HORTICULTURE AND JUICE QUALITY ATTRIBUTES OF EUROPEAN APPLE CIDER CULTIVARS

A FINAL REPORT TO THE ONTARIO CRAFT CIDER ASSOCIATION

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Horticulture and Juice Quality Attributes of European Apple Cider Cultivars – A Final Report

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EXECUTIVE SUMMARY

Research plots were established in 2015 at five grower co-operator orchards across Ontario including the University of Guelph, Simcoe. Twenty-nine cultivars on M.9 rootstock were planted at various spacings and orchard systems. Commercial sites were monitored for tree growth, survival, winter injury and insect and disease susceptibility at two locations. Detailed horticultural and juice attributes were measured at the Simcoe location. Overall, tree growth and mortality varied by location and was more a function of orchard management and growing conditions than growing region. At the Simcoe research station, all cultivars have grown well and yielded a significant amount of fruit in their third leaf.

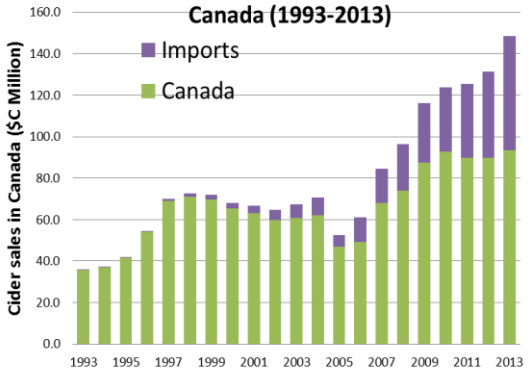
In terms of horticultural characteristics, Bramley, Enterprise and Calville Blan d'Hiver produced the largest fruit while Bramley's Seedling, GoldRush, and Bullmer's Norman produced the highest cumulative yields to date. Tydeman's Late Orange, Binet Rouge, and Golden Russet produced the tallest trees; while several cultivars displayed unproductive 'blind' wood on the leader and scaffolds. Tree survival at Simcoe has been excellent (92-100%) with no significant differences among cultivars. Full bloom dates ranged over a 3-week period from 10-28 May in 2017, with many cultivars exhibiting

secondary bloom on axillary buds on 1-yr old shoots. All cultivars required considerable hand-thinning of fruit in their 3rd leaf, after an abundance of flowering leading to high fruit set. Cultivars matured as early as mid-August and as late as Oct 31. Many cultivars exhibited pre-harvest drop, in part because there are susceptible to this phenomenon, but also may have been picked over-mature given many of the harvest dates are unknown for our growing conditions. With respect to juice characteristics, GoldRush, Bramley's Seedling, Bulmer's Norman, and Crimson Crisp had the highest juice extraction efficiency after pressing. Ashmead's Kernel, Tydeman's Late Orange, and Golden Russet produced juice with the highest sugar (BRIX) while Tydeman's Late Orange, Breakwell's Seedling and Bramley's Seedling had juice with the highest titratable acidity. Many cultivars exhibited high polyphenol levels (which include tannins); the highest were Stoke Red, Porter's Perfection, BInet Rouge, Bulmer's Norman amongst others.

1.0 INTRODUCTION

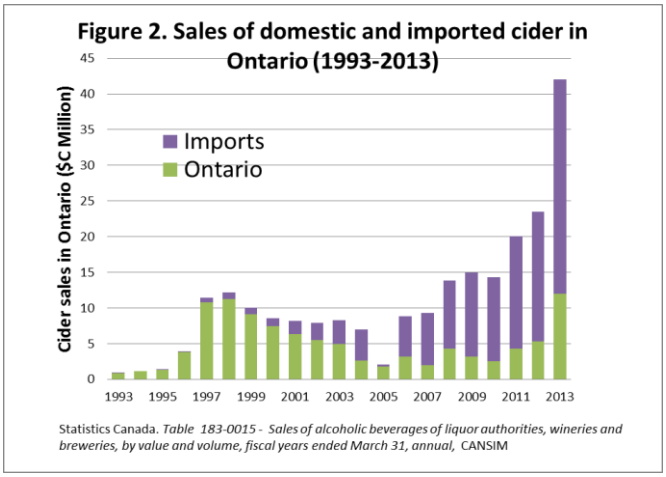
Over the past few decades and more specifically over the past ten years, there has been a resurgence of interest in hard cider in North America. Many Canadian cider makers have distinguished themselves among top producers, and because of increasing consumer demand for cider products, there are growing market opportunities both nationally and overseas. Based on recent statistics, the sale of imported and Canadian ciders is growing rapidly (Fig. 1), creating a significant opportunity for Ontario craft cider makers to expand their presence in the marketplace.

Figure 1. Sales of domestic and imported cider in Canada (1993-2013)



Statistics Canada. *Table 183-0015 - Sales of alcoholic beverages of liquor authorities, wineries and breweries, by value and volume, fiscal years ended March 31, annual,* CANSIM

In Ontario, sales of cider have increased dramatically between 2005 and 2013 (Fig. 2). This demand has led to a shortage of bittersweet, bittersharp, and sharp apples, particularly in Ontario where few of these cultivars are currently growing. This increase in sales includes production by the large producers and new smaller 'craft' producers, as well as wineries and breweries also entering the cider market. To keep up with this growth, most hard cider producers are using any 'juice' apples they can obtain – including fresh market culinary cultivars. Several cultivars grown for the fresh market, such as Gala, Idared, McIntosh, and to a lesser extent Jonagold, are widely used as the base apples for blending, however, they alone do not provide many of the attributes required to making a distinct product.



Craft cider makers, by nature, are trying to develop more unique blends that use traditional apple cultivars with higher levels of tannins, acids, sugars, and aromatics. Supply of the traditional European bittersweets and bittersharps in Canada is very limited, as they are not normally used for the dual purpose of cider making and fresh eating. With their high tannin or polyphenolic concentration, bittersweet and bittersharp apple varieties contribute complex flavours to finished ciders. Great Britain, France, and Spain are recognized for their cider industries, where production is based on cultivars that have these unique flavor profiles and that been used for centuries. These cultivars have been characterized for their range in sweetness, acidity and tannins.

In Ontario, there is a limited supply of traditional European cultivars, and it is difficult to import trees because many are not virus indexed, a CFIA requirement for importation. Additionally, the chemical composition of apples may vary somewhat according to region, horticulture practices, and seasonal growing conditions. There is very limited research that compares the horticultural and enological properties of cider varieties grown in the North America.

Apple producers interested in growing fruit for hard cider producers may have several questions before they venture into this enterprise or expand existing orchards. For example, what cultivar and rootstock are best to plant? How precocious and productive are these cider selections and what are their horticultural strengths and weaknesses? Are they vigorous, biennial bearing, prone to winter injury, tip bearing, are among other questions. What are their disease and pest strengths and weaknesses? Is the cultivar prone to fireblight, apple scab, and powdery mildew? Many of these questions remain unanswered based on available information in Ontario.

The goals of this project are to provide local performance data of twenty-nine cultivars with respect to juice quality for local craft cider makers and secondly provide essential orchard and disease management information on which cultivars perform best in the five growing regions of the province. These data will provide a benchmark from which growers can compare and/or expect when establishing new orchards. Specific objectives of the project are to establish commercial orchards in five growing regions in Ontario that differ in climate and soil conditions and measure the horticultural attributes of each cultivar. Once fruiting, the compositional juice quality for hard cider production will be assessed.

2.0 MATERIALS AND METHODS

Research plots were established in 2015 at five grower co-operator orchards including the University of Guelph, Simcoe. The following twenty-nine cultivars on M.9 rootstock were planted: Ashmead's Kernel, Baldwin, Binet Rouge, Bramley's Seedling, Breakwell's Seedling, Brown Snout, Brown's Apple, Bulmer's Norman, Calville Blanc d'Hiver, Chisel Jersey, Cox's Orange, Crimson Crisp, Dabinett, Enterprise, Esopus Spitzenburg, Foxwhelp,Fréquin Rouge, Golden Russet, Goldrush, Grimes Golden, Harry Masters Jersey, Kingston Black, Médaille d'Or, Michelin, Muscadet de Dieppe, Porters Perfection, Roxbury Russet, Somerset Redstreak, Stoke Red, Sweet Alford, Tolman Sweet, Tremlett's Bitter, Tydeman's Late Orange, Yarlington Mill. Specific planting details for each location are indicated below. Orchard management guidelines were left to the discretion of the grower at each site. The orchards established in Caledon, Simcoe, Lambton Shores, and Waupoos are conventionally managed while the orchard in Clarksburg follows certified organic management.

2.1 Horticultural Measurements

Harvest and sample collection**:** Based on previous records of maturity found in the literature, fruit from each cultivar were sampled at regular intervals prior to their expected date of maturity. At each sampling, fruit ripeness was determined by monitoring seed coat colour change and by starch-iodine test. For each cultivar, when the majority of fruit were considered to be mature, trees from all replications were hand-harvested and total yield and number of harvested fruit per tree were recorded. Total yield and number of preharvest dropped fruit per tree were also recorded. For each replication, 5 representative fruit were selected from each of the 3 trees and combined for a total of 15 fruit per replication. Fruit were immediately placed in air storage at 4°C until processing and analyses. The storage time varied from a few days to a few weeks.

2.2 Juice Analysis

Juice quality characteristics**:** Fruit were removed from cold storage, allowed to warm to room temperature, and weighed. They were then cut, milled using a commercial juicer (Omega 8006 Nutrition System Masticating Juicer, Omega Products Inc., Harrisburg, PA), and pressed through several layers of cheesecloth using a small hand operated hydraulic press and stainless steel collection plate. Equipment was thoroughly washed between each sample. The expressed juice was analyzed for juice yield, total soluble solids, pH, titratable acidity, and formol number. Juice yield was expressed as the volume of juice per weight of pressed fruit. Total soluble solids were measured using a temperature-compensating digital refractometer (Model PR-100, Atago, Japan) where ~1 mL of juice was applied to the test window of the instrument. Juice pH was measured with a digital pH meter (pH 700 Benchtop Meter, Oakton, Vernon Hills, IL). Titratable acidity (expressed as malic acid equivalents) was determined by titrating 5 mL of juice diluted 1:10 in distilled

water to a pH of 8.2 by addition of 0.1 N aqueous sodium hydroxide (NaOH) with an auto-titrator (G20 Compact Titrator, Mettler Toldeo AG, Schwerzenbach, Switzerland). Formol number (expressed as yeast assimilable nitrogen) was determined by titrating 2 mL of juice diluted 1:25 in distilled water according (HI 84533 Formol Number Minititrator, Hanna Instruments, Laval, QC). A 50 mL aliquot of juice was then stored at -80°C and used to determine total polyphenols at a later date.

Sample preparation for Folin-Ciocalteu assay: Frozen juice was thawed to 4°C and a 2 mL aliquot was centrifuged (3000*g* for 10 min) to precipitate any suspended solids from the juice. The supernatant was referred to as the untreated sample. Since non-phenolic compounds such as ascorbic acid are known to interfere with the Folin-Ciocalteu assay, an additional sample treatment step was included. Using a protocol adapted from Bridi et al. (2014), 1 mL of untreated sample was transferred to a 1.5 mL microcentrifuge tube containing 0.1 g of the polyphenol-binding agent polyvinylpolypyrrolidone (PVPP; Sigma-Aldrich, St. Louis, MO) and the mixture was vortexed for 20 s, incubated on ice for 15 min, then centrifuged (3000*g* for 10 min) to precipitate the PVPP-bound polyphenols. The supernatant was transferred to a new 1.5 mL microcentrifuge tube and centrifuged again (3000*g* for 5 min) to precipitate any remaining debris. The supernatant resulting from the PVPP treatment was referred to as the PVPP-treated sample.

