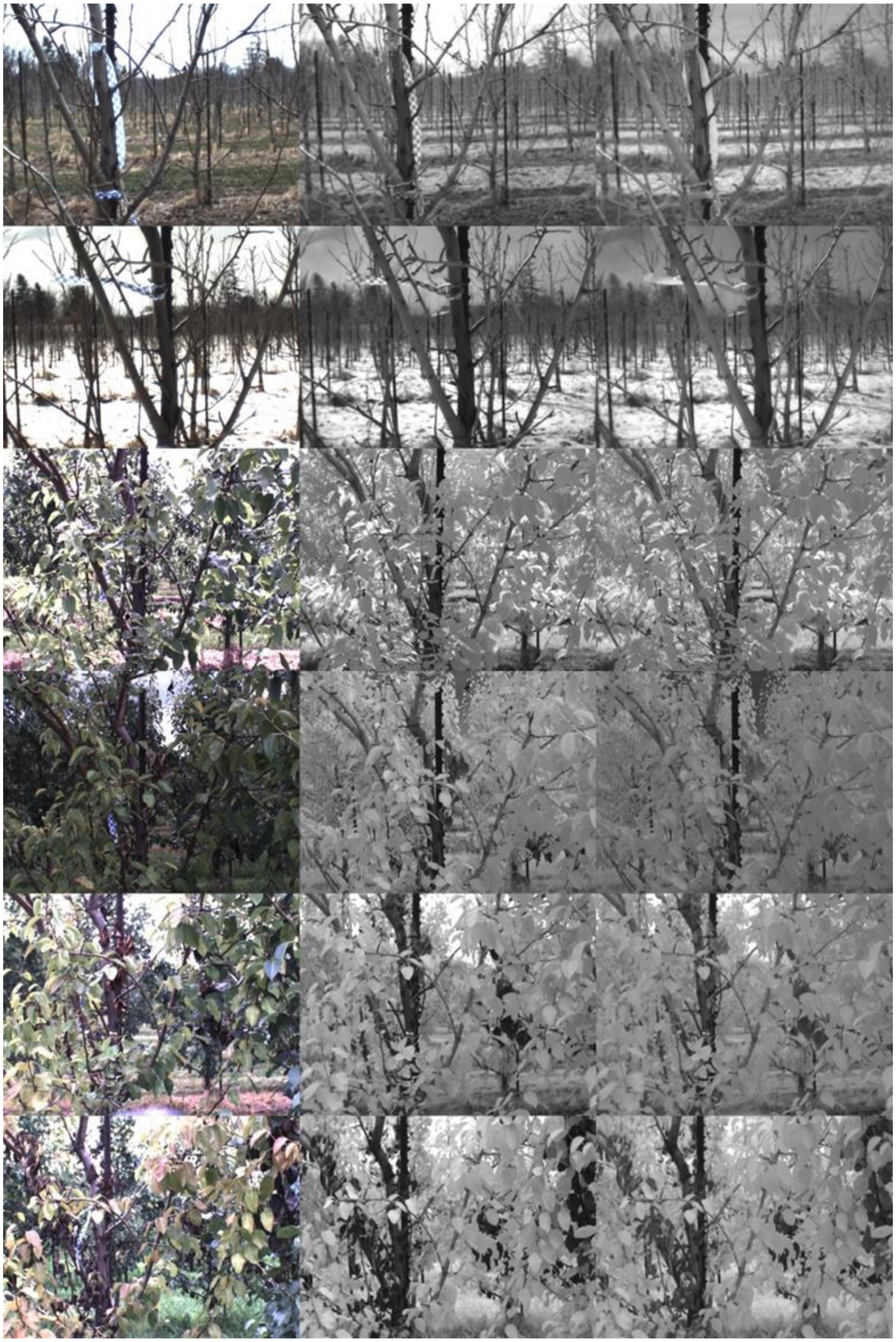

Figure 8. Progression of fire blight across the following dates: (2022-03-22 --> 2022-03-28 --> 2022-06-02 --> 2022-06-22 --> 2022-07-13 --> 2022-08-09). Each column represents a different channel (RGB, NIR1, NIR2) from the multi-sensor camera

