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ORCHARD NETWORK

For Commercial Apple Producers

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In this issue…

Orchard Management

Growing Multi-Leader Trees

Amanda Green, Tree Fruit Specialist, OMAFRA

Growing multi-leader trees is gaining interest in North America, especially with two leader trees, also referred to as twin leaders or bibaum. The growing interest in two leaders was evident on the International Fruit Tree Association (IFTA) study tour to Washington State (Figure 1). Alberto Dorigoni, a researcher from Italy, has been pushing further, demonstrating at the Fondazione Edmund Mach research orchard that growing apple trees with more leaders is possible. He has performed trials with up to eight leaders and presented his findings at the IFTA's Annual Conference in Grand Rapids, Michigan.

Why have multiple leaders?
The main goal for training multi-leader trees is to reduce the secondary structure resulting in fruit growing centripetally, closer to the trunk. This will create a wall of fruit which will obtain more uniform light interception through the canopy and produce fruit with more uniform size and colour. With four or more leaders, the vigour is more dispersed among the leaders creating a shorter tree; this creates a pedestrian orchard which could potentially eliminate the use of a ladder or platform, reducing the cost of production. Other advantages of having multi-leader orchards include:

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This issue of the **Orchard Network Newsletter** was compiled by Carolyn Prieur, Client Service Representative, OMAFRA, Vineland Station

- Decreased summer pruning
- Mechanical blossom thinning is more feasible
- Mechanical pruning is easier
- Anti-rain nets (1.1m wide) are possible with a narrow canopy of four or more leaders
- Cost of planting decreases with less trees to plant per hectare

As mechanization increases on the farm, Dorigoni's hypothesis is that it is simpler to adjust the tree to mechanization than it is to adjust mechanization to the tree.

Figure 1: Apple trees with two leaders in Washington State

Comparison of number of leaders

When comparing a tall spindle orchard with two leaders, Dorigoni found that there were a greater number of apples that had better colour with two leaders. Within the height of the tree, the distribution of apples and the colour was more uniform. Over the first eight years of production, cumulative yield of two leaders was equal to or slightly less than tall spindle in 'Fuji' apples and lower yielding with 'Gala'. There was an improvement of colour with 'Gala' apples in a two leader system.

In a trial comparing one, two, three, four, six and eight leaders, Dorigoni found that trees are more precocious in the first six years of production with one, two, or three leaders (three leaders being the greatest) than with four, six or eight leaders, quantified in tons/ha. Looking at kg/tree, three and six leaders had the highest yield over the first six years of production. With these results, it would be quick to rule out four or more leaders but yield per hectare can be increased by decreasing row width. Because the vigour is distributed through more leaders, the height is shorter and therefore you can decrease the row width and still obtain optimal light interception.

In another trial comparing two leaders with four leaders, Gala had a higher yield per hectare with two leaders and Fuji had a greater or equal yield per hectare with four leaders.

Training

Two– leaders

- Start with trees that have two buds grafted on each side at the nursery

or

- Head off whips from the nursery and train up two side shoots
- Can equalize the vigour between the two leaders by taking the most vigourous leader and make two scores, deep enough to cut into the xylem and phloem, one on each side of the leader, 3-4 inches apart and about 8-12 inches away from trunk

Three-leaders

- Start with a single leader tree, keep the main leader and prune off the feathers except for two that you can train upwards (Figure 2)
- To take out vigour on the central leader, girdle it with a plastic zip tie

Four or more leaders

- With a single leader tree, make a heading cut and take the two side shoot to train up
- Take the lower inside branch off of these two side shoots to make the 3rd and 4th leader (Figure 3)
- Four or more leaders can also be trained similarly like a grapevine as a guyot or double guyot
  - Trees need to be angled in nursery
  - Bend the leader to grow horizontally
  - If training a double guyot, take the lowest branch and bend it to grow horizontally in the opposite direction to the first leader
  - Train side branches to grow upright to become leaders

Figure 2. Three-leader trees in a Michigan orchard seen on the tour day of the IFTA Annual Conference

Overall, leaders should be at least 12” apart and optimally 18” apart. Vigour can also be evened out, while the orchard is being established, by cropping the more vigorous leaders to reduce the height.

Are multi-leaders in your future? Multi-leader systems show some great advantages, especially with adaptability to mechanization. Two or three leader systems show the greatest benefit with uniform colour and size of fruit while also maintaining high yields, especially in the early years. If you are considering ways to reduce ladder use and are not interested in investing in a platform, perhaps establishment of a shorter, multi-leader pedestrian orchard may be of interest.

Figure 3. A demonstration by Dorigoni on how to train a two leader tree to be a four leader tree. The new leaders to be trained are in the inside of the original two leaders and are highlighted in red.

References

- Dorigoni, A., Optimized Training Systems for Fuji, Gala, Honeycrisp. International Fruit Tree Association 2016 Pre-Conference Intensive Workshop. Grand Rapids, Michigan, Feb. 6, 2016.
- Dorigoni, A. Precision Apple Production Systems: Modular, Pedestrian, Fruiting Walls. International Fruit Tree Association 2016 Annual Conference. Grand Rapids, Michigan, Feb. 8-10, 2016.

Dormancy and Chill Units

Amanda Green, Tree Fruit Specialist, OMAFRA

This winter, temperatures have been fluctuating greatly with unseasonable mild days, thanks to El Niño. These temperatures have brought out questions on what the effects are on the apple buds and how do chill units affect dormancy. Chill units usually aren't much of concern for Ontario because our winter temperatures usually don't rise much more than a few degrees above zero which will keep buds dormant until spring. In more southern temperate areas, like California, chill units are a concern because seasonal temperatures are higher and they need to get enough chill hours to overcome dormancy. This winter in Ontario the number of chill units that have accumulated is a concern because warm temperatures may signal trees to start coming out of dormancy. To better understand the significance of chill units, it is important to know that there are two types of dormancy that buds go through in the winter:

Endodormancy: Buds are dormant because of internal physiological blocks that prevent growth, even under ideal external conditions for growth. A specific amount of chilling units are required to break through this dormancy. If buds are still in the endodormancy stage, warm temperatures will have no influence on bud growth (Westwood, 1993).

Ecodormancy: Buds are dormant as a result of external conditions unfavorable to growth. Buds will go into the ecodormancy stage once endodormancy is complete. Buds will remain dormant until temperatures are favourable for bud growth (Westwood, 1993).