Total polyphenols via Folin-Ciocalteu assay: Total polyphenols were measured using the Folin-Ciocalteu assay as described elsewhere (Jones & Saxena, 2013) with gallic acid as the standard. Standards were prepared as a 5-step, 2-fold serial dilution with a range of 31.25 mg/L to 500 mg/L. In a 96-well flat bottom microplate (Corning, Corning, NY), 10 µL of sample, gallic acid standard, or distilled water (used as a negative control) were aliquoted into designated wells, followed by 100 µL of 1:10 Folin-Ciocalteu reagent (Sigma-Aldrich, St. Louis, MO). After 5 minutes, 80 µL of 0.25 M sodium carbonate (Na_2CO_3) solution was added. After a 1-hr reaction time in the dark at room temperature, absorbance at 765 nm was measured using a microplate reader (Epoch 2 Microplate Spectrophotometer, BioTek, Winooski, VT). Standards and samples were analyzed in triplicate. Individual blanks were also prepared where 180 µL of distilled water was added to 10 µL of sample or standard. Measurements of these blanks were subtracted from the sample and standard values. Total polyphenol content was determined by linear regression from the standard curve and expressed as gallic acid equivalents. Uncorrected polyphenol values were obtained from the untreated samples while values for interfering compounds were obtained from the PVPP-treated samples. Adjusted polyphenol values were calculated by subtracting measurements obtained from the untreated samples by those from the PVPP-treated samples. All results were expressed as means ± standard error of the three replications.

Simcoe: University of Guelph, Simcoe (42.86 long, -80.27 lat). 580 trees were planted in the spring of 2015 at a spacing of 1.5 x 4.0 m (1667 trees/ha) using a vertical axes training system. A randomized complete design with 4 replications of 5 trees per cultivar will be

used. The two outside trees of each group of five will serve as ‘buffer’ trees and data are recorded from the inside three trees. Trees are trickle irrigated to supplement natural rainfall when necessary. Trees were headed at planting, fertilized, lightly pruned and trained to a wire trellis and overall, are managed for optimal tree establishment, growth and early fruit production in 2016. Integrated pest management of disease and insect pest was followed according to local recommendations for fresh apple production (OMAFRA, 2016). A list of all spray trees sprays (excluding herbicides) are indicated in Table 15.

2.3 Cider Orchards

Waupoos: County Cider (44.02 lat, -79.96 long). 580 trees were planted in the spring of 2015 using a slender spindle training system. A total of 20 trees of each cultivar were planted within the row and laid end to end with approximately 6 cultivars per row across 4 rows. No supplement irrigation is provided. Trees were not headed or pruned at planting. Trees were minimally managed in 2015 during the establishment phase.

Clarksburg: Apple Top Farms (44.50 lat, -80.46 long). 580 trees were planted in the spring of 2015 at a spacing of 0.45 x 3.6 m (6099 trees/ha) using a super spindle orchard system. A total of 20 trees of each cultivar were planted within the row and laid end to end with 14 or 15 cultivars per row across 2 rows. Trees are trickle irrigated to supplement natural rainfall when necessary. Trees were headed at planting, fertilized, lightly pruned and trained to a wire trellis and overall, are managed for optimal tree establishment, growth and early fruit production in 2017. Trees were managed using a certified organic system.

Caledon: Spirit Tree Estate Cidery (43.75 lat, -79.94 long). 294 trees were planted in the spring of 2016 using a central leader training system. The following cultivars (number of trees of each in parenthesis) were planted within the row and laid end to : Ashmoods Kernel (20), Baldwin (20), Binet rouge (20), Bramley Seedling (20), Brown Snout (20), Browns apple (20), Chisel Jersey (20), Cox's Orange (20), Dabinette (13), Esopus Spitzenburg (20), Foxwhelp (20), Frequine Rouge (20), Golden Russet (20), Kingston Black (20), Michelin (20), Roxbury Russet (20), Stokes Red (20), Tolman Sweet (20), Tremlett's Bitter (20). Trees established quite well despite the dry growing season, however 19 trees died by the fall of 2016.

Lambton Shores: Twin Pines Orchard and Cider House (43.187 lat, -81.846 long). 580 trees were planted in the spring of 2015 at a spacing of 1.2 x 3.8 m (2 153 trees/ha) using a vertical axes training system. A total of 20 trees of each cultivar were planted within the row and laid end to end with 3 cultivars per row across 10 rows. Trees are trickle irrigated to supplement natural rainfall when necessary. Trees were headed at planting, fertilized, lightly pruned and trained to a wire trellis and overall, are managed for optimal tree establishment, growth and early fruiting, some cultivars fruited in 2016.

2.4 Horticultural Data Measurements

Initial trunk diameter 30 cm above the soil on each tree after planting was measured on the following dates: May 29 (Simcoe), July 9 (Lambton Shores), July 20 (Clarksburg), and July 27 (Waupoos). Thereafter, in the fall of each year trunk circumference was measured at same location on the tree to estimate tree size and growth. In the spring and fall of each year, tree mortality was determined in order to estimate losses from winter injury or disease. At the Simcoe location in 2016, tree height and width were measured in the fall, as well as the number and weight of fruit per tree for those cultivars that produced fruit in the second leaf.

On July 21 in Simcoe, leaf samples mid-way on current season's extension shoots were collected for nutrient analysis. Three fully expanded leaves were selected per extension shoot up to a total of 24 leaves per tree. Leaves were taken from the middle three trees of each experimental unit for a total of up to 72 leaves per replication. Once collected, leaves were rinsed three times in distilled water, transferred to labelled paper bags, then placed in a forced air drying oven (60°C) and dried to constant weight. Dried leaf tissue was then ground using a Wiley mill and transferred to a coin envelope. This provided approximately 10 g of dried tissue for nutrient analyses. Samples were analyzed by a commercial lab for nitrogen, calcium, phosphorus, potassium, magnesium, copper, manganese, zinc, iron, boron, and sulphur.

The number of flower clusters was counted for each tree in Simcoe on 13-May 2016. Separate counts were done for the leader and for the lateral branches. The average phenological growth stage was also recorded for flowers on the leader and on lateral branches of each tree. This was done by determining the stage of the majority of flowers on either the leader or on lateral branches by comparing them a phenology chart developed by Washington State University (Bollard et al., 1973).

The incidence and severity of several diseases and insects was recorded on each of the cider cultivars at Clarksburg, Lambton Shores, and Simcoe in 2016. The diseases included: fireblight, apple scab, powdery mildew, and black rot, bitter rot. Insects included: spring feeding caterpillars, mullen bug, plum curculio, lepidoptera, codling moth, oriental fruit moth, oblique banded leaf roller, Japanese beetle, apple leaf curling midge, tarnished plant bug, and spotted tentiform leafminer.

Meteorological data were obtained from weather stations with publicly available daily weather data closest to the orchard sites. For the Waupoos site, data were collected from the Weather Underground Lakeview Monitoring Station, Cherry Valley, ON (Elev 101 m lat 43.957, -long 77.146). For the Clarksburg orchard, data were collected from a private weather station in Clarksburg, ON (Elev. 235m, lat 44.469, long -80.501), For the Caledon orchard, data were collected the Weather Underground station in Sleswick/Caledon, ON (Elev 310 m lat 43.908, long -79.991). For the Lambton Shores orchard, data were collect

from the Weather Underground station in Lambton Shores, ON (Elev 207 m lat 43.16, long 81.85) and for the University of Guelph, data were collect from a weather station on the research premises (Elev. 210 m, lat 42.855, long -80.268).

3.0 RESULTS & DISCUSSION

3.1 General comments

Cultivar differences in tree growth, leaf size and development, tree habit, and time of flowering existed within the second year of planting in 2016. Tree establishment and growth has varied across sites, due to local weather, soils, and management differences. Tree mortality has differed significantly across planting locations. Air temperatures in the winter of 2016 were coldest at the Waupoos location (min. -30.9^{o}C) followed by Clarksburg and Simoce (Table 6). Lambton shores had the most precipitation during the growing season (1 May – 31 Oct) while Simcoe experienced the warmest days (max 38.2 ^{o}C) and highest number of degree days during the growing season. Air temperatures in the winter of 2017 were coldest at the Waupoos location (min. -19.9^{o}C) followed by Caledon and Clarksburg (Table 6). Caledon had the most precipitation during the growing season (1 May – 31 Oct) and the warmest day (max 38.7^{o}C) while Lambton Shores had highest number of degree days during the growing season.

3.2 Thedford/Lambton Shores

Trees grew moderately well at the Lambton Shores site (Table 1). Tree mortality of ‘Brown Snout’, ‘Brown’s Apple’, ‘Dabinett’, ‘Enterprise’, ‘Frequin Rouge’, ‘Golden Russet’, ‘Médaille d'Or‘, ‘Michelin’ and Tolman Sweet’, have exceeded 25%, with many losses occurring being the 2016 and the end of the 2017 growing season (Table 1). No tree losses were observed for ‘Bulmer’s Norman’, ‘Cline Russet’, ‘GoldRush’ and ‘Grimes Golden’. In 2016, several of the ‘Browns Apple’ trees were infected with fireblight.

At the end of the 2017 growing season, Binet Rouge, Bramley's Seedling, and Tydeman’s Late Orange were the largest trees based on trunk cross-sectional area (TCSA) while Brown Snout, Bulmer’s Normal, Cline Russet, Cox Orange Pippin, Crimson Crisp, Dabinett, Grimes Golden, Médaille d'Or, and Yarlington Mill were the smallest.

Over the 2016 growing season, trees were assessed for the following pests and diseases: fireblight, apple scab, spring feeding caterpillars, leaf curling midge, powdery mildew, black rot, bitter rot, mullen bug, plum curculio, internal Lepidoptera, codling moth, oblique banded leaf roller, Japanese beetle, leaf hopper, tarnished plant bug, spotted tentiform leaf miner. ‘Brown’s Apple’ appears prone to winter injury.

3.3 Clarksburg

Trees grew growing well between 2015 and 2017 at the Clarksburg site. This is particularly important as the site is being managed using ‘organic’ practices. Detailed observations of cultivar susceptibility to insects and diseases were monitored in 2016 and 2017 with collaboration from OMAF crop specialists. Tree survival has been excellent to date with only 5-11% mortality of ‘Golden Russet’, ‘Medaille d’Or’ and ‘Yarlington Mill’ trees, respectively (Table 1). In 2015/16, Brown’s Apples, ‘Kingston Black’, ‘Sweet Alford’, ‘Tremlett’s Bitter ‘and ‘Tydeman Late Orange’ suffered winter injury as indicated by dieback on shoot tips.

Trees that had the greatest vigor after three growing seasons were Porter's Perfection Calville Blanc d'Hiver, Kingston Black, and Binet Rouge based on TCSA. The trees with the least amount of vigor were Brown Snout, Cline Russet, Golden Russet, Dabinett, Yarlington Mill, Muscadet de Dieppe, Fréquin Rouge, Tolman Sweet, Brown's Apple and Goldrush.