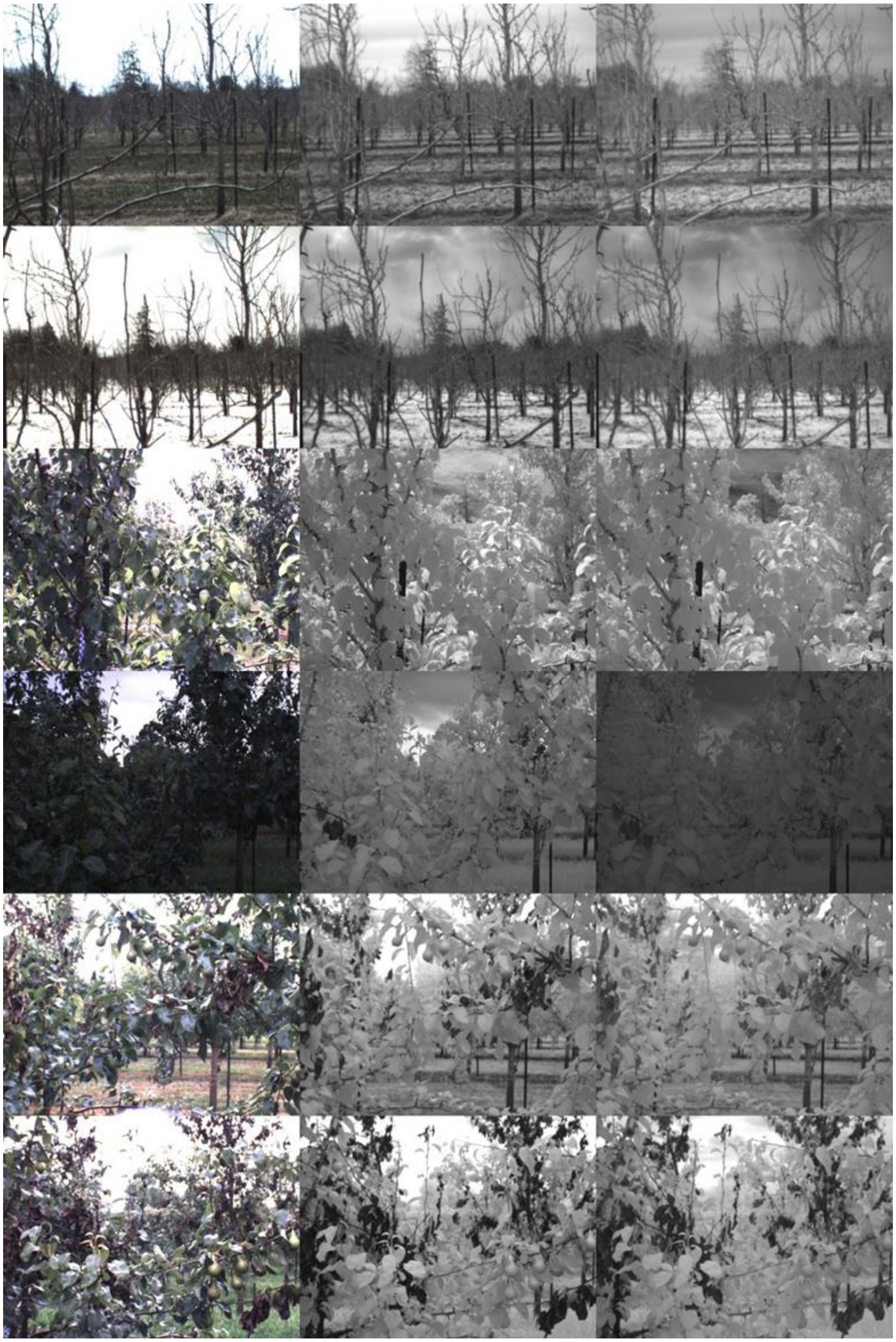

Figure 9. Progression of fire blight across the following dates: (2022-03-22 --> 2022-03-28 --> 2022-06-02 --> 2022-06-22 --> 2022-07-13 --> 2022-08-09). Each column represents a different channel (RGB, NIR1, NIR2) from the multi-sensor camera.

