

ORCHARD NETWORK

For Commercial Apple Producers

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Orchard Management

Virtual 'Honeycrisp' Meetup: All Summaries

Erika DeBrouwer, Tree Fruit Specialist, OMAFRA

The four-part 'Honeycrisp' specific webinars took place throughout June and July. The events were hosted by Washington State University, Michigan State University, Cornell University, along with the IFTA and Good Fruit Growers.

Crop Load Management Summary

Overview

To kick off the event, participants and hosts including Mario Miranda Sazo, Anna Walis, Bernardita Sallato, Terence Robinson, Lee Kalcsits, Lailiang Cheng, Gregory Lang, Greg Peck, Esmaeil Fallahi, and Stefano Musacchi.

The meeting then showed a compilation of video footage taken from orchards across the three states showcasing different crop load management practices. This footage was compiled from the 2021 Virtual IFTA Conference that took place in February.

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Grower Perspectives

Bruce Allen, Washington Grower
Stated from his experience, the most effective crop load management tool is dormant pruning – as it is a tough task to chemically thin if you have a target of 95 yet have over 130 blooms per tree. He tries to chemically thin whenever possible to decrease the need for hand thinning in his orchard.

Jason Woodworth, New York Grower
Stated that his recent change to ATS application and use of the pollen tube growth model (PTGM) has had its risks in New York but has ultimately paid off. He measures apples with his employees for 3 or 4 days to make sure his fruit count is precise. During pruning he has dedicated people counting buds (2 fruit:1 vegetative) and delivers this information to the people pruning in order to have a real time approach when managing crop load.

Chris Kropf, Michigan Grower
Stated that his chemical thinning strategy changes based on the year and tries different rates and products to get a better idea of what works well in his orchard. He stated that there is promise with NAA application during bloom and the product has become a dedicated part of his return bloom program.

Presentations

After the video portion of the webinar, Terrance Robinson followed with a short presentation about the importance of crop load. Terrance went over how proper crop load management can (1) Control biennialism (2) Obtain proper fruit size (3) Optimize fruit quality. He stressed that when growers want to manage crop load, what they are focusing on is the seed load. He went on to say that - from a physiological standpoint - gibberellins that are produced within the seeds and shoot tips inhibit flower initiation and that the balance between flower promoting hormones and gibberellins determines whether terminal meristems are converted to a floral meristem or remains vegetative. The amount of seeds per cluster becomes an important factor in spur gibberellin levels. In a season with high blossom density, the seed count if high and therefore gibberellin level is extremely high. The gibberellin levels are critical during flower initiation, which for 'Honeycrisp', was found to occur in June (New York).

From this theory, Robinson states that controlling bud number through various methods is important. He recommends (1) pruning and (2) blossom thinning to decrease the biennial bearing nature of 'Honeycrisp' trees. Pruning is his number one resource for reduction in crop load, recommending a 1.8x target fruit count. This is because excessive flower buds divides your resources (nitrogen, carbohydrates and cytokinin) leading to weak buds with low set, small fruit and more biennial bearing tendencies. Another reason is because excessive flower buds results in high gibberellins for the following year, making it very difficult to overcome the negative effects of gibberellin. An example showing the dramatic difference in seed count between recommended pruning versus high floral buds is below.

'**Honeycrisp' with recommended pruning:**
131 flowering spurs * 5 fruit/spur = 6,550 seeds
'**Honeycrisp' with excessive flowering spurs:**
300 flowering spurs * 5 fruits/spur = 15,000 seeds

Blossom thinning is also important in 'Honeycrisp' trees to lower seed count and limit gibberellin activity, which inhibits flower development from bloom to hand thinning time. Terrence reiterated the importance of early fruit reduction to manage fruit number targets better and improve flower initiation.

Terrence touched on why applications of NAA or Ethrel result in inconsistent return blooms, and attributes this to timing of sprays due to the earliness of flower initiation in 'Honeycrisp'. He suggested using bloom thinners earlier, but keep in mind that application could cause excessive thinning. This is a riskier strategy, but no bloom next year is even more risky, from Terrence's perspective.

Overall, four takeaways were given:

1. Pruning to the optimum bud number (1.8 buds per final target fruit number) will reduce biennial bearing tendencies and improve fruit quality
2. Blossom thinning is essential in biennial bearing cultivars
3. Seed load per spur and per tree are important determinants of biennial bearing characteristics
4. Early return bloom sprays are more likely to stimulate flower initiation then later sprays

After Terrence completed his presentation, Stefano Musacchi followed with a presentation summarizing his findings on multiple studies. He stated that there was a definitive link between crop load, fruit weight, colouration, dry matter. He found that the higher the crop load, the lower the fruit weight and dry matter, along with a decreased presence of blush colouration. He went on to describe that dry matter is of importance to consumers, as it relates to fruit quality. Stefano complimented Robinson's presentation, reiterating the importance of crop load management in 'Honeycrisp'. Stefano found that 'Honeycrisp' has been shown to be very responsive to gibberellin, where crop load adjustment the year prior affected return bloom.

Stefano then covered other studies conducted on rootstocks, crop load and fruit quality. Showing that not all rootstocks behave the same in response to crop load and fruit weight. This was also shown in regard to dry matter, soluble sugar content and index of absorbance difference (I_{AD}). Bud9 showed higher levels of dry matter in comparison to the other rootstocks (G41, G11, G935 and M9-337). Stefano conducted fruit mineral analyses as well, displaying that potassium levels slowly lowered in Bud9 with an increased crop load, while G41 remained constant. Calcium levels increased in Bud9 rootstocks with crop load and zinc decreased with crop load on G41.

Finally, a ratio between potassium and calcium was analyzed in 'Honeycrisp' fruit on different rootstocks, showing an overall decrease with an increase in crop load on Bud9. Stefano's stated that a ratio of 23 between potassium and calcium resulted in no bitter pit in Bud9, G41, G11, G935 and M9-337 rootstocks. Stefano displayed a graph illustrating rootstocks more prone to the incidence of bitter pit in 2019 showing that G41 had the highest incidence, followed by V5, V6, V7, G30 then M9-337 and others. In conclusion, Stefano stated that further information would be proved during the 'Rootstock Meet-up' session.

Question & Answer Period

During the Q&A period many different topics were covered, but some standout points are listed below.

- Growers with more than 200 flower clusters at bloom is in trouble. It is recommended that pruning and early chemical thinners are applied to lower the flower cluster amount and reduce biennial nature.
- Floral initiation in 'Honeycrisp' is early and occurs a week after full bloom. Bourse shoots stop early due to the low vigour of the variety. This can be assessed when the growth from one node to another slows i.e. it takes 5 to 6 days rather than 2 to 3 days for another node to develop. This means flower induction is occurring.
- Bloom thinners are recommended 'Honeycrisp' to reduce the biennial bearing nature of the cultivar. If a grower could reach 60-70% of spurs each year rather then 100% to 0% year to year, this would lead to a more consistent crop, leading to better management and preparation.
- Too late of chemical thinner applications leads to a higher seed load and will make it more difficult to reduce the biennial nature of 'Honeycrisp'
- Terrence theorizes that 10 nodes need to develop before a floral bud develops for the following season at the tip of new growth. Drought affects return bloom in this sense, where not enough growth could occur due to drought in 2020 during late May and early June.

Review

Overall, Terrence, Stefano and the grower panel all insist on pruning and blossom thinning to better manage the crop load of 'Honeycrisp' and decrease the biennial bearing nature of this variety. Terrence theorized that gibberellin levels are high

in the seeds of fruitlets, inhibiting the conversion from a vegetative meristem to a floral meristem. Stefano focused on his research findings stating that crop load is important for growing quality 'Honeycrisp' apples and that rootstock plays a very important role in all aspects of a successful consumer experience and grower production strategies.

Please keep in mind that these findings, suggestions and comments are based off of New York, Washington and Michigan data and experiences. If you would like to watch the recorded sessions, along with the question and answer portions of the meet-ups, please feel free to email me at erika.debrouwer@ontario.ca for the direct link.

Rootstock Summary

Overview

Terrence Robinson covers various topics on rootstocks, including the economic impact on rootstock selection, bitter pit analysis, calcium ratios and the Cornell SAP analysis. Tom Auvil, a North American Plant Horticulturist, discusses differences between rootstocks grown across the country. Grower discussions with Rod Farrow, Chris Kropf and Bruce Allen speak on the impact of rootstock choices, followed by a question and answer period.

Presentation Notes

Terrence started off the meeting with stating the important factors that need to be considered when choosing a rootstock to provide optimal growth and yield – scion vigour, soil vigour, climate vigour and rootstock vigour.

'Honeycrisp' is known to be a low vigour variety and Terrence uttered this sentiment throughout his presentation, stating that 'Honeycrisp' needs to fill the space in 2-3 years upon planting. Terrence echoed the importance of rootstock selection to get maximum fruit value and income for growers, which was demonstrated in his findings.

Terrence analyzed two commonly discussed topics, bitter pit and rootstock choice. From his research, B9, G65 and G214 had the lowest incidence of bitter pit, but he stated that this wasn't the full picture. He wanted to analyze the economic impact of choosing a different rootstock over multiple years. To get these values, he analyzed overall yields based on common densities with various rootstocks, then compared them to bitter pit free yields. He found that G214 and G935 were the highest in regard to crop value (roughly $1,300,000/ha), M9T337 sat in the mid to high range earning roughly $1,100,000/ha, while B9 was among the lower spectrum, earning roughly $9,000,000/ha.

Another question that Terrence briefly discussed was the management of fertilization based on rootstock selection. When discussing 'Honeycrisp', he made the following suggestions based on potassium and calcium ratios taken from the Cornell SAP Analysis/Peel Analysis (https://www.goodfruit.com/an-a-peeling-approach-for-bitter-pit-prediction/):

Orchards with High K:Ca (>27)

- Increase quantity of Ca in foliar sprays
- Avoid application of ReTain or Harvista
- Avoid application of SmartFresh
- Eliminate annual N applications
- Eliminate annual K applications
- Increase lime applications

Orchards with Moderate K:Ca (23-27)

- Increase quantity of Ca in foliar sprays
- Reduce annual N applications by 50%
- Reduce annual K applications by 50%
- Increase lime applications

Tom Auvil followed Terrence's presentation, where Tom spoke about the differences in rootstock choices throughout the US dependent on location. He noted that rootstocks are affected by longitude along with elevation. Most of his findings were based on Washington sites, where more precocious rootstocks had higher yields, due to filling in the fruit canopy faster. He noted that B9 rootstocks had to be planted closer, ending up with double the number of trees to reach consistent yields and have competitive productivity.

Grower Perspectives

Three growers from different states were given the opportunity to discuss their experience with different rootstocks.

Rod Farrow, New York Grower
Rod stated that most of his orchard is on B9 and B10 for simplicity. He wanted to have multiple varieties from the nursery and for ease of ordering, he chose these rootstocks. He learned to adapt to the difficulty of the low vigour in B9 but is now eyeing his 'Honeycrisp' levels. He is a strong believer in assessing your canopy and states that if you only have a 60-70% full canopy, that you should only expect that in your yield.