3.4 Waupoos

Trees have grown moderately to poorly over three growing seasons and had difficulty establishing likely because of dry conditions and high weed pressure. There are also so areas of the orchard with poor drainage, that has impacted tree health. ‘Brown Snout’, ‘Brown’s Apple’, ‘Cline Russet’, ‘Dabinett’, and ‘Kingston Black’, had greater than 50% mortality as of the fall of 2016 (Table 1). Overall tree vigor has been lowest of all sites and trees on Fréquin Rouge, Cline Russet, Tremlett's Bitter, Crimson Crisp, Tydeman's Late Orange, Breakwell's Seedling, Tolman Sweet, Goldrush, Médaille d'Or, and Michelin have grown the least, based on TCSA. Trees with the greatest vigor have been Ashmead's Kernel, Golden Russet, Sweet Alford, Enterprise, and Bramley's Seedling.

3.5 Caledon (Table 5)

Trees failed to grow after plating in 2005 and a new reduced orchard of 15 cultivars (Table 5) was therefore established in the spring of 2016. Trees have grown well. Tree morality has been greater than 5% on ‘Baldwin’, ‘Chisel Jersey’, ‘Dabinett’, ‘Esppus Spitzenberg’, ‘Frequin Rouge’, ‘Michelin’, and ‘Roxbury Russet’.

Table 1. 2017 survival and trunk cross-sectional growth of 29 cider apple cultivars planted in 2015 at three commercial orchards in Ontario.

	Tree survival fall 2017 (%)			Trunk cross-sectional area fall 2017 (cm^2)			
Cultivar[y]	Thedford	Clarksburg	Waupoos	Thedford	Clarksburg	Waupoos	Mean
Ashmead's Kernel	90	100	90	4.2	4.4	3.1	3.9
Binet Rouge	80	100	80	6.0	7.3	2.5	5.3
Bramley's Seedling	80	100	100	4.8	4.6	3.7	4.4
Breakwell's Seedling	90	100	86	4.6	4.4	1.6	3.5
Brown Snout	70	100	0	2.9	2.9	ND	2.9
Brown's Apple	53	100	21	3.5	4.2	2.3	3.4
Bulmer's Norman	100	100	95	2.8	5.5	2.4	3.6
Calville Blanc d'Hiver	95	100	ND	4.1	6.2	ND	5.2
Cline Russet	100	100	9	2.1	3.2	1.5	2.3
Cox's Orange	90	100	44	3.1	4.7	2.4	3.4
Crimson Crisp	85	100	53	2.4	4.5	1.6	2.8
Dabinett	68	100	20	3.2	3.8	2.3	3.1
Enterprise	35	100	79	4.0	5.6	3.5	4.3
Esopus Spitzenberg	95	100	ND	4.6	4.4	ND	4.5
Fréquin Rouge	65	100	33	3.5	4.1	1.2	2.9
Golden Russet	60	89	92	3.5	3.4	3.2	3.4
Goldrush	100	100	53	4.0	4.3	1.8	3.4
Grimes Golden	100	100	65	3.0	4.4	2.3	3.2
Kingston Black	80	100	18	3.7	6.3	2.6	4.2
Médaille d'Or	63	95	70	3.2	4.8	1.9	3.3
Michelin	50	100	41	3.9	5.3	2.0	3.7
Muscadet de Dieppe	95	100	ND	4.4	4.0	ND	4.2
Porter's Perfection	80	100	80	4.0	5.9	2.8	4.2
Stoke Red	80	100	67	4.7	5.1	2.4	4.1
Sweet Alford	90	100	71	3.7	5.1	3.3	4.0
Tolman Sweet	40	100	70	4.2	4.2	1.6	3.3
Tremlett's Bitter	85	100	21	3.6	4.7	1.6	3.3
Tydeman's Late Orange	85	100	55	5.3	4.9	1.6	4.0
Yarlington Mill	95	95	100	2.3	4.0	2.1	2.8
Mean	79	99	58	3.8	4.7	2.3	3.7

ND- No data available

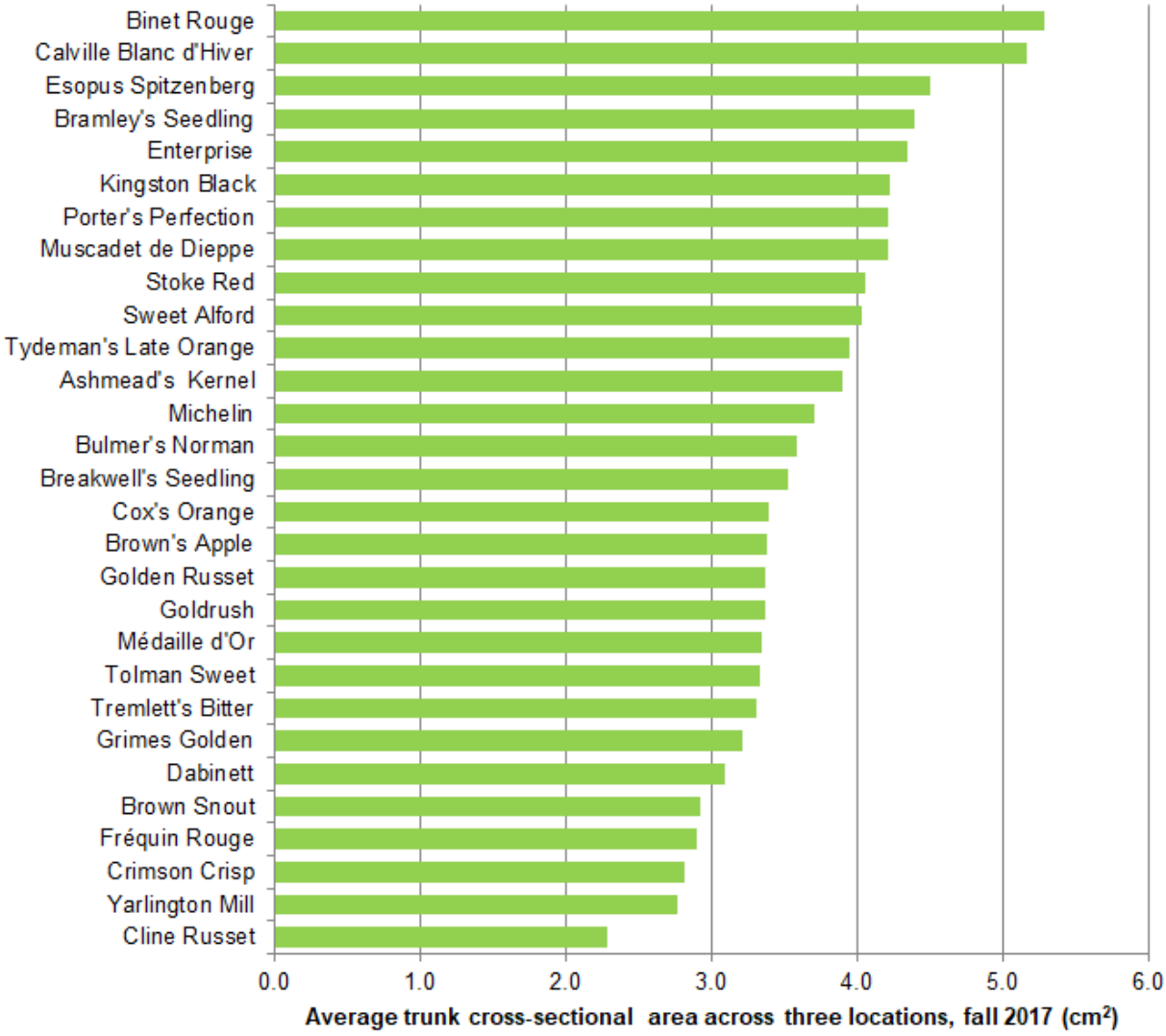


Figure 3 – Overall average trunk cross-sectional area of twenty-nine hard cider cultivars grown in Waupoos, Lambton Shores, and Clarksburg, ON. Measurements were taken in the fall of 2017. Not all cultivars performed similarly across locations, so consult the specific location for detailed growth performance.

3.5 University of Guelph, Simcoe

Trees have grown very well and responded to trickle irrigation and early tree training and light pruning in 2015, resulting in well-developed tree canopies and some flowers in the spring of 2016. ‘Bramley's Seedling’, ‘Calville Blanc d'Hiver’, ‘Binet Rouge’ produced the largest trees as of the fall 2017 based on trunk-cross sectional area (TCSA) (Table 7). ‘Cline Russet’, ‘Brown Snout’, ‘GoldRush’ and ‘Crimson Crisp’ have produced the smallest trees.

Bloom date and duration varied widely among cultivars (Figure 4). In addition, many cultivars had flowers which persisted well after full bloom, when approximately 80% of the flowers are open. Late bloom reduces the risk of potential frost damage, but if bloom persists over a several weeks, this may predispose trees to greater fireblight (*E. amylovora)* injury if the cultivar is susceptible. The bloom dates can be roughly classified into five categories (very early, early, mid-season, late, and very late), based on time and duration of flowering. The 2017 phenology data indicated Binet Rouge and Calville Blanc d’Hiver were very early with initial bloom starting around 5-May. Stoke Red, bloomed the latest, with a full bloom date of 30-May. All other cultivars bloomed between these two dates. Full boom dates ranged from 10-May to 30-May, displaying the wide variation in the germplasm and their origins. While beyond the scope of this study, synchronizing bloom dates for cross-pollination with other compatible cultivars or crab apples is extremely important to maximize fruit set and also for managing bee hives if used to assist in pollination.

Tree height and spread varied among cultivars (Table 8). In 2017, ‘Tydenman’s Late Orange’ was the tallest while ‘Fréquin Rouge’, and ‘Kingston Black’ where the shortest. ‘Bramley's Seedling’ and ‘Binet Rouge’ produced trees with the greatest spread while ‘Breakwell's Seedling’, ‘Kingston Black’, and ‘Brown Snout’ had the narrowest canopy, all less than 1 m. There was a poor relationship between TCA and tree height in the fall of 2017, indicating the TCA may not be the best indicator of tree size (Figure 4).

As of the fall of 2017, no statistical differences in tree mortality have been observed among the 29 cultivars, however numerically, losses have ranged from 0 to 8%. ‘Breakwell Seedling’, ‘Cline Russet’, ‘Dabinett’, ‘Michelin’, and ‘Tydeman Late Orange’ all experienced total losses of 8% (2 of 25 trees) which occurred at various stages over the three years (Table 9).

In 2017, there were significant cultivar difference in yield, cumulative yield, crop load, and average fruit weight (Table 10). ‘Michelin’, ‘Brown Snout’ and ‘Goldrush’ produced the greatest number of fruit per tree in 2016 white ‘Sweet Alford’, ‘Stoke Red’, ‘Cox Orange Pippin’, ‘Cline Russet’, ‘Crimson Crisp’, ‘Medaille d'Or’, ‘Tydeman Late Orange’, ‘Dabinett’, and ‘Frequin Rouge’ did not fruit at all in 2016 (data not shown). In 2017, ‘Bramley’s Seedling’, and ‘Goldrush’ had the highest yields exceeding 9.9 kg/tree. ‘Brown

Snout', 'Tydeman's Late Orange', 'Kingston Black',' Esopus Spitzenberg', and 'Fréquin Rouge' yielded the lowest, all below 3 kg/tree. GoldRush' and 'Bramley's Seedling' displayed the highest cumulative yields since planting, which represent the 2016 and 2017 harvests. Nineteen cultivars had cumulative yields less than 5 kg/tree for the same period.