An example set of images is shown in Figure 10 and the corresponding labels are showing in Figure 11. These labelled images are being used to train the algorithms to automatically identify fire blight.

Figure 10. Sample image of flagged canker from different channel (RGB, NIR1 and NIR2) from the multi-sensor camera

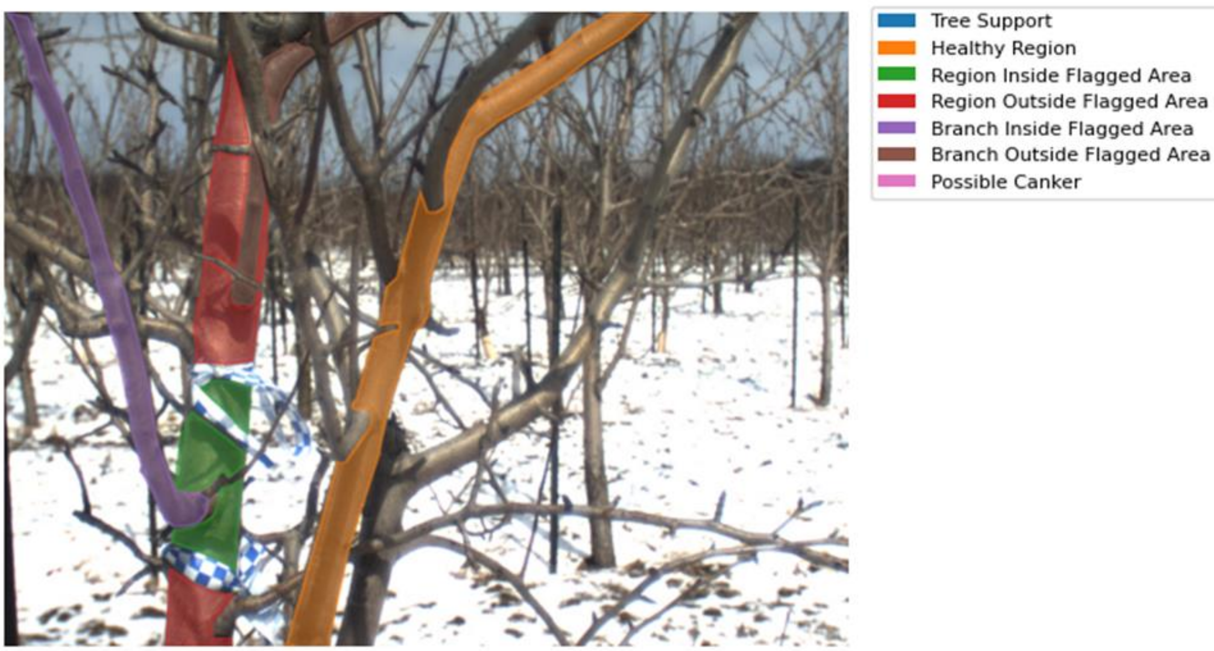

Figure 11. Sample image labelling applied to each set of images

Consideration – Visibility of Cankers and Part-of-Tree-Labeling

An important aspect to note, is that while cankers represent sources of entry for fire blight into the tree - even though there are no leaves present obstructing the visibility of the canker during the early season - the canker itself may or may not be visible to the camera. Thus, this labeling strategy was devised to help specifically anchor the set of labeled data to what can be observed in the images. For example, in Figure 11, these sections include the specific flagged region (green), the region outside of the flagged region (red), as well as a small degree of separation from these labels (e.g., purple, brown).

Consideration - Labeling

Generating labels for the early-season blight is a time-consuming effort. As the images collected by the RGB-NIR cameras are restricted in their field-of-view, the labeler is required to cross-reference the larger images of the scene to accurately identify the different degrees of separation noted above. In addition, each of the areas above must be carefully traced over with the aid of a labeling tool such as coco-annotator (https://github.com/jsbroks/coco-annotator).