Chris Kropf, Michigan Grower
Chris echoed Rod, stating that although B9 takes time to fil the canopy the low pruning in later years pays itself. He tried M9 rootstocks but were too vigourous and ended up pulling the trees. Chris believes that B9 works for him, as once the space is filled the trees are easy to manage. He also brought up that it is difficult to change rootstocks when growers have adapted maintenance strategies and are comfortable with their choice.

Bruce Allen, Washington Grower
Bruce has every rootstock, except B9, which was mostly due to availability. He stated that the most important dynamic in growing 'Honeycrisp' is what Terrence stated, "the marketable yield is the driver of economic efficiency". Although he agreed with this statement, he also said that there are so many other factors to consider, other than just bitter pit free rootstocks. Winter hardiness, fire blight resistance, among other characteristics are also valuable when selecting a rootstock.

Question & Answer Period
During the Q&A period many different topics were covered, but some standout points are listed below.

- Tom noted that B9 is non-replant friendly in his experience if the soil goes unfumigated. He also stated that Geneva rootstocks in general have been more successful for replanting due to their vigour. He also stated that unfumigated Geneva rootstocks performed better than fumigated B9 or other non-Geneva rootstocks.
- Tom and Terrance both noted that it would be interesting to test various rootstocks in relation to tree density to establish ideal tree spacing for each rootstock against various performance measures.
- A topic of study is water-use efficiency on scion management, as stomates react differently.
- Apogee or Kudos applications at pink can calm down vigorous rootstocks, but it is not a solution to the vigour problem.
- Lee Kalcsits stated that some rootstocks are more responsive to water limitations or excess (i.e. G890) which can affect growing habits, but B9 isn't one of these rootstocks.
- Artificial freezing study ongoing on various rootstocks, as in recent years there have been cold snaps in late fall that have devastated nursery trees. It is hard to make blanket statements about cold hardiness as warming and cooling throughout critical times can affect the response.

Review
In closing, Terrence stated that he believes rootstock choice will affect your bottom line and is an economic question that he believes growers make without knowing the true economic repercussions of their choice. The grower panel agreed with this statement to an extent, where they believe additional factors other than bitter pit and closing canopies should be considered when determining the best rootstock for their operations.

Please keep in mind that these findings, suggestions and comments are based off of New York, Washington and Michigan data and experiences. If you would like to watch the recorded sessions, along with the question and answer portions of the meet-ups, please feel free to email me at erika.debrouwer@ontario.ca for the direct link.

Nutrient Management Summary
Overview
Lailiang Cheng, a professor from Cornell University started off this meetup discussing nutrient management in regard to growing habits and bitter pit. Essie Fallahi, from the University of Idaho, followed showing results of various studies on bitter pit indicators and thinning timing relation to bitter pit development. Lee Kalcsits finished the presentations urging growers to make educated decisions on rootstock choice based on site location and management practices, he then concluded with studies on the application of foliar calcium. Growers Rod Farrow, Chris Kropf and Bruce Allen spoke about what rootstocks and applications work on their farm. This was followed by a question and answer period.

Presentation Notes

Lailiang started with the growing habit of 'Honeycrisp', stating that it is a weak variety that is sensitive to nitrogen and prone to bitter pit. Suggesting that the best way to manage 'Honeycrisp' trees is to optimize nitrogen status to achieve quality fruit and maintain tree vigour. He also stated that bitter pit it not only a calcium deficiency, but rather a balance of calcium with potassium and magnesium to mitigate the post harvest disorder.

Throughout the growing season nitrogen levels are high, promoting shoot growth and cell division, but nitrogen lowers throughout the season to guarantee fruit quality and wood maturity. Zonal chlorosis occurs as nitrogen levels diminish, meaning that testing should be completed before chlorosis visualization. Nitrogen leaf levels are expected to be between 2 to 2.2% in late June to early July, while fruit nitrogen should be less than 0.25%. Lailiang suggested due to the growing habit of 'Honeycrisp' the growers want to make nitrogen available during shoot growth, as this is when demand is highest. More specifically he suggested the following:

- Fertigation: utilize during petal fall
- Ground application: between bud break and petal fall

Lailiang also stated that the later nitrogen is applied, the higher the nitrogen levels are within the fruit. Sandy soils play a role in the application of nitrogen, where Lailiang suggested to apply right after harvest, stating that this could promote root growth in the fall as the trees would have a reserve.

Going into bitter pit, Lailiang explained that it is a localized calcium deficiency that occurs that the cellular level where cells die causing the sunken pits growers see externally. Calcium plays an integral role in maintaining cell structure and membrane integrity, but the nutrient is limited later in the season as calcium is transported through the xylem, which functions through transpiration. Shoots transpire more then fruit, meaning calcium is primarily delivered to shoots. Further, the delivery of calcium to the calyx end of apples depends on the vascular bundles within the fruit. Some studies theorize that the vascular bundles within 'Honeycrisp' apples are less efficient than Gala in delivering calcium, which could be why bitter pit is more prone in the variety. There is also a link with potassium, where it can inhibit calcium uptake at the root level when potassium is too high within the soil. To mitigate this factor, Lailiang suggests choosing a rootstock that takes up calcium more efficiently or one that takes up less potassium.

Lailiang's final sentiment covered the Cornell SAP analysis, which analyzes water soluble nutrients only within the peel of the apple. He believes that this could be used as a great indicator for fruit nutrient status, suggesting the submission of 30 fruit per block.

Essie Fallahi then followed Lailiang's lead, where he analyzed different types of calcium assessments for better indication of bitter pit. He looked at the following: (1) calyx flesh calcium, (2) calyx skin calcium, (3) calyx flesh and skin calcium, (4) wedge flesh calcium, (5) wedge skin calcium and (6) wedge flesh and skin calcium. He found that 3 (calyx skin calcium) and 4 (calyx flesh and skin calcium) were the best indicators for bitter pit prevalence. He then explained that from his research, yield was found to be proportionate to fruit weight, where later thinning resulted in lower yield and smaller fruit. He also noted that a heavy thinning early in the season resulted in higher bitter pit at harvest.

Lee Kalcsits, from Washington State University, covered various rootstock studies that he has conducted. Starting with the relationship between crop load, rootstock, and nutrient management. His findings were based on trials in 10 different locations (across the U.S.) over three years. He noted that crop load was not a perfect relationship in regard to rootstock, but a common theme across rootstocks. He then proceeded to state that the potassium to calcium relationship, along with rootstock, environment, soil and crop load all play a factor in bitter pit development. A strong linear relationship between calcium and potassium, or nitrogen and calcium were shown in regard to bitter pit development. If there was a low potassium to calcium ratio, along with a high crop load the incidence of bitter pit was also shown to be low. In 'Honeycrisp', he found that bitter pit tolerant rootstocks included B.9, G.969 and CG.4003, while bitter pit vulnerable rootstocks included G.41, G.11 V.6. These findings were consistent across the 10 locations studied.

Moving on from rootstocks, Lee discussed foliar calcium applications. Stating that application is highly dependent on fruit surface contact and only has a 1-2% efficacy on cortex absorption. This also relies on crop load and vigour, where calcium concentrations would need to be 200-300% higher to increase fruit calcium by 10%.

He concluded with a few suggestions regarding nutrient management:

- Foliar sprays:
    - Spray throughout the season and start as early as possible
    - Be careful with nitrogen, magnesium or potassium applications – especially late in the season (antagonists)
- Transitioning from establishment to production

    - First 2 to 3 years are crucial and can make or break orchard long-term profitability
    - Account for nutrient reserves and tree vigour when going into production
- Soil Applications
    - Soil applications are beneficial, but nutrient uptake is related to soil type, rootstock and conditions (environment, crop load etc.)

Grower Perspectives

Bruce Allen: Washington Grower
Bruce noted that in Washington, soils aren't lacking in calcium, and on his farm he has mostly silt loam with low organic matter and high pH. He broadcasts nitrogen at 10-30 lbs per acre based on tree vigour. Throughout the season he has an aggressive nutrient leaf sampling strategy to make sure nutrient levels are appropriate. He normally applies zinc and boron in the spring and fall. Utilizes foliar nitrogen post harvest based on time and weather. Every time they spray the orchard calcium is incorporated (as long as there isn't a compatibility issue), this ends up being once a week with foliar calcium chloride. He noted that you can never get enough calcium applied.

Chris Kropf: Michigan Grower
Chris has different sites, where one is a clay loam and the other is more of a loam sand soil. He noted that he pays particular attention to trees in their first 3 years, making sure they have everything they need to fill space. In the first year he gives the trees enough water, but doesn't want to over water, he then hits the trees with water hard in their second year. At their farm nutrients are applied hard in year 2 and 3, where the trees are band applied with calcium nitrate, but lightens up this application once the space has been filled. He noted that with the extreme weather it has been difficult to manage bitter pit as they had a 6-week drought then had 5-7 inches of rain.

Rod Farrow: New York Grower
Rod has tried various applications throughout his orchard, he currently applies foliar nitrogen to all of the established blocks within his orchard after harvest. His sites have a high organic matter, so there is normally lots of nitrogen available in each season. He noted that drought stress after bloom has influenced his irrigation system, where if there is any sense of a deficit, he applies water. He has also trialed different forms of calcium to mitigate bitter pit but hasn't noticed much of a difference, so he relies on calcium chloride. He noted that his focus is on risk management and each grower manages this differently.

Question and Answer Period

During the Q&A period many different topics were covered, but some standout points are listed below.

- There was no consensus on whether more applications of calcium throughout the season mitigated bitter pit, as some growers noted success, but others didn't.
- Essie stated that irrigation on Fuji apples changes potassium uptake, where drip irrigation had lower potassium uptake compared to other high-volume water irrigation setups.
- Deficit irrigation has been trialed in Washington to mitigate bitter pit, but this year was unsuccessful due to extreme weather (heat).
- Early uptake of calcium is important for cell membrane development, meaning root uptake early in the season is crucial. Therefore, if a grower has a vigorous rootstock, it should be controlled later in the season (when calcium can't reach the fruit).
- Bruce went into detail about how to prepare land for replant, where he suggested the best approach is to be well organized to avoid timing issues. You should be prepping the soil – deep ripping, fumigating, nutrient application (compost, manure etc.), having irrigation lined up, supplies for trellis.

Review

Overall, Lailiang noted that due to 'Honeycrisp"s biennial nature, nitrogen should be evaluated each year and to look out for chlorosis timing, as this happens when nitrogen is low. That being said, Lee suggested that foliar applications of nutrients shouldn't be solely relied on and they should be treated as a tool to utilize. Due to the relationship of calcium, potassium and nitrogen in regard to bitter pit, it is better to secure calcium earlier in the season when the xylem is more functional. Control of vigour should occur later in the season as nitrogen and potassium transport more efficiently then calcium at this time.

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Post Harvest Summary

Overview

Randy Beaudry from Michigan State University presented on the post harvest issues with 'Honeycrisp' apples, noting characteristics, and findings in his research. Chris Watkins, from Cornell University, then followed with other post harvest issues and findings in New York.