Apples require 1000 to 1200 chilling units. There are several models that exist for calculating chill units:

- The Chilling Hours Model gives 1 chill unit for every hour that temperatures are between 0 and 7.2 ˚C
- The Utah Model assigns partial, whole and negative chill units depending on the temperature:
  - 1 hour below 1.4 ˚C = 0 chill units
  - 1 hour 1.4-2.4 ˚C = 0.5 chill units
  - 1 hour 2.4- 9.1 ˚C = 1 chill unit
  - 1 hour 9.1- 12.4 ˚C = 0.5 chill units
  - 1 hour 12.4-15.9 ˚C = 0 chill units
  - 1 hour 15.9- 18.0 ˚C = - 0.5 chill units
  - 1 hour above 18.0 ˚C = -1 chill units
- Cornell Extension uses a model developed by Hauagge and Cummins, 1991 which follows this formula: Chilling Unit= $0.277 + 0.1940t - 0.0124t^2$, t= Celsius temperature. It works similarly to the Utah Model, where maximum chilling units are achieved around 7˚C and partial units are assigned for temperatures between -1 and 16 ˚C with a larger fraction of a chilling unit given to temperatures that are closer to 7˚C.

In Table 1, I used the Chilling Hours Model and the model used by Cornell Cooperative Extension to calculate the chilling hours accumulated for various locations in the province and the date when 1200 chilling units were accumulated. Chill units were calculated from October 1st to February 26th. There is quite a large a difference between the two models. The dates when 1200 chilling units were accumulated, under the model used by Cornell Extension, match very closely with what was calculated for New York State.

Table 1. Chilling units accumulated in various locations in Ontario using two different models using temperature data from October 1st 2015, February 26th, 2016.

	Chilling Hours Model (0-7.2˚C)		**Model used by Cornell Cooperative Extension**	
Weather Station Location	**Chilling Units Accumulated as of Feb. 26**	**Date that 1200 Chilling Units Accumulated**	**Chilling Units Accumulated as of Feb. 26**	**Date that 1200 Chilling Units Accumulated**
Cedar Springs	1286	Feb. 19	1867	Dec. 16
Simcoe	1246	Feb. 21	1711	Dec. 16
Fenwick	1279	Feb. 19	1800	Dec 14
Prince Edward County	1291	Feb. 7	1928	Dec. 6
Collingwood	1387	Feb. 1	1792	Dec. 12

Data for all locations except Collingwood was taken from the Vine and Tree Fruit Innovations website:
Collingwood data was taken from the Environment Canada website.

Crop Protection

Reminder to Apple Growers: Last Year to Use Diazinon

Kristy Grigg-McGuffin, Pome Fruit IPM Specialist, OMAFRA

Health Canada's Pest Management Regulatory Agency (PMRA) conducted a re-evaluation of diazinon uses in Canada and determined that most uses could no longer be supported due to health and environmental risk concerns. Through consultation with stakeholders, critical uses of diazinon that had no alternative control strategies were identified for longer-term phase-out to provide more time to develop a risk management plan. In June 2013, PMRA communicated the phase-out dates for diazinon products and the mitigation measures required to further protect workers and the environment, which can be found in their consultation document titled [REV2013-01, *Diazinon Risk Management Plan*].

How will this phase-out affect Ontario apple growers?
In apples, the last date of use for both registered diazinon products, Diazinon 50 WSP (PCP #29976) and Diazinon 500 E (PCP #11889) is **December 31, 2016**.

Alternative options for diazinon are available for most apple pests. However, alternative products may be limited based on the number of different chemical groups to rotate between for resistance management and/or certain alternatives may not provide as effective or consistent control as diazinon for some insect pests (e.g., mullein bug, wooly apple aphid). The following table provides a list of insect pests that Ontario growers are more likely to use diazinon for control of and the alternative products that are registered.

With relatively few alternative options for some pests, it is important to take the following steps to avoid development of insecticide resistance:

- For pests with discrete generations (ie., mullein bug, apple maggot, scale, leafcurling midge), do not use insecticides from the same group for more than one generation. Within a generation, if more than one spray is required, use a product from the same chemical group.
- For pests with rapidly building and overlapping generations (ie., aphids), do not use products containing the same chemical group in consecutive applications.

See Publication 360, Guide to Fruit Production for more information on uses of alternative products for the mentioned pests and others listed on the diazinon labels.

Pest	Alternative products registered
Mullein bug	*Group 4:* Admire 240 F, Alias 240 SC, Assail 70 WP, Actara 25 WG, Calypso 480 SC
Apple maggot	*Group 1:* Imidan 70-WP Instapak *Group 4:* Assail 70 WP, Calypso 480 SC *Group 5:* GF-120 Fruit Fly Bait *(suppression)* *Group 28:* Altacor *(suppression)*, Exirel *Group NC (not classified):* Surround WP
Rosy apple aphid Green apple aphid	*Group 4:* Actara 25 WG, Admire 240 F, Alias 240 SC, Assail 70 WP, Calypso 480 SC, Closer, Clutch 50 WDG, TwinGuard *(Group 4+5)* *Group 9:* Beleaf 50 SG *Group 23:* Movento 240 SC *Group 28:* Exirel *Group NC (not classified)*: Purespray Green Spray Oil 13 E *(suppression, RAA only)*
Wooly apple aphid	*Group 1:* Malathion 25 W, Malathion 85 E *Group 4:* Closer SC *(suppression)*, TwinGuard *(Group 4+5, suppression)* *Group 23:* Movento 240 SC
San Jose scale	*Group 4:* Closer SC *Group 23:* Movento 240 SC *Group NC (not classified):* Purespray Green Spray Oil 13 E, Superior 70 Oil
Apple leafcurling midge *(Diazinon 50 WSP only)*	*Group 3:* Mako *(formerly Ripcord)*, Up-Cyde 2.5 EC

Time to Get Your Apple IPM Program Ready

Kristy Grigg-McGuffin, Pome Fruit IPM Specialist, OMAFRA

Despite this recent blast of winter weather reminding us that it's not spring just yet, the apple growing season will be here before you know it. Now is the time to get your tools ready for an effective IPM program for your orchard.

Don't have a monitoring plan in place yet for your IPM program? Here is a checklist to help you prepare:

Refresh your knowledge of identification, biology and monitoring techniques for common insect and disease pests by taking an IPM Training Workshop. OMAFRA specialists offer a series of free IPM workshops starting in late April and throughout the month of May. The Apple IPM Workshop will be held in Simcoe on May 4th this year. To register, call the Agriculture Information Contact Centre at 1-877-424-1300. Watch for more information on this and workshops for other crops on the ONfruit blog.

If you prefer a more self-directed refresher, check out Ontario AppleIPM. Here you will find interactive online training and information on apple pests and pest management, including scouting calendars, threshold guides, and information on using pheromone and visual traps.

Make sure your farm map is up-to-date. In as much detail as you can, outline new plantings or blocks that have been removed, including information on cultivars, planting dates, etc. Circle where you have had pest problems in the past, such as mite or weed hot spots; or where you've had issues with diseases, such as powdery mildew or fire blight. Use your map to develop a reporting template for your scout or workers to quickly identify where they have found problems.