Mid-Late Season Fire Blight Symptom Development

The second approach being developed is an application of deep-learning techniques that are typically used for crowd-counting, to the problem of fire blight symptom detection. In this formulation, we adapt the strategy of counting the size of crowds based on counting the number of visible human heads to counting the number of fire blight symptoms, based on the number of infected / dead / wilting leaves in a tree. The approach attempts to learn an image -- image mapping, similar to semantic segmentation, but where the output image represents a density map of fire blight instances. Based on the (RGB, NIR)-paired images shown above, these leaves are quite distinctive across the different sensor channels and dates.

Consideration - Labeling

Compared to the labeling efforts required for the Early-season detection, the labels used in this work are generated by clicking on individual leaves within an image, and then recording an (x, y) clicked pixel location. Figure 12 is an image from the 2021 growing season that was used as a proof-of-concept for this approach, and labeling efforts for data collected across the multiple weeks of the 2022-growing season are still underway.

Figure 12: Symptoms of fire blight during Mid-Late growing season 2021. Proof of concept. Left: RGB Image, Right: Labeled point-wise symptom instances

Acknowledgements

Funding for this project is through the Ontario Agri-Food Research Initiative program in collaboration with OMAFRA specialists (Kristy Grigg-McGuffin, Wendy McFadden-Smith). We greatly acknowledge the grower cooperators who provided access to their orchard.

Low-Cost Orchard Drone Scouting – Is It Worth It?

Kristy Grigg-McGuffin, Horticulture IPM Specialist, OMAFRA

Melanie Filotas, Horticulture IPM Specialist (Specialty Crops), OMAFRA

Background

Yield losses to pest damage, and costs of pesticides are repeatedly cited by Ontario growers as major impediments to the successful production of most horticulture crops in Ontario, including tree fruit and hops. Integrated pest management, including the ability to assess pest populations easily and accurately throughout the entire surface area of the crop, is critical to making cost-effective control decisions. A major impediment to this for growers of large crops are the challenges inherent in identifying plant health problems in the upper canopy, where many pest issues arise.

Tall crops such as tree fruit and hops present a pest monitoring challenge because the upper canopy, which can be in excess of 16 feet high (in the case of hops) is difficult for scouts to easily or quickly view. Current options include using the naked eye, which is unreliable, or binoculars or ladders, which are time consuming and rarely used for routine scouting.

The inability to properly assess pest populations in the upper portion of the canopy can mean that some pest populations are missed in their earlier stages, when they are easier to control, or that pest densities within a tree are under- or over-estimated. Utilizing technologies such as drones to provide an aerial view of the upper canopy is one potential solution to this problem.

As drone technology has improved, newer models have become available on the market that are affordable for most growers and can generate high resolution images from the air while still being small enough that they can be operated without requiring a drone licence or the need to hire a company. This project evaluated the use of a relatively low cost, widely available drone that does not require a license for operation to scout two tall crops (apples and hops) and compare its effectiveness and ease of use to traditional scouting methods.

Drone

The drone purchased was a DJI Mini 2 Quadcopter Drone (Figure 1). For under $750, this drone offered:

- 10 km video transmission
- 4K-Ultra HD camera stabilized on a 3-axis gimbal
- remote controller that connects to smart phone
- spare propellors
- 3 rechargeable lithium-ion batteries with a charging hub

The total weight of the system is 249 g which is below the weight limit requiring licencing and registration with Transport Canada. It also features auto take-off and landing, which is helpful for less experienced users.

Figure 1. DJI Mini 2 Quadcopter Drone

Image Collection

The following images were collected during drone flights (Figure 2) within the Simcoe Research Station hopyard (Figures 3-5) and apple orchard (Figures 6 & 7).

Evaluation of use and efficacy

For apples, drones did not improve efficiency of scouting compared to traditional methods as similar pest damage was identified from the ground. However, more accurate identification of fruit damage (eg., stink bug) and severity of minor foliar pest damage (eg., Japanese beetle, leafcurling midge, rosy apple aphid, frogeye leaf spot) in the upper canopy was observed with drone imaging.

Figure 2. Images were collected from the upper canopy of randomly selected plants within the field.

Figure 3. Aerial view of hopyard can provide information on hot spots, growth habits and/or variation between research treatments.

Figure 4. Damaged cones in upper canopy of hops detected by drone assessment.

Figure 5. Over-row view of upper canopy of hops gives view of cones, foliage and general growth habits that cannot be observed with traditional ground scouting.