Presentation Notes

Randy Beaudry kicked off his presentation saying that 'Honeycrisp' is the problem child of apple varieties. He noted that 'Honeycrisp' apples are difficult to time harvest, where maturity is more than one feature of development. Many post harvest disorders are dependent on maturity, which could be why there are many challenges associated with the variety. Randy then went into detail about the various post harvest issues related to 'Honeycrisp':

Senescent breakdown
- Increases with maturity
- Firm until the end then starts - browning from the outside inward.
- A higher storage temperature leads to increase
- Controlled by low oxygen and 1-MCP

Soggy Breakdown
- Increases with maturity
- Not affected with 1-MCP
- Suppressed by elevated temperatures and preconditioning

CO2 (CA) Injury
- Decreases with maturation
- Can be worse under low oxygen
- Controlled by DPA (need three days to internalize)
- Minimized by preconditioning
- Can be enhanced by 1MCP (but not always)
- Damage occurs within the first 6 weeks of storage, but as quickly as 3 days.

Soft Scald
- Increases with maturity
- Reduction with field application of 1-MCP
- Suppressed by preconditioning
- Not controlled by CA

Diffuse Internal Browning
- Highly variety dependent
- Rare in 'Honeycrisp'
- Primary chilling related (worse in cool years)
- Not controlled by DPA
- Associated with lower Ca/Mg and Ca/K ratios
- Damage occurs 3-5 months into storage

Bitter Pit (BP)
- Know it's related to Calcium, but unsure how its related
- Number of things associated with BP
- Early harvest could be associated
- BP can be accentuated with conditioning
- Conducted study with field conditioning, 0, 1, 3, 5 and 7 days in field. Observed that apples are responding to the change in environment – 7 days showed no PH disorders.

Randy is currently studying lower oxygen limit of apples, where he found that Empire and McIntosh have a regular curve, while 'Honeycrisp' shows an erratic behaviour and different types of analysis gave different results.

Randy concluded his presentation with a slide related to CA injury:
- Do not use CA storage, rather store in air with 1-MCP treatment
- Delayed CA, 30 days before establishment, <1%CO2
- High temperature condition followed by CA
- DPA treatment followed by CA

Chris Watkins then started his presentation with an interesting statement, "People would always say that 'Honeycrisp' was a grower's nightmare and a researcher's delight, well I believe that it too is a researcher's nightmare". Chris mentioned the difference between ReTain and Harvista, where ReTain is an inhibitor of ethylene biosynthesis and Harvista is and inhibitor of ethylene action, but essentially have similar responses.

Chris then went onto explain his findings comparing 'Honeycrisp' apples treated with the following (i) control without 1-MCP (ii) control with 1-MCP (iii) Harvista without 1-MCP and (iv) Harvista with 1-MCP, where he found the following in relation to storage disorders:

Bitter Pit was lower when treated with only 1-MCP, but bitter pit it is known to be associated with early harvest and is something to keep in mind.

Leather Blotch was shown to be exacerbated by 1-MCP and had an additive effect when used with Harvista. Chris believes that leather blotch could be related to bitter pit, but it has never been demonstrated.

Core Browning is an internal disorder that was significantly increased by 1-MCP application. It is not affected by plant growth regulators, but Chris has found that this is not always the case.

Senescent breakdown has been shown to be more consistent with less mature fruit. Less breakdown was seen with Harvista use and slightly less with 1-MCP application.

Wrinkly Skin is a disorder that happens irregularly and don't have a handle on cause, but Chris assumes that it could be associated with water loss. There was a significant decrease with Harvista application, which suggests that it could be maturity related.

The following storage disorders were placed into storage directly at 0.5°C with no conditioning.

Greasiness was shown to dramatically decrease with Harvista and 1-MCP application.

Core Browning was shown to have 55-60% control with 1-MCP application.

Soft Scald was significantly reduced by Harvista application.

In a different trial on McIntosh and Empire apples, the comparison between control, Harvista, ReTain along with and without 1-MCP was observed in **carbon dioxide injury** and **core browning**. It was found that both field applications of Harvista and ReTain had similar affects in increasing the disorders.

Question & Answer Period

During the Q&A period many different topics were covered, but some standout points are listed below.

- Problem with most growers seems to be taking off apples at the proper time, as they cannot get all of the apples off of one variety before the next is at the ideal harvest timing.
- Most growers find that 'Honeycrisp' apples seem to have different issues each year – whether that be related to weather, timing, crop load etc.
- Bruce, a Washington grower, suggested that every year a grower should be planning their harvest in relation to labour and ideal timing. He also suggested that targeting blocks and varieties by rate or by multiple picks to meet ideal maturity.
- Chris Watkins believes that storage and application to improve apple longevity is becoming more precise and could in fact be precision agriculture due to growers knowing their operation, distribution timing, along with the analytical approach of PGR application.
- Carolina Torres, from Washington State University, briefly spoke about mineral concentrations in pack outs, as more lenticel breakdown has been observed in Gala. She noted that water changes should be conducted regularly.

Review

Overall, Randy concluded that 'Honeycrisp' ripens similarly to McIntosh but 'Honeycrisp' is slower to colour. He believes that preharvest applications of ReTain and 1-MCP are beneficial, but to keep in mind the chilling sensitivity of 'Honeycrisp'. In closing, Chris stated that with longer storage periods, the effects of PGR's and postharvest 1-MCP should be considered. He also noted that PGR's shouldn't be used in blocks with a high prevalence to bitter pit. Leather blotch and core browning are of significant concern as 1-MCP increase the susceptibility in fruit treated with PGR's.

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Grower Trial on the Pollen Tube Growth Model

Erika DeBrouwer, Tree Fruit Specialist, OMAFRA

Many growers have heard of the Pollen Tube Growth Model (PTGM). This model was developed by Virginia Tech. to better assist in timing of applying blossom thinners in apples. It is a model that is varietal specific and has been integrated within the NEWA system in the United States. In Ontario, we have been trialling the PTGM with commercial growers to see the efficacy and applicability of this modeling system within our growing region. The PTGM is still being validated and is currently being tested in Washington, Virginia, and New York. It is currently under review within Ontario to determine whether the model can be adapted to the province's climate, weather stations and apple cultivars.

Background

The PTGM model uses the ideal number of king blooms for a target crop load, weather data and king style length to determine the best timing for bloom thinner application. This modelling system uses the theory that based on style length, a certain amount of time needs to pass for proper fertilization of the flower.

How To Use:

1. Growers start by assessing their orchard to determine their target crop load
2. Once the amount of king blooms is equal the targeted crop load, step 3 should be conducted
3. Collection/Measurement of 25 to 50 king styles occurs
4. Using this information, the king style lengths are inputted into the modelling system
5. The PTGM then uses predictive weather data to assess the best time and date for effective bloom thinning application
6. This timing changes based on variety, chemical thinner, weather etc.
7. Application of chemical thinner is applied
8. Grower checks on trees and assesses whether a second chemical thinner application is warranted
9. The PTGM will give another date and time for a second chemical thinner application

Site Location and Treatments

Two grower sites were chosen in 2020 to test the model on 'Honeycrisp' apple trees, where site one was in district 3 and site two was located in district 2.

Table 1. Site descriptions of the apple sites used for the Pollen Tube Growth Model

Site One:	Site Two:
District: Three Variety: 'Honeycrisp' Rootstock: M9 Tree Spacing: 10 feet x 8 inches Tree Age: 2011 and 2007 plantings Irrigation: Drip	District: Two Variety: 'Honeycrisp' Rootstock: M9 Tree Spacing: 14 feet x 8 feet Tree Age: 2005 plantings Irrigation: Drip

Site one had four treatments including:

1. Control (no chemical thinner application)
2. Ammonium thiosulfate (ATS) at grower timing
3. ATS at PTGM timing (1 application)
4. ATS at PTGM timing (2 applications)

Site two had three treatments including:

1. Control (no chemical thinner application)
2. Lime sulphur (LS) at PTGM timing
3. ATS at PTGM timing

Site data was taken differently due to the growing habit, structure, and density of trees at each location. At site one return bloom data was taken between wires, representing bottom, middle and top wires. Site two return bloom data was taken from two branches in each portion of the tree, representing the bottom, middle and top.

Findings

In this preliminary trial we found varying results. At site one, the control treatment had the lowest amount of fruit per tree, while at site two the opposite was found (Table 2). This could be due to the small area utilized for control at site one in comparison to site two. At site one, when comparing grower timing versus at PTGM timing with one application of ATS we see an increase in average fruit count, average return fruit bud, average return bud overall and a higher fruit to vegetative bud percentage. Site two (Table 3) displayed lower fruit count, but higher average fruit weight and average return fruit bud count with PTGM timing and thinners. These findings are to be expected, as thinners will decrease the average fruit count, thereby increasing fruit weight on the tree due to tree energy focuses on the fewer fruit that have stayed on the tree. Return bloom in the control treatment versus the LS and ATS treatments demonstrated that application of chemical thinners increases return bloom.

Table 2. Site one findings regarding fruit count and return bloom

Treatment	Average Fruit Count Per Tree*	Average Return Fruit Bud (Count)	Average Return Bud (Count)	Average Fruit to Vegetative Bud (%)
Control	34.6	7.9	60.9	14.92
ATS Grower Timing	43.6	9.5	56.1	20.43
ATS PTGM (1 application)	53.4	16.1	58.3	38.25
ATS PTGM (2 applications)	51.8	9.4	57.4	19.66

*Data taken in 2020

Table 3. Site two findings regarding fruit count, weight and return bloom count

Treatment	Average Fruit Count Per Tree*	Average Fruit Weight (grams)*	Average Return Fruit Bud (Count)
Control	197.8	244.6	5.9
LS PTGM	149.4	286.0	15.0
ATS PTGM	143.6	263.7	12.2

*Data taken in 2020

Figures 1 and 2 demonstrate the average return fruit bud counts based on the bottom, middle and top sections of trees, along with the average in comparison to the different treatments at both sites. Site one showed that the highest return fruit buds occurred in the ATS PTGM (1 app.) treatment (16.1 count), followed by ATS Grower Timing (9.5 count), then ATS PTGM (2 apps.) (9.4 count) and control (7.9 count). Site two showed that control had the lowest amount of fruit return buds (5.9 count), ATS PTGM treatment had a count of 12.2 and the LS PTGM treatment had the highest return fruit buds with a count of 15 count. The control treatment was expected to have the lowest return fruit bud due to no thinning practices being utilized, which was seen at both locations. When analyzing the growers standard timing at site one, it was comparable to ATS PTGM (2 apps.), meaning that the grower has a great understanding of their orchard in determining the best time to apply chemical thinners and that the ATS PTGM (2 apps.) could have been over thinned, resulting in lower return fruit buds. The ATS PTGM (1 app.) had the most effect in return fruit bud count, demonstrating that the model has ***potential*** in being successful for ideal chemical thinning timing in Ontario. This was further exemplified at site two, where both treatments showed an increase in return fruit buds in comparison to control.