Despite hand thinning in 2017, 'Goldrush', 'Médaille d'Or', 'Michelin', 'Stoke Red', 'Tremlett's Bitter', 'Porter's Perfection', Binet Rouge', 'Bulmer's Norman', and 'Grimes Golden' and crop loads that exceeded 7 fruits per cm^2 trunk cross-sectional area (Table 10). These trees were likely over-cropped, which affected average fruit weight and will very likely reduce the bloom and fruiting of these cultivars in 2018. In retrospect, these cultivars needed to be thinned more to ensure adequate fruit size and prevent biennial bearing. Fruit set of many cultivars in 2017 was such that the trees needed to be thinned in order to improve final fruit size at harvest, but also equally important, to mitigate biennial bearing.

Large differences in average fruit weight were observed among cultivars in 2017 and ranged from 51 – 341 g/fruit (Table 10). Ten cultivars had fruit larger than 150 g (Bramley's Seedling, Enterprise, Calville Blanc d'Hiver, Crimson Crisp, Dabinett, Cox's Orange, Sweet Alford, Ashmead's Kernel, Tydeman's Late Orange, and Goldrush) while eight cultivars had fruit less than 100 g (Muscadet de Dieppe, Médaille d'Or, Fréquin Rouge, Brown Snout, Stoke Red, Michelin, Porter's Perfection, and Binet Rouge). Small fruit require more labour and cost to harvest for cidermakers, however this may be offset if the cultivars have excellent juice characteristics. Small fruit size would be much less a concern if fruit are harvested mechanically, an practice that requires further investigation in Ontario.

Harvest dates of cider cultivars ranged from 23-August to 31-October 2017 (Table 11). Brown's Apple were the first to mature, while 'GoldRush' was the last. Harvest dates were based on evidence of any pre-harvest fruit drop and conversion of starch to sugar using the starch index (data now shown). Harvest dates can be grouped into five categories: very early, early (September 1^{st} – 15^{th}), mid-season (September 16^{th} – 31^{st}), late (October 1^{st} –15^{th}), and very late (after September 15^{th}).

Pre-harvest fruit drop was significant for many cultivars in 2017 (Table 12). Fifteen cultivars had pre-harvest fruit drop that exceeded 25% (by fruit number). However, considering that the harvest dates of many cultivars were not fully known for Ontario, drop would likely had been less if the fruit were harvested earlier. Nevertheless, many of these cultivars were selected for cider production in the UK and France, where the cider industry relies on mechanical harvesting of fruit from the ground, so natural drop is a desirable trait in this instance. Because of food safety concerns and to prevent contamination of presses, cidermakers in Ontario are using hand-picked apples. Further research of the stop-drop compounds NAA or ReTain to mitigate pre-harvest of prone cultivars is

warranted.

Cider juice characteristics after pressing are indicated in Table 13. Significant cultivar differences existed for all the measured parameters. Ashmead's Kernel, Brown Snout, Frequin Rouge, Golden Russet, and Tydemans's Late Orange produced juice with the highest (> 16% Brix) soluble solids concentration. Juice pH ranged from a low of 3.0 (Bramley's Seedling) to a high of 4.8 (Sweet Alford) while titratable acidity ranged from 31 to 176 (mg malic acid/100 ml juice). Bramley's Seedling, Breakwell's Seedling, Médaille d'Or, and Tydeman's Late Orange had the highest titratable acidity ("Sharps" based on the British Classification) while many cultivars how low titratable acidity. There was a curvilinear relationship between juice pH and titratable acidity, where juice with higher pH values had lower titratable acidity (data not shown).

There was a significant difference in yeast assimilable nitrogen (YAN) between cultivars, as measured by formal titration (Table 13). Eighteen cultivars had levels below 140 mg/L YAN, with the lowest levels found in 'Médaille d'Or', 'Breakwell's Seedling', 'Goldrush', 'Bramley's Seedling', and 'Stoke Red'. In contrast, 'Golden Russet', 'Brown Snout', and 'Tydeman's Late Orange' had the highest level of YAN, all above 160 mg/L.

The juice extraction efficiency, that is, the amount of juice extracted from each cultivar on a volume:weight basis, differed significantly amount cultivars (Table 13). 'GoldRush' had the greatest amount of juice at 0.71 L/Kg of fruit, while several cultivars (Muscadet de Dieppe, Yarlington Mill, Dabinett, Fréquin Rouge, Binet Rouge, Cox's Orange, Kingston Black, Ashmead's Kernel) yielded less than 0.56 L/Kg fruit. Lower extraction efficiencies can be related to over mature fruit where it is difficult to extract juice from the pulp (eg, Dabinett) or simply because the fruit have a lower percentage of juice. Juice extraction efficiency is particular relevant to those pressing fruit, not only to obtain the higher yields of juice, but also for ease of juicing and clogging the filters of the press.

In this study, total phenols rather than total tannins, a component of plant phenolic compounds, were measured, primarily because this method is more rapid and cost effective. Most of the earlier published work on cider apples determined tannins using the Lowenthral method, and the 'bitter' designation for cider apples was based on this measurement. A relationship between total phenols and Lowenthral tannin levels has not been published in the literature, making it difficult to directly relate the two measurements. Notwithstanding, juice with higher total phenols should produce the desired characteristic 'bitter' cider that may craft cidermakers are seeking. Levels of total phenols differed significantly among cultivars and ranged nearly ten-fold from 184 mg/L gallic acid equivalents (GAE) to 1042 mg/L GAE (Table 13). Cultivars with the highest total phenols included 'Brown's Apple', 'Tremlett's Bitter', 'Bulmer's Norman', 'Binet Rouge', 'Porter's Perfection', and 'Stoke Red'. Cultivars with moderate total phenols (500-750 mg/L GAE) included 'Fréquin Rouge', 'Médaille d'Or', 'Michelin', 'Brown Snout', 'Muscadet de Dieppe', 'Yarlington Mill', and 'Brown's Apple'. All the other cultivars had relatively low

total phenols (< 500 mg/L GAE) in comparison with the other cultivars.

Over the 2016 growing season, trees were assessed for the following pests and diseases: fireblight, apple scab, spring feeding caterpillars, leaf curling midge, powdery mildew, black rot, bitter rot, mullen bug, plum curculio, internal lepidoptera, codling moth, oblique banded leaf roller, Japanese beetle, leaf hopper, tarnished plant bug, spotted tentiform leaf miner. Brown's Apple appears prone to winter injury while the bark on 'Calville Blanc d'Hiver' trees was peeling in the fall of 2015 for unknown reasons.

Horticultural and juice attributes of top performing cultivars based on fruit size, cumulative yield, tree height, preharvest drop, BRIX, titratable acidity, juice extraction efficiency and total polyphenols after three growing seasons in Simcoe are summarized in Table 14. Any one of the cultivars does not rank highest in all the categories, therefore producers and cidermakers will need to select cultivars based on the most important characteristics they seek. Based on horticultural attributes, 'GoldRush', 'Crimson Crisp', 'Bramley's Seedling', 'Bulmer's Norman', 'Yarlington Mill', and 'Enterprise' are good choices for cider apples. Based on juice attributes, the choice of cultivar is more complex, as the selection will depend on the desired level of sugar, acidity, and tannins/phenol levels, as well as juice extraction efficiency/ease of pressing.

Table 2. Survival, trunk cross-sectional growth, and growth rate of 29 cider apple cultivars planted in 2015 at a commercial orchard in Thedford, Ontario.

	Tree survival (%)				Trunk cross-sectional area (cm^2)				Relative growth in 2015 (cm^2)	Relative growth in 2016 (cm^2)	Relative growth in 2017 (cm^2)
Cultivar[y]	Spring 2015	Spring 2016	Fall 2016	Fall 2017	Spring 2015	Spring 2016	Fall 2016	Fall 2017			
Ashmead's Kernel	100	100	100	90	1.00	1.70	2.05	4.19	0.70	0.35	2.14
Binet Rouge	95	80	80	80	1.67	2.33	2.90	6.02	0.66	0.57	3.11
Bramley's Seedling	100	100	100	80	1.38	1.80	2.16	4.84	0.41	0.36	2.73
Breakwell's Seedling	100	100	100	90	1.28	1.75	2.13	4.56	0.47	0.38	2.39
Brown Snout	100	100	79	70	0.89	1.18	1.43	2.94	0.29	0.23	1.48
Brown's Apple	100	79	79	53	1.31	1.71	1.89	3.55	0.37	0.18	1.65
Bulmer's Norman	100	100	100	100	1.40	1.64	1.67	2.82	0.24	0.03	1.15
Calville Blanc d'Hiver	100	95	95	95	1.64	2.02	2.14	4.10	0.38	0.12	1.96
Cline Russet	100	100	100	100	1.00	1.24	1.30	2.13	0.24	0.05	0.84
Cox's Orange	100	100	100	90	1.03	1.48	1.77	3.12	0.45	0.29	1.35
Crimson Crisp	100	100	100	85	0.67	0.98	1.22	2.39	0.31	0.24	1.18
Dabinett	95	84	79	68	1.03	1.37	1.87	3.21	0.31	0.48	1.43
Enterprise	95	55	60	35	1.20	1.92	2.20	3.95	0.64	0.33	1.67
Esopus Spitzenberg	100	100	100	95	1.11	1.91	2.47	4.59	0.80	0.56	2.12
Fréquin Rouge	100	100	100	65	0.92	1.46	1.81	3.45	0.54	0.35	1.51
Golden Russet	100	100	100	60	0.81	1.24	1.58	3.51	0.44	0.34	1.93
Goldrush	100	100	100	100	1.24	1.97	2.40	4.04	0.74	0.43	1.64
Grimes Golden	100	100	100	100	1.11	1.50	1.54	2.98	0.39	0.04	1.44
Kingston Black	100	90	85	80	1.39	1.83	2.35	3.69	0.43	0.53	1.35
Médaille d'Or	100	100	100	63	1.30	1.70	1.97	3.22	0.40	0.28	1.29
Michelin	100	80	50	50	1.35	1.91	2.50	3.89	0.57	0.44	1.30
Muscadet de Dieppe	100	100	100	95	1.31	1.95	2.28	4.39	0.64	0.33	2.10
Porter's Perfection	100	90	85	80	1.45	1.87	2.15	3.95	0.41	0.27	1.80
Stoke Red	100	95	95	80	1.20	1.88	2.60	4.70	0.66	0.72	2.07
Sweet Alford	100	100	90	90	1.39	1.80	2.25	3.69	0.41	0.41	1.44
Tolman Sweet	100	70	45	40	1.13	1.76	2.09	4.16	0.63	0.27	1.91
Tremlett's Bitter	100	100	100	85	1.13	1.64	1.89	3.58	0.52	0.25	1.75
Tydeman's Late Orange	100	95	85	85	0.95	1.65	2.57	5.34	0.70	0.94	2.77
Yarlington Mill	100	100	100	95	1.20	1.53	1.58	2.26	0.33	0.05	0.69

[y] Cultivars ranked in alphabetical order.

Table 3. Survival, trunk cross-sectional growth, and growth rate of 29 cider apple cultivars planted in 2015 at a commercial orchard in Clarksburg, Ontario.

