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# ORCHARD NETWORK

*For Commercial Apple Producers*

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## Orchard Management

### Ethylene Production of Different Apple Cultivars

*Amanda Green, Tree Fruit Specialist, OMAFRA*
*Dr. Jennifer DeEll, Fresh Market Quality Specialist-Hort Crops, OMAFRA*

As apples mature, growth slows and ethylene production begins. Ethylene is involved in the ripening process and will promote abscission of fruit. There are two plant growth regulators, ReTain (Aviglycine hydrochloride) and Harvista (1-Methylcyclopropene or 1-MCP), that are available to growers that work to reduce ethylene production and therefore delay maturity along with other fruit quality benefits. For application guidelines see http://www.omafra.gov.on.ca/english/crops/hort/plantgrowthregulators.htm. Knowing which apples that are high and low producers of ethylene (Table 1) can help when determining application timing and rate. For instance, you may want to apply ReTain 3 weeks ahead of predicted harvest date for low producing cultivars rather than 4 weeks ahead.

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**This Newsletter is brought to you by the Ontario Apple Team:**

Amanda Green, Simcoe
ONNL Editor
Tree Fruit Specialist
(519) 426-1102
amanda.green@ontario.ca

Dr. Jennifer DeEll, Simcoe
Fresh Market Quality Specialist
(519) 426-1408
jennifer.deell@ontario.ca

Dr. John Cline
University of Guelph, Simcoe
(519) 426-7127, ext. 331
jcline@uoguelph.ca

Louise Agius, Guelph
Risk Management Specialist
louise.agius@ontario.ca
(519) 826-6610

Kristy Grigg-McGuffin, Simcoe
Horticulture IPM Specialist
(519) 426-4322
Kristy.Grigg-McGuffin@ontario.ca

Hannah Fraser, Guelph
Entomologist-Horticulture
519-824-4120,ext 52671
hannah.fraser@ontario.ca

Christoph Kessel, Guelph
Soil Fertility Specialist-Horticulture
(519) 824-4120 ext. 52480
christoph.kessel@ontario.ca

Anne Verhallen, Ridgetown,
Soil Management Specialist-Horticulture
(519) 674-1614
anne.verhallen@ontario.ca

Dr. Jason Deveau, Simcoe,
Application Technology Specialist
(519) 426-8934
jason.deveau@ontario.ca

John Zandstra
University of Guelph, Ridgetown
(519) 674-1500 ext 63627
jzandstra@ridgetownc.uoguelph.ca

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**Table 1.** Ratings of ethylene production for common apple cultivars grown in Ontario.

| Variety | Ethylene Production |
|---|---|
| Ambrosia | Low |
| Empire | Low |
| Fuji | Low |
| Red Delicious | Low |
| Crispin | Low-Medium |
| Golden Delicious | Medium |
| Honeycrisp | Medium |
| Idared | Medium |
| Jonagold | Medium |
| Spartan | Medium |
| Gala | Medium-High |
| Northern Spy | Medium-High |
| Cortland | High |
| McIntosh | Very High |

## Wild Bee Communities in Ontario Apple Crops

*Sisley Irwin, University of Guelph; Hannah Fraser, Entomologist – Horticulture, OMAFRA; Kristy Grigg-McGuffin, Horticulture IPM Specialist, OMAFRA; Nigel Raine, University of Guelph*

### Introduction

Native wild bees rely heavily on nectar and pollen resources from many flowering plant species. Mass flowering crops such as apples have been found to provide early emerging species with necessary floral resources for growth and reproduction. In addition, apple crops rely on animal vectored cross-pollination to provide adequate fruit set. Commercial apple producers have traditionally used managed honey bees for pollination services, however, recent surveys in the United States have demonstrated that in orchards with abundant and diverse wild bee populations, supplementation with honey bees may not always be necessary (1). Preliminary work conducted in 2018 indicated there was little wild bee activity in most commercial orchards in southern Ontario, although sampling protocols may have led to an under-representation of diversity and abundance. Baseline data on wild bee pollinators in apple orchards is lacking in Ontario apple orchards. This information is required if landowners choose to encourage populations of local bees through habitat provisioning. This article will summarize pollinator sampling work conducted in 6 Ontario orchards during May 2019 which looked at both abundance and diversity of native bee populations in blooming apple orchards.

### Methods

Abundance and diversity surveys of wild bees were conducted at four apple orchards in Norfolk County and two apple orchards in Georgian Bay during May 2019. In order to account for variation in bee activity, morning and afternoon sampling periods took place during early bloom, peak bloom, and late bloom. The morning sampling period was conducted between 9:00 am and 11:00 am and the afternoon sampling period was conducted between 1:30pm and 3:30pm.

Six timed, 5-minute visual counts of all foraging pollinators in a 1 $m^2$ block on the apple tree took place during each sampling period to determine abundance. Bee diversity was measured with timed, 30-minute hand-held collections of all foraging bees. The collector moved freely throughout the rows of apple using vials to collect bees seen on flowers.

All collections were frozen for preservation and identified using the *Discover Life taxonomic key* and *Bumble Bee's of North America Identification Guide.* Diversity of bees for each site was calculated using the Shannon index. A greater index value indicates greater diversity at the site.

**Results and Discussion**

A total of 32 species (9 genera) and 19 species (5 genera) were collected during the surveys in Norfolk County (N1-N4) and Georgian Bay (GB1-GB2), respectively (Figure 1). Species diversity differed between sites, with both sites N1 and N4 showing high levels of diversity (Shannon Diversity Index ranking: N1>N4>GB2>GB1>N3>N2). *Andrena* (mining bees) (Figure 2) was the dominant genera collected at all sites except N2, where a single *Bombus griseocollis* (bumble bee) was collected during all sampling periods. Bumble bee species (Figure 3) were collected at only 3 of the sites despite visually observing many individuals, particularly in the top of the canopy in a number of these sites.

The prevalence of *Andrena* is expected as these species emerge early in the spring and have been found to be a dominant wild bee pollinator of apple in other areas. We were able to determine that the native bee population within Norfolk County, and possibly Georgian Bay, is relatively robust at some sites. We can conclude that a native bee population exists within these agricultural habitats and that they are most likely contributing to pollination services in apple.

Factors such as landscape ecology can be predictors of native bee abundance and diversity (2). Although we did not measure parameters (size of farm, size of blocks, adjacent landcover, within row groundcover, etc.) in this study, landscapes between sites were visually different. Many of wild bees represented in the surveys are ground nesting species, and greater levels of available nesting habitat can be critical in maintaining these populations. Creating field margins with open dirt patches for nest building, avoiding clean-up of twigs (Figure 4) and other weeds between rows, planting native flowers and