Familiarize yourself with using pheromone traps, weather monitoring equipment and degree day models to predict precise timing of pest control strategies. The majority of insecticides on the market now are highly targeted to specific pests and with short residual activity, making application timing critical. For example, the timing for products for first generation codling moth range from 83-138 DDC (base 10°C) and could be a difference of 1-2 weeks, depending on the temperature in any one year. For guidelines on using insect pheromone and visual traps, including information on trap type, number, placement and when to deploy for each pest, check out Ontario AppleIPM. Visit the OMAFRA website for a list of pest monitoring equipment suppliers. Be sure to store all lures in the fridge until you are ready to put them out.

Will you have a scout monitoring your orchard this year? **Set up a communication plan with the scout to report findings, such as a weekly scouting template or email.** Keep the scout up to date on when and what crop protection materials have been applied and when it is safe to re-enter the block.

Planning to monitor your orchard on your own? **Designate someone on your farm to monitor on a weekly basis**. Having this determined before the season starts will help ensure this job doesn't get forgotten when all sorts of other issues are pushing you in different directions.

Make up a pest management kit with the right tools for monitoring. This should include a 16-20x hand lens, traps, tapping tray, collection bags and vials, flagging tape, pocket knife, notebook or record sheets, markers, a copy of the farm map and resources on hand, such as *Publication 310, Integrated Pest Management for Apples*, *Publication 360, Guide to Fruit Production* and *Publication 75, Guide to Weed Control.*

Take another look at AppleTracker.com to see how it can help you keep better records. This system provides growers with an innovative, extensive management tool for record keeping and analysis of production events, including tree/block information, food safety and traceability, pest management, crop protection, as well as harvest, storage and shipping event tracking. Now that's being organized! The system is free for all Ontario Apple Grower (OAG) members and each member has their own personal login. Don't have your login information? Email Matt Deir at matthew.deir@dragonflyit.ca.

Stay informed with current pest management topics by subscribing to the new Ontario Fruit Blog: ONfruit. To receive the most timely information, subscribe to the blog by using the "Follow" button. Posts will appear in your email as soon as they're posted.

Coming Soon! 2016-2017 Publication 360, Guide to Fruit Production

Kristy Grigg-McGuffin, Pome Fruit IPM Specialist, OMAFRA

A full revision of the OMAFRA Publication 360, Guide to Fruit Production will be available in late March 2016. This will have the latest information on pest management for commercial production of fruit crops, including apples, berries, grapes, tender fruit and tree nuts, as well as comprehensive sections on crop nutrition, pesticide safety, resistance management, growth regulators and thinning tree fruit.

The Ontario Apple Growers will be purchasing a copy for all their members again this year. In the meantime, information on new product additions and label expansions in the apple calendar can be found in the following previous Orchard Network Newsletter issues:

[Volume 18, Issue 4, December 2014](#)

- Fungicide - Phostrol
- Insecticide/Miticide - Nealta, TwinGuard
- Mating Disruption - Isomate OFM TT
- Plant Growth Regulator - Fruitone L

[Volume 19, Issue 2, April 2015](#)

- Fungicide - Allegro, Pristine, Vivando
- Insecticide/Miticide - Agri-Mek SC, Purespray Green Spray Oil 13 E
- Mating Disruption - Semios OFM Plus

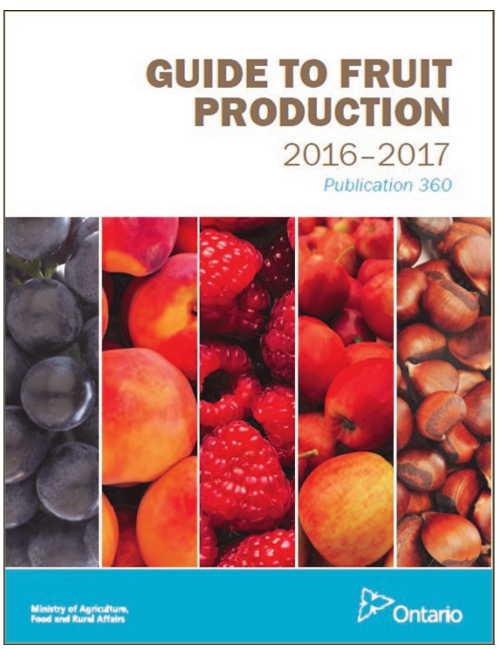
[Volume 19, Issue 4, December 2015](#)

- Fungicide - Aprovia, Cueva, Double Nickel 55, Fullback 125 SC, Regalia Maxx, Sercadis, Serenade OPTI
- Insecticide/Miticide - Mako
- Surfactant - Xiameter OFX-0309

Publication 360, along with many other factsheets, publications and resources, can be ordered from ServiceOntario:

- Online at ontario.ca/publications
- By phone through the ServiceOntario Contact Centre, Monday-Friday, 8:30 am-5:00 pm
  - 416-326-5300
  - 416-325-3408 (TTY)
  - 1-800-668-9938 (Toll-free across Canada)
  - 1-800-268-7095 (TTY Toll-free across Ontario)
- In person at any OMAFRA Resource Centre.

For a complete list of publications from OMAFRA, visit www.ontario.ca/omafra and click on the Publications tab.



A Proposal: Crop-Adapted Spraying in Apple Orchards

Jason Deveau, Application Technology Specialist, OMAFRA

An orchard spraying scenario

Picture this: An orchardist following an IPM protocol identifies a pest that poses an economic threat. This is no surprise because it's an annual pest and spraying is only a matter of when, not if. The operation is 150 acres and runs three airblast sprayers; two have a tower and one does not. Multiple varieties are planted in several blocks on different rootstocks and they are at different stages of maturity. The newer blocks are trellised high density trees and the older blocks are semi-dwarf on different row spacings. Just for fun, let's imagine the pruning team hasn't finished yet, so some trees are not pruned.

Fortunately, the orchardist has the pesticide label to guide them! It helpfully prescribes a range of doses per planted area, depending on the pest pressure. It advises that the orchardist mix an absolute amount of product in "enough water" to ensure the tree is sprayed "to the point of runoff", ostensibly assuming that if the tree is saturated, it will have received the "correct dose".

Our protagonist recognizes that this label is vague, and elects to rely on what has worked historically: A water-soluble pouch is dropped into each tank (close enough), and each sprayer operator is instructed to drive at an efficient speed (get it done because the rain is coming), spraying until the tank is empty (which means they must have hit the target). If a tank is running low before the job is done, they speed up to stretch it. If the spray is overshooting a younger planting, they simply turn off the top nozzles.

It's a fanciful scenario, but I'll bet you recognize your own operation in there somewhere. The question is: Is there a problem with spraying this way if it results in a respectable crop of quality apples? Agricultural engineers specialising in application technology in Spain, Australia, Great Britain and the United States say there is a problem, and on behalf of Canada, I completely agree with them.