	Tree survival (%)				Trunk cross-sectional area (cm^2)				Relative growth in 2015	Relative growth in 2016	Relative growth in 2017
Cultivar[y]	Spring 2015	Spring 2016	Fall 2016	Fall 2017	Spring 2015	Spring 2016	Fall 2016	Fall 2017	(cm^2)	(cm^2)	(cm^2)
Ashmead's Kernel	100	100	100	100	0.93	1.69	2.50	4.37	0.76	0.80	1.87
Binet Rouge	100	100	100	100	1.09	2.37	3.62	7.31	1.29	1.25	3.69
Bramley's Seedling	100	100	100	100	1.08	1.76	2.42	4.61	0.68	0.66	2.19
Breakwell's Seedling	100	100	100	100	1.17	2.00	2.51	4.38	0.83	0.50	1.87
Brown Snout	100	100	100	100	0.65	1.22	1.54	2.89	0.57	0.32	1.36
Brown's Apple	100	100	100	100	0.73	1.93	2.70	4.23	1.20	0.77	1.53
Bulmer's Norman	100	100	100	100	0.94	2.10	3.00	5.52	1.15	0.90	2.52
Calville Blanc d'Hiver	100	100	100	100	1.18	2.44	3.46	6.23	1.26	1.03	2.77
Cline Russet	100	100	100	100	0.67	1.28	1.70	3.16	0.61	0.43	1.46
Cox's Orange	100	100	100	100	0.71	1.94	2.57	4.67	1.23	0.63	2.10
Crimson Crisp	100	100	100	100	0.57	1.55	2.37	4.48	0.98	0.82	2.12
Dabinett	100	100	100	100	0.73	1.49	2.03	3.80	0.77	0.54	1.76
Enterprise	100	100	100	100	1.00	1.88	3.04	5.63	0.88	1.16	2.59
Esopus Spitzenberg	100	100	100	100	0.65	1.78	2.45	4.40	1.13	0.67	1.95
Fréquin Rouge	100	100	100	100	0.78	1.70	2.45	4.08	0.93	0.75	1.63
Golden Russet	89	89	89	89	0.60	1.16	1.86	3.41	0.56	0.69	1.55
Goldrush	100	100	100	100	0.95	1.72	2.17	4.28	0.77	0.45	2.12
Grimes Golden	100	100	100	100	0.94	1.84	2.51	4.38	0.89	0.68	1.86
Kingston Black	100	100	100	100	1.20	2.48	3.55	6.33	1.28	1.08	2.78
Médaille d'Or	95	95	95	95	0.89	2.32	3.43	4.84	1.43	1.12	1.41
Michelin	100	100	100	100	1.12	2.38	3.10	5.25	1.26	0.72	2.15
Muscadet de Dieppe	100	100	100	100	1.14	1.92	2.48	4.04	0.78	0.56	1.55
Porter's Perfection	100	100	100	100	1.18	2.28	3.07	5.90	1.10	0.79	2.83
Stoke Red	100	100	100	100	1.00	2.08	3.35	5.09	1.08	1.26	1.74
Sweet Alford	100	100	100	100	1.15	1.87	2.59	5.06	0.72	0.71	2.47
Tolman Sweet	100	100	100	100	0.75	1.87	2.43	4.19	1.12	0.56	1.76
Tremlett's Bitter	100	100	100	100	0.69	1.78	2.58	4.75	1.08	0.80	2.17
Tydeman's Late Orange	100	100	100	100	0.60	1.38	2.20	4.94	0.78	0.82	2.73
Yarlington Mill	100	100	100	95	0.84	1.85	2.58	3.98	1.01	0.73	1.38

[y] Cultivars ranked in alphabetical order.

Table 4. Survival, trunk cross-sectional growth, and growth rate of 29 cider apple cultivars planted in 2015 at a commercial orchard in Waupoos, Ontario.

	Tree survival (%)				Trunk cross-sectional area (cm^2)				Relative growth in 2015	Relative growth in 2016	Relative growth in 2017
Cultivar[y]	Spring 2015	Spring 2016	Fall 2016	Fall 2017	Spring 2015	Spring 2016	Fall 2016	Fall 2017	(cm^2)	(cm^2)	(cm^2)
Ashmead's Kernel	100	95	90	90	0.94	1.43	1.84	3.11	0.47	0.38	1.27
Binet Rouge	100	85	89	80	1.40	1.73	1.92	2.54	0.27	0.19	0.57
Bramley's Seedling	100	100	100	100	1.43	1.98	2.12	3.71	0.56	0.14	1.59
Breakwell's Seedling	100	100	100	86	1.03	1.29	1.39	1.63	0.26	0.10	0.24
Brown Snout	100	29	0	0	0.66	1.03	ND	ND	0.26	ND	ND
Brown's Apple	71	29	21	21	1.01	1.26	1.66	2.35	0.13	0.25	0.68
Bulmer's Norman	100	95	95	95	1.13	1.42	1.55	2.41	0.28	0.13	0.86
Calville Blanc d'Hiver	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cline Russet	45	11	11	9	0.74	0.87	0.92	1.54	0.19	0.05	0.62
Cox's Orange	94	56	50	44	0.90	1.34	1.58	2.36	0.41	0.24	0.75
Crimson Crisp	84	58	53	53	0.63	0.94	1.07	1.58	0.21	0.10	0.50
Dabinett	93	42	31	20	0.93	1.18	1.48	2.25	0.17	0.32	0.70
Enterprise	89	79	79	79	0.98	1.38	1.66	3.46	0.37	0.28	1.80
Esopus Spitzenberg	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Fréquin Rouge	75	50	50	33	0.59	0.68	0.77	1.17	0.11	0.09	0.35
Golden Russet	92	92	92	92	0.88	1.34	2.24	3.19	0.46	0.90	0.96
Goldrush	84	79	74	53	0.82	1.09	1.16	1.77	0.26	0.07	0.57
Grimes Golden	65	65	65	65	0.93	1.19	1.31	2.28	0.26	0.12	0.97
Kingston Black	65	41	35	18	1.05	1.41	1.56	2.64	0.23	0.08	0.92
Médaille d'Or	75	70	70	70	0.81	1.07	1.37	1.95	0.26	0.30	0.58
Michelin	100	67	67	41	0.97	1.30	1.59	1.98	0.28	0.29	0.36
Muscadet de Dieppe	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Porter's Perfection	85	85	80	80	1.38	1.72	2.09	2.79	0.35	0.37	0.71
Stoke Red	100	67	67	67	1.05	1.23	1.72	2.37	0.15	0.41	0.65
Sweet Alford	82	82	71	71	1.00	1.31	1.53	3.34	0.31	0.23	1.81
Tolman Sweet	85	75	70	70	0.92	1.10	1.28	1.65	0.17	0.16	0.36
Tremlett's Bitter	95	59	59	21	0.79	0.91	1.06	1.57	0.14	0.15	0.41
Tydeman's Late Orange	80	65	60	55	0.66	0.91	1.00	1.58	0.20	0.08	0.58
Yarlington Mill	100	100	100	100	1.10	1.46	1.54	2.06	0.36	0.08	0.52

[y] Cultivars ranked in alphabetical order.
ND - no data available

Table 5. Survival, trunk cross-sectional growth, and growth rate of 29 cider apple cultivars planted in 2016 at a commercial orchard in Caledon, Ontario.

Cultivar[y]	Tree survival (%)			Trunk cross-sectional area (cm^2)			Relative growth in 2016 (cm^2)	Relative growth in 2017 (cm^2)
	Spring 2016	Fall 2016	Fall 2017	Spring 2016	Fall 2016	Fall 2017		
Baldwin	95	90	90	0.86	1.03	1.60	0.15	0.55
Bramley's Seedling	100	100	100	1.01	1.07	1.52	0.06	0.45
Brown Snout	100	95	95	0.99	1.11	1.39	0.12	0.26
Chisel Jersey	90	85	85	0.62	0.74	0.98	0.14	0.24
Cox's Orange	100	100	90	0.56	0.63	0.98	0.07	0.36
Dabinett	85	69	69	0.55	0.58	0.91	0.04	0.30
Esopus Spitzenberg	95	95	90	0.75	0.90	1.26	0.15	0.36
Foxwhelp	100	100	100	0.76	0.85	1.33	0.09	0.48
Fréquin Rouge	100	100	85	0.70	0.77	1.18	0.07	0.41
Golden Russet	95	95	95	0.62	0.77	1.09	0.15	0.33
Kingston Black	100	100	100	0.75	0.90	1.48	0.15	0.58
Michelin	95	80	70	0.73	0.83	1.28	0.11	0.38
Roxbury Russet	90	85	80	0.74	0.80	0.93	0.03	0.18
Tolman Sweet	100	100	100	0.54	0.68	1.08	0.14	0.39
Tremlett's Bitter	100	100	95	0.96	1.04	1.56	0.08	0.51

[y] Cultivars ranked in alphabetical order.

Table 6. Air temperatures, precipitation and growing degree days at weather stations in close proximity to the provinical apple hard cider trials.

	Cherry Valley, Prince Edward County[2]	Clarksburg[3]	Sleswick/ Caledon[4]	Lambton Shores[5]	Univ. of Guelph, Simcoe[6]
			2015		
Average temperature (°C)	9.2	7.2	7.2	8.3	8.5
Minimum temperature (°C)	-30.0	-31.4	-30.2	-27.3	-29.2
Maximum temperature (°C)	30.9	32.3	33.3	33.8	31.1
Total precipitation (mm)	1455	610	497	731	764
Precipitation (May-Oct 31) (mm)	519	394	280	546	520
Degree days (May-Oct) (°C)	3906	2093	2013	2254	2263
			2016		
Average temperature (°C)	9.6	9.5	8.1	9.8	10.0
Minimum temperature (°C)	-30.9	-27.3	-32.8	-20.3	-24.7
Maximum temperature (°C)	32.8	33.8	38.3	35.0	38.2
Total precipitation (mm)	648	633	897	876	721
Precipitation (May-Oct 31) (mm)	343	349	623	812	323
Degree days (May-Oct) (°C)	2340	2158	2195	2426	2612
			2017 [1]		
Average temperature (°C)	15.1	9.7	9.4	11.6	11.3
Minimum temperature (°C)	-19.9	-18.8	-19.5	-11.8	-14.7
Maximum temperature (°C)	30.8	32.9	38.7	34.3	31.9
Total precipitation (mm)	851	870	1229	726	850
Precipitation (May-Oct 31) (mm)	598	519	776	489	461
Degree days (May-Oct) (°C)	2104	1927	1753	2306	2237

1 - includes Jan-Oct, 2017 only

2 - Source: Weather Underground Lakeview Monitoring Station, Elev 101 m 43.957, -77.146

3 - Source private weather station, Clarksburg, ON Elev. 235 44.469, -80.501

4 - Source Weather Underground Elev 310 m 43.908, -79.991

5 - Source Weather Underground Elev 207 m 43.16 °N, 81.85 °W

5 - University of Guelph, Simcoe ON Elev. 210 m, 42.844, -80.306

Table 7. Growth, as indicated by trunk cross-sectional area, of 29 cider apple cultivars planted in 2015 at the University of Guelph Simcoe Research Station, Ontario. Trees trained to the vertical axe orchard system.