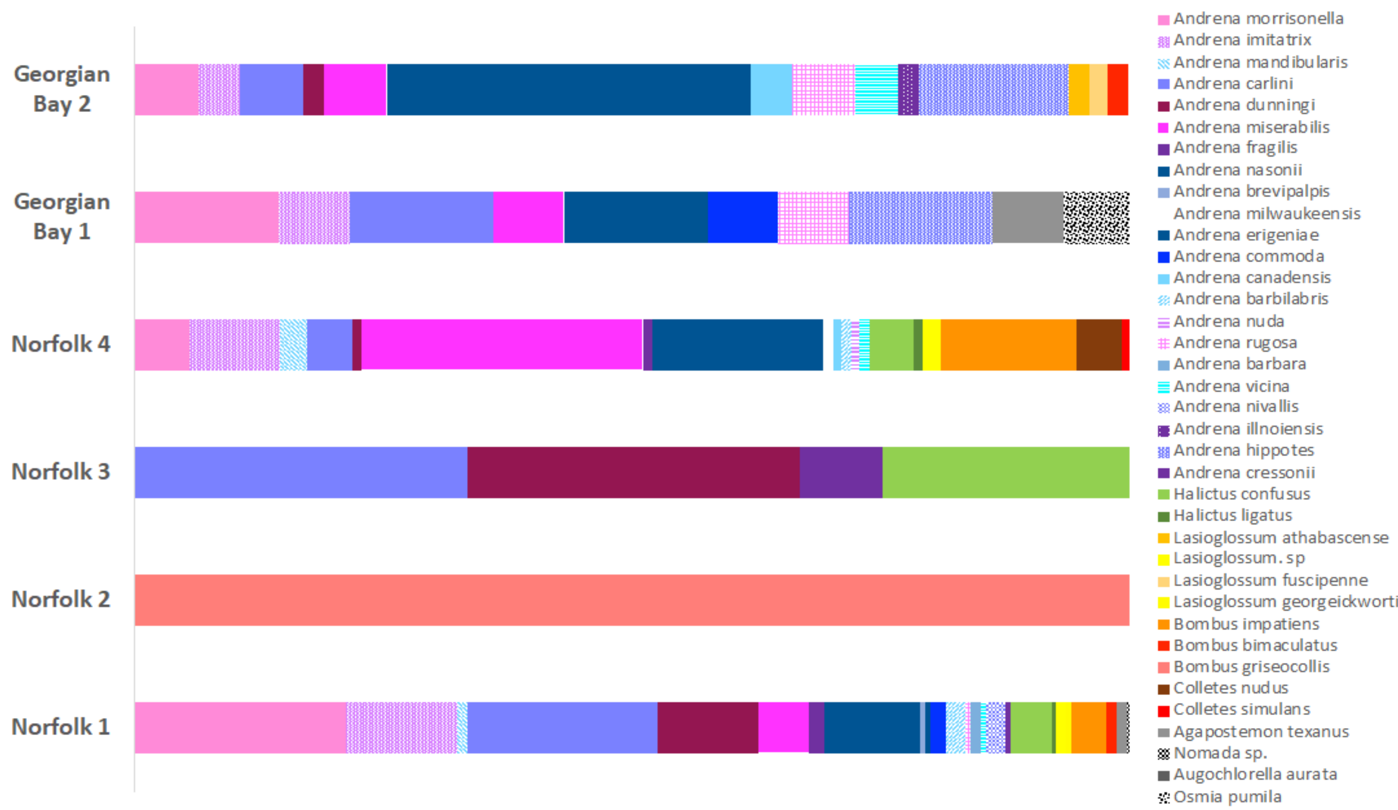


**Figure 1.** Composition of native bee species at 4 sites in Norfolk county and 2 sites in Georgian Bay (expressed as a %). Each color represents a species, size of the bar represents the abundance of that species within each site. Norfolk 1) N= 200, Shannon Diversity Index = 2.6; Norfolk 2) N= 1, Shannon Diversity Index = 0; Norfolk 3) N = 12, Shannon Diversity Index = 1.3; Norfolk 4) N= 111, Shannon Diversity Index = 2.3; Georgian Bay 1) N= 14, Shannon Diversity Index = 2.2; Georgian Bay 2) N = 47, Shannon Diversity Index = 2.2

practicing targeted integrated pest management can help to ensure native bee success within apple orchards.

This research provides important preliminary information on native bee diversity within southern Ontario apple orchards. Success of surveys or grower-led self-assessments will depend on sampling at the right time (full bloom, multiple varieties) and when weather conditions are favourable (warm, sunny days).

**Acknowledgements**

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If you are interested in determining the abundance and diversity of wild bee communities on your farm please check out this link: https://rvpadmin.cce.cornell.edu/uploads/doc_515.pdf

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**Figure 2.** *Andrena* are an early emerging species and are therefore the dominant native bee pollinator during apple bloom.

**Figure 3.** *Bombus impatiens* – the common bumble bee species in southern Ontario

**Figure 4.** Wild bees can use sticks and stems (in this case a raspberry cane) to create nests.

## Optimizing Red Colour in Apples

*Emma Somerville, Horticultural Assistant, and Amanda Green, Tree Fruit Specialist, OMAFRA*

Fruit colour is an important determinant of consumer acceptance and marketplace quality for red apple strains, but obtaining good fruit colour can be a tricky process involving many different factors. In this article we explore what is biologically responsible for apple colour, what contributes to changes in colour, and how you can optimize the red colour of your apples.

The main biological cause for red pigmentation in apple skin is the concentration of anthocyanins (1). Throughout maturation, anthocyanins will steadily increase in the fruit, reaching peak concentrations when the fruit approaches its most ripe colouring (1). Anthocyanins do not directly play a role in photosynthetic reactions, but act as protection for chlorophyll against damage by UV light (2). Although anthocyanins appear to be the main molecule responsible for optimizing colour, chlorophyll and carotenoid concentrations also impact the final colour of the fruit (3). Chlorophyll is involved in photosynthetic processes and gives apples their green colour before ripening (4). As fruit matures, chlorophyll degrades while yellow or orange carotenoids and red or purple anthocyanins increase in concentration, this causes the fruit to change from its immature green colour to yellow, orange, and red colours (4). These important biological factors are regulated by both internal and external influences such as temperature, light exposure, plant growth regulators, genetics, and nutrient levels.

Temperature has been shown to influence the expression of genes that regulate the production of anthocyanins. For both apple and pear trees it has been found that low temperatures increase the expression of genes that create anthocyanins and, therefore, the concentration of anthocyanins itself (3). High temperatures, on the other hand, can reduce the expression of these anthocyanin biosynthetic pathway genes (3). Generally, prolonged temperatures above 20°C will begin to cause this reduction in anthocyanin concentrations, resulting in less red colouring on the fruit (3). However, even short lengths of exposure to lower temperatures can kick-start anthocyanin concentration recovery (3). The optimal cool temperature for colour development depends on the variety. ‘McIntosh’ apples thrive in temperatures below 21°C, ‘Fuji’ in temperatures around 16°C, and ‘Redchief Delicious’ in temperatures around 11°C (4). Although temperature is largely out of one’s control, cooling irrigation systems used at sunset and sunrise have proven effective in improving fruit colour during hot weather (5). As even a single day at temperatures around 30°C can erase the effects of many cool days, a sprinkler system should be considered if a heat wave of this level is to be expected (4).

Light penetration is another factor that greatly influences fruit colour and can be increased using various pruning methods, orchard systems and crop load. Studies have found that low crop loads produce higher percentages of red fruit colour (18), and that densities surpassing 5 fruit/cm$^2$ of trunk cross-sectional area will develop a weaker fruit colour (4).Summer pruning appears to be an effective way to increase light penetration to the canopy however there have been mixed results on effectiveness of increasing red colour. Some studies have found there to be a positive influence on red colour development (19,20) while some other studies have reported no effect on fruit colour (6,7). With orchard systems, it has been shown that slender spindle orchards can produce more red fruit as light penetration is increased in comparison to larger canopies (8,9). Therefore using cultural methods to increase light penetration through canopy management and cropload can have an effect on red colour.

Another way to increase light penetration to the canopy is through reflective products. Reflective mulch and groundcover films have been widely demonstrated as good options for increasing fruit yield and quantity (10,11,12), but their efficiency in increasing red colouration is less supported. Although there have been many cases of positive impacts on fruit colour due to reflective mulch or films increasing the anthocyanin and flavonoid content of fruits (11,13,14), some have found no improvement (10,12). Even with mixed results, groundcover reflective mulches and reflective plastic films do perform better than reflective alternatives, such as particle-based metallized polyethylene or kaolin films sprayed straight to the tree or between rows (13).

Plant growth regulators can also affect fruit colour. Ethephon application can show an increase of fruit colouration by increasing anthocyanins without influencing other flavonoid compounds (15,16). Blush, a plant growth regulator (PGR) that contains the natural plant hormone prohydrojasom that can increase anthocyanin accumulation if applied at the right time, resulting in a deeper red colour for bi-colour apples (17). The anecodotal results of growers trialing this product have been variable and recommendations for when to best apply this product are being adjusted.

All in all, there are multiple factors that can have an influence on red colour development in fruit. Some factors we have no control over, like the temperature and amount of sun; and the other factors we can work to optimize.

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# Cool Spring Weather Effects on Apple Size and Maturation

*Amanda Green, Tree Fruit Specialist, OMAFRA*

This spring was one for the books with the greater than normal amount of rain and cool temperatures that Ontario received. Many thought summer may never come, tree planting was delayed in medium to heavy soil and many pondered what the effects of the cool spring would have on the cell division phase of fruitlet growth and harvest dates. This spring we have received cooler high/low temperatures and growing degree days (GDD) than the 10-year average (Tables 1,2 and 3). There has been past research done in controlled environments and in the field that have shown that the temperature in the period following bloom does have an effect on cell division, final fruit weight and maturity (1,2).

**Cell Division and Final Fruit Weight**

Cell division occurs during the first 4-6 weeks after bloom depending on the weather conditions (3). During periods of warm temperatures, the cell division stage will be shorter than during periods of cooler temperatures (1). Research has shown that differences in temperature during the period of 10-40 days after full bloom (DAFB) have the greatest impact on fruitlet growth and final fruit weight (1). Fruit expansion rates were approximately 10 times greater in trees exposed to 20°C mean temperatures, compared to 6°C mean temperatures during the 10-40 DAFB (1). Even with a smaller difference in temperature reduction, the mean fruit expansion rates were significantly impacted with a high/low temperature change of 22/12°C down to 19/9°C (1). However, this small temperature change did not significantly impact the final harvest weight. Decreasing to a temperature regime by 6 degrees did, however, significantly decrease the final fruit weight (1). Fortunately, in Ontario, differences in temperature from the 10-year average and 2019 ranged from 0-3° in the first 40 DAFB (Table 1 and 2), so changes in final fruit size should be minimal if comparing average temperature highs and lows.

In another study the response of fruit growth changed at different stages of growth (4). At the 6 mm stage, fruit increased fairly linearly from 12/7 to 33/38˚C temperature regimes but at the 11 and 18 mm stage of growth, growth was optimal with high/ low temperatures of 19/14°C (4) . At the 27 mm growth stage, there was very little temperature effect on the fruit growth rate (4).