Orchard and Sprayer Variability

The fundamental problem is inconsistent spray coverage and excessive waste (of time, water and pesticide) due to variability. Our scenario notes multiple sprayer operators, different models of sprayers, and a range of morphologies, orchard layouts and canopy management practices. International peer-reviewed journal articles stretching back to the sixties have conclusively demonstrated order-of-magnitude differences in the area-density of orchard canopies from one acre to the next. There can even be fold-differences in canopy area-density in the same planting as the season progresses. A label prescribing a fixed dose based on the area planted is not appropriate for any vine, bush or tree crop, and the result is that more crops are over- or under-sprayed than crops that would receive appropriate coverage.

Let us not forget the variability that comes from an un-calibrated or poorly adjusted sprayer. I won't attempt to quantify the impact here (journal articles have suggested order-of-magnitude differences from sprayer to sprayer). I will, however, illustrate it as a conceptual "before" (Figure 1) and "after" (Figure 2):

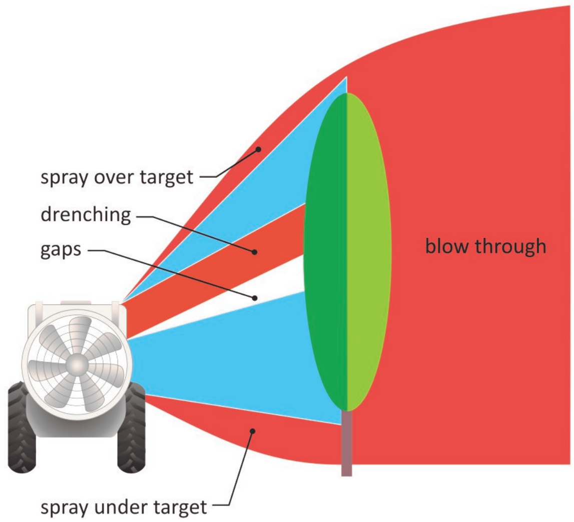


Figure 1 - Potential spray loss and inconsistency before adjusting sprayer to match the canopy.

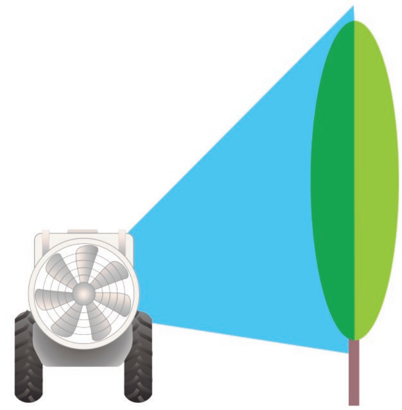


Figure 2 - Potentially improved spray coverage after adjusting sprayer to match the canopy.

Beyond the immediate impact on efficiency, variability makes it difficult to diagnose pesticide effectiveness. As an example, there was a scab outbreak in Ontario a few years ago that elicited questions about timing, weather, product choice and resistance. There was very little attention given to spray coverage, which in my mind should have been the first question if only to eliminate it as a potential culprit. This is because each operation interprets labels differently, and very few confirm coverage in any quantifiable way. This practice makes it difficult to identify a cause when crop protection fails.

Optimizing pesticide rates

That was a lot of preamble to describe an issue that many orchardists are already aware of. What is needed is a way to adjust the amount of pesticide per unit ground area (i.e. the label's prescription) to achieve consistent foliar coverage for canopies of varying shape and density. The concept is visualized in Figure 3. In addition, the method has to be simple, intuitive and effective.

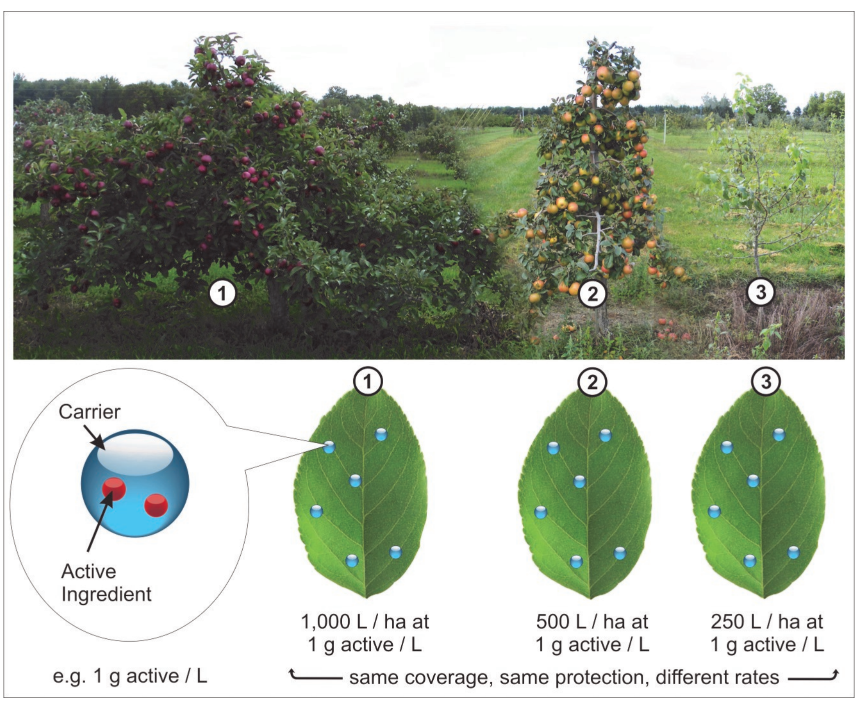


Figure 3 - When coverage is acceptable, and concentration and deposition remains constant, it should not matter if less spray is used per acre.

Many models have been proposed to tackle this issue, including Tree-Row Volume, Leaf Area Index, Leaf Wall Area, PACE+ and DOSAVIÑA. There are advantages and disadvantages to each method. Standing on the shoulders of giants, we combined aspects of each of these models, including incorporating dose expression research from USDA ARS work in nurseries, to develop the Crop-Adapted Spraying (CAS) method. It is neither complicated nor sophisticated. It formalizes a series of qualitative calibration techniques and the objective is to achieve a target foliar coverage pattern. When achieved with sufficient accuracy, pesticide efficacy is maintained and waste is greatly reduced.

Caveats

Perhaps I shouldn't point out flaws before I describe the model's effectiveness, but it's important to understand that CAS relies on a few critical assumptions.

The first assumption is that the sprayer operator's typical ratio of formulated product to carrier is appropriate. We need a starting point for adjusting the amount of pesticide per unit area, and typically the label is too subjective. Further, the operator might be tank-mixing other products and electing to reduce the dose of each tank-mix partner, or adjusting the ratio of product to carrier to reflect pest pressure. The appropriateness of this assumption is evidenced by a history of satisfactory pest control in the orchard.