Cultivar[w]	Spring 2015 (cm^2)		Fall 2015 (cm^2)		Fall 2016 (cm^2)		Fall 2017 (cm^2)	
Ashmead's Kernel	0.8	e-h	1.8	d-j	5.1	cd	7.9	c-f
Binet Rouge	1.1	a-d	2.4	bc	6.4	ab	9.9	bc
Bramley's Seedling	1.3	a	2.9	a	7.4	a	11.2	ab
Breakwell's Seedling	1.1	abc	2.0	c-i	5.5	bc	9.2	b-e
Brown Snout	0.6	fgh	1.6	g-k	3.1	gh	4.4	j
Brown's Apple	1.0	b-e	1.7	e-j	4.3	c-g	6.6	f-i
Bulmer's Norman	1.2	ab	2.3	b-e	5.1	cd	6.8	fgh
Calville Blanc d'Hiver	1.3	a	2.7	ab	7.2	a	12.3	a
Cline Russet	0.8	e-h	1.4	jk	3.2	fgh	4.3	j
Cox's Orange	0.8	e-h	1.7	f-j	4.3	c-g	6.5	f-i
Crimson Crisp	0.5	h	1.1	k	2.8	h	4.7	ij
Dabinett	0.8	d-h	1.6	g-k	4.4	c-g	6.3	f-j
Enterprise	0.8	d-h	2.0	c-i	4.8	cde	7.4	e-h
Esopus Spitzenberg	0.7	e-h	1.5	ijk	4.0	d-h	6.4	f-i
Fréquin Rouge	0.7	e-h	1.7	f-j	4.2	d-g	6.4	f-i
Golden Russet	0.6	gh	1.5	h-k	4.3	c-g	6.4	f-i
Goldrush	0.8	d-g	1.7	f-j	3.7	e-h	4.7	ij
Grimes Golden	0.9	b-g	1.9	c-j	4.3	c-g	6.1	f-j
Kingston Black	1.0	b-e	2.1	c-g	4.2	d-g	5.5	hij
Médaille d'Or	0.9	b-g	1.6	f-k	4.1	d-g	5.8	g-j
Michelin	1.2	ab	2.1	c-f	4.9	cde	7.4	e-h
Muscadet de Dieppe	1.1	ab	2.4	bc	5.2	bcd	7.8	d-g
Porter's Perfection	1.3	a	2.3	bcd	6.5	ab	9.7	bcd
Stoke Red	0.9	b-g	1.6	h-k	4.0	d-h	6.1	f-j
Sweet Alford	1.1	ab	2.0	c-i	5.0	cd	7.8	d-g
Tolman Sweet	0.9	b-f	1.9	c-j	4.4	c-f	6.3	f-j
Tremlett's Bitter	0.8	c-g	2.1	c-h	4.7	cde	6.2	f-j
Tydeman's Late Orange	0.8	c-g	1.8	e-j	4.7	cde	9.4	b-e
Yarlington Mill	0.8	c-g	2.0	c-i	4.7	cde	6.9	fgh
Significance[y]	***		***		***		***	
P Value[z]	<0.0001		<0.0001		<0.0001		<0.0001	

[w] Cultivars ranked in alphabetical order.

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

[z] ns, *, **, ***, indicates not significant, and significant differences at P= 0.10, P=0.05, and P=0.01 respectively.

Table 8. Growth, as indicated by tree height and canopy width, of 29 cider apple cultivars planted in 2015 at the University of Guelph Simcoe Research Station, Ontario. Trees trained to the vertical axe orchard system.

Cultivar[x]	Tree height 2015 (m)		Tree height 2016 (m)		Tree Height 2017 (m)		Canopy width[w] 2015 (m)		Canopy width 2016 (m)		Canopy width 2017 (m)	
Ashmead's Kernel	1.60	d-j	2.41	d-j	3.04	abc	0.20	cd	1.20	a-g	1.35	d-h
Binet Rouge	1.85	a-d	2.91	ab	3.11	ab	0.43	abc	1.40	abc	1.70	a
Bramley's Seedling	1.76	a-g	2.36	e-k	2.93	a-f	0.48	abc	1.34	a-d	1.68	a
Breakwell's Seedling	1.28	kl	1.86	nop	2.42	fg	0.23	cd	0.87	hij	0.97	ijk
Brown Snout	1.51	g-k	1.99	m-p	2.50	ghi	0.11	d	0.67	j	0.84	k
Brown's Apple	1.36	jkl	2.14	i-n	2.50	ghi	0.18	cd	0.98	f-i	1.33	d-h
Bulmer's Norman	1.54	g-j	2.12	j-n	2.71	c-h	0.30	bcd	1.08	d-i	1.33	d-h
Calville Blanc d'Hiver	1.98	a	2.93	a	3.00	a-d	0.45	abc	1.39	abc	1.57	a-d
Cline Russet	1.72	b-g	2.32	f-l	2.76	b-h	0.32	a-d	1.00	e-i	1.13	g-k
Cox's Orange	1.60	e-j	2.24	h-m	2.80	a-g	0.39	abc	1.16	a-h	1.33	d-h
Crimson Crisp	1.41	i-l	2.18	h-m	2.79	a-g	0.27	cd	1.10	c-i	1.19	f-j
Dabinett	1.55	f-j	2.10	k-n	2.70	c-h	0.32	a-d	1.23	a-g	1.33	d-h
Enterprise	1.58	f-j	2.41	d-i	2.79	a-g	0.39	abc	1.43	ab	1.67	ab
Esopus Spitzenberg	1.75	a-g	2.70	a-d	2.91	a-f	0.38	abc	1.44	a	1.52	a-e
Fréquin Rouge	1.17	l	1.72	p	2.20	i	0.21	cd	0.95	g-j	1.17	g-j
Golden Russet	1.73	a-g	2.59	c-f	3.06	abc	0.39	abc	1.33	a-d	1.59	a-d
Goldrush	1.96	ab	2.83	abc	2.86	a-f	0.50	ab	1.14	b-h	1.08	h-k
Grimes Golden	1.86	abc	2.64	b-e	2.86	a-f	0.35	abc	1.26	a-f	1.36	c-h
Kingston Black	1.35	jkl	1.77	op	2.23	i	0.21	cd	0.82	ij	0.94	jk
Médaille d'Or	1.53	g-k	2.27	g-m	2.73	c-h	0.19	cd	1.15	a-h	1.31	d-h
Michelin	1.84	a-e	2.56	c-g	2.99	a-e	0.28	cd	1.24	a-g	1.37	b-h
Muscadet de Dieppe	1.69	c-h	2.24	h-m	2.65	d-h	0.26	cd	1.06	d-i	1.27	e-i
Porter's Perfection	1.66	c-i	2.44	d-h	2.98	a-e	0.31	a-d	1.29	a-e	1.55	a-e
Stoke Red	1.80	a-f	2.62	b-e	3.04	abc	0.29	bcd	1.19	a-g	1.48	a-f
Sweet Alford	1.56	f-j	2.10	k-n	2.64	e-h	0.38	abc	1.30	a-d	1.43	a-g
Tolman Sweet	1.87	abc	2.54	d-g	2.84	a-g	0.36	abc	1.32	a-d	1.50	a-e
Tremlett's Bitter	1.45	h-k	2.04	l-o	2.61	fgh	0.25	cd	1.09	d-i	1.33	d-h
Tydeman's Late Orange	1.85	a-e	2.55	c-g	3.14	a	0.52	a	1.43	ab	1.65	abc
Yarlington Mill	1.97	ab	2.60	c-f	2.96	a-f	0.44	abc	1.32	a-d	1.55	a-e
Significance[y]	***		***		***		***		***		***	
P Value[z]	<0.0001		<0.0001		<0.0001		<0.0001		<0.0001		<0.0001	

[x] Cultivars ranked in alphabetical order.

[w] Canopy width was determined by adding the between row and in-row canopy width measurements and dividing the value by 2.

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

[z] ns, *, **, ***, indicates not significant, and significant differences at P= 0.10, P=0.05, and P=0.01 respectively.

Table 9. Survival of 29 cider apple cultivars planted in 2015 at the University of Guelph Simcoe Research Station, Ontario. Trees trained to the vertical axe orchard system.

Cultivar[x]	Spring 2015 (%)	Fall 2015 (%)	Fall 2016 (%)	Fall 2017 (%)
Ashmead's Kernel	100	100	100	100
Binet Rouge	100	100	100	100
Bramley's Seedling	100	100	100	100
Breakwell's Seedling	100	100	92	92
Brown Snout	100	100	100	100
Brown's Apple	100	100	100	100
Bulmer's Norman	100	100	100	100
Calville Blanc d'Hiver	100	100	100	100
Cline Russet	100	100	92	92
Cox's Orange	100	100	100	100
Crimson Crisp	100	100	100	100
Dabinett	92	92	92	92
Enterprise	100	100	100	100
Esopus Spitzenberg	100	100	100	100
Fréquin Rouge	100	100	100	100
Golden Russet	100	100	100	100
Goldrush	100	100	100	100
Grimes Golden	100	100	100	100
Kingston Black	100	100	100	100
Médaille d'Or	100	100	100	100
Michelin	100	100	100	92
Muscadet de Dieppe	100	100	100	100
Porter's Perfection	100	100	100	100
Stoke Red	100	100	100	100
Sweet Alford	100	100	100	100
Tolman Sweet	100	100	100	100
Tremlett's Bitter	100	100	100	100
Tydeman's Late Orange	100	92	92	92
Yarlington Mill	100	100	100	100
Significance[y]	ns	ns	ns	ns
P Value[z]	0.3931	0.5744	0.5757	0.5339

[x] Cultivars ranked in alphabetical order.

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

[z] ns, *, **, ***, indicates not significant, and significant differences at P= 0.10, P=0.05, and P=0.01 respectively.

Table 10. Fruiting characteristics of 29 cider apple cultivars planted in 2015 at the University of Guelph Simcoe Research Station, Ontario. Trees trained to the vertical axe orchard system.

Cultivar[w]	Total fruit yield 2016 (kg/tree)		Total fruit yield 2017 (kg/tree)		Cumulative yield 2016-2017 (kg/tree)		Crop load at harvest 2017 (no/cm^2 TCSA[x])		Average fruit weight 2017 (g)	
Ashmead's Kernel	0.0	c	3.8	c-i	3.8	c-j	3.14	i-l	160	cde
Binet Rouge	0.0	c	3.9	c-i	4.0	b-j	7.88	b-f	51	n
Bramley's Seedling	0.3	abc	10.7	a	11.0	a	2.86	jkl	341	a
Breakwell's Seedling	0.0	c	4.6	b-i	4.6	b-j	3.70	i-l	143	d-g
Brown Snout	0.4	ab	2.1	i	2.4	ij	5.48	c-k	84	klm
Brown's Apple	0.0	c	3.6	d-i	3.6	d-j	5.32	c-l	111	hij
Bulmer's Norman	0.0	c	6.5	b	6.5	b	7.64	c-g	127	f-i
Calville Blanc d'Hiver	0.1	bc	5.8	b-e	5.8	b-e	2.48	kl	201	b
Cline Russet	0.0	c	3.5	d-i	3.5	d-j	6.01	c-j	143	d-g
Cox's Orange	0.0	c	4.5	b-i	4.5	b-j	4.48	f-l	163	cde
Crimson Crisp	0.0	c	3.2	f-i	3.2	f-j	3.85	h-l	173	c
Dabinett	0.0	c	4.6	b-i	4.6	b-j	4.78	e-l	165	cd
Enterprise	0.0	c	5.1	b-h	5.1	b-h	3.25	i-l	227	b
Esopus Spitzenberg	0.0	c	2.8	ghi	2.8	hij	3.10	i-l	138	efg
Fréquin Rouge	0.0	c	2.8	ghi	2.8	g-j	5.18	d-l	90	j-m
Golden Russet	0.1	bc	5.3	b-g	5.5	b-g	5.88	c-k	144	d-g
Goldrush	0.5	a	9.9	a	10.5	a	14.40	a	147	d-g
Grimes Golden	0.0	c	6.2	bc	6.2	bc	7.21	c-h	145	d-g
Kingston Black	0.0	c	2.7	hi	2.8	hij	5.09	d-l	101	ijk
Médaille d'Or	0.0	c	6.1	bcd	6.1	bcd	11.10	ab	95	jkl
Michelin	0.4	ab	4.6	b-i	5.0	b-i	8.71	bc	69	lmn
Muscadet de Dieppe	0.0	c	3.7	c-i	3.7	c-j	5.39	c-l	96	jkl
Porter's Perfection	0.0	c	4.9	b-h	4.9	b-i	8.01	b-e	65	mn
Stoke Red	0.0	c	3.9	b-i	3.9	b-j	8.47	bcd	79	klm
Sweet Alford	0.0	c	4.9	b-h	4.9	b-i	4.38	g-l	162	cde
Tolman Sweet	0.2	bc	3.3	e-i	3.4	e-j	3.67	i-l	142	d-g
Tremlett's Bitter	0.0	c	6.2	bc	6.2	bc	8.42	bcd	123	ghi
Tydeman's Late Orange	0.0	c	2.1	i	2.1	j	1.97	l	151	c-f
Yarlington Mill	0.2	bc	5.6	b-f	5.8	b-f	6.50	c-i	132	fgh
Significance[y]	***		***		***		***		***	
P Value[z]	<0.0001		<0.0001		<0.0001		<0.0001		<0.0001	

[w] Cultivars ranked in alphabetical order.