**Table 1.** Average high temperatures in the days following bloom in 2019 compared to the 10-year average. 10-year data was not available for all of the sites listed.

| Location | Days After Bloom | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 0-28 Days | | | 0-40 days | | | 0-50 days | | |
| | 10-year | 2019 | Difference | 10-year | 2019 | Difference | 10-year | 2019 | Difference |
| Harrow | 23.1 | 21.0 | 2.1 | 24.0 | 22.8 | 1.2 | 24.4 | 23.2 | 1.2 |
| Blenheim | | 21.6 | | | 21.5 | | | 24.0 | |
| St. Thomas | 23.9 | 21.7 | 2.2 | 24.7 | 22.8 | 1.9 | 25.1 | 23.5 | 1.6 |
| Strathroy | | 21.8 | | | 23.2 | | | 24.6 | |
| London | 23.6 | 21.8 | 1.8 | 24.2 | 23.0 | 1.2 | 24.7 | 24.2 | 0.5 |
| Simcoe | 23.9 | 21.0 | 2.9 | 24.7 | 22.3 | 2.3 | 25.1 | 23.4 | 1.8 |
| Beamsville | 23.0 | 21.3 | 1.7 | 23.7 | 23.1 | 0.6 | 24.4 | 24.0 | 0.4 |
| Brantford | | 21.5 | | | 23.1 | | | 24.3 | |
| Waterloo | 23.5 | 21.5 | 2.0 | 23.9 | 23.1 | 0.9 | 24.6 | 24.2 | 0.3 |
| Hamilton | 23.5 | 21.2 | 2.3 | 24.3 | 23.1 | 1.1 | 25.0 | 23.9 | 1.1 |
| Milton | 25.1 | 21.6 | 3.5 | 25.3 | 23.6 | 1.8 | 25.9 | 24.6 | 1.3 |
| Oshawa | 22.3 | 20.9 | 1.4 | 23.2 | 23.0 | 0.2 | 23.7 | 23.8 | -0.1 |
| Cobourg | 20.0 | 18.6 | 1.4 | 20.8 | 20.4 | 0.4 | 21.3 | 20.7 | 0.7 |
| Prince Edward County | 23.7 | 20.7 | 3.0 | 24.5 | 22.8 | 1.7 | 25.2 | 23.6 | 1.6 |
| Collingwood | 21.7 | 19.2 | 2.4 | 22.6 | 21.1 | 1.5 | 23.2 | 22.0 | 1.2 |
| Ottawa | 23.7 | 22.4 | 1.4 | 24.5 | 24.1 | 0.4 | 25.0 | 24.8 | 0.2 |

## Harvest Maturity Dates

Differences in GDD and temperature during the period of cell division can have an effect on apple maturation. Another study examined the effects of a change in GDD on fruit growth and maturity in 3 different growing areas of New Zealand over 3 years (2). This study found that there was a strong correlation with GDD (base 10°C) in the first 30 DAFB and the time from pollination to harvest (2). The range in time from pollination to harvest over the 3-year study was 17 days (2). The controlled temperature study previously mentioned also found that there was a delay in maturation of fruit when there was a decrease in average high/low temperatures by 6 °C (1).

In Ontario this spring, there was a difference of 42-91 GDD (base 10°C) between 2019 temperatures and the 10-year average in the first 4 weeks after bloom (Table 3), it is expected that harvest will be delayed. Many growers in Ontario are predicting that harvest will be a week behind based on other fruit grown in the area.

To conclude, the temperatures experienced during the cell division period were probably not low enough to affect final fruit size but will probably cause a delay in maturity.

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**Table 2.** Average low temperatures in the days following bloom in 2019 compared to the 10-year average. 10-year data was not available for all of the sites listed.

| | Days After Bloom | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 0-28 Days | | | 0-40 days | | | 0-50 days | | |
| Location | 10-year | 2019 | Difference | 10-year | 2019 | Difference | 10-year | 2019 | Difference |
| Harrow | 14.2 | 12.1 | 2.1 | 15.2 | 13.0 | 2.3 | 15.8 | 14.4 | 1.4 |
| Blenheim | | 9.8 | | | 10.8 | | | 14.4 | |
| St. Thomas | 11.6 | 10.8 | 0.8 | 12.6 | 11.5 | 1.1 | 13.1 | 12.4 | 0.7 |
| Strathroy | | 10.9 | | | 12.1 | | | 13.1 | |
| London | 12.1 | 10.8 | 1.3 | 12.9 | 11.8 | 1.1 | 13.3 | 12.8 | 0.5 |
| Simcoe | 11.0 | 10.9 | 0.1 | 11.9 | 12.0 | -0.1 | 12.3 | 13.2 | -0.9 |
| Beamsville | 12.8 | 10.6 | 2.3 | 13.7 | 12.1 | 1.7 | 14.4 | 13.0 | 1.4 |
| Brantford | | 10.4 | | | 11.6 | | | 12.4 | |
| Waterloo | 12.5 | 9.2 | 3.3 | 13.1 | 10.1 | 3.0 | 13.5 | 10.7 | 2.8 |
| Hamilton | 12.0 | 10.2 | 1.9 | 12.8 | 11.8 | 1.0 | 13.2 | 12.5 | 0.8 |
| Milton | 11.0 | 11.3 | -0.3 | 11.5 | 12.8 | -1.3 | 11.6 | 13.7 | -2.1 |
| Oshawa | 13.1 | 10.2 | 2.9 | 13.8 | 12.1 | 1.8 | 14.4 | 12.4 | 2.0 |
| Cobourg | 11.9 | 10.2 | 1.7 | 12.6 | 11.8 | 0.8 | 13.3 | 12.4 | 0.9 |
| Prince Edward County | 12.9 | 9.4 | 3.4 | 13.6 | 11.1 | 2.5 | 14.1 | 11.9 | 2.2 |
| Collingwood | 11.5 | 9.8 | 1.8 | 12.6 | 11.3 | 1.3 | 13.3 | 12.1 | 1.2 |
| Ottawa | 12.8 | 10.7 | 2.1 | 13.6 | 12.3 | 1.3 | 14.0 | 13.1 | 0.9 |

**Table 3.** Growing degree days (base 10°C) accumulated in the days following bloom in 2019 compared to the 10-year average. 10-year data was not available for all of the sites listed.

| Location | Days After Bloom | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 0-28 Days | | | 0-40 days | | | 0-50 days | | |
| | 10-year | 2019 | Difference | 10-year | 2019 | Difference | 10-year | 2019 | Difference |
| Harrow | 242 | 183 | 58 | 384 | 291 | 93 | 504 | 439 | 64 |
| Blenheim | | 161 | | | 272 | | | 400 | |
| St. Thomas | 218 | 175 | 42 | 344 | 250 | 94 | 454 | 304 | 150 |
| Strathroy | | 179 | | | 307 | | | 379 | |
| London | 219 | 175 | 44 | 342 | 296 | 46 | 449 | 402 | 47 |
| Simcoe | 209 | 167 | 42 | 331 | 287 | 44 | 435 | 414 | 21 |
| Beamsville | 221 | 166 | 55 | 350 | 304 | 46 | 471 | 426 | 45 |
| Brantford | | 161 | | | 287 | | | 218 | |
| Waterloo | 224 | 151 | 73 | 340 | 258 | 82 | 452 | 367 | 85 |
| Hamilton | 217 | 143 | 74 | 340 | 277 | 64 | 456 | 378 | 78 |
| Milton | 225 | 180 | 45 | 336 | 328 | 8 | 437 | 457 | -20 |
| Oshawa | 216 | 155 | 61 | 341 | 302 | 39 | 453 | 406 | 46 |
| Cobourg | 167 | 123 | 43 | 268 | 244 | 24 | 365 | 327 | 38 |
| Prince Edward County | 232 | 142 | 91 | 362 | 277 | 85 | 482 | 387 | 95 |
| Collingwood | 185 | 127 | 58 | 305 | 249 | 56 | 411 | 352 | 59 |
| Ottawa | 229 | 176 | 53 | 361 | 319 | 42 | 475 | 440 | 34 |

# Crop Protection

## What's Your Apple IPM Report Card?

*Kristy Grigg-McGuffin, Horticulture IPM Specialist, OMAFRA*

Do you know how effective your pest management program was this year? With only a small time commitment required, a harvest assessment can provide information on what part of your management program went well (or not so well).

Advantages to doing a harvest assessment:

- Knowledge of this year's problems will help you **better prepare** your IPM program next year.
- Provides an accurate read of not only the **type** of damage but also the **extent** of damage in a block or orchard.
- Preparedness for **early season** pest management needs, such as sprayer calibration, urea and/or leaf shredding for scab control, dormant oil for San Jose scale or early season copper and other fungicides for fire blight, scab and powdery mildew.
- Understanding what practices worked and what didn't will **save money** in input costs for future management programs.
- Improves **fruit quality**, by managing any late season pest issues that may be observed prior to harvest. This is particularly helpful if your scout has finished.
- Highlights any **susceptible varieties** or **hot spots** in a block or orchard, which allows targeted monitoring and potential spot treatments in future years.
- Provides a **historical record** for reference and increased awareness of potential challenges.