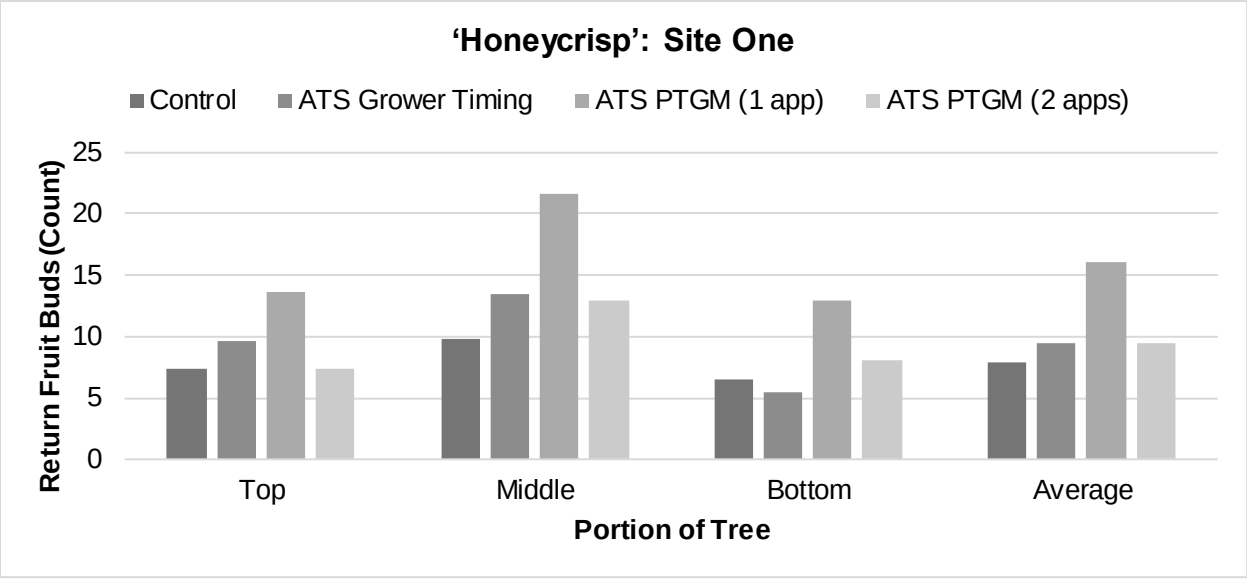


Figure 1. Graph illustrating return bloom in top, middle and bottom portions of apple trees, along with the average return bloom at site one.

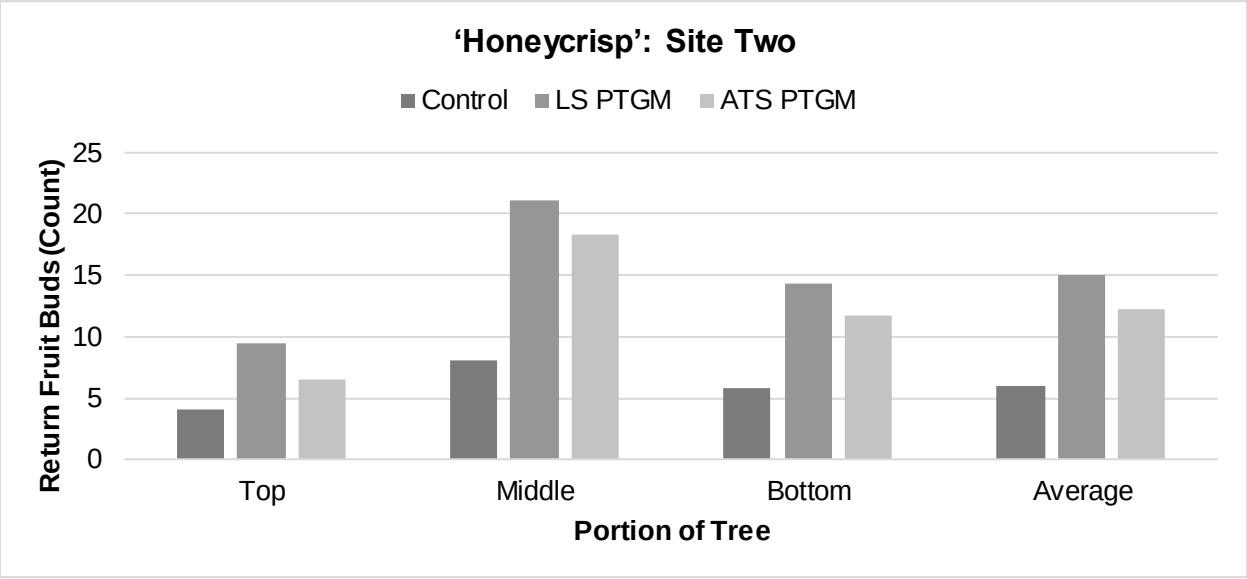


Figure 2. Graph illustrating return bloom in top, middle and bottom portions of apple trees, along with the average return bloom at site one.

Grower Comments

Both growers stated that the model would be worth using in the future, as it is another tool to become more efficient with chemical thinning. It is a guideline that could be invaluable when utilizing chemical thinners, where one grower stated that it requires less work then other models currently being used. The grower also stated that the PTGM could be used across the province on various orchard production styles. Both growers were interesting in utilizing the PTGM specifically in 'Honeycrisp' apples due to the biennial nature of the variety. The only challenge associated with the PTGM would be the integration of the model for grower accessibility.

Summary

This preliminary grower trial demonstrated that the PTGM could have a place for use in Ontario, showing positive results in blossom thinning, return bloom and crop load management.

This preliminary trial demonstrated that chemical thinners could decrease the biennial nature of ''Honeycrisp'' apples, but further research should be conducted, trialing the Pollen Tube Growth Model on different cultivars with various thinners and applications.

Thank you to Dr. John Cline who assisted with analysis and the growers who permitted trialing the model on their orchards.

Crop Protection

Comparing Three Brands of Water Sensitive Paper

Jason Deveau, Application Technology Specialist, OMAFRA

Introduction

Spray coverage describes the degree of contact between spray droplets and the target surface area. This metric can be used to predict the success of an application. One of the easiest methods for visualizing coverage is to use water sensitive paper (WSP), which is a passive, artificial collector that turns from yellow to blue when contacted by water.

WSP is often used to evaluate iterative changes to a spray program. Placed strategically throughout a target canopy, or directly on the ground, achieving uniform, threshold coverage translates into improved efficacy, reduced waste, reduced off-target contamination and reduced risk of pesticide resistance development. WSP were also used to develop a system that measures the area covered by the effective radial distance in an attempt to relate the area covered by a stain to a larger area where sufficient pesticide activity is taking place.

WSP tends to underestimate the spreading effect that can occur on plant surfaces (especially when surfactants are used), but they are effective as a relative index.

A brief history of WSP

In 1970, a journal article described a new method for sampling and assessing spray droplets. Photographic paper treated with bromoethyl blue created a yellow surface that changed colour when it encountered moisture. The pH-based reaction was fast and irreversible, leaving a distinct blue stain to mark the deposition.

Ciba-Geigy Ltd. made water sensitive paper commercially available in 1985 (later as Novartis in 1996 and as Syngenta since 2000). It is produced in several formats, but aluminum foil packages of 50, 76 x 22 mm (1 x 3 in.) papers are the most popular. Odds are if you've ever used water sensitive paper, it originated from Syngenta in Switzerland. Recently, two new options have been made commercially available: Innoquest's SpotOn Paper (United States) and WSPaper (Brazil). At the time of writing, there has been no impartial comparative evaluation of these three products.

Once dry, the blue stains on WSP are irreversible and papers can be stored for long periods of time. However unstained portions will continue to react to moisture from humidity, dew, or fingerprints, so care must be taken in their handling and storage.

Comparing WSP brands

The three commercially-available brands of WSP were subjected to a series of comparisons. The intention was not to rank these products, but to determine if they performed in a similar fashion and to alert users to any significant differences.

1. ***Packaging and Appearance***

Each package was donated for the study. The SpotOn (SO) papers had a "sell-by" date of November 2023, the Syngenta (SY) papers (provided via Spraying Systems Co.) were dated February 2021 and the WSPaper (WS) was their newest formulation (white package, not silver), received June 2021. The comparison was performed on July 5, 2021.

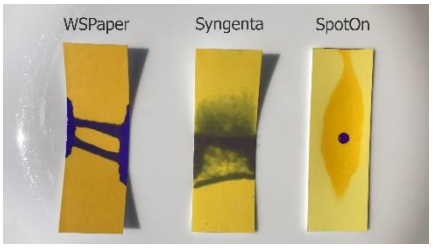
Each product was a foil or plasticized bag of 50, 26 x 76 mm papers. SO and WS had a re-sealing feature similar to a that of a sandwich bag. SO also included a package of silica gel desiccant to capture moisture and a pair of plastic forceps to facilitate handling.

Users are encouraged to label papers to ensure they know their relative position and sprayer pass for later analysis. It was possible to write in ink on the faces of the SY and SO papers, but not WS. It was possible to write on the back of all brands.

The three papers were different shades of yellow. Further, in the author's experience, the colour can be visibly different between batches of the same brand. In the case of larger experiments where more than 50 papers are required, it would be prudent to ensure papers are not only from the same manufacturer, but the same production batch. This would not be an issue when subjectively comparing papers, but when using software that employs colour thresholding to identify deposits, it could create artifacts. Presently, only Syngenta has a batch number (found on a sticker on the back of the bag).

1. Bleed Through

SP is often placed in foliar canopies which are subject to dew and transpiration that can cause the papers to react prematurely. This can be particularly limiting when moisture soaks through the backs of papers. Each brand of paper was placed face-up on a drop of water to see if the water would bleed through.

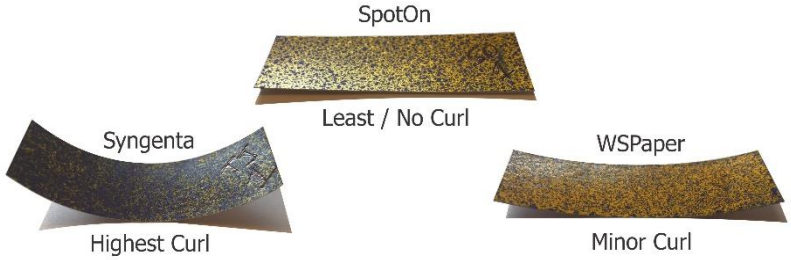


WS quickly curled as the water wicked in from the edges. Within five minutes the water soaked through from the back as well. Within five minutes SY also curled, but the colour reaction was entirely due to water soaking through and not wicking along the edges of the paper. SO did not curl and there was no colour reaction save a minor wicking reaction at one edge. It did however produce a dark yellow patch. In order to see if a colour reaction was still possible, a single drop of water was placed on the face and the colour reaction was distinct and instantaneous.

Note: Others have since replicated this experiment and reported that the response depends on the amount of water used and how long you leave it. We repeated our experiment with higher volumes and longer wait times (see image below). Ultimately, no brand of WSP is water proof from the back. Nevertheless, with small volumes of water (such as from dew) the original assessment of each brand is still valid.

2. Deformation and Drying Time

Users of water sensitive paper may be familiar with its occasional tendency to curl when one side is sprayed. In extreme cases, this movement could create smears if the paper contacted other wetted surfaces in dense foliage. The degree of curling was significantly different by brand, with SY becoming convex when wet and then flexing back into a concave form once dry. WS deformed as well, but only to a minor degree. SO did not appear to deform at all. Syngenta has noted that the degree to which their papers curl depends on the batch. Their manufacturing process has changed over the years in response to regulatory requirements and minor adjustments are still occasionally made.



There was no appreciable difference in the time it took for any brand to dry. This is based on attempts to smear papers every 30 seconds. All were dry in under five minutes.