[x] Trunk cross-sectional area.

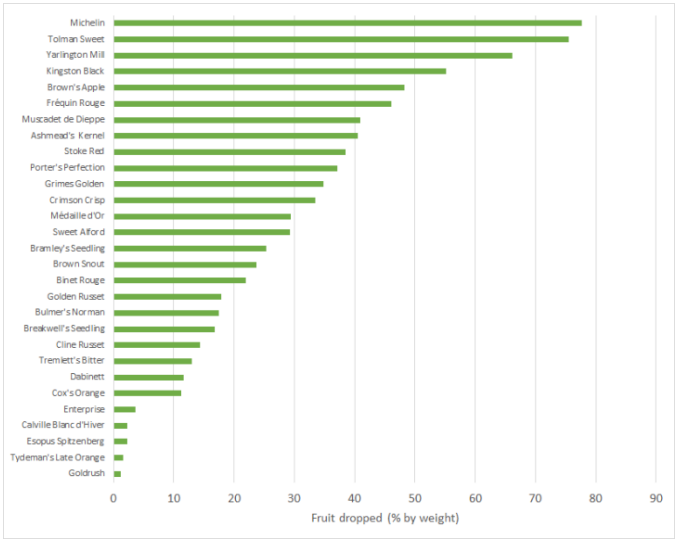
[y] Mean values with the same letter within a given column are not significantly different according to the Tukey-Kramer test at P=0.05.

[z] ns, *, **, ***, indicates not significant, and significant differences at P= 0.10, P=0.05, and P=0.01 respectively.

	Table 11. Maturity dates of select hard cider apple cultivars in 2017 and the University of Guelph, Simcoe		
	Cultivar	Category	Maturity Date
V. Early	Brown's Apple	Sharp	23-Aug
Early	Bulmer's Norman	Bittersweet	01-Sep
	Fréquin Rouge	Bittersweet	10-Sep
	Tremlett's Bitter	Bittersweet	10-Sep
	Binet Rouge	Bittersweet	15-Sep
	Kingston Black	Bittersharp	15-Sep
	Muscadet de Dieppe	Bittersweet	15-Sep
	Stoke Red	Bittersharp	15-Sep
Mid-Season	Michelin	Bittersweet	20-Sep
	Yarlington Mill	Bittersweet	20-Sep
	Cox's Orange	Sweet	21-Sep
	Bramley's Seedling	Sharp	25-Sep
	Crimson Crisp	Sweet	25-Sep
	Médaille d'Or	Bittersweet	25-Sep
	Porters Perfection	Bittersharp	25-Sep
	Enterprise	Sharp	28-Sep
	Esopus Spitzenburg	Sharp	28-Sep
	Grimes Golden	Sweet	28-Sep
	Breakwell's Seedling	Bittersharp	30-Sep
Late-season	Ashmead's Kernel	Sharp	01-Oct
	Calville Blanc d'Hiver	Sweet	01-Oct
	Dabinett	Bittersweet	01-Oct
	Golden Russet	Sweet	01-Oct
	Tolman Sweet	Sweet	01-Oct
	Brown Snout	Bittersweet	03-Oct
	Tydeman's Late Orange	?	05-Oct
Very Late	Sweet Alford	Sweet	25-Oct
	Goldrush	Bittersweet	31-Oct
	Dates do not necessarly represent the ideal harvest date for cidermakers. Pre-harvest fruit drop, starch, and BRIX levels are required to fine-tune these dates over several seasons.		

Table125. Fruiting characteristics of 29 cider apple cultivars planted in 2015 at the University of Guelph Simcoe Research Station, Ontario. Trees trained to the vertical axe orchard system.

Cultivar[x]	Percent dropped fruit by weight 2017 (%)	
Ashmead's Kernel	40.6	c-f
Binet Rouge	22.0	g-j
Bramley's Seedling	25.3	f-j
Breakwell's Seedling	16.8	h-k
Brown Snout	23.8	f-j
Brown's Apple	48.3	bcd
Bulmer's Norman	17.5	h-k
Calville Blanc d'Hiver	2.3	k
Cline Russet	14.4	ijk
Cox's Orange	11.3	jk
Crimson Crisp	33.4	d-h
Dabinett	11.7	ijk
Enterprise	3.7	k
Esopus Spitzenberg	2.3	k
Fréquin Rouge	46.1	cde
Golden Russet	17.9	h-k
Goldrush	1.2	k
Grimes Golden	34.9	d-h
Kingston Black	55.2	bc
Médaille d'Or	29.4	e-i
Michelin	77.6	a
Muscadet de Dieppe	40.9	c-f
Porter's Perfection	37.1	d-g
Stoke Red	38.5	c-g
Sweet Alford	29.2	e-j
Tolman Sweet	75.5	a
Tremlett's Bitter	13.0	ijk
Tydeman's Late Orange	1.7	k
Yarlington Mill	66.2	ab
Significance[y]	***	
P Value[z]	<0.0001	



[x] Cultivars ranked in alphabetical order.

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

[z] ns, *, **, ***, indicates not significant, and significant differences at P= 0.10, P=0.05, and P=0.01 respectively.

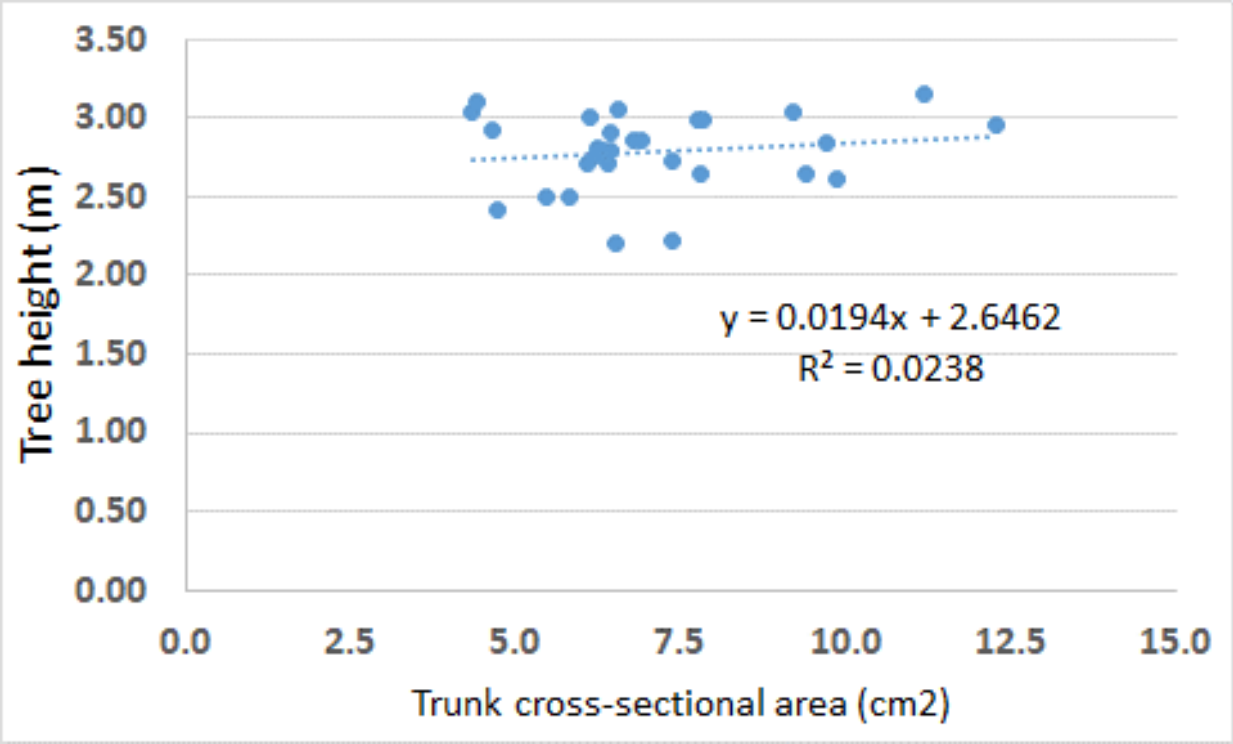


Figure 4. Relationship between trunk cross-sectional area and tree height in the fall of 2017 for 29 hard cider apple cultivars. Equation (insert) shows a very poor linear relationship between tree height and trunk cross-sectional area.

Table 13. Juice quality of 29 cider apple cultivars planted in 2015 at the University of Guelph Simcoe Research Station, Ontario. Trees trained to the vertical axe orchard system.