**How should you do it?**

In the field:

- Choose at least 10 (large trees) to 20 (dwarf trees) healthy trees randomly throughout the block.
- Select 200-400 apples (20-40 apples per tree), turning each to see all sides of the fruit without removing it.
- Randomly choose fruit from different positions on the trees: upper, inner and outer part of the canopy.
- Keep records for reference. Use the following Apple Harvest Assessment Sheet or template from Appendix H in Publication 310: Integrated Pest Management for Apples.

If a field assessment is just not feasible prior to harvest, a post-harvest evaluation of fruit can be done. However, this type of assessment will only provide information on severity of damage and not the location in the block this damage occurred. Examine 400-500 randomly selected fruit for each variety from harvest containers. If damage is found, you may want to increase the sample size in order to thoroughly assess the damage.

**What should you look for?**

Anything causing **2–5% damage** is of concern. Look for presence of:

Larvae or larval feeding from oriental fruit moth, codling moth or other caterpillars

  - Oriental fruit moth: tunnel from calyx or stem end; tunnel in flesh of fruit
  - Codling moth: piles of frass at hole which can be on the side or bottom of fruit; tunnel to seed cavity of fruit
  - European apple sawfly: ribbon-like scar spiralling from calyx
  - Obliquebanded leafroller: surface feeding; scarred and misshapened fruit; leaves often webbed to fruit
- Black caps of San Jose scale and/or halos on fruit surface
- Distorted fruit caused by spring feeding caterpillar or rosy apple aphid
- Pits or stings caused by tarnished plant bug, stink bug or apple maggot
- Raised bumps by mullein bug, plum curculio or other plant bug
- Blotches/lesions caused by scab, sooty blotch/fly speck, rust or calyx end rot
- Lace-like russetting caused by powdery mildew
- Fruit rot
  - Black rot: firm lesion; black fruiting bodies
  - Bitter rot: sunken lesion; orange to salmoncoloured spores
- Vertebrate feeding such as deer, turkey or other birds

As you walk through the orchard, also make note of damage to leaves, branches and graft unions caused by pests such as fire blight, scab, powdery mildew, leafroller, tentiform leafminer, leafcurling midge, mites and borer.

Go to Ontario AppleIPM for more information on these pests including descriptions and pictures of typical damage.

**Which block should you do?**

To get the best idea of what's happening in your orchard, assess all blocks. If time is limited, give yourself half an hour to one hour per block and select representative areas of the orchard. If you assess the same block every year, you can compare your results and notice trends over time.

Remember, simply determining this year's IPM report card will put you ahead of the game for next year's management program.

**Provincial report card to date**

Early harvest assessments have indicated an overall successful year for pest management despite the extremely wet spring. There were some orchards where fungicide programs failed or residues were no longer present and apple scab, powdery mildew, black rot and the beginning signs of flyspeck/sooty blotch were observed. The cooler weather over bloom kept blossom blight infection low; however, late season shoot blight continues to develop on vigorous trees. Damage caused by bloom and early petal fall insect pests such as mullein bug, tarnished plant bug, European apple sawfly and plum curculio can be found in many blocks. This is likely due to the extended bloom period this spring preventing early intervention. Leafcurling midge remains a season-long issue in many orchards while others experienced higher pressure from potato leafhopper. Some codling moth fruit damage can be found in blocks where residue was washed off in heavy rain.

## A Brief Look at Maryblyt and Cougar Blight as Predictive Models of Fire Blight Infection

*Michael Pupulin, OMAFRA Summer Student*

On the OMAFRA website, we run a 7-day prediction map for fire blight risk in southwestern Ontario. We make maps for both apples and pears where each farm zone will display a daily potential risk of a fire blight infection occurring. The possible values displayed are LOW, CAUTION, HIGH, EXTREME or EXCEPTIONAL. These risk values come from the Cougar Blight model developed by Washington State University. The model and its manual can be found on the Washington State University Cougar Blight 2010 website.

I aim to compare the model we use, Cougar Blight, to another fire blight prediction model called Maryblyt. Maryblyt was developed at the University of Maryland and can be downloaded on the Virginia Tech Maryblyt website. The Maryblyt model takes more input into its predictions and, therefore, puts out a greater amount of information. Where Cougar Blight uses only the daily high temperature and precipitation/leaf wetness events (eg., dew), Maryblyt further utilizes inputs such as key developmental stages, daily low temperature, trauma events and allows users to enter in when they applied a spray. Maryblyt then generates predictions regarding Epiphytic Infection Potential (EIP) and anticipated appearance of blossom, canker, shoot or trauma blight symptoms. Although Maryblyt offers a more personalized experience, Cougar Blight is downloaded as an excel spreadsheet, which allows users to quickly utilize all of Excel's tools if they want to perform an analysis on their data. That being said, Maryblyt has a built-in function to plot the outputs listed above. This gives users the ability to look at how data such as EIP, temperature and blossom blight symptoms are related. Both models take phenology into account and are designed to be run once the first flowers begin to bloom.

As mentioned above, Cougar Blight will return either LOW, CAUTION, HIGH, EXTREME or EXCEPTIONAL risk levels based off the sum of the last four daily risk values for apples, and last five daily risk values for pears. Here's how Washington State University classifies these risk levels:

- **Low** - Wetting of flowers during these conditions has not led to new flower blight infections in past years.
- **Caution** - Wetting of flowers by rain, 2+ hours of dew, or light irrigation under these conditions is not likely to lead to infection, except within a few yards (meters) of an active blight strike.
- **High** - Numerous serious blight outbreaks have occurred in past years when 4-day risk value totals near or exceed this threshold and blossoms are wetted by rain, 2+ hours of dew or light irrigation.
- **Extreme** - Some of the most damaging fire blight epidemics have occurred during the time from primary bloom through late spring when numerous blossoms are wetted by rain (usually more than a trace), 2+ hours of dew on the flowers, or light wetting by irrigation under these temperature conditions.

Maryblyt's output of interest in this comparison is the EIP which has a very high correlation with Cougar Blight's 4-day Total Risk Values. EIP is expressed as a percentage and can be used to estimate the risk of an infection occurring. The Maryblyt manual states:

> "As a general rule, if the EIP is less than 100%, few, if any, infections are likely to occur; an EIP of 100-150 % is low but is sufficient to support an epidemic of blossom blight; an EIP of more than 200-250% indicates that large numbers of infections are likely should a wetting event occur."

**Comparing the two models**

The high correlation between Maryblyt's EIP and Cougar Blight's Risk-Value allowed for a direct comparison between the two. EIP values were categorized similar to Cougar Blight's risk levels based on categories developed by George Sundin, Michigan State University:

- $0 \leq$ EIP < 70 was recorded as LOW
- $70 \leq$ EIP < 100 was recorded as CAUTION, or moderate
- $100 \leq$ EIP < 200 was recorded as HIGH
- $200 \leq$ EIP was recorded as EXTREME/ EXCEPTIONAL

For Cougar Blight, one of its benefits is that it produces risk levels for three different scenarios:

1. No fire blight in your neighborhood last year
2. Fire blight occurred in your neighborhood last year
3. Fire blight is now active in your neighborhood

Scenario 2 is the default setting and was used for this comparison. It made the most sense as Maryblyt calculates EIP under the assumption that abundant inoculum is available for an infection. Based on the severe infection year in 2016, it is also safe to say fire blight inoculum is present in most apple growing regions of the province.

Historical data provided by The Weather Network from 10 locations across southwestern Ontario was used to compare the Cougar Blight and Maryblyt models using apple growth stage information specific for these regions. These locations included Harrow, Blenheim, London, Simcoe, Grimsby, Fonthill, Niagara-on-the-lake, Clarksburg, Port Perry and Newcastle.

The same weather data was fed into both models, which predicted values from the approximate start of their bloom period to petal fall. The EIP values were then placed into one of the four risk categories listed above and the results graphed.

**Results**

In total, there were 128 daily predictions across the 10 Ontario locations for each model. Of these predictions, 84 predicted values, or **65.625%,** were the same between both models. Of the 44 predicted values that did not match, only one of those predictions had Maryblyt predicting a higher risk value than Cougar Blight. This means that **Cougar Blight predicted a higher risk level than Maryblyt about one-third of the time**. However, the higher predicted risk levels for Cougar Blight, or greatest separation between the models, tended to be during times of moderate to extreme risk.

The following graphs show the comparison between predictions for a few locations where the differences are most clear (Figure 1).

**Discussion**

There are a few very important things to keep in mind while looking at these results. First, and possibly most important, the risk values that the EIP values were categorized as may not directly correlate to the Cougar Blight risk levels. It could be that the intervals used for EIP are too high, resulting in more lower risk level predictions from Maryblyt. Further, the intervals for both models may simply be too broad. For example, an EIP of 99 is much closer to an EIP of 100 as opposed to an EIP of 90, yet the values of 99 and 90 would be grouped


**Figure 1.** Predictions of fire blight infections, comparing the Maryblyt (blue) and Cougar Blight (red) models for four different locations in southwestern Ontario

together as “Moderate risk” while an EIP of 100 is categorized as “High risk”.