Experimental Design

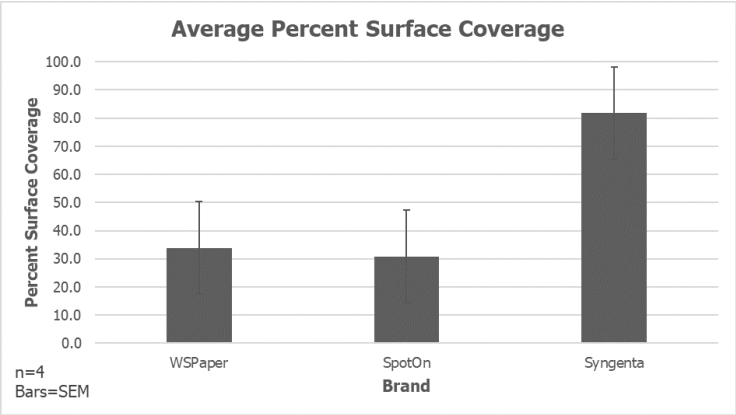
While there is considerable variability inherent to spraying, every effort was made to maintain consistent conditions. Papers were sprayed in a closed room with no appreciable air currents (21.5 °C and 64% RH). Papers were paired randomly, side-by-side on a plastic sled. The sled was pulled at 2.5 kmh (~1.5 mph) through the centre of a spray swath (the coarsest portion of the swath) produced by a TeeJet XR80015 positioned 50 cm (20 in.) above the targets. The nozzle operated at 2.75 bar (40 psi) to produce ~270 L/ha (~29 gpa) with Fine spray quality. Six passes were made, producing four sprayed papers for each brand.

All papers were dry to the touch after two minutes. They were removed to a cooler, low humidity space and were digitized and analyzed using the SprayX DropScope (v.2.3.0) within an hour of spraying. We noted that while WS and SO fit easily into the DropScope port, the SY papers were sometimes slightly wider and had to be forced. Learn more about how to digitize and analyze WSP in this series of articles: https://sprayers101.com/assessing_wsp_pt1/

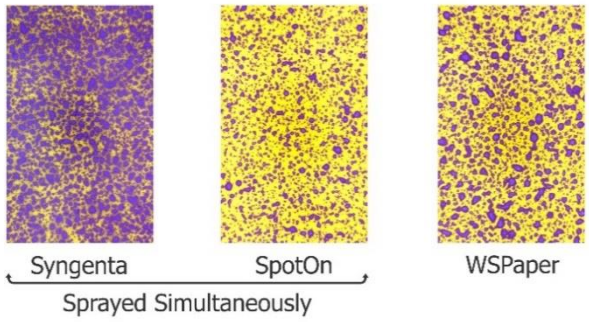
The "ground" option was selected, and each brand of paper was processed using its specific spread factor. DropScope employs a lower detection threshold for deposits less than 35 µm in diameter. This is appropriate as the smallest droplet diameter that can be resolved by any brand of WSP is ~30 µm (Syngenta, Innoquest, SprayX – Personal Communication).

Percent Surface Covered

The average percent surface covered was calculated with standard error of the mean for each paper. WS and SO produced similar values between 30 and 35%. While all three brands exhibited similar variability, SY approached saturation at approximately 80% coverage. Therefore, WSPaper exhibited a slightly higher degree of spread than SpotOn, while the Syngenta paper exhibited a significantly higher degree of spread.

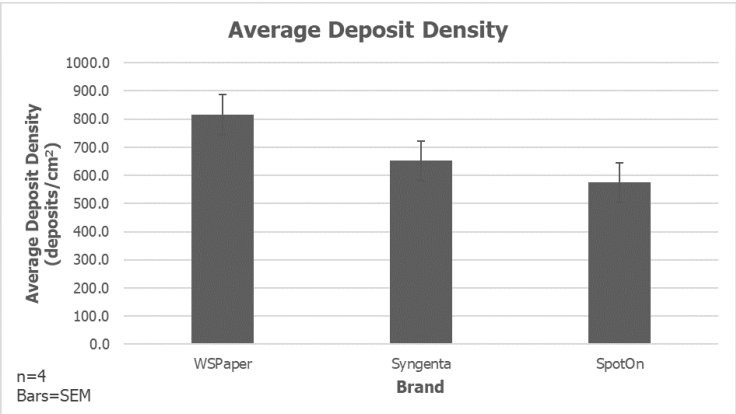


For reference, it can be difficult to determine if a stain represents a single deposit or is the result of multiple overlapping deposits. This becomes a problem when the surface of the WSP exceeds 20% total coverage. Further, it becomes increasingly difficult to distinguish a stain from the background, unstained surface when papers exceed 50% total coverage.



Deposit Density

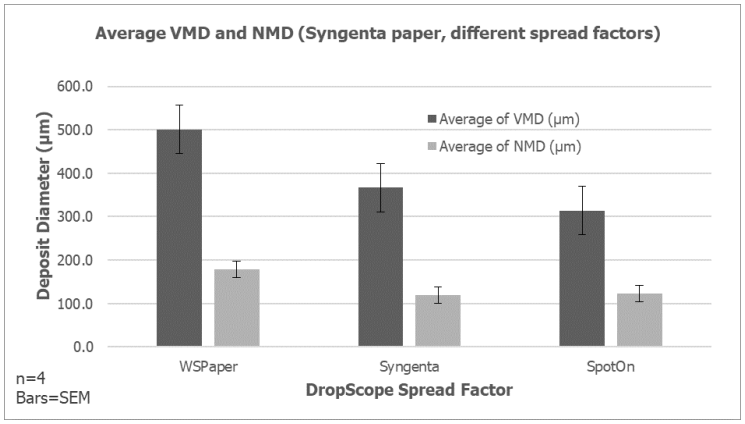
The average deposit density is a count of discrete objects (i.e. stains) per cm2. WS appeared to resolve the highest count, followed by SY and then SO. The process for determining what is a discrete object, and not the result of anomalies such as overlapping deposits, elliptical deposits or imperfections in the paper itself is complicated and computationally heavy. The algorithms employed by DropScope treated each paper consistently. So, while some differences are attributed to variations in spraying, they also reflect the paper's innate ability to resolve individual deposits.

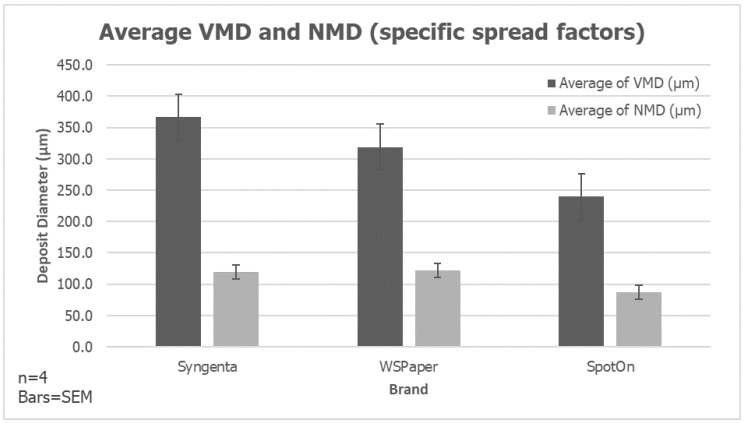


Droplet Diameter

It is not the intent of this article to determine if WSP should be used to extrapolate the original droplet size. The many assumptions and inconsistencies inherent to this process are well known. Nevertheless, some researchers do use WSP in this manner, so a comparison was warranted.

DropScope bins deposit diameters by size to produce histograms of deposit size by count. These stain diameters are used to extrapolate $DV_{0.1}$, $DV_{0.5}$ (VMD), $DV_{0.9}$ and NMD, which describe the population of droplets that produced the stains. $DV_{0.5}$ is the **V**olume **M**ean **D**iameter, or the droplet diameter where half the volume is composed of finer droplets and the other half by coarser droplets. **N**umerical **M**ean **D**iameter is the droplet diameter where half the total droplets are finer, and half the total droplets are coarser.





Each brand of WSP will permit a certain degree of spread when a droplet of water contacts the surface. This spread factor is specific to the brand of paper. Further, the spread factor is not constant for all droplet sizes; Finer droplets will spread less than coarser droplets.

When processing data using DropScope, selecting the appropriate spread factor makes a significant difference to the output. For example, here are the same four SY papers processed using the Syngenta-specific spread factor as well as the spread factors intended for SpotOn and WSPaper.

Therefore, each brand of water sensitive paper was analyzed using its brand-specific spread factor (according to DropScope), to produce the following graph.

SY produced a VMD higher than that of WS, and both were higher than SO. There was less variability in the NMD, but this was expected given the high droplet count on the finer side of a hydraulic nozzle's droplet size spectrum.

Conclusion

Water sensitive paper has immeasurable value in agricultural spraying. It is far more important to encourage its use than to quibble over brands. However, when these tools are used for more rigorous evaluations of spray coverage, brand-specific variability must be addressed.

The differences in how each brand responds to moisture (i.e. discolouration and deformation) may factor into which brand is most appropriate for a given situation. Further, there appear to be significant differences in how each brand resolves coverage. Once again, this may be irrelevant for those spray operators who occasionally use WSP to inform their spraying practices, but for consultants and researchers it is suggested that they use a single brand for an experiment, with papers produced in the same batch run.

Syngenta, Spraying Systems Co., SprayX, WSPaper and Innoquest are gratefully acknowledged for their contribution of materials and time informing this article.

Apple Viruses in Ontario

Kristy Grigg-McGuffin, Katie Goldenhar & Erika DeBrouwer, OMAFRA

Summary

OMAFRA conducted a survey to investigate the spread of known apple viruses across the province. In March, we sampled 'Ambrosia' apple trees ranging from 5 to 12 years old and found that of the 40 trees randomly selected from 10 locations, 65% had apple chlorotic leaf spot virus (ACLSV), 52.5% had apple stem pitting virus (ASPV) and 20% had apple mosaic virus (ApMV). These incidence rates are very high, and of significant concern, 22 (55%) trees had multiple viruses detected. All samples where virus was detected were from M9 rootstock. Virus was not detected in alternative rootstock. While the full impact of viral infections in apples is not known, viruses can contribute to reduced tree vigor and long-term yield loss. Increasing the awareness of viruses in apple tree production is important for careful selection of where growers receive propagative material.

Background

Viral infections are one of many factors that can negatively affect apple production. Viruses have been shown to reduce vigor, limiting the productive lifespan leading to reduced yields by 8-67% (Cembali et al., 2003). Canadian Food Inspection Agency have identified several viruses including ACLSV, ASPV, apple stem groove virus, tomato ring spot virus and tobacco ring spot virus as having the potential to play a role in reducing overall tree health and the inability for a grower to manage the viruses once in the orchard.

In 2016 and 2017, a survey conducted on 2620 apple trees in New York showed that over 54% had a single viral infection, with ASPV being the most frequent at 33% followed by ACLSV at 12% (Fuchs et al., 2018). For co-infections (two or more viruses in the same tree), the most common combination (8% of trees) had both ASPV and ACLSV. Both ASPV and ACLSV are latent viruses and are currently being investigated at Cornell University for their role in rapid apple decline.

Figure 1. Apple mosaic virus on Ambrosia

Ontario has been dealing with rapid collapse in apple trees since 2016. To date, no single organism or disorder has been shown to cause the significant collapse in orchards. On-going research from researchers at Agriculture and Agri-Food Canada (AAFC) has shown a significant number of viruses present in healthy and declining trees. The impact from viruses on decline is still being investigated.