The second assumption lies in defining a threshold for sufficient coverage, and this is a real challenge. Applications can be concentrate or dilute. Some products (albeit few) are locally systemic while others have limited redistribution. Even the droplet size employed (e.g. A mist blower's fines compared to coarse droplets produced by an air induction nozzle) will have bearing. So, how does one draw a universal line in the sand and say "this much is enough"?

A literature review, combined with practical experience, has led us to propose 10-15 % coverage, comprised of a minimum of 85 medium-sized droplets per cm^2, as a reference point for satisfactory foliar coverage. The figure is intended to be practical and versatile to safely represent sufficient coverage for most foliar insecticides and fungicides. It is not intended to be a rigorous, scientific absolute. For example, a drench application, such as streptomycin or dormant oils, will obviously require more coverage. Plant growth modifiers like thinners, stop-drops and foliar nutrients may or may not have their own unique criteria.

It is the nature of models and assumptions that they may not hold in every situation. However, they allow us to define a fairly simple and robust method that we have tested in Ontario for the last three years.

The method

Step 1 - The sprayer should receive all seasonal maintenance prior to the first use and undergo a visual inspection before each spray day.

Step 2 - Park the sprayer in an alley between rows of trees and tie 25 cm (10 in) lengths of ribbon to the ends of the deflectors (if present) and the nozzle bodies. Turn on the air and extrapolate where the nozzles and deflectors are aimed. Adjust deflectors and turn off nozzles that will spray over or under the tree canopy. Consider using air-induction hollow cones in the top positions of each boom to reduce drift. You may have to increase the rate in those positions to compensate for the fact that nozzles producing larger droplets produce fewer droplets.

Step 3 - Confirm ground speed with a half-full sprayer in the orchard using GPS or a calibration formula.

Step 4 - Affix 25 cm (10 in) ribbons to far side of three trees. Tie them at the top and at the widest portions of the canopies. Drive past in the spraying gear at the ideal RPMs with the air on, and ensure the ribbons waft outwards. This will determine if more/less air is required from the airblast sprayer, and if operator should speed up or slow down during spraying. This is also an opportunity to perform Gear-Up-Throttle-Down if sprayer is using a positive displacement pump.

Step 5 - Place water-sensitive paper at the top, centre and bottom of the tree canopy and spray water. As an approximation, if coverage exceeds 10-15% surface-area and 85 discrete droplets per square centimetre, reduce output in those positions by replacing nozzles with lower outputs. If less than ideal coverage is achieved, increase the nozzle rates in those positions. Excessive coverage may be unavoidable in the outer edge of the canopy, given that spray must pass through to get to the centre. Be aware that ambient wind speed and humidity have significant impacts on coverage. Therefore, only test coverage in conditions similar to your typical spraying conditions.

Step 6 - When the canopy grows and fills in sufficiently, usually after petal fall, repeat steps 4 and 5 (this is typical for semi-dwarf, but likely isn't required for young and/or high density plantings). If you are suspicious that the spray is being stretched too thin or you are unsatisfied with the coverage, you may have to increase the output. This is more of an issue with larger trees. Early in the season, wind travels relatively unimpeded in a high-density orchard and will blow the spray off course, reducing coverage and requiring higher water volumes or possibly more air to compensate. As the trees fill in, the average wind speed is reduced and more spray can impact on the target. Therefore, increasing spray volume after petal fall may not be required in a high-density orchard.

When the correct sprayer settings and volumes have been determined, the operator will mix their spray tank as they would for their typical application. The sprayer will likely cover more orchard than it has in the past, and the operator will have to re-assess how many tanks are required pre- and post petal fall. It is not advisable to go below 400 L/ha (~40 gpa).

This method of application is really no more sophisticated than turning off nozzles that are aiming at the ground or above the target. It will take time for operators to get comfortable with the new volumes (and potentially reduced dosage) and regular scouting is highly encouraged to confirm they are achieving control.

The three year study

Three Ontario apple orchards (and one Nova Scotia orchard) agreed to test the model. A block of trees was randomly selected from each operation to serve as the treatment condition. These trees received spray according to the CAS model. The rest of the orchard was sprayed according to the grower's traditional methods. The orchards included several varieties and represented both semi-dwarf and high density plantings (see Table 1).

Table 1 – Executive summary of participating orchards

Orchard	Typical spray volume (Control)	CAS spray volume (Treatment)	% Savings	Varieties (age)	Orchard Structure	Years in study
Orchard 1	486 L/ha	373 L/ha	23%	Gala + g. Del (~10 yr)	High density	3
Orchard 2	748 L/ha	478 L/ha & 608 L/ha = 543 L/ha	28%	Macs + Empires (~30 yr)	Semi-dwarf	3+
Orchard 3	577 L/ha (660 L/ha)	407 L/ha	39% (38%)	Gala + Fuji (~20 yr)	High density	2
Nova Scotia	544 L/ha	416 L/ha	33%	Jonogold (~10 yr)	High density	1+

According to the model, each grower sprayed anywhere from 20-35% less per hectare in the CAS block than in their traditionally-sprayed block. In many cases, the overall canopy coverage was improved in the CAS block compared to the traditional method simply by aiming formally wasted spray into the canopy and reducing volume in those areas that were unnecessarily drenched.

A scout was dispatched to monitor insect and disease activity each week for ~15 weeks. They observed a typical IPM scouting protocol and were not informed which block was the traditional control and which block was the CAS treatment. Data was transformed where appropriate for analysis of variance. In almost every case, there was no significant difference in counts between the CAS treatment and the grower's traditionally-sprayed control (p=0.05). In those few cases where a pest had higher counts in the CAS block, the counts were so far below a spray threshold as to be insignificant.

If we look more closely at the three (of 128) ANOVA comparisons of control to treatment, we see that economic thresholds are rarely an issue, and essentially, difference between control and treatment are moot (Figures 5-7).