That being said, the results suggest that Cougar Blight tends to predict a higher risk level than Maryblyt. I believe this is due to the data required for each model. Cougar Blight takes only the daily high temperature and precipitation, whereas Maryblyt also includes the daily low temperature into its calculation of EIP. Temperatures below 15ºC can influence the rate bacteria multiply and move into the flower to establish infection. Without considering the daily low temperature, it is possible to overpredict that conditions for infection have been met. This would become particularly evident within the moderate to high risk when temperatures are reaching levels conducive to infection.

However, Dewdney et al. (2007) compared the accuracy of the two fire blight models in the different environments of the east (Michigan, New York, Quebec, Vermont and West Virginia) and west (British Columbia an Washington) coasts of North America. They found that both models predicted an infection with almost equivalent success rates. Interestingly, they also found that Cougar Blight was not as effective as Maryblyt when used for highly susceptible apple cultivars such as Gingergold, Idared, Jonagold, Paulared and Royal Gala. As the Ontario apple industry moves towards more susceptible varieties, Maryblyt may be a more accurate model to use.

I would like to find a way to compare the numerical risk values used by Cougar Blight to the EIP values produced by Maryblyt. I intend to follow up on this next year with a more in-depth look at how reliable a 7-day prediction is for each model. I believe this will lead to not only a better comparison of the two but may also support the findings that the two models are more similar than our numbers suggest.

**Conclusion**

As with any model, the fire blight prediction maps should be a decision-making tool within your management program. Consider how your orchard microclimate, phenology, control program in place and historical disease pressure may influence the infection risk as well. Environmental conditions may be more or less conducive for fire blight infection in your orchard than what is indicated by the maps. For more accurate predictions, I encourage you to run either model with data generated in your orchard.

If you have the time and interest in running a forecasting model for your own operation, consider experimenting with both Cougar Blight and Maryblyt using weather data for this past bloom period alongside a date as to when you first noticed fire blight infection in your orchard. This practice will help you determine which model you prefer in terms of ease of use, information required and your level of confidence with prediction values.

Overall, Maryblyt and Cougar Blight are both very useful tools that can save you time and money when used properly.

**References:**

Dewdney, M.M., A. R. Biggs and W.W. Turechek. A statistical comparison of the blossom blight forecasts of *MARYBLYT* and *Courgarblight* with receiver operating characteristic curve analysis. Phytopathology 97:1164-1176

## Rainfastness of Insecticides and Fungicides on Fruit

*Kristy Grigg-McGuffin, Horticulture IPM Specialist (Apple) and Wendy McFadden-Smith, Horticulture IPM Specialist (Tender Fruit & Grape), OMAFRA*

In view of the frequent heavy rains in many regions this season, understanding rainfastness, or the ability of a pesticide to withstand rainfall, is important to ensure proper efficacy. All pesticides require a certain amount of drying time between application and a rain event. Typically, residue loss by wash-off is greatest when rain occurs within 24 hours of spraying. After this point, the rainfastness of a product will depend on formulation, adjuvants and length of time since application.

**Rainfastness of Insecticides**

John Wise, Michigan State University has studied rainfastness of common tree fruit insecticide groups and his findings are summarized below. For the complete article, refer to https://www.canr.msu.edu/news/rainfast_characteristics_of_insecticides_on_fruit. Note that some products listed in this article may not be registered for use in Canada. Check with your local supplier or refer to the 2018-2019 Publication 360: Guide to Fruit Production and 2019 Supplement for a complete list of registered products.

According to Wise, the impact of rain on an insecticide’s performance can be influenced by the following:

1. **Penetration** into plant tissue is generally expected to enhance rainfastness.

- Organophosphates have limited penetrative potential, and thus considered primarily surface materials.
- Carbamates and pyrethroids penetrate the cuticle, providing some resistance to wash-off.
- Spinosyns, diamides, avermectins and some insect growth regulators (IGR) readily penetrate the cuticle and move translaminar (top to bottom) in the leaf tissue.
- Neonicotinoids are considered systemic or locally systemic, moving translaminar as well as through the vascular system to the growing tips of leaves (acropetal movement).
- For products that are systemic or translaminar, portions of the active ingredient move into and within the plant tissue, but there is always a portion remaining on the surface or bound to the waxy cuticle that is susceptible to wash-off.

2. **Environmental persistence** and **inherent toxicity** to the target pest can compensate for wash-off and delay the need for immediate re-application.

- Organophosphates are highly susceptible to wash-off, but are highly toxic to most target pests, which means re-application can be delayed.
- Carbamates and IGRs are moderately susceptible to wash-off, and vary widely in toxicity to target pests.
- Neonicotinoids are moderately susceptible to wash-off, with residues that have moved systemically into tissue being highly rainfast, and surface residues less so.
- Spinosyns, diamides, avermectins and pyrethroids are moderate to highly rainfast.

3. **Drying time** can significantly influence rainfastness, especially when plant penetration is important. For instance, while 2 to 6 hours is sufficient drying time for many insecticides, neonicotinoids require up to 24 hours for optimal penetration prior to a rain event.

4. **Spray adjuvants** that aid in the retention, penetration or spread will enhance the performance of an insecticide.

The following tables can serve as a guide for general rainfastness to compliment a comprehensive pest management decision-making process.

**Table 1.** General characteristics for insecticide chemical classes

| Insecticide Group | Rainfastness ≤ 0.5 inch (1.25 cm) | | Rainfastness ≤ 1 inch (2.5 cm) | | Rainfastness ≤ 2 inches (5 cm) | |
|---|---|---|---|---|---|---|
| | Fruit | Leaves | Fruit | Leaves | Fruit | Leaves |
| **Carbamates (1A)** *Lannate* | M | M/H | M | M | L | L |
| **Organophosphates (1B)** *Imidan, Malathion* | L | M | L | M | L | L |
| **Pyrethroids (3A)** *Decis, Mako, Matador, Perm-Up, Pounce, Silencer, Up-Cyde, Ambush* | M/H | M/H | M | M | L | L |
| **Neonicotinoids (4A)** *Actara, Admire, Alias, Assail, Calypso, Closer, Clutch, Cormoran, Sivanto* | M,S | H,S | L,S | L,S | L,S | L,S |
| **Spinosyns (5)** *Delegate, Entrust, Success, TwinGuard* | H | H | H | M | M | L |
| **Avermectins (6)** *Agri-Mek, Minecto Pro* | M,S | H,S | L,S | M,S | L | L |
| **IGRs (15 & 18)** *Rimon, Cormoran, Confirm, Intrepid* | M | M/H | M | M | L | L |
| **Diamides (28)** *Altacor, Exirel, Harvanta* | H | H | H | M | M | L |

**H** –highly rainfast (≤30% residue wash-off), **M** –moderately rainfast (≤50% residue wash-off), **L** –low rainfast (≤70% residue wash-off), **S** –systemic residues remain with plant tissue

**Table 2.** Insecticide persistence, plant penetration and rainfastness rating

| Insecticide Group | Persistence | Penetration | Rainfast rating |
|---|---|---|---|
| **Carbamates (1A)** *Lannate* | Short | Cuticle | Moderate |
| **Organophosphates (1B)** *Imidan, Malathion* | Medium-long | Surface | Low |
| **Pyrethroids (3A)** *Decis, Mako, Matador, Perm-Up, Pounce, Si-lencer, Up-Cyde, Ambush* | Short | Cuticle | Moderate-high |
| **Neonicotinoids (4A)** *Actara, Admire, Alias, Assail, Calypso, Closer, Clutch, Cormoran, Si-vanto* | Medium | Translaminar, acropetal | Moderate |
| **Spinosyns (5)** *Delegate, Entrust, Suc-cess, TwinGuard* | Short-medium | Translaminar | Moderate-high |
| **Avermectins (6)** *Agri-Mek, Minecto Pro* | Medium | Translaminar | Moderate |
| **IGRs (15 & 18)** *Rimon, Cormoran, Con-firm, Intrepid* | Medium-long | Translaminar | Moderate |
| **Diamides (28)** *Altacor, Exirel, Harvanta* | Medium-long | Translaminar | Moderate-high |

*Tables adapted from "Rainfast characteristics of insecticides on fruit" by John Wise, Michigan State University Extension, https://www.canr.msu.edu/news/rainfast_characteristics_of_insecticides_on_fruit

Based on simulated rainfall studies to combine rainfastness with residual performance after field-aging of various insecticides, including carbamates (Lannate), organophosphates (Imidan, Malathion), pyrethroids (Capture), neonicotinoids (Assail, Actara, Admire), IGRs (Rimon, Intrepid), spinosyns (Delegate) and diamides (Altacor), Wise recommends the following re-application decisions for apples. Additional work was done on grapes and blueberries; see Wise's article for this information. Among the crops, variation in rainfastness of a specific insecticide occurs since the fruit and leaves of each crop have unique attributes that influence the binding affinity and penetrative potential.