We wanted to know the presence of known apple viruses across the province in randomly selected trees showing no symptoms of decline. In 2020, several growers reported the cultivar 'Ambrosia' showing irregular chlorosis on the leaves (Figure 1) and were positively identified as ApMV as well as ACLSV and ASPV. To investigate this further, a small survey was conducted in March of 2021 in 'Ambrosia' trees from ages 5 to 12.

Methods

Samples were collected before bud break, from March 2 to 17, 2021. Dormant bud sticks were collected at the base of 1-year-old wood (Figure 2). Samples close to leader were used where possible. One stick from 10 major scaffold limbs were taken per tree and packaged together in a zip lock bag. Pruners were sanitized in between each tree and each tree was a separate sample. Four trees were samples randomly throughout a block at 10 locations, two from each of the 5 apple growing districts.


Figure 2. Collection of 1-year dormant wood on Ambrosia for virus detection, March 2021.

Samples were stored at 4-6°C before sending to the Plant Disease Clinic at University of Guelph to be processed for apple chlorotic leaf spot virus (ACLSV), apple stem pitting virus (ASPV), apple mosaic virus (ApMV), apple luteovirus 1 (ALV-1), tobacco ringspot virus (TRSV) and tomato ringspot virus (ToRSV). An ELISA test was used to detect TRSV and ToRSV and RT-PCR tests was used for ACLSV, ASPV, ALV-1 and ApMV. For more information on diagnostic methods used, please contact aflinfo@uoguelph.ca.

Results

Nine out of ten locations had at least one tree that was infected with a virus (Table 1). At five locations, all trees were infected with at least one virus.

The common viruses detected were:

- 26 trees (65%) were infected with ACLSV
- 21 trees (52.5%) were infected with ASPV
- 8 trees (20%) were infected with ApMV
- Most of these were co-infections with only ACLSV having single infections
- ALV-1 was only detected once with three other viruses

Multiple viruses were detected in 22 trees (55%):

- ACLSV was found in all co-infected trees
- 14 trees (35%) were infected with ACLSV and ASPV
- 6 trees (15%) had ACLSV, ASPV and ApMV
- 1 tree (2.5%) had ACLSV and ApMV
- 1 tree (2.5%) had ACLSV, ASPV, ApMV and ALV-1

Apple chlorotic leaf spot virus

ACLSV was the most common virus detected. In this survey, 10% of the trees were only infected with ACLSV, and it was found in all co-infection trees (22 of 40 trees, 55%). This was also the most common virus found in a New York survey. ACLSV can infect pome and stone fruit. It is considered a latent virus, often showing no discernable symptoms but can be impactful with other latent viruses, on susceptible cultivars and certain rootstock combinations. The extent of damage is not known but has been estimated as much as a 30% yield loss.

Table 1. Incidence of viruses in apple orchards in Ontario on 'Ambrosia'

Orchard (district)	N[1]	Single virus infection						Multiple virus infection			
		TRSV	ToRSV	ACLSV	ALV-1	ApMV	ASPV	ACLSV ASPV	ACLSV ApMV	ACLSV ASPV ApMV	ACLSV ASPV ApMV ALV-1
1 (1)	4	0	0	0	0	0	0	3	0	1	0
2 (1)	4	0	0	0	0	0	0	0	0	1	0
3 (2)	4	0	0	0	0	0	0	0	0	0	0
4 (2)	4	0	0	0	0	0	0	4	0	0	0
5 (3)	4	0	0	2	0	0	0	0	0	0	0
6 (3)	4	0	0	0	0	0	0	2	0	2	0
7 (4)	4	0	0	0	0	0	0	2	0	0	0
8 (4)	4	0	0	0	0	0	0	1	0	2	1
9 (5)	4	0	0	1	0	0	0	2	1	0	0
10 (5)	4	0	0	1	0	0	0	0	0	0	0
Totals	**40**	**0 (0%)**	**0 (0%)**	**4 (10%)**	**0 (0%)**	**0 (0%)**	**0 (0%)**	**14 (35%)**	**1 (2.5%)**	**6 (15%)**	**1 (2.5%)**

[1]N=number of trees collected from and tested for apple chlorotic leaf spot virus (ACLSV), apple stem pitting virus (ASPV), apple mosaic virus (ApMV), apple luteovirus 1 (ALV-1), tobacco ringspot virus (TRSV) and tomato ringspot virus (ToRSV).

Apple stem pitting virus

ASPV was found in no single infection but was the most common co-infection with ACLSV (52.5% of samples). ASPV can infect pome fruit. It is considered a latent virus, meaning symptoms are unlikely, leading to undetected infection. Fruit yield has been shown to decrease when co-infected with ACLSV. Pits can be seen in the woody cylinder when infection is severe which can lead to reduced tree vigor.

Apple mosaic virus

ApMV was found in no single virus detection, and only in one co-infection with ACLSV and six co-infections with ACLSV and ASPV. ApMV is named for its characteristic mosaic-like symptoms on leaves. It has a wide host range, including pome, stone fruit, berries, hops and hazelnuts. Most common apple cultivars will remain asymptomatic after infection; however, some will produce symptomatic leaves that may be confined to a certain limb or erratically throughout the tree. Reduced growth in ApMV infected trees has been shown leading to reduced lifespan and yields. The main method of transmission of this virus is grafting (Grimova et al., 2016).

Apple luteovirus 1

ALV-1 was only detected in one tree that was co-infected with ACLSV, ASPV and ApMV. ALV-1 is a recently discovered virus detected in North America. It was found in trees exhibiting apple decline but was also detected in asymptomatic trees. There is ongoing research at AAFC with this virus on apples as its impact on apples is not known.

Tomato and tobacco ring spot virus

TRSV and ToRSV were tested in this survey and not found. These have been shown to infect apples in other regions but have not been commonly detected in Ontario.

Apple stem grooving virus

We did not include apple stem grooving virus (ASGV) in this survey due to lab testing restrictions. This virus is often detected in trees infected with ACLSV and ASPV. It is likely present in Ontario orchards as well and along with the other viruses detected it can result in economic losses.

Next Steps

For these viruses, there are no reported insect vectors and they are not seed transmitted. Most spread has been associated with grafting. This can come from infected budwood or infected rootstock.

There is no management option once in an established orchard. The importance in managing this virus is using clean budwood and rootstock. It is highly recommended to not collect budwood from surveyed orchard or others where virus is also suspected.

Further research is needed to determine the impact of multiple and latent viral infections. Ongoing research at AAFC may lead to insight on the impact to tree decline in Canada. New York researchers at Cornell are investigating the role of common viruses, mainly ACLSV and ASPV, on weakening the root systems of established trees. It is clear from this preliminary survey that viruses are abundant in Ontario apple orchards and need to be considered when propagating and planting new orchards for long term success.

We would like to acknowledge the growers who participated in this survey.

Additional Resources & References

Going underground: Grant roots out rapid apple decline culprit, https://cals.cornell.edu/news/going-underground-grant-roots-out-rapid-apple-decline-culprit

Distribution of Viruses in New York Apple Orchards https://nyshs.org/wp-content/uploads/2019/05/Fuchs-Pages-from-NYFQ-BOOK-WInter-2018.1-27-19-3.pdf

ACLSV Factsheet, https://ecommons.cornell.edu/handle/1813/43944

ASPV Factsheet, https://ecommons.cornell.edu/handle/1813/43945

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Fashionably Late: Apple Insect Pests at Harvest

Kristy Grigg-McGuffin, Horticulture IPM Specialist, OMAFRA

The extreme heat this summer has caused insect flight and development to be earlier and/or extended in some areas of the province. While harvest will undoubtedly take most of a grower's attention, it is still important to continue monitoring for pests and applying control measures where needed. There are some late season insect pests of apples that will remain active up until harvest and if left uncontrolled can wreak havoc on a potentially good crop.

Apple Maggot

With the high soil moisture across many regions of the province, apple maggot emergence has been fairly consistent this season and some orchards are seeing higher than normal pressure. This activity can carry on until the first hard frost, which means late season sprays may be needed if insecticide residues are no longer present (generally 2-3 weeks, depending on product).

Apple maggot damage can occur in two ways. The female creates oviposition stings on the fruit surface by laying her eggs under the skin, leaving a sunken or dimpled appearance (Figure 1). After hatching, the larvae tunnel within the fruit and cause breakdown and discoloration of the pulp (Figure 2). Invasion by disease fungi, such as *Alternaria* spp. and *Pseudomonas* spp. leads to further decay and heavily infested fruit can become completely rotten.

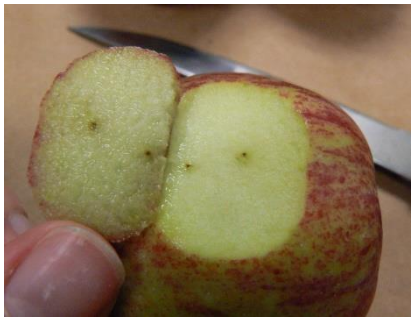

Figure 1. Apple maggot oviposition sting on fruit

Figure 2. Internal breakdown and discoloration of fruit as a result of apple maggot larval feeding.

In Table 1, adapted from research done by John Wise at Michigan State University (2019), the characteristics of apple maggot products are summarized. Organophosphates (Imidan) and neonicotinoids (Aceta, Assail, Calypso) are the only insecticide groups that have activity on the adults as well as a curative effect on the eggs and larvae due to their ability to penetrate into the flesh of the fruit.

Table 1. Summary of insecticides used to manage apple maggot

Product Name	Chemical Group	Life-Stage Activity	Efficacy	Residual Activity	Mite Flaring Potential	Rainfast Rating
Imidan	Organophosphate (1B)	Eggs, larvae, adults	Excellent	14+ days	Low	Low
Ambush, Mako, Perm-Up, Pounce, Up-Cyde	Pyrethroid (3)	Adults	Fair-Good	7-10 days	High	Moderate – High
Aceta, Assail, Calypso, Cormoran	Neonicotinoid (4A)	Eggs, larvae, adults	Good-Excellent	10-14 days	Low-Moderate	Moderate
Delegate, TwinGuard, GF-120 Fruit Fly Bait	Spinosyn (5)	Adults	Fair	7-10 days	Moderate	Moderate – High
Altacor, Exirel, Harvanta, Vayego	Diamide (28)	Adults	Fair-Good	10-14 days	Low	Moderate – High
Surround	Not classified	Adults (deterrent)	Fair	7-10 days	Low	unknown

Adapted from John Wise, MSU: https://www.canr.msu.edu/news/managing-apple-maggots-with-insecticides and https://www.canr.msu.edu/news/rainfast_characteristics_of_insecticides_on_fruit

The timing of apple maggot sprays usually coincides with codling moth control applications, and as a result a single insecticide spray can often be used to manage both of these pests. It is important to remember that while some chemistries such as Altacor or Delegate provide effective management of codling moth, they will only provide apple maggot suppression in low pressure orchards. Exirel seems to have good activity on apple maggot. However, this product cannot be tank-mixed or used in sequential applications with strobilurins, copper or captan fungicides. The previously mentioned products as well as the neonicotinoids have residual activity that lasts 10-14 days, so re-application will be necessary. The organophosphate, Imidan is effective in managing both codling moth and apple maggot in orchards, and the residual lasts 18-21 days. For most products registered for apple maggot, re-application will likely be necessary following a significant rainfall (>1 inch rain). See Table 1 for rainfast rating of each chemical group.