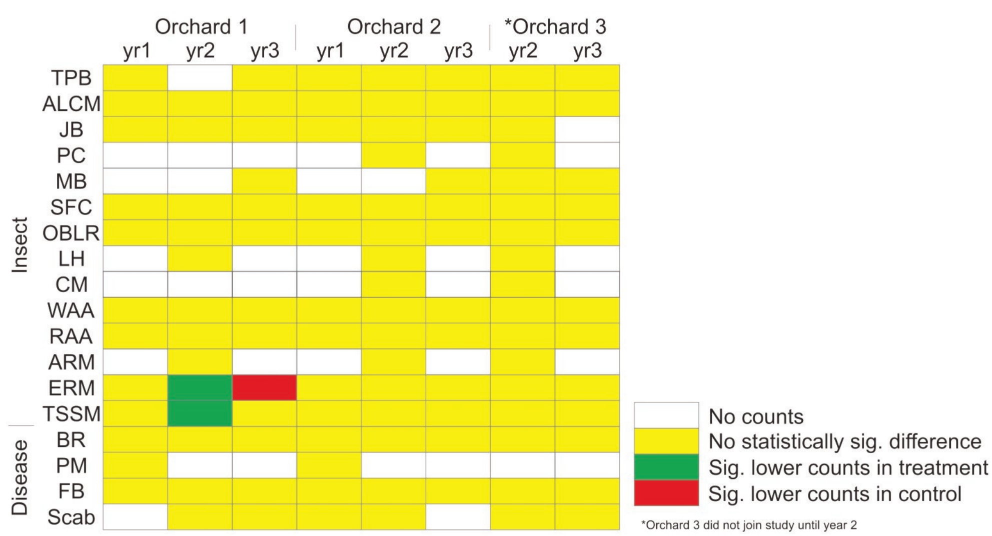


Figure 4 - Matrix illustrating the ANOVA results

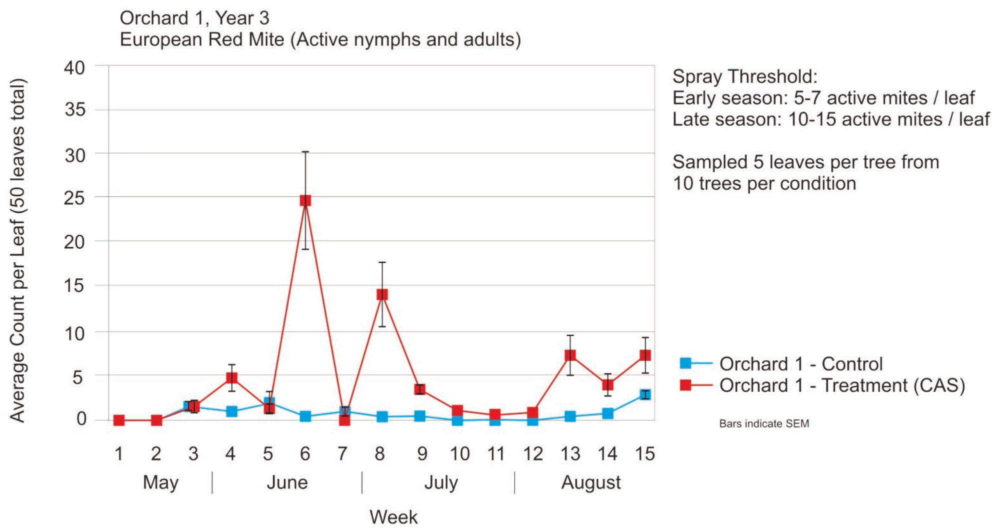


Figure 5 - European red mite counts from Orchard 1, Year 3

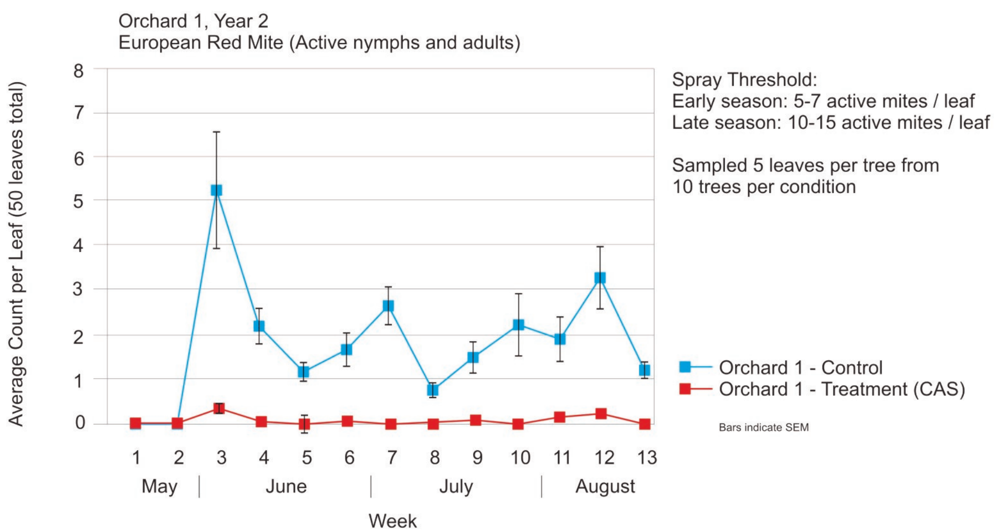


Figure 6 - European red mite counts from Orchard 1, Year 2

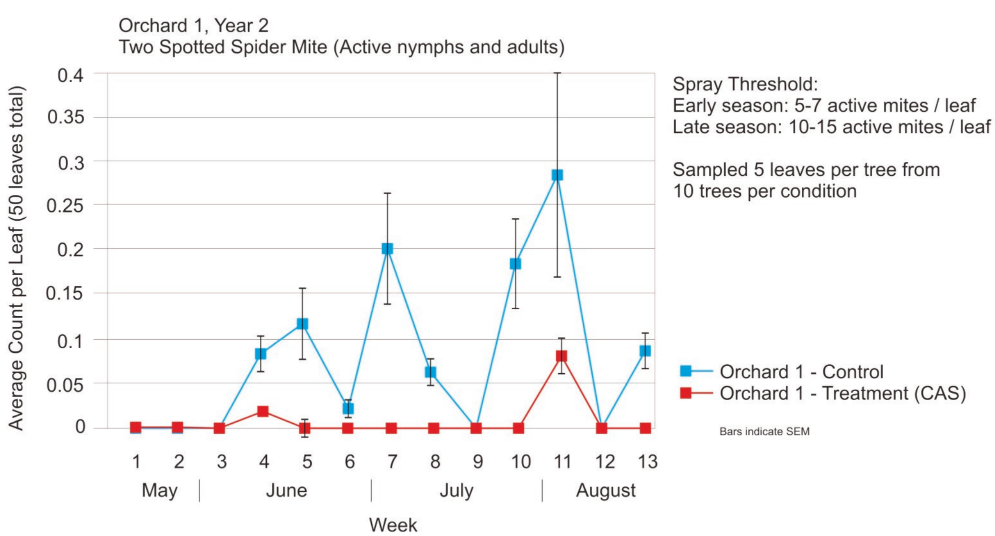


Figure 7 - Two-spotted spider mite counts from Orchard 1, Year 2

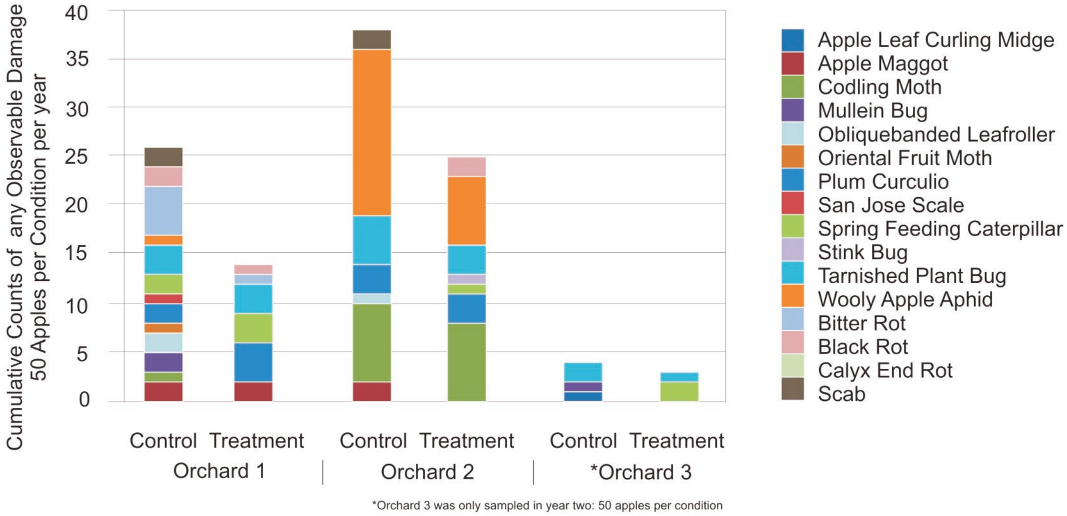


Figure 8 - Cumulative counts of apple damage

This study was repeated over three years. Having examined the data to determine if three years of optimized doses had any effect on pest populations, results suggest there is no such effect.

Apples were randomly sampled for destructive analysis at harvest and the total counts of any and all damage are shown here (Figure 8). This is simply a tally, and no statistical significance is implied. Note that Orchard 3 was only involved in the study for two years, and unfortunately a killing frost destroyed their harvest in their second year.

An important part of knowledge transfer is whether or not growers will choose to adopt a method once the instructor is gone. By year two the biggest challenge was ensuring the orchardists in the study continued to spray the control block at their traditional volumes! They were more than willing to adopt the method wholesale and all three will do so, starting in 2016. Further, colleagues in Nova Scotia have been performing their own CAS trial for the last two years, and report no significant difference in pest activity or apple quality. They've done so simply by following a written protocol.

The orchardist's enthusiasm, the ability for the study to be replicated without my direct involvement, and the successful results speak to the viability of the method.

OrchardMAX

We have beta tested an app for Apple and Android smartphones that will help a sprayer operator determine the best sprayer settings for their apple orchard. Information about the sprayer and orchard block is entered only once; product information and a few specifics about the orchard are entered the day of the application. The app will then propose a nozzling solution for a conventional airblast sprayer as well as describe how much product and water should be used per tank. It then creates a permanent spray record. The app still requires the sprayer operator to follow the sprayer calibration method and coverage should be confirmed with water sensitive paper. The app is based on the Excel formulae used to determine the sprayer outputs for our three year CAS study and will be available for free download by the end of February, 2016 from www.sprayers101.com .

More information

The maintenance, calibration and operation of an airblast sprayer is an involved process. Collectively, the sprayer setup, weather and crop morphology all influence the coverage obtained from an application. A fundamental understanding of application technology is required before attempting to optimize dosage using the CAS method. For more information about airblast spraying, download a free copy of Airblast101 – A Handbook of Best Practices in Airblast Spraying:
You can also download the power point presentation describing the CAS method and the trials from Sprayers101.

If you would like to attend a series of workshops planned for spring, where the CAS method will be demonstrated in each of the five Ontario apple growing districts, please email: Amanda.green@ontario.ca

Acknowledgements