- **½ inch (1.25 cm) rainfall:** All products with 1-day old residues could withstand ½ inch of rain. However, if the residues have aged 7 days, immediate re-application would be needed for all products but Assail, Rimon, Delegate or Altacor on apples.
- **1-inch (2.5 cm) rainfall:** In general, most products would need re-application following a 1-inch rainfall with 7-day old residues, whereas Delegate and Altacor could withstand this amount of rain on apples and would not need to be immediately re-applied. Some products such as Imidan on apples could withstand 1 inch of rain with 1-day old residues.
- **2-inch (5 cm) rainfall**: For all products, 2 inches of rain will remove enough insecticide to make immediate re-application necessary.

It is important to note, not all products registered for the selected pests were included in this study. Refer to Publication 360 for a complete list of management options.

**Rainfastness of Fungicides**

There is no comparable research on rainfastness of fungicides and few labels provide this kind of information. A general rule of thumb often used is that 1 inch (2.5 cm) of rain removes approximately 50% of protectant fungicide residue and over 2 inches (5 cm) of rain will remove most of the residue. However, with many newer formulations or with the addition of spreader-stickers, some products may be more resistant to wash-off. Avoid putting on fungicides within several hours before a rainstorm as much can be lost to wash-off regardless of formulation. As well, there are exceptions to the general rule in regard to truly systemic fungicides such as Aliette and Phostrol.

The effectiveness of sticker-spreaders with fungicides is variable and product/crop specific. Penetrating agents don't help strobilurins; in fact, some fungicide/crop combinations have been associated with minor phytotoxicity due to excessive uptake. Captan, which is intended to stay on the surface, is notorious for causing injury when mixed with oils or some penetrating surfactants that cause them to penetrate the waxy cuticle. Consult labels for minimum drying times for individual products and recommendations for using surfactants.

Annemiek Schilder, Michigan State University suggests the following to improve fungicide efficacy during wet weather:

- During rainy periods, systemic fungicides tend to perform better than protectant (or contact) fungicides since they are less prone to wash-off.
- Applying a higher labelled rate can extend the residual period.
- Apply protectant fungicides such as captan (Supra Captan, Maestro), mancozeb (Manzate, Dithane, Penncozeb) and metiram (Polyram) during sunny, dry conditions to allow for quick drying on the leaves. These types of fungicides are better absorbed and become rainfast over several days after application.
- Apply systemic fungicides such as sterol inhibitors (Nova, Fullback, Inspire Super), SDHI (Fontelis, Sercadis, Kenja, Aprovia Top, Luna Tranquility) and strobilurins (Flint, Sovran, Pristine) under humid, cloudy conditions. The leaf cuticle will be swollen, allowing quicker absorption. In dry, hot conditions, the cuticle can become flattened and less permeable, so product can breakdown in sunlight, heat or microbial activity, or be washed off by rain.

For the complete article, refer to: https://www.canr.msu.edu/news/how_to_get_the_most_out_of_your_fungicide_sprays.

## Fashionably Late: Apple Pests at Harvest

*Kristy Grigg-McGuffin, Horticulture IPM Specialist, OMAFRA*

While harvest will undoubtedly take most of a grower's attention, it is still important to continue monitoring for pests and applying control measures, if needed, right up until the fruit is in the bin. There are some late season pests of apples that will remain active until harvest and if left uncontrolled can wreak havoc on a potentially good crop. However, not all pests can be effectively managed at this time of the year. Making note of the presence of damage will also help with management decisions in the subsequent year.

**Pin-point scab**

Pin-point scab (Figure 1) develops when fruit becomes infected within the last several weeks before harvest. Fruit with late season infection may not exhibit symptoms at harvest. However, lesions can develop on fruit during the first 30-45 days in storage. They appear as either pin-point sized lesions or jet-black spots. Fortunately, scab will not spread from diseased to healthy fruit in storage.

Scab can be found in a number of orchards across the province where fungicide programs did not manage primary scab infection during this exceptionally wet spring. Optimum conditions for pin-point scab include: 1) abundant scab inoculum; 2) lack of fungicide residue prior to harvest; and 3) wetting periods longer than 30-36 hours. Unlike foliar infections, pin-point scab can be substantially reduced by the presence of a dry period between wetting events. Research has shown that a 24-hour dry period commencing 24, 48 and 72 hours after inoculation at 20ºC can reduce the amount of scab by 67, 87 and 36%, respectively.

Captan (Supra Captan, Maestro) or Pristine cover sprays should be applied leading up to harvest in orchards with optimum conditions for pin-point scab. The preharvest interval for these products is 7 and 5 days, respectively. A preharvest cover spray is important regardless of whether scab was active in the orchard. There is a possibility that lesions are present but have been missed during routine scouting, especially if they are at the top of the canopy.

**Fly speck & sooty blotch**

Sooty blotch (Figure 2) appears as brown to olive green, cloudy blotches with irregular margins on the surface of the skin, often more obvious on light-coloured fruit. Fly speck (Figure 3) appears as groups of few to several small (0.5 mm), shiny black fungal bodies, or thyriothecia on the fruit surface. 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. These two diseases often appear together and do not damage the flesh. However, in storage, fruit with sooty blotch infection shrivel more readily than uninfected fruit.

Although symptoms typically don't appear until mid-summer to harvest with fly speck and sooty blotch, infection often occurs about 2-3 weeks after petal fall. Spores are dispersed from infected twigs by splashing rain and wind in the spring and early summer. First symptoms are usually apparent 20-25 days after infection, but can appear in 8-12 days under optimal conditions. Symptoms are usually more common and severe during years with cool, wet springs and late summer rains very similar to what we are experiencing this year.

Flyspeck and sooty blotch are caused by very slow-growing fungi. Both can go dormant during unfavorable weather conditions such as hot, dry weather, and then continue development when favorable conditions return. This means symptoms of sooty blotch and flyspeck appear most often during the harvest season, even though infections may have taken place much earlier. If these pathogens have been an issue in the past, be sure to maintain fungicide residues every 14-21 days or when there has been more than 2 inches of rain since last application.

### Bitter rot

Bitter rot (Figure 4) overwinters in mummified fruit, crevices in the bark and cankers. Typically, symptoms appear late summer to harvest following a period of hot, humid weather with thunderstorms. Infection appears as small spots that quickly enlarge into circular, sunken, light to dark brown rots on infected fruit. During humid conditions, salmon-coloured masses of spores are produced on the surface of the rotting fruit. These spores can then be rain-splashed to other fruit resulting in further infections. If the spores land on fruit just before or during harvest, infection can occur and small lesions will develop slowly while in cold storage.

Management of bitter rot is through good orchard sanitation. Removing old fire blight, black rot and other cankers will reduce the potential overwintering source of this disease. Mulching or removing infected fruit on the orchard floor will also help reduce inoculum.

Granuflo T, Allegro and Pristine are registered for the control of bitter rot in Ontario. However, some fungicides registered for the management of apple scab such as captan may also provide some protection. Fungicide applications should be made every 10-14 days during dry, warm summer months, but shortened to 7 days if frequent rain is experienced. If possible, timing an effective fungicide application just prior to a rain event or thunderstorm will protect fruit from rain-splashed spores.

### Apple maggot

Damage from apple maggot 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 5). After hatching, the larvae tunnel within the fruit and cause breakdown and discoloration of the pulp (Figure 6). Invasion by disease fungi, such as *Alternaria* spp. and *Pseudomonas* spp. leads to further decay and heavily infested fruit can become completely rotten.

As there is zero tolerance for fruit damage caused by apple maggot, sprays should be applied 7-10 days after first adult catch on a yellow sticky trap. If possible, differentiate between male and female since males often emerge prior to females. By peak flight (end of July, early August), the proportion of males to females is 1:1 and mating is on-going. Activity of this pest can continue until the first hard frost, which means applications should continue every 14-21 days if trap catches warrant a need.

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. The preharvest interval for Imidan is 14 days. Border sprays are not recommended for other registered apple maggot products. Table 1 has been adapted from John Wise, Michigan State University to describe the characteristics of apple maggot products available to Ontario growers. Organophosphates (Imidan) and neonicotinoids (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 the flesh of the fruit.

**Table 1.** Summary of Insecticides Used to Control Apple Maggot (Adapted from John Wise, MSU: https://www.canr.msu.edu/news/managing-apple-maggots-with-insecticides)

| Product Name | Chemical Group | Life-Stage Activity | Efficacy | Residual Activity | Mite Flaring Potential |
|---|---|---|---|---|---|
| **Imidan** | Organophosphate | Eggs, larvae, adults | Excellent | 14+ days | Low |
| **Ambush, Mako, Perm-Up, Pounce, Up-Cyde** | Pyrethroid | Adults | Fair – Good | 7 – 10 days | High |
| **Assail, Calypso** | Neonicotinoid | Eggs, larvae, adults | Good – Excellent | 10 – 14 days | Low – moderate |
| **Delegate, Twin-Guard, GF 120 Fruit Fly Bait** | Spinosyn | Adults | Fair | 7 – 10 days | Moderate |
| **Altacor, Exirel, Harvanta** | Diamide | Adults | Fair – Good | 10 – 14 days | Low |
| **Surround** | Not classified | Adults | Fair | 7 – 10 days | Low |

**San Jose scale**

Limb injury from San Jose scale appears as reddish discoloration when bark is cut away. Heavy infestations reduce tree vigour, growth and productivity. Fruit injury is most abundant around the calyx and stem ends, often resulting in a red inflamed ring surrounding each spot where a scale settles (Figure 7). Severe infestations may result in small, deformed fruit or the apples may not colour properly. Monitoring in Ontario has found the summer generations tend to overlap, which means the risk of fruit injury is present once first-generation crawlers begin to emerge mid-June and continue until harvest.

