Editorial

Editorial: Premier Apple Cooperative, Inc

What is the Premier Apple Cooperative, Inc (Premier) and why is it important to the apple industry?

Premier was formed by a group of concerned apple industry leaders (Producers) from New York State in 2001 (22 years ago), under the leadership of George Lamont. A "Producer" as defined by the Cooperative's Bylaws is a person or company engaged in the production of agricultural or horticultural products. The Producers were concerned about the low prices of apples and the returns to growers. Premier was organized as a Cooperative having status as an association recognized under the Copper–Volstead Act (7 U.S.C. # 291,292). This status allows members (producers) to legally discuss prices. Premier quickly realized that to be effective, the Cooperative needed to add Producers from other states in the same geographic area. Currently, there are Producers from the following states: Michigan, Ohio, New York, Massachusetts, Maine, Pennsylvania, Virginia, West Virginia, and North Carolina.

One of Premier's goals is to give the Producer members accurate and up to date pricing information on apple varieties being sold. This has been accomplished by a marketing committee of Premier that meets every two weeks to discuss market conditions and the prices they are receiving for fruit. Premier then creates a report showing the high and average suggested prices for each variety. Premier also generates a storage report for each month during the apple season. This report gives the number of bushels by variety that are in storage to be sold for each state. This information comes from US Apple's "USAppleTracker" report. A new Apple Juice Committee was formed one year ago to work on supply and pricing issues for the juice Producers.

Premier also hosts an annual forum to promote communication, cooperation, and education for the apple industry. Speakers from all areas of the fruit industry will present topics such as: Health of the Apple Industry, New Varieties and what Growers are Planting, U.S. and Canada History and Forecast of the Apple Crop, Federal Regulatory issues, Marketing Perspectives by Sales Agencies, Apple Juice and Cider Issues. This meeting also serves as a great networking opportunity for the industry.

Premier members and staff have advocated for apple industry issues at the federal level. This has involved trips to Washington D.C., where industry leaders educate members of Congress on apple and agriculture issues. Future industry concerns:
With the potential of a large apple crop in 2023, can the industry hold on to the price increases received in 2022?

Can the apple industry profitably market the number of apple varieties grown and new varieties being offered.

As a recently retired apple grower, I was approached to become the Executive Director of Premier in 2022. I have been passionate about growing apples in Upstate New York for the past 48 years and gladly agreed to come aboard. Historically, I've served on many boards including a term as Chairman of NY Apple, Chairman of US Apple, as well as other civic organizations. It's been an honor to be associated with the Premier Apple Cooperative and I look forward to continuing to work with apple industry leaders in the future.

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"Frost damaged apples from the May 18 statewide frost". Photo courtesy of Mario Miranda Sazo

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Apple Cultivars, Patent Names, Trademark Names and Brands

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There are many new apple cultivars being developed and marketed in the world in addition to those from our program at Cornell. This article is a review of many of the new cultivars. This information should help apple growers track and understand the opportunities with new varieties from other breeding programs.

There exists new apple cultivars around the world. In this article we will review many of these new cultivars. Often a cultivar is given a name with which it is patented but then is also given a trademarked brand name for the packed fruit. When discussing an apple cultivar, it is important not to use the brand name. Thus, NY 1 trees and fruit only become 'SnapDragon®' when they are marketed as fruit. Despite this important stipulation to protect trademarks, we are making an exemption in this article where we describe the apples by their brand name followed by their cultivar name on the patent since many readers have seen/heard the brand name, while the cultivar name may not be known. It is also common that multiple names have been given to the same cultivar. Where a cultivar is known by several names, we have noted that in this article.

Several varieties that have been released, have faded quickly in the market, while others have made a slow but steady ascent. Also, a cultivar's success often depends on the marketing program used to promote it. The multi-million marketing budget for WA38 has helped that cultivar in both the US and international markets. It has also been surprising to see that after 'Delicious' was toppled from its "king of the mountain" position, inflation and its lower price per pound have revived sales of this cultivar. We are all curious to see which varieties will remain competitive, and which will perish. Dual hemisphere production is often seen as a big benefit to the success of a cultivar, yet the disastrous cyclone in NZ will likely result in a 50% reduction of crop this year. What will that mean for club varieties that promote their year-round availability?