Figure 6. Damaged fruit in upper canopy of apple tree detected by drone assessment.

Figure 7. Over-row view of upper canopy of apple tree gives view of fruit, foliage and general growth habits that cannot be observed with traditional ground scouting.

Evaluation of use and efficacy

For apples, drones did not improve efficiency of scouting compared to traditional methods as similar pest damage was identified from the ground. However, more accurate identification of fruit damage (eg., stink bug) and severity of minor foliar pest damage (eg., Japanese beetle, leafcurling midge, rosy apple aphid, frogeye leaf spot) in the upper canopy was observed with drone imaging.

The following overview of the advantages and disadvantages of drone use as a low-input scouting aide is based on our experience with a DJI Mini 2 Quadcopter Drone.

Advantages

1. **Greater accuracy or confidence in identification of pest issues**
   - More detailed pest imaging and information for tall crops such as hops with the ability to zoom into trouble areas. Some pixellation occurs when zooming into photos taken with this drone, however it is possible to view details not visible from the ground.
   - More refined photographs and better area of view than could be captured by traditional ground scout.
   - Better assessment of impact of pest control efforts across upper canopy. Top down view of tall plants also facilitates detection of issues related to exposure of upper plant parts to sun or heavy wind as well as growth pattern irregularities.
   - Better assessment of pest distribution and patterns across entire field which helps to detect hot spots.

2. **User friendly**
   - User friendly even for those with limited experience with drones.
   - Assuming line-of-sight maintained, can be used while standing outside orchard or field. This has potential for use when access is limited due to restricted entry intervals (to be explored further in coming years).
   - Potential to use drone to assess efficiency of equipment and/or coverage (e.g. above orchard photos of sprayer or fertilizer applicator) to determine if chemicals are being adequately applied to target crops.

3. **Economical**
   - Relatively inexpensive drone models are available. Note – although limited in use compared to more expensive models, drone used for this project was less than $1,000 and adequately met needs.
   - Depending on drone purchased, extra parts for commonly damaged or worn parts such as propellors are included. Warranty and protection plans may also be available.
   - For experienced fliers, time spent in flight may be less compared to manual scout – but must also factor in time assessing photos.
   - Eliminates need for crop destruct to identify plant health issue in upper canopy of tall crop.

Disadvantages

1. **Useability**
   - Where drone is used near to adjacent land or homes, communication with neighbouring landowners will be required to address privacy or other concerns.
   - User should be aware of Transport Canada's regulations and restrictions, for example, weight limits, licensing, flight zones, proximity to commercial air zones, and maximum flight height.
   - Depending on drone, installation of app on phone may be required for use. Apps may not be available or limited in use on some phone platforms.
   - During use, drone requires flat surface for take-off and landing which may be challenging in long grasses, bare ground or uneven surfaces.
   - For trellised crops, photos tend to be limited to either side of the trellis due to difficulties maneuvering the drone too close to the structure. This means it is not always possible to get photos of issues on all sides of leaves, or of plant parts deep within the canopy.

2. **Time investment**
    - May be more time-consuming than conventional ground scout for inexperienced fliers.
    - Depending on light conditions, users may not be able to assess images in real-time due to limited view on phone screen.
    - Potential for large number of photographs that must then be assessed in office following flight.
    - Without ability to reliably assess images in the field under all conditions, hots spots are not always flagged in real-time.
    - Limited to 30 minutes of flight activity per battery charge which may be reduced under extreme heat or cold conditions.

3. **Weather impacts**
    - Due to light weight, drone is sensitive to windy conditions.
    - Easily damaged if blown off-course or comes in contact with crop, structure, etc.
    - Delayed or weak signal between drone and base common under extreme heat with phone, depending on model, frequently overheating with extended use.
    - Battery charge reduced under extreme heat or cold conditions.

Conclusions

The use of low-cost drones is not likely to replace traditional in-field scouting for most growers or consultants but could be integrated as an additional support tool. With experienced fliers, drones offer the potential for improved accuracy and detection of pest issues, growth irregularities and/or other production issues in the upper canopy of tall crops that wouldn't normally be observed using traditional scouting methods.