If scale has been detected in a block, the best method of control is an annual dormant oil application to target overwintering immature scales before they develop a protective waxy layer. However, complete coverage and timing are essential with the use of oils since they only smother immature nymphs with no impact on adults. This means delaying a dormant oil spray to target mites will reduce the efficacy on scale.

Movento, Sivanto Prime, Closer and TwinGuard are registered for summer control of the crawler stage of scale. While these products do help to protect fruit during the growing season, they should be used to supplement, not substitute, a dormant oil spray.

**Codling moth**

Codling moth larvae cause damage by tunnelling into the fruit and feeding on the pulp and seeds, causing extensive interior breakdown of tissue. The exit hole – where mature larva emerged – is often plugged with frass (Figure 8) on the side or bottom of fruit.

While there are usually 2 generations of codling moth in Ontario, it is possible to see a 3$^{rd}$ generation in some orchards during warmer than average seasons. Codling moth larvae normally enter diapause during the 3$^{rd}$ week of August. However, in warm years, some pupate instead and go on to produce another flush of adults. If this occurs, use pheromone traps to establish a biofix when flight activity increases and apply a spray when the following degree days (DDC) (base 10°C) accumulate:

- Imidan, TwinGuard, Delegate, Altacor: Apply at 138 DDC.
- Assail, Calypso: Apply at 111-138 DDC. Note: PHI for Calypso is 30 days.
- Exirel, Harvanta, 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, Harvanta) or none at all (Intrepid, Confirm). Take this into consideration when choosing a late season spray.

**Oriental Fruit Moth**

Damage from oriental fruit moth is fairly similar to codling moth. While codling moth larvae feed directly on the seed cavity, oriental fruit moth larvae tunnel in the flesh of the apple (Figure 9).

Adult flight of oriental fruit moth can last into early October, with damage occurring up to harvest. 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, Isomate CM/OFM TT only lasts up to 90 days for oriental fruit moth, so late season sprays may be needed.

**Obliquebanded leafroller**

While some orchards may still be catching adult obliquebanded leafroller in pheromone traps or seeing larvae and/or damage (Figure 10), we have passed the point where management is worthwhile. Late season obliquebanded leafroller development is not synchronized and sprays would affect only a small portion of the population that is active at this time. Instead of spraying, keep an eye out for late season damage during harvest. If damage is found, be sure to apply a petal fall spray targeting leafrollers 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. It's easy to miss both the presence of the bug and early signs of injury (Figure 11), which can take up to two weeks before it is obvious enough to detect without intensive monitoring (Figure 12). 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 dry July and August, 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. Products registered in apple include Lannate Toss-N-Go (1 application, 8 day PHI) for control or 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. Malathion 85E was a conditional registration and is no longer labeled for BMSB.

**Figure 1.** Pin-point scab on apple.

**Figure 2.** Sooty blotch on apple.

**Figure 3.** Fly speck on apple.

**Figure 4.** Bitter rot on apple.

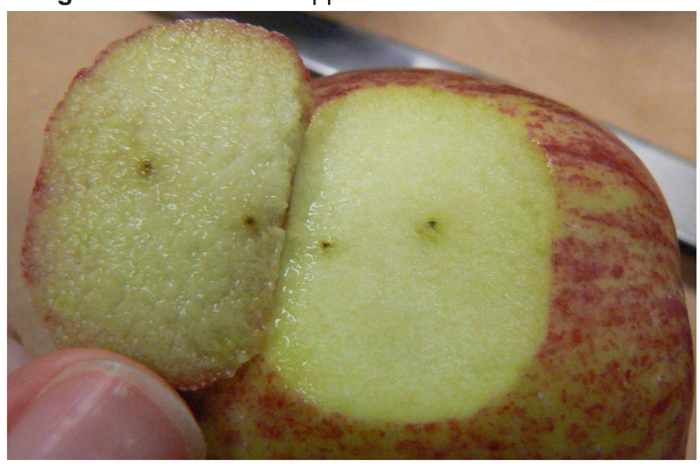

**Figure 5.** Apple maggot oviposition sting on fruit

**Figure 6.** Internal breakdown of fruit due to apple maggot damage.

**Figure 7.** San Jose scale on apple.

**Figure 8.** Codling moth damage to apple.

**Figure 9.** Oriental fruit moth damage to apple.

**Figure 10.** Obliquebanded leafroller damage to

**Figure 11.** Early brown marmorated stink bug damage to apple.

**Figure 12.** Initial brown marmorated stink bug damage develops into obvious depressions over time.

# Post Harvest

## Harvesting Apples at Optimum Maturity for Storage

*Dr. Jennifer DeEll, Fresh Market Quality Specialist – Hort Crops, OMAFRA*

For successful long-term storage, apples must be harvested when they are physiologically mature but not ripe. Each cultivar must be harvested at the proper maturity in order to achieve maximum storage life and marketing season. If apples are harvested too early, they are of poor color, small size and have little flavour, they will fail to ripen or may ripen abnormally, and the overall quality will be poor. High water loss, low sugar content, high acidity, low aroma volatile production, and high starch content are characteristics of immature apples that contribute to inadequate flavor development. Immature apples are also more likely to develop storage disorders like superficial scald and bitter pit. Harvesting apples too late can result in a short storage life. Such apples are too soft for long-term CA storage, and are more susceptible to mechanical injury and disease infection. Over-mature apples may develop poor eating quality and off-flavors, and are more susceptible to watercore and internal breakdown, as well as soft scald and soggy breakdown in a cultivar like 'Honeycrisp'.

For the above reasons, the determination of optimum apple maturity for harvest is essential for maximum storage life and quality, while minimizing postharvest losses. Numerous methods have been suggested for determining harvest date, but no single test is completely satisfactory, and some are too unpredictable, complicated or expensive. Days after full bloom is generally fairly constant, but can vary in any one year. Therefore, days after full bloom should be used as a general reference to indicate the approximate date when apples might reach harvest maturity, which is then confirmed using tests such as internal ethylene concentration (IEC), starch-iodine staining, flesh firmness, and soluble solids content (sugars).

In general, and especially for older cultivars, IEC of 1 ppm is considered to be the ultimate threshold above which fruit ripening and flesh softening are initiated and progress rapidly. Harvest for long-term storage should be completed before 20% of the apples have an IEC higher than 0.2 ppm. New cultivars do not always follow that rule, such as 'Honeycrisp'.

Using the starch-iodine test, most apples destined for long-term storage should have 100% of the core tissue starch degraded (no stain) with greater than 60% of the flesh tissue still having starch present (stain). Again, new cultivars do not always follow that rule, such as 'Honeycrisp'. It is also important to note that not all apples mature and ripen in the same manner each year, and often there will be a need to compromise between correct maturity and the required firmness and sugar levels for market.

The following chart represents harvest guidelines for apples destined for long-term CA storage (Table 1). Extreme weather during the growing season can influence fruit maturity, so actual values may vary during such seasons. Of course, you also need proper color to market the fruit.

**Table 1.** Suggested starch index values and firmness at harvest for apples going into long-term storage.

| Cultivar | Starch Index (1-8)* | Firmness (lb) |
|---|---|---|
| Ambrosia | 2.5 – 4.0 | >17 |
| Cortland | 2.5 – 3.5 | >15 |
| Crispin | 3.5 – 4.5 | >17 |
| Delicious (Red) | 2.5 – 3.5 | >17 |
| Empire | 2.5 – 3.5 | >17 |
| Gala | 2.5 – 3.0 | >16 |
| Golden Delicious | 3.0 – 4.0 | >16 |
| Honeycrisp | >5.0 | >14 |
| Idared | 3.0 – 4.0 | >15 |
| McIntosh | 2.5 – 3.5 | >15 |
| Northern Spy | 2.5 – 3.5 | >18 |
| Spartan | 2.5 – 3.5 | >15 |

* Cornell Starch Iodine Index Chart

The delta absorbance (DA) meter has been recently added into the toolbox for evaluating fruit maturity. It provides a measure of chlorophyll content (green color) of the fruit. In comparing our Ontario data through collaborations with colleagues in Minnesota and Maine, we found no consistent effect of DA values among apple cultivars, growing location, orchard blocks, and harvest times. However, the DA meter could be a useful tool if one takes the time to develop standardized readings during the harvest period for a given cultivar and orchard block.

Apples can be segregated into lots at harvest by their storage potential. The following types of apples should not be designated for long-term storage because of their potential for problems: 1) large fruit from lightly cropped trees, 2) fruit from excessively vigorous trees, 3) fruit from young trees just coming into bearing, 4) fruit from interior portions of trees that are heavily shaded, 5) early-picked fruit high in starch, 6) late picked fruit with advanced maturity, and 7) fruit with low seed count (< 5 per fruit).