Surround (kaolin clay) can be an effective tool for managing apple maggot. However, applications must be applied to orchards prior to adult emergence, and be maintained as long as flies continue to be captured. At this point in the season, it is too late to begin using this product effectively if it is not already in place. In orchards where Surround is being applied, use starch iodine tests to monitor fruit maturity in the last 2 weeks of crop development.

Imidan border sprays can be effective later in the season when the longer re-entry restrictions won't interfere as much with work that needs to be done. However, keep an eye on preharvest interval restrictions. As well, if trap catches remain consistently high or if damage is detected during routine monitoring of the orchard, return to a full cover spray program. Border sprays are not recommended for other registered apple maggot products at this time.

Figure 3. Codling moth infested apple. Note the entry/exit hole plugged with brown frass.

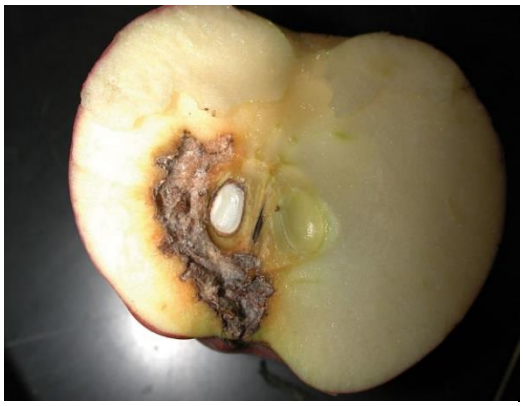

Figure 4. Internal flesh damage of apple by oriental fruit moth. Note, oriental fruit moth feed on flesh while codling moth tunnel and feed directly on core and seeds.

Figure 5. Late season obliquebanded leafroller damage. Fruit damage is often associated with foliar feeding where the leaves are in contact with the fruit.

Codling moth

While there are usually 2 generations of codling moth in Ontario, it is possible to see a 3rd generation (often known as a suicide generation) in some orchards during warmer than average seasons. Codling moth larvae normally enter diapause during the 3rd week of August. However, in warm years and locations, some pupate instead and go on to produce a 3rd generation of adults and worm-infested fruit at harvest if control measures are not taken (Figure 3).

If this occurs, use pheromone traps to establish a new biofix when flight activity increases and apply a spray when the following degree days (DDC) accumulate:

- *Imidan, TwinGuard, Delegate, Altacor*: Apply at 138 DDC.
- *Aceta, Assail, Calypso*: Apply at 111 - 138 DDC. Note – PHI for Calypso is 30 days.
- *Exirel, Harvanta, Vayego, Confirm, Intrepid*: Apply at 83-111 DDC.

It is important to remember that while some of the chemistries listed above provide effective management of codling moth, they will only provide apple maggot suppression in low pressure orchards (Delegate, Altacor) or none at all (Intrepid, Confirm). Take this into consideration when choosing a late season spray.

Oriental fruit moth

Adult flight of oriental fruit moth can last into early October, with damage occurring up to harvest. This late season damage is often quite difficult to detect because larva are so small, similar to codling moth. Infested apples can easily get through packing lines undetected and storage problems can occur as a result (Figure 4).

Monitor pheromone traps in orchards into September to keep an eye on populations. Remember that late season sprays may be needed, especially on light skinned varieties.

For growers using mating disruption, Isomate OFM TT are designed to last for the entire season. However the combined Isomate CM/OFM TT only last up to 90 days for oriental fruit moth, so late season sprays may be needed.

Obliquebanded leafroller

Although both larvae and damage can be found in orchards at the present time and up to harvest, we have passed the point where managing this pest is worthwhile. Late season obliquebanded leafroller development is not synchronized, and sprays affect only the small portion of the population that is active at this time. Instead of spraying, keep an eye out for late season damage during harvest (Figure 5). If damage is found, be sure to apply a petal fall spray targeting leafroller next spring.

Brown Marmorated Stink Bug

As we head onwards towards harvest, the risk of brown marmorated stink bug (BMSB) injury to apples increases in areas where the pest is established. To date, with yearly surveys, there remain to be very few reports in the province of economic loss caused by BMSB.

It's easy to miss both the presence of the bug and early signs of injury (Figure 6), which can take up to two weeks before it is obvious enough to detect without intensive monitoring (Figure 7). What this means is that the pest may be gone by the time you see the injury. Adults are strong flyers that readily move between hosts, including landscape plants and crops, which is why most injury occurs around areas bordered by woods.
With the earlier part of the season being so dry for many, some orchards may see an increase in damage by native stink bugs such as the brown or green stink bug. Damage looks very similar to BMSB but will often occur earlier with damage being quite apparent prior to harvest.

There are very few options for managing BMSB in Ontario and this presents a considerable challenge since activity can extend into early October. For late season use, the current product available is Clutch (1 application if at high rate, 7 days PHI) for suppression. Actara is also registered for suppression but has a PHI of 60 days. Unfortunately, this will be the last year these products will be available as registration has been cancelled. Efficacy studies in Ontario and various regions in US have found few effective alternative products.

Figure 6. Early brown marmorated stink bug damage to apple.

Figure 7. Initial brown marmorated stink bug damage develops into obvious depression over time in storage.

Timing is Everything for "Summer" Apple Disease

Kristy Grigg-McGuffin, OMAFRA Horticulture IPM Specialist

The term 'summer diseases' can be rather misleading when referring to common pathogens of apples such as black rot, bitter rot, fly speck and sooty blotch (FSSB). While symptom development often doesn't really start to appear until later in the summer or into the fall, infection actually occurs much earlier in the season. Missing these timings can cause quite the headache for the remainder of the year.

But firstly, what are these diseases?

Black rot

Lesions begin as sunken black spots (Figure 1) often located in close proximity to mummified fruit left from chemical thinners. Eventually these lesions enlarge into a firm tan or brown rot with concentric rings and black fruiting bodies, or pycnidia (Figure 2). Black rot can be considered a "firm" rot in that the fruit maintains its round shape as the lesion progresses. Varieties which retain mummified fruit such as Gala, 'Honeycrisp', Cortland and Northern Spy are most susceptible.

Figure 1. Black rot symptoms on fruit and leaves (known as frog-eye leaf spot) on apple

Figure 2. Advanced black rot lesion on apple

Figure 3. Bitter rot on apple

Bitter rot

Appear as brown spots that enlarge into sunken lesions (Figure 3) that may be surrounded by a red halo depending on the variety. Especially during wet or humid conditions, masses of salmon-colored spores are produced on surface of lesion. A diagnostic V-shaped rot progressing towards the core can be observed when infected fruit are cut open. Susceptible varieties include Empire, Ambrosia, Gala, 'Honeycrisp' and Idared.

Figure 4. Fly speck on apple

Fly speck

Appear as groups of few to several small (0.5 mm), shiny black fungal bodies, or thyriothecia on the fruit surface (Figure 4). Although these fungal bodies appear to exist individually, they are connected by mycelium to form colonies, typically in round or irregular groups 1-3 cm in diameter. Fly speck often appears together with sooty blotch and does not damage the flesh.

Figure 5. Sooty blotch on apple

Sooty blotch

Appear as brown to olive green, cloudy blotches with irregular margins on the surface of the skin, often more obvious on light-coloured fruit (Figure 5). These blotches can be removed with vigorous rubbing. In storage, fruit with sooty blotch infection shrivel more readily than uninfected fruit.

When does infection occur?

Fruit rot spores can overwinter in dead wood, cracks, cankers and mummified fruit. Black rot infection can occur as early as bud break under high pressure; however, most commonly activity begins between late tight cluster and bloom. Early indication of spore activity is the presence of black rot infection on leaves, known as frog-eye leaf spot. Look for these lesions following a period of wet weather.

While the biology of bitter rot is not as well understood as black rot, especially in Ontario, early evidence suggests this pathogen also begins activity over bloom. Infection can remain dormant for an extended period. Symptom development for fruit rots typically peak mid- to late summer following higher temperatures accompanied by rain or thunderstorms.

Spores of FSSB overwinter on branches, culled fruit and woody wild hosts such as brambles, grapes, oak, ash, elm and maple. These spores are moved into the orchard by wind or rain for 1-2 months beginning after bloom. However, first symptoms typically develop 2-3 weeks after infection. In unsprayed trials, sooty blotch seems to appear first because of a shorter incubation period, beginning approx. 2-3 weeks after petal fall versus 4-6 weeks after petal fall for fly speck. There is a fly speck forecasting model that predicts the start of infection beginning 175 leaf wetting hours after petal fall with symptom development appearing after another 175 leaf wetting hours, or 350 leaf wetting hours from petal fall.

How can these diseases be managed?

While infection does occur earlier, late season control of these diseases is still critical, especially when things are beginning to relax back on scab management for the summer. As scab fungicide residues are depleted, these other pathogens can resume growth and produce symptoms. Several studies have shown that while common scab fungicides can stop the in-season development of rots and FSSB, these products may not eradicate infection, leading to issues at harvest or in storage.

For management of summer diseases, follow a 14-21-day application interval until harvest to ensure fruit remains protected. Table 1 summarizes activity of fungicides that could be used for summer disease control. Residual protection will vary depending on the product used. For example, Pristine can provide reasonable residual control of summer disease up to 3 weeks at the labelled rate in ideal conditions; however, captan should not be pushed further than 14-days between sprays particularly since it is not as strong on fly speck and sooty blotch as other control products. In all cases, reduce interval to 7 days during times of hot, wet weather. Re-apply if there has been >2 inches of rain since the last application.

Table 1. Activity of registered fungicides on fly speck / sooty blotch (FSSB), black rot and bitter rot

Product	Group	PHI	Scab	FSSB	Black rot	Bitter rot
Captan	M	19 days*	+++(+)	++(+)	+++(+)	+++
Folpan (NR)	M	1 day	++(+)	++(+)	++(+)	+++
Senator (NR)	1	1 day	+++	++++	+++	+
Aprovia Top	3+7	30 days	++++	+++	—	—
Inspire Super	3+9	14 days	++++	+++(+)	—	—
Pristine	7+11	5 days	+++(+)	+++(+)	+++(+)	+++(+)
Merivon	7+11	0 days	+++(+)	+++(+)	+++(+)	+++(+)
Flint	11	14 days	++++	++++	+++	++(+)
Allegro	29	28 days	++	+++	+	+++
Phostrol	33	1 day	—	++	—	—
Regalia Maxx	P5	0 days	+(+)	+(+)	++	+(+)

*PHI 19 days for low/standard orchards, 15 days for high density; NR = Not registered for all pests listed. See label; — = activity is unknown for this pest

Be sure to keep in mind preharvest intervals for all early and late-harvest varieties. Some products that may be most effective for summer disease cannot be used for fruit that will be harvested in the coming weeks. At the same time,

residues will need to be maintained on late-harvested varieties into the fall, especially if the hot weather trend continues in September and October.

It is also important to consider maximum seasonal application restrictions. While the label restriction applies to the active ingredient, one common resistance management strategy is to consider this restriction across the chemical group. For instance, the Pristine label states a maximum of 4 applications per year. For resistance management, where possible, try to limit this to 4 applications of products belonging to Group 11, not just Pristine. However, in an earlier year like the one we've had or during times of high scab pressure, this may not always be feasible.