Upper canopy drone scouting may have a good fit for crops greater than 12-feet such as hops or standard nut or fruit trees. However, with semi-dwarf high-density fruit trees that are below 12-feet, visual observations from the ground may be just as efficient and accurate.

The use of drones for scouting may provide access to a field where entry is restricted, such as following a pesticide application. This would enable the grower or consultant to still gather critical pest information such a biofix or early symptom development within a restricted entry interval that would otherwise be unattainable.

We will continue to assess efficacy for crop scouting at various points in the season, including those times when access to the field is limited due to restricted entry intervals. We also plan to further investigate the use of drones for monitoring multiple styles of insect traps (e.g., diamond or delta traps, yellow or white sticky cards) as a low-cost alternative to camera traps which can run upwards of $2000 per trap and do not offer algorithms for all orchard pests.

Announcements

Registration Now Open for 2023 Ontario Fruit & Vegetable Convention

February 22 & 23, 2023

The Ontario Fruit and Vegetable Convention (OFVC), Canada's premier horticultural event, is returning to the Niagara Falls Convention Centre, Ontario on **February 22-23, 2023**. Registration is now open. For more information on pricing, trade show and speaker program, visit http://www.ofvc.ca.

New this year! The Apple speaker program will be adding an additional half-day session, taking place Wednesday afternoon, Thursday morning & Thursday afternoon.

Wednesday, February 22

AFTERNOON

2:00 pm	**Grower Panel – Apple Disease Management: Alternatives to Group M Fungicides** *Brian Rideout, Manitree Fruit Farm; Pat Johnson, AppleTop Farm; Manus Boonzaier, Algoma Orchards; Katie Goldenhar, OMAFRA*
2:30 – 4:00 pm	**Roundtable Discussion: Strategies for Apple Disease Management** *Facilitator - Kristy Grigg-McGuffin, OMAFRA*

Thursday, February 23

MORNING

9:30 am	**Rootstocks and Nutrient Uptake in Apples** *Dr. Lee Kalcsits, Washington State University*
10:00 am	**Hexanal: An Unexpected Saviour of Bitter Pit in Honeycrisp** *Dr. Jay Subramanian, University of Guelph*
10:30 am	**Mitigating Risk of Internal Browning in Apples** *Dr. Jennifer DeEll, OMAFRA*
11:00 am	**A Root Cause Analysis of Declining Apple Trees** *Dr. Marc Fuchs, Cornell University*

AFTERNOON

2:00 pm	**Characterizing Apple Rootstock and Scion Genotypes for Cold Hardiness and Dormancy** *Dr. Jason Londo, Cornell University*
2:30 pm	**Optimizing Chemical Management for Control of Bitter Rot and Marssonina Blotch** *Dr. Kari Peter, Penn State University (live stream)*
3:00 pm	**Dealing with Ambrosia – A British Columbia Perspective** *Hank Markgraf, Syngenta*
3:30 pm	**Your Apple Thinning Calendar** *Erika DeBrouwer, OMAFRA*

Other educational sessions that may be of interest to apple growers include:

- AgRobotics
- Cider
- Irrigation
- Labour
- Soil Fertility
- Workforce
- Mental Health

- Transition Planning
- Waste Reduction
- Women in Agriculture
- Young Farmer Forum
- …and more!

For the full speaker program, visit https://www.ofvc.ca/sessions.html.

Updates Continue for the Ontario Crop Protection Hub

With the soft launch of the Ontario Crop Protection Hub in Spring 2022, OMAFRA has been working hard to integrate the feedback received to continue to improve this digital service. Thank you to all who continue to explore this new platform and provide feedback.

Over the winter, you will see new features and content added for apples including:

- New product registration
- Direct link to PMRA label search
- Option to skip growth stage in pest search
- Search function and filter options in product listing
- Apple landing page with additional tables and resources

More information on these features and other new content to come shortly. Be on the lookout for training opportunities specific to apple growers over the winter. Subscribe to ONfruit for the most up to date event listings.

Agricultural Information Contact Centre: **1-877-424-1300**
E-mail: ag.info.omafra@ontario.ca
Northern Ontario Regional Office: **1-800-461-6132**

www.ontario.ca/omafra