We have tried in this article to also indicate what is known of each cultivar's resistance or susceptibility to new and existing diseases. In particular the disease known as bitter rot caused by *Colletotrichum* species is escalating worldwide and we reference new discoveries in each cultivar where it is described as a challenge. Recently Khodadadi et al. (2020) identified and characterized *Colletotrichum* species causing apple bitter rot in New York, while Acimovic et al. (2020) reviewed the topic in the Fruit Quarterly and Martin et al. (2021) described the impacts of weather patterns and cultivar susceptibility on spread of the pathogen. 'Honeycrisp' and many of its progeny are very susceptible to bitter rot. Another fruit disorder/disease that is increasing in prevalence is a group of lenticel disorders. Bill Shane at MSU hypothesized that combined high heat and sunlight stress can weaken the skin and lenticels, allowing weak pathogens to colonize the area. Lenticels can also be weakened by an extended dry period followed by rain. Lenticels that "split" appear as enlarged and roughened lenticels on fruit at harvest. Many of our popular new cultivars are prone to a variety of lenticel disorders as described below.

Varieties (in alphabetical order):

'Ambrosia': There has been a renewed interest in this chance seedling, which is believed to be a cross of 'Delicious' x 'Golden Delicious'. 'Ambrosia' apple' patent has expired and it is open to everyone for trial. The fruits are crisp and sweet. This cultivar is susceptible to scab and to fire blight and must be thinned to prevent alternate bearing. 'Ambrosia' apples also had 20% incidence of white haze and 15% dry lenticel rot when grown in Italy (Garello et al., 2019). *Marssonina/diplodia* has also been reported. Ehsani-Moghaddam and DeEll (2009) found that increased ethylene concentration (IEC) in 'Ambrosia' apples during storage was related to higher incidences of core browning and lenticel damage, yet lower internal browning. Xu et al. (2022) studied sunburn browning of fruit and rootstock-dependent damage of 'Ambrosia'™ apple after the 2021 summer heat events in the Pacific Northwest. Heat led to considerable sunburn browning (SB). External and internal quality attributes of SB 'Ambrosia' apple were studied on five rootstocks. The cell integrity of layers of fruit skins with SB was compromised. Anthocyanin decreased in damaged cells, and stress-related compounds accumulated. The affected sun-exposed skin had a significant increase in differential absorbance between 670 nm and 720 nm, measured with a handheld apple DA meter, highlighting the potential to use this method as a non-destructive, early indicator for damage. Sunburn browning led to lower fruit weight, an increase in dry matter, soluble solids, acidity, decreased weight retention, quicker firmness loss, and accelerated ethylene emission. Significant inconsistencies were found between the sun-exposed and shaded sides in SB apples in dry matter content, firmness, and tissue water potential, which implied preharvest water deficit in damaged tissues and the risk of quicker postharvest quality decline. 'Ambrosia' on Geneva® 935 (G.935), a dwarfing rootstock, had higher water transport capacity which resulted in a higher yield of disorder-free apples, suggesting rootstock selection could mitigate summer heat stress. Lu and Toivonen (2022) studied whether scheduling adequate irrigation would mitigate postharvest soft scald (SS) of Ambrosia™ apples grown in a semiarid zone. They found that intensive water deficits could cause fruit to be susceptible to SS and that adequate watering during fruit expansion in the late season had a mitigating effect on SS in Ambrosia™ apples grown in a dry region. They also suggested that deficit irrigation prior to midsummer did not always cause SS susceptibility in 'Ambrosia'.

'Arctic Apples®': ('Arctic Gala', 'Arctic Golden' 'Arctic Granny' and 'Arctic Fuji') These cultivars were modified through genetic engineering to not turn brown when cut. They were approved in February 2015 by the USDA, becoming the first genetically modified (GMO) apples accepted for sale in the US (Tennille, 2016). They are the only transgenic apples currently being marketed. They are sold as dried apple bits on Amazon and the company is targeting the food service industry offering convenience and less preparation time with their cultivars. Arctic- apples have achieved 17 million pounds of production in recent years. 'Arctic Fuji's are currently being tested with consumers and the Food Industry. Silencing of a gene by a genetic engineering technique was used to limit the production of polyphenol oxidase (PPO), thus preventing enzymatic browning of the fruit after it has been sliced open, leading to extension of shelf life after cutting (Chi et al. 2014). Interestingly, these apples are sold as processed slices to bakeries and restaurants rather than directly to customers, emphasizing their convenience and effectively skirting any potential negative perception of their being GMOs (genetically modified organisms).