Important cultural management recommendations include:

- Prune and thin clustered fruit to facilitate drying and improve fungicide coverage.
- Remove potential sources of inoculum such as dead branches, fruit mummies (where possible), infected fruit on the orchard floor and alternate hosts including brambles (blackberry, raspberry) from surrounding hedgerows or woodlots.
- Toss pruning cuts and thinned fruit in the row middle and mulch.
- Reduce tree stress by irrigating and/or applying a sun protectant, especially ahead of a heat wave.

Getting to the (Moldy) Core of Apples

Kristy Grigg-McGuffin, OMAFRA Horticulture IPM Specialist

Moldy core is a disease caused by many different species of fungi that naturally occur in the orchard. Often this issue is not evident until the apple is cut open, showing thick yellow mold and seeds rimmed with white mold (Figure 1). However, affected fruit may also ripen and drop prematurely.

Figure 6. Moldy core in apples has thick yellow mold and seeds rimmed with white mold.

The fungi that cause this disease colonize the flower parts as soon as the blossoms open, entering the developing fruit through an opening in the calyx. Fruit are infected when the spores from these fungi move into the core of the fruit through the calyx. Varieties that generally have an open calyx such as Red Delicious and Idared are more susceptible to moldy core.

Warm weather and humidity favour moldy core development as well as environmental conditions that prevent the calyx from closing in the early fruitlet stage which provide an opportunity for spores to infect the fruit. Once a moldy core fungus infects the core of the apple, fungicide programs are unable to eliminate the disease. Since moldy core penetrates the

flesh during long-term storage and causes rot, it is wise to market fruit that is suspected to have this issue as soon as possible.

This year has been a season for many areas that may have favoured development of this disease as moldy core is more of a problem during years with light fruit set or in years when dry weather in early summer is followed by heavy rains in late summer. Wet weather during bloom also creates conditions favorable for the fungi to produce spores.

Once in an orchard, moldy core does not spread and its presence does not give an indication of future problems. Although some studies have found fungicides used during bloom help to reduce moldy core, results are erratic and fungicides are rarely recommended. However, cultural practices to open the tree canopy and encourage airflow and light penetration help promote fast drying of plant surfaces and can reduce the incidence of moldy core.

Post Harvest

High Quality 'Ambrosia' Apples Depends on Harvest Maturity

Dr. Jennifer DeEll, Fresh Market Quality Specialist – Horticulture Crops, OMAFRA, Simcoe

It is **very important NOT to wait until the background color is yellow to start harvesting** 'Ambrosia' that will go into storage. When the background color is yellow, the fruit will be over-mature and more prone to internal browning and splitting. 'Ambrosia' background color should show more green than yellow at harvest time for good storability.

The starch index can be an overall useful indicator of 'Ambrosia' fruit maturity. **Starch values of 2.5 to 4.0 at harvest time are optimal** for fruit storage. 'Ambrosia' with starch values above 4 should not be stored for long periods of time, as these will be prone to internal browning and splitting.

'Ambrosia' produces very little ethylene during maturation on the tree. As starch is degraded and color changes, there continues to be only trace amounts of internal ethylene present (<1 ppm). This makes **internal ethylene a poor indicator of fruit maturity for 'Ambrosia'.**

I_{AD} readings from a delta absorbance (DA) meter can be useful for accessing fruit maturity in 'Ambrosia'. It has been suggested that **'Ambrosia' should be harvested when I_{AD} readings average 0.7 to 0.6 for storage.** Fruit with values near 0.5 and below should not be stored for extended periods, while those with less than 0.3 should be marketed as soon as possible. Be sure to take DA meter readings on the margin between the blush and non-blush areas, and not directly on the blush or shade sides of the fruit.

Optimum harvest of 'Ambrosia' for storage tends to be **around the same time as 'Empire'.** 'Ambrosia' in Norfolk County (ON) at optimum maturity have measured <1 ppm internal ethylene concentration, fruit firmness ~18-20 lb, starch index ~2 to 4, and background color yellow 2 to 3 on the BC color chart (Figures 1 and 2). Apples harvested later tended to become mealy and soften more rapidly, as well as develop more disorders and greasiness during storage.

Figure 1. 'Ambrosia' ready for harvest.

Figure 2. British Columbia color chart for 'Ambrosia' apples.

Low Oxygen Storage Reduces Internal Browning in 'Ambrosia'

Dr. Jennifer DeEll, Fresh Market Quality Specialist – Horticulture Crops, OMAFRA, Simcoe

'Ambrosia' apples harvested at optimum maturity for storage can be held long-term (i.e. ~8 months) with little firmness loss or disorder development. Optimum fruit maturity at harvest generally consists of more green than yellow background color (2 to 3 on the BC color chart), <1 ppm internal ethylene concentration, fruit firmness above ~18 lb, and starch index between 2 to 4 (Cornell starch chart).

'Ambrosia' responds well to 1-MCP, with reduced firmness loss and mealiness, lower internal ethylene, higher acidity, and reduced greasiness. Controlled atmosphere (CA) storage also improves 'Ambrosia' fruit quality during storage and oxygen levels below 2% are best.

The following CA regimes at 0.5ºC were evaluated during 2018-19:

1) 2.5% O_2 + 2.0% CO_2
2) 1.7% O_2 + 1.0% CO_2
3) <1% O_2 + 0.5% CO_2

The <1% O_2 regime was based on fruit respiration measurements using LabPod™ technology (Storage Control Systems Inc., Michigan). There was an initial flush down to 1.7% O_2 and then oxygen was decreased gradually to 0.6% over several weeks and to 0.4% after a couple months. Postharvest 1-MCP treatments (SmartFresh™) before or after storage were also evaluated in this study, but there was no significant difference due to application timing so these data were combined.

After 8 months of CA storage at 0.5ºC, apples held in 2.5% O_2 were softer (less ~1 lb) and had more internal browning than those held in 1.7% O_2 (Table 1, Figure 1). Apples held in <1% O_2 had much less internal browning (<1% incidence) than fruit from the higher O_2 regimes. No other storage disorders or fruit splitting were noted.

Table 1. Incidence of internal browning in 'Ambrosia' apples after 8 months in CA storage at 0.5ºC.

CA regime	Treatments	Internal Browning (%)
<1% O_2 (LabPod)	**No SmartFresh**	0.7 ^{D}
<1% O_2 (LabPod)	**+ SmartFresh**	0.4 ^{D}
1.7% O_2	**No SmartFresh**	8 ^{C}
1.7% O_2	**+ SmartFresh**	8 ^{C}
2.5% O_2	**No SmartFresh**	24 ^{A}
2.5% O_2	**+ SmartFresh**	16 ^{B}

Figure 1. Internal browning in 'Ambrosia'.

Acknowledgements

Thanks to the Ontario Apple Growers, Norfolk Fruit Growers' Association, Apple Marketers' Association of Ontario, AgroFresh Inc., Pommes Philip Cassidy Inc., GRB Ag. Technologies Inc., Storage Control Systems Inc., Decco US Post-Harvest Inc., and the Canadian Horticultural Council (BC, ON, QC, and NB apple growers) for their continuous support, as well as Sky Lesage, Geoff Lum, and Younes Mostofi for their technical assistance. Recent work was funded in part through the Canadian Horticultural Council's Canadian Agri-Science Cluster for Horticulture 3.

Factors Influencing Internal Browning in 'Gala' Apples during Storage

Dr. Jennifer DeEll, Fresh Market Quality Specialist – Horticulture Crops, OMAFRA, Simcoe

Advancements in controlled atmosphere (CA) storage technology and the advent of postharvest treatments with 1-methylcyclopropene (1-MCP) have enabled apples to be stored longer than ever before. Unfortunately keeping apples longer has also allowed for certain storage disorders to become more problematic. Internal browning is one such problem for 'Gala' apples.

Radial flesh browning near the stem-end (shoulder) of the apple is usually the first sign of internal browning (Figure 1). This can progress towards the calyx end of the fruit, becoming the more common internal browning that can found be when cutting the apple horizontally across the equator. The following is a summary of research results found during our many years of study...

Figure 1. Internal stem-end (shoulder) browning in 'Gala' apple.

High incidence of internal browning is often found when apples are harvested late, at advanced maturity stages. Fruit maturity at harvest time is a major factor affecting this disorder and it is something that can be easily corrected. Research has shown a main effect of harvest time, across several years, with much higher incidence of internal browning in fruit from later harvests (higher than 3 on Cornell starch chart). 'Gala' strain further affects browning development, with some newer strains showing less susceptibility.

Preharvest 1-MCP (Harvista™ orchard spray) can be very effective at reducing internal browning, as it delays advanced maturity (ripening) at harvest time. On the other hand, postharvest 1-MCP treatment does not have consistent effects on internal browning. For example, 'Gala' stored in air at 0.5°C had significantly lower incidence of browning with 1-MCP treatment than without, but only in some years and not consistently. Significant reduction in internal browning due to postharvest 1-MCP was found in CA-stored 'Gala' after 9 months of storage when incidence was extremely high, while other results in certain years showed significant increases in browning with postharvest 1-MCP.

Rapid cooling (to 3°C within 24 hours) right after harvest resulted in more internal browning in 'Gala' apples, compared to slow cooling during 7 days (DeEll, *The Grower, May 2017*). 'Gala' that were cooled rapidly and stored in CA for 8 months at 1°C had 23-32% and 52-59% browning incidence after 1 and 7 days at room temperature, respectively, compared to 0-5% and 6-11% in fruit cooled slowly.

Internal browning increases with longer storage durations, as well as increased time at room temperature following removal from storage. For example, 'Gala' stored in air at 0.5°C had no internal browning after 2 months, 12% after 4 months, and 18% after 6 months. Similarly, 'Gala' held in controlled atmosphere of 2.5% O_2 + 2.0% CO_2 at ~1°C had little internal browning through 5 months of storage, but then the disorder increased significantly with storage time thereafter (up to 59% after 9 months). Furthermore, internal browning increased with subsequent holding at room temperature.

Low oxygen storage or dynamic CA with less than 1% oxygen reduces the development of internal browning. 'Gala' held in oxygen as low as 0.4% using SafePod technology to monitor fruit respiration (Storage Control Systems Inc., Michigan) had zero internal or stem-end browning, compared to 17% incidence of stem-end browning in standard CA (2.5% O2 + 2% CO2) and 6% incidence in low oxygen of 1.5% O2 + 1.1% CO2.

Overall, it is important to remember that there are many factors that influence the development of internal browning in apples. These can range from orchard management, fruit maturity at harvest time, postharvest treatments, to storage conditions and duration.

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Thanks to the Ontario Apple Growers, Norfolk Fruit Growers' Association, Apple Marketers' Association of Ontario, AgroFresh Inc., Pommes Philip Cassidy Inc., GRB Ag. Technologies Inc., Storage Control Systems Inc., Decco US Post-Harvest Inc., and the Canadian Horticultural Council (BC, ON, QC, and NB apple growers) for their continuous support, as well as Sky Lesage, Geoff Lum, and Younes Mostofi for their technical assistance. Recent work was funded in part through the Canadian Horticultural Council's Canadian Agri-Science Cluster for Horticulture 3.

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