# Storage of 'Honeycrisp' Apples

*Dr. Jennifer DeEll, Fresh Market Quality Specialist – Hort Crops, OMAFRA*

Harvesting at proper fruit maturity is the first thing necessary to maximize storage life and maintain good quality apples. However, determining the optimum harvest maturity for 'Honeycrisp' is difficult. Standard maturity indices, such as internal ethylene concentration, starch index, soluble solids concentration and fruit firmness are not always consistent. In general, harvest should occur when **the ground color begins to change from green to yellow and the starch index value is close to 6** (on the Cornell chart). It is important to note that differences in maturity do not always exist among 'Honeycrisp' apples with varying levels of red color. For example, brilliant red fruit can exhibit very similar internal ethylene concentrations, starch content, and firmness values as those having poor red coloration.

Immature 'Honeycrisp' harvested too early will not ripen properly and those fruit do not develop good flavor and quality characteristics. Conversely, late harvested or over-mature 'Honeycrisp' can develop fermentation products, such as ethanol and acetaldehyde, which cause undesirable flavors and poor fruit quality. 'Honeycrisp' harvested at advanced maturity are also more prone to soft scald (Fig. 1) and soggy breakdown.

Prior to cold storage, **conditioning at 10°C for 1 week** is recommended to reduce the incidence of soft scald and soggy breakdown. Soft scald is a major chilling-related disorder that is characterized by sharply defined, irregularly shaped, smooth, brown lesions of the skin. Peel tissue is initially affected and then hypodermal tissue is damaged as the disorder continues to develop. Skin lesions are often then invaded by secondary pathogens and disease. Soggy breakdown is another major chilling-related disorder, which is distinguished by moist, soft, brown, spongy flesh tissue, which can form complete rings in severe cases. Apples harvested at advanced maturity are more susceptible to soft scald and soggy breakdown, while chilling temperatures in the orchard before harvest will further promote development. Both disorders have been found in 'Honeycrisp' apples prior to harvest.

Conditioning 'Honeycrisp' apples at temperatures above 10°C has been shown to substantially reduce acidity levels, and this has also been noted within sensory evaluations. Bitter pit (Fig. 1) can develop more rapidly at warmer temperatures, so conditioning at 10°C is a compromise between bitter pit development and chilling-related disorders such as soft scald. Bitter pit may appear prior to harvest or during storage, and usually develops in the calyx end of the fruit. Pits are dark, sunken lesions at or beneath the fruit surface. The cause for bitter pit is a mineral imbalance in the apple flesh, associated with low levels of calcium. **Delaying the establishment of CA storage for 1 to 2 months** has been shown to reduce these disorders. Treatment with diphenylamine (DPA) can also decrease the incidence of $CO_2$ injury in 'Honeycrisp' apples.

Ethylene production, respiration, and greasiness can be reduced by **postharvest application of 1-MCP** (i.e. SmartFresh™) on 'Honeycrisp'. 1-MCP tends to be slightly more effective when applied at the onset of the conditioning period at 10°C, compared to after that 1-week period. However, always be aware of any $CO_2$ accumulation during the 1-MCP treatment, as this has potential to cause $CO_2$ injury even though in air storage. There is little loss of firmness in 'Honeycrisp' during short-term storage (4 months), so any improved firmness retention caused by 1-MCP treatment may only become apparent during later months of storage. **Preharvest application of 1-MCP** (i.e. Harvista™) has been shown to significantly reduce soft scald development, but spray rate and application timing are important factors.

**Acknowledgements**

*Thanks to the Ontario Apple Growers, Apple Marketers' Association of Ontario, Les producteurs de pommes du Québec, BC Fruit Growers' Association, AgroFresh Inc., and Storage Control Systems Inc. for their support; as well as to Norfolk Fruit Growers' Association and Pommes Philip Cassidy Inc. for their direct collaboration. Recent work pertaining to 'Gala' storage was funded in part through Growing Forward 2, as part of the Canadian Agri-Science Cluster for Horticulture 2 and the Agri-Innovation program in partnership with Agriculture and Agri-Food Canada and the Canadian Horticultural Council. Thanks to Geoff Lum, Sky Lesage, Younes Mostofi, and Lorie Walker for their technical assistance*

**Figure 1:** Soft scald (left), bitter pit and peel blotch (center), and internal $CO_2$ injury (right) in 'Honeycrisp' apples.

# Internal Browning in 'Gala' Apples

*Dr. Jennifer DeEll, Fresh Market Quality Specialist – Hort Crops, OMAFRA*

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 (Fig. 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 (Fig. 2).

Internal browning **increases with longer storage durations, as well as increased time at room temperature following removal from storage**. Our research found 'Gala' stored in air at 0.5°C had no internal browning after 2 months, whereas significantly higher incidence was found after 6 months (18%) compared to 4 months (12%). 'Gala' held in standard CA (2.5% $O_2$ + 2.0% $CO_2$) at ~1°C had little internal browning through 5 months of storage, but then this disorder increased significantly with storage time thereafter. Furthermore, internal browning increased with subsequent holding at room temperature, with 20 days at ~20°C having up to 43% incidence.

**1-MCP does not seem to have consistent effects on internal browning**. 'Gala' stored in air has had lower browning incidence with 1-MCP treatment than without, but this is not always the case. Significant reduction in internal browning due to 1-MCP was only found in CA-stored 'Gala' after 9 months of storage when incidence was extremely high (59 down to 43%). In contrast, other research has shown significant increases in browning when 1-MCP was applied to 'Gala' (DeEll, unpublished data).

An interesting factor that has been observed for the past few years is that 'Gala' from the bottom of a notable hill (running throughout one orchard of various blocks) developed consistently more internal browning than similar fruit from the top of the hill (17-22% vs 0-1% and 43-59% vs 11-17% after 7 and 9 months of CA storage, respectively). Therefore, browning **incidence can vary within an orchard or block** when tree management and systems are all the same. In this case it may be related to varying orchard temperatures or nutrition due to the rolling hill.

**Higher incidence of internal browning is generally found when apples are harvested late at advanced maturity stages**. For example, some previous research showed a main effect of harvest time, with 4 and 12% browning incidence in 'Gala' from Harvest 1 and 2, respectively (DeEll, unpublished data). Late harvesting in some seasons can be a very large contributor to high percentages of internal browning. 'Gala' strain further affects browning development, with some newer strains showing less susceptibility.

Previous research also showed that **rapid cooling within 24 hours to 3°C 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.

Low oxygen storage of 1-2% or dynamic CA with less than 1% oxygen can reduce the development of internal browning in 'Gala'. Past research found 17 and 6% incidence of stem-end browning in 'Gala' stored in standard CA (2.5% $O_2$ + 2% $CO_2$) and low oxygen (1.5% $O_2$ + 1.1% $CO_2$), respectively, while 'Gala' held in oxygen as low as 0.4% using SafePod technology to monitor fruit respiration (Storage Control Systems Inc., Michigan) had no internal or stem-end browning (DeEll, unpublished data).

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

**Acknowledgements**

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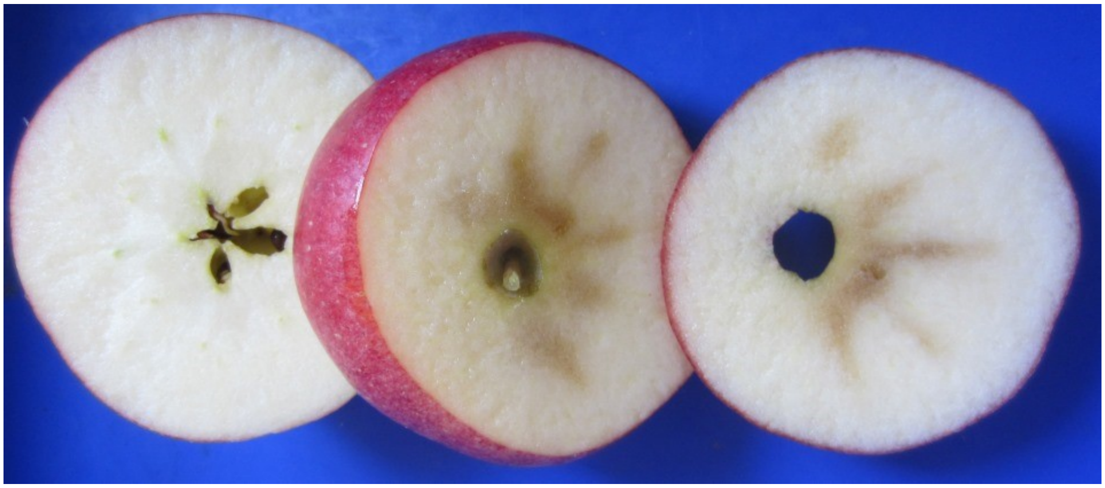

**Fig. 1:** Internal stem-end (shoulder) browing in ‘Gala’ apple.

**Fig. 2:** Internal browning in ‘Gala’ apple.