Cultivar[v]	Fruit soluble solids 2017 (% Brix)		pH 2017		Titratable acidity 2017 (mg malic acid· 100 ml-1)		Formol nitrogen 2017 (mg/L YAN[w])		Juice extraction efficiency 2017 (L/kg)		Juice extraction efficiency 2017 (L/lb)		Corrected total phenolic compounds 2017 (mg/L GAE)	
Ashmead's Kernel	18.3	a	3.5	hi	95.5	ef	148.3	bcd	0.56	d-j	0.25	d-j	365.8	i-m
Binet Rouge	15.1	c-j	4.4	c	36.8	k	104.5	d-h	0.53	g-j	0.24	g-j	914.9	abc
Bramley's Seedling	12.7	lmn	3.0	n	145.2	bc	72.5	fgh	0.69	ab	0.31	ab	275.5	j-m
Breakwell's Seedling	11.4	no	3.1	mn	157.7	b	69.3	gh	0.65	a-e	0.29	a-e	445.9	g-j
Brown Snout	16.4	bcd	4.1	ef	57.7	ij	170.0	ab	0.61	b-g	0.28	b-g	579.9	efg
Brown's Apple	10.6	o	3.3	jk	101.5	e	115.6	c-f	0.62	b-f	0.28	b-f	780.9	bcd
Bulmer's Norman	12.0	mn	4.1	ef	37.4	k	156.8	bc	0.69	ab	0.31	ab	840.5	bcd
Calville Blanc d'Hiver	14.1	g-l	3.2	lm	132.2	cd	96.6	fgh	0.65	a-d	0.29	a-d	316.7	j-m
Cline Russet	14.5	e-k	3.7	g	59.8	hi	81.6	fgh	0.68	abc	0.31	abc	229.8	lm
Cox's Orange	15.7	b-f	3.5	hi	82.3	fg	146.1	bcd	0.53	f-j	0.24	f-j	256.3	klm
Crimson Crisp	13.7	jkl	3.5	h	74.5	gh	103.5	d-h	0.68	abc	0.31	abc	271.3	j-m
Dabinett	14.9	d-j	3.5	hi	81.9	fg	144.6	b-e	0.51	hij	0.23	hij	256.4	klm
Enterprise	14.2	f-l	3.4	ijk	101.9	e	117.5	c-f	0.65	a-d	0.30	a-d	309.4	j-m
Esopus Spitzenberg	15.4	c-h	3.4	ijk	97.3	ef	112.7	c-g	0.62	a-f	0.28	a-f	250.3	lm
Fréquin Rouge	16.0	b-e	4.6	b	32.0	k	147.9	bcd	0.52	g-j	0.24	g-j	514.8	f-i
Golden Russet	16.6	bc	3.5	hi	84.8	fg	165.9	ab	0.63	a-f	0.28	a-f	379.7	h-l
Goldrush	12.9	lmn	3.3	kl	89.3	efg	70.7	fgh	0.71	a	0.32	a	246.4	lm
Grimes Golden	13.8	i-l	3.5	hi	92.9	ef	81.3	fgh	0.64	a-e	0.29	a-e	274.7	j-m
Kingston Black	14.0	h-l	3.5	hi	86.0	efg	79.9	fgh	0.55	e-j	0.25	e-j	437.4	g-k
Médaille d'Or	15.3	c-i	3.2	lm	136.6	cd	59.9	h	0.67	abc	0.30	abc	557.2	e-h
Michelin	13.0	klm	4.2	e	43.0	jk	144.8	bcd	0.59	c-i	0.27	c-i	563.7	efg
Muscadet de Dieppe	12.9	lmn	4.0	f	39.5	k	97.0	e-h	0.49	j	0.22	j	692.8	def
Porter's Perfection	14.6	e-k	3.3	kl	121.0	d	103.9	d-h	0.61	b-g	0.28	b-g	925.1	ab
Stoke Red	12.8	lmn	3.4	hij	101.3	e	78.4	fgh	0.64	a-e	0.29	a-e	1042.1	a
Sweet Alford	15.7	b-g	4.8	a	31.5	k	82.0	fgh	0.60	b-i	0.27	b-i	212.7	lm
Tolman Sweet	14.6	e-k	4.5	c	34.2	k	155.4	bc	0.61	b-h	0.27	b-h	185.4	m
Tremlett's Bitter	11.5	mno	4.1	ef	35.3	k	148.1	bcd	0.68	abc	0.31	abc	829.7	bcd
Tydeman's Late Orange	17.1	ab	3.2	lm	176.4	a	206.3	a	0.60	b-h	0.27	b-h	314.3	j-m
Yarlington Mill	14.1	h-l	4.3	d	39.7	k	83.0	fgh	0.51	ij	0.23	ij	737.3	cde
Significance[y]	***		***		***		***						***	
P Value[z]	<0.0001		<0.0001		<0.0001		<0.0001		<0.0001		<0.0001		<0.0001	

[v] Cultivars ranked in alphabetical order.

[w] Yeast assimilable nitrogen.

[x] Gallic acid equivalents.

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

[z] ns, *, **, ***, indicates not significant, and significant differences at P= 0.10, P=0.05, and P=0.01 respectively.

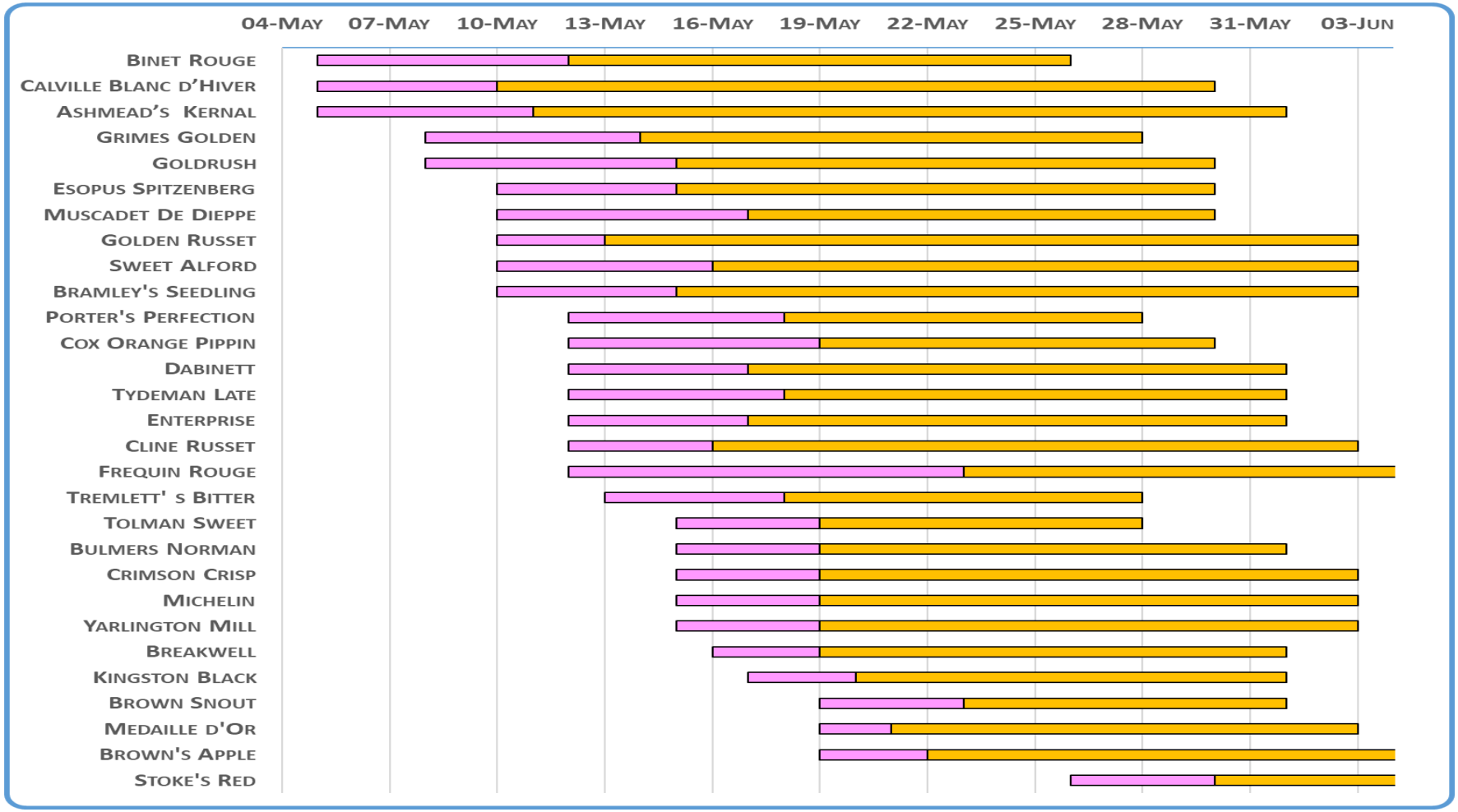


Figure 4. 2017 First bloom, full bloom and secondary bloom of cider apple cultivars at the University of Guelph, Simcoe Research Station in 2017. The pink bars represent the period from first bloom to full bloom and the orange bars represent the period of secondary bloom (from full bloom until no flowers remained on the tree).

Table 14. Summary of rankings of various horticultural and juice attribute characteristics of twenty-nine cider cultivars based on 2017 data at the University of Guelph, Simcoe.

Largest fruit size	Greatest Cumulative Yield	Tallest Trees	Least amount of pre-harvest fruit drop (<5%)
Bramley's Seedling	Bramley's Seedling	Tydeman's Late Orange	GoldRush
Enterprise	GoldRush	Binet Rouge	Tydeman's Late Orange
Calville Blanc d'Hiver	Bulmer's Norman	Golden Russet	Esopus Spitzenberg
Crimson Crisp	Grimes Golden	Ashmead's Kernel	Calville Blanc d'Hiver
Dabinett	Tremlett's Bitter	Stoke Red	Enterprise
	Médaille d'Or		
	Calville Blanc d'Hiver		
	Yarlington Mill		
	Golden Russet		
	Enterprise		

Highest BRIX	Highest titratable acidity	Highest juice extraction efficiency	Highest total polyphenols (> 500 mg/L GAE)
Ashmead's Kernel	Tydeman's Late Orange	GoldRush	Stoke Red
Tydeman's Late Orange	Breakwell's Seedling	Bramley's Seedling	Porter's Perfection
Golden Russet	Bramley's Seedling	Bulmer's Norman	Binet Rouge
Brown Snout	Médaille d'Or	Crimson Crisp	Bulmer's Norman
Fréquin Rouge	Calville Blanc d'Hiver	Tremlett's Bitter	Tremlett's Bitter
			Brown's Apple
			Yarlington Mill
			Muscadet de Dieppe
			Brown Snout
			Michelin
			Médaille d'Or
			Fréquin Rouge

Table 15. Application dates and rates of products applied to twenty-nine apple cider cultivars in 2017. Trees planted in 2015 at the University of Guelph, Simcoe Research Station, Simcoe, Ontario. Trees trained to the vertical axe orchard system.

Application date	Product name	Active ingredient	Product rate
05-Apr-17	Ferbam 76 WDG	ferbam	3.5 kg/ha
05-Apr-17	Purespray Green Spray Oil 13 E	mineral oil	20 L/1000 L water
10-Apr-17	Kocide 2000	copper	5.0 kg/ha
20-Apr-17	Scala SC	pyrimethanil	1.0 L/ha
27-Apr-17	Maestro 80 DF	captan	2.0 kg/ha
27-Apr-17	Manzate Pro-stick	mancozeb	3.0 kg/ha
03-May-17	Manzate Pro-stick	mancozeb	6.0 kg/ha
12-May-17	Streptomycin 17	streptomycin sulphate	600 g/1000 L water
12-May-17	Polyram DF	metiram	3.0 kg/ha
12-May-17	Flint	trifloxystrobin	140 g/ha
17-May-17	Streptomycin 17	streptomycin sulphate	600 g/1000 L water
19-May-17	Nova	mycobutanil	340 g/ha
19-May-17	Dithane Rainshield	mancozeb	3.0 kg/ha
01-Jun-17	Sevin XLR	carbaryl	1 L/1000 L water
05-Jun-17	Flint	trifloxystrobin	140 g/ha
05-Jun-17	Maestro 80 DF	captan	2.0 kg/ha
05-Jun-17	Calypso 480 SC	thiacloprid	290 mL/ha
13-Jun-17	Delegate	spinetoram	420 g/ha
13-Jun-17	Polyram DF	metiram	3.0 kg/ha
13-Jun-17	Nova	mycobutanil	340 g/ha
26-Jun-17	Sovran	kresoxim-methyl	240 g/ha
26-Jun-17	Manzate Pro-stick	mancozeb	3.0 kg/ha
26-Jun-17	Success	spinosad	182 mL/ha
04-Jul-17	Movento 240 SC	spirotetramat	365 mL/ha
19-Jul-17	Altacor	chlorantraniliprole	285 g/ha
19-Jul-17	Nova	mycobutanil	340 g/ha
19-Jul-17	Manzate Pro-stick	mancozeb	3.0 kg/ha
03-Aug-17	Exirel	cyantraniliprole	1.5 L/ha
03-Aug-17	Luna Tranquility	fluopyram + pyrimethanil	800 mL/ha
05-Sep-17	Decis 5 EC	deltamethrin	200 mL/ha
03-Nov-17	Urea (46-0-0)		5.0 kg/100 L water

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