I would like to thank the researchers that developed the methods CAS is based upon, statistician Behrouz Eshani, the orchards that cooperated in the study, my OMAFRA colleagues and the OMAFRA summer students that scouted those orchards for three years.

Postharvest

Delayed Controlled Atmosphere Storage for 'Honeycrisp' Apples

Dr. Jennifer DeEll, Fresh Market Quality Program Lead – Hort Crops, OMAFRA

'Honeycrisp' is extremely susceptible to CO_2 injury, which can be exacerbated by the high CO_2 concentrations found in controlled atmosphere (CA) storage. CA can induce the development of internal CO_2 injury with lens-shaped cavities in 'Honeycrisp' and/or larger irregularly margined dark brown flesh lesions without cavities (Figure 1). Therefore, CA storage has not been common practice for this apple cultivar.

Delaying the establishment of CA can be a beneficial strategy for the reduction of storage disorders in apples. For example, delaying CA for 1 or 2 months at 1°C has been shown to reduce external CO_2 injury and flesh browning in Ontario 'Empire' apples.

Therefore, the objective of this study was to investigate the effects of delayed CA storage on fruit quality and disorders in 'Honeycrisp' apples. For three consecutive years, 'Honeycrisp' apples were harvested from the same commercial orchard and conditioned for 4 days at 12-19° C immediately after harvest. Apples were then held in ambient air at 3°C for 0, 2, 4, 8, or 14 weeks, followed by CA storage (3% O_2 and 1.5% CO_2) at 3°C for 6 or 7 months of total storage time. The effect of SmartFresh™ (1-MCP; 1 $\mu L\ L^{-1}$) was also investigated.

Delaying the establishment of CA for at least 4 weeks reduced the incidence of internal CO_2 injury, with or without flesh cavitation (from as high as 15%, down to less than 4%). Furthermore, higher incidence of CO_2 injury required longer delay of CA to reduce the disorder. In some years, delayed CA also resulted in increased lenticel breakdown, bitter pit/blotch and greasiness.

SmartFresh treatment reduced lenticel breakdown when CA establishment was delayed 4 weeks or more. There was variation in fruit firmness among years and durations of CA delay and some increase in firmness was also observed during storage. This was not unexpected, as temperature conditioning (i.e. 4 days at 12-19°C) to reduce chilling-related disorders, such as soft scald and soggy breakdown, can result in higher firmness levels in 'Honeycrisp' apples. However, SmartFresh-treated fruit showed little change in firmness with delayed CA. There was also little effect of delayed CA on internal ethylene concentration, soluble solids concentration, and malic acid content.

In summary, these results suggest that delayed CA storage (in combination with conditioning) has beneficial and varying effects on certain disorders in 'Honeycrisp'. Delaying the establishment of CA consistently reduced internal CO_2 injuries, but in some years this benefit was compromised by the development of lenticel breakdown, bitter pit/blotch and greasiness. SmartFresh provided additional benefit by reducing lenticel breakdown when CA establishment was delayed 4 weeks or more.

The author gratefully acknowledges the support of the Ontario Apple Growers, Norfolk Fruit Growers' Association, and AgroFresh Inc. and Storage Control Systems Inc. throughout the duration of this research, as well as the technical assistance of Behrouz Ehsani-Moghaddam, Geoffrey Lum, and Lorie Walker. This project is part of the Canadian Agri-Science Cluster for Horticulture 2, funded by Agriculture and Agri-Food Canada under its Agri-Innovation Program, and administered by the Canadian Horticultural Council.