'Aurora Golden Gala' (856923): An apple from the breeding program at Pacific Agri-Food research Station in British Columbia, Canada. This yellow 'Splendour' x 'Gala' hybrid was released by C. Hampson and colleagues in 2005. This apple is sweet and of good quality. Aggressive thinning is needed for optimum quality and to reduce fruit bruising. Small spots of superficial scald in bins/boxes may occur unless fruit is covered with a tarp or by bins of other apples.

'Bravo®' (ANABP 01): This cultivar is known as 'Bravo®' in Australia and 'Soluna®' in areas outside of Australia. It is a cross of 'Royal Gala' x 'Cripps red' and currently is selling for $2.00 to $3.00/apple in western Australia.

'Cameo': A hybrid of Red 'Delicious' and 'Golden Delicious' that has been well received. Unfortunately, fruits and leaves are susceptible to *Marssonina* (information from Kari Peters and OMFRA). Also prone to black rot in the NE183 trial and to *Colletotrichum*.

'Candine®': A hybrid between 'Fuji' and 'Ariane' (scab resistant) cultivar marketed by Blue Whale in France. 'Candine' is grown exclusively in France and is being tested in markets in China. The attractive red fruit has white flesh, strong aroma, is juicy and crisp, and has a long storage life.

'Canopy'. Green apple from IFO. Scab resistant (V_f). S2S23 self-incompatibility alleles, with S23 unique. Acidity like 'Granny Smith'. Blooms and ripens with 'Granny Smith'.

'Charlo®': See 'Sweetie'. 'Charlo®' is the name for 'Sweetie' (Prem A280) when it is grown in China.

'Cheekie®': A hybrid of 'Granny Smith' x 'Splendor' that originated in New Zealand. 'Cheekie' has a distinctive flavor that is described as slightly tropical with a hint of passion fruit. With a very slight tartness, it is a crisp and dense fleshed apple with a dark red blush. 'Cheekie' is marketed as having an explosively juicy crunch that is both satisfying and enjoyable. 'Cheekie' is grown in NZ and by Sage Fruits in Washington State. In Canada it is exclusive to Freshco.

'Cherish®' (PremA34): 'Cherish®' is a trademarked brand from New Zealand and is a cross of 'Pacific Rose®' (Sciros) x 'Pinkie' apples. Scab resistant. This attractive, pink-colored apple has a refreshing tropical flavor and stores well. Trial plantings have been established in the UK, the US, and other locations.

'Civpeak: A new sport of 'Rubens'- patented in 2020s. USPP#32,392. Skin appears very bumpy in photos but is a rich red color. High Brix (16.3).

'Coryphée' (Zouk 32). Tolerance to scab comes from its 'Rubinstep' parent. First grown exclusively in Belgium as a low residue apple. Bred by J. Nicolai. Testing in the UK. Described as crisp, firm, and juicy. Harvested 10 to 14 days after 'Gala' and should be grown in areas with good color development of 'Gala'.

'Cosmic Crisp®' (WA 38): ('Enterprise' × 'Honeycrisp') Bruce Barritt (retired professor from Washington State University) is the breeder and Proprietary Variety Management (PVM) owns the master license for global cultivation rights. The first commercial quantities were produced in 2021, and there is an aggressive roll- out and acreage ramp up in WA State and overseas. This cultivar has a good storage ability, the fruit remains very crisp and juicy while keeping its flavor. 'Cosmic Crisp®' has been introduced in the US and is entering European markets in partnership with South Tyrol's apple sector. The logo from the US branding and the color scheme were not changed. The imagery was adapted to European requirements and has photos. The brand slogan is: "Heavenly taste. With every bite." 'WA 38' has a self-thinning trait, where most fruits shed within the first 8 weeks after bloom, leaving some clusters empty, and the rest with only 1 to 2 apples. Serra et al. (2022) studied flower biology and low fruit set in 'WA 38'. Their research characterized the effective pollination period (EPP) of 'WA 38' by studying stigmatic receptivity, pollen tube growth, and ovule longevity. Pollen tube growth of 5 fully compatible pollinizer varieties were compared in 'WA 38' pistils, and fruit and seed set resulting from controlled pollinations with these 5 pollinizers was assessed. WA 38's effective pollination period (EPP) was ~3.2 days in 2019 and only 1.4 days in 2020. Differences in pollen source did not result in

significant differences in fertility in 'WA 38' flowers. Mechanisms other