Figure 1: Internal CO_2 injury (with and without flesh cavitation) in 'Honeycrisp' apples.

Preventing Patulin Accumulation in Apples During Long-term Storage

Louise Agius, Risk Management Specialist, OMAFRA

What is patulin?
Patulin is a fungal mycotoxin routinely found in the rotten tissue of decaying apples and signs of rot in the fruit indicate that patulin may be present. Several species of mould produce patulin, but *Penicillium expansum* is primarily responsible for patulin in apples and apple cider. Because lower-grade apples are typically diverted for cider processing, patulin contamination is of particular concern with non-fermented cider products. Patulin detected in cider is characteristically associated with poor culling practices in which damaged or rotting apples are included for processing. However, even when apples are diligently sorted prior to storage, complete elimination of mould spores is very difficult. Germination of even a few spores can lead to mould growth and patulin accumulation over several months. In addition, signs of mould are not always visible (e.g. internal rot), and infected apples that appear sound are liable to be stored and later processed. Therefore, in addition to apple culling, the risk of patulin must be managed through best practices specific for long term apple storage.

Because of its toxic effects in humans, which include nausea, vomiting, potential kidney damage from acute poisoning, and potentially DNA damage, tumour formation or defects during embryonic development from low level chronic exposure, Health Canada has laid down maximum patulin levels of 50 µg/kg for apple juices including cider. This limit aligns with international standards.

Patulin production
Sporulation and patulin production by *P. expansum* seem to be linked in that they are both triggered when normal growth is complete or has been challenged by environmental stress. Either way, research suggests that patulin production by *P. expansum* does not occur at the same time as regular growth, and so a lack of mould growth does not necessarily indicate that patulin is not being produced. In general, however, larger volumes of mould in apples correspond with higher levels of accumulated patulin. Therefore, whether or not *P. expansum* will produce patulin and the amount of patulin produced depend on a) environmental factors, b) the level of growth achieved, and c) the aggressiveness of a *P. expansum* strains.

Controlled atmosphere (CA) storage
CA storage is an environment in which the oxygen (O_2) level, or the carbon dioxide level (CO_2), or both, are modified to delay senescence and allow for extended storage of apples. Typically, O_2 is reduced to 1-3% and/or CO_2 is increased to 1.5-5%. Negative effects on apple quality limit the practical applications of high CO_2 regimes for some growers, and so O_2 modification in conjunction with refrigeration is commonly used.

On its own, refrigeration is not enough to prevent patulin production, although *P. expansum* growth is increasingly slowed, the colder the temperature. There is also evidence that environments of limited stress (e.g. reduced temperature or O_2) can potentially stimulate patulin production in some aggressive strains, which could be a reason for the detection of patulin during conventional cold storage and even with some CA storage regimes. However, a combination of limited stress conditions created by CA storage results in reduced formation of the toxin, therefore CA remains the recommendation for long term storage of apples. A temperature of 1°C combined with 1% O_2 has proven most effective for controlling patulin. Under these conditions, there is significant inhibition of patulin production, regardless of strain. In practice, temperature and O_2 should be reduced as low as possible for long term apple storage.

Ambient storage
The length of time apples spend at ambient temperatures after they are removed from CA storage for processing is even more critical for preventing patulin. Several studies corroborate that while mould growth is slowed or halted during CA storage, it proceeds very rapidly as soon as apples are transferred to warmer temperatures. During this period, patulin can accumulate to levels in excess of 50 ppb, resulting in contaminated cider. Accordingly, staging of apples at ambient temperatures post-CA storage should be limited to as little time as possible (e.g. under 24 hours), or avoided altogether.

Hygienic conditions during storage
The cleanliness of storage rooms, harvest containers, storage bins, and any other food contact surface, is another important factor in limiting rot development and subsequent patulin accumulation in stored apples. Research on *P. expansum* growth in apples has shown that the likelihood of mould developing, as well as the rate of mould growth, are both higher when the number of spores transferred to apples during a contamination event is greater. Therefore, the number of spores in storage rooms and on other equipment should be minimized through excellent hygiene. Cleaning and sanitizing of surfaces used during harvest, transportation, storage, and processing should be performed on a regular basis using potable water, detergent, and a sanitizing agent. In the storage room, walls, ceilings, floors, fans, refrigeration units, and vents should not be overlooked as sources of mould spores and should be cleaned regularly. Excellent hygiene is critical to control mould growth and patulin development.

Apple Sampling
Removal of damaged or decayed apples prior to storage and again before processing is essential to prevent patulin contamination in cider. This practice helps prevent the transfer of spores to sound apples, thereby

helping to preserve apple lots and discourages the introduction of spores inside storage rooms. However, infection with *P. expansum* is not always visible and apples with internal rot can bypass inspection and end up in processed cider. Therefore, cutting open a representative sample of apples and examining for internal rot is strongly encouraged. If most or all apples cut open from a lot sample reveal inner tissue that is mouldy, this indicates that the lot is likely not suitable for cider processing.

Conclusion

The risk of patulin accumulation in apples during storage is best managed by a) CA storage with temperature and oxygen levels as close to 1°C and 1%, respectively, as possible; b) minimizing or removing the time apples spend at ambient temperatures once they are removed from storage; and c) improving the hygienic conditions of storage facilities, as well as all surfaces in contact with apples leading up to storage. Patulin management also relies on limiting the introduction of spores into storage facilities in the first place, and so the importance of removing damaged and decaying apples from going into long term storage cannot be overstated. Cutting open a sample of apples should also supplement visual inspection to account for internal rot that is not visible on the apple exterior.

Announcements

OMAFRA Welcomes Mackenzie Lespérance, Weed Management Lead

Mackenzie recently joined the Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA) as the weed management lead – horticulture crops, while Kristin Obeid is on maternity leave. Mackenzie is located at the Harrow Research and Development Centre in Harrow Ontario.

Mackenzie will be focusing her efforts on greenhouse trials for herbicide resistance screening, collaborative work with the University of Guelph on herbicide resistant pigweed in carrot production, assisting in the development of herbicide resistant field molecular testing in field vegetables and adding to the list of new herbicide registrations for Ontario horticulture producers.

Mackenzie is fascinated by plants and the ways they get around human imposed stresses. She's a self-described "plant nerd" who earned a Bachelor of Science (honours) in Plant Biology and then a Master of Science in Plant Agriculture from the University of Guelph. During her university research in herbicide resistance, Mackenzie found that giant ragweed could survive a lethal dose of glyphosate through its own genetic programming.

Mackenzie is an active member of the Canadian Weed Science Society and the Weed Science Society of America.

Mackenzie can be contacted by phone at 519-738-1232 or by email at Mackenzie.lesperance@ontario.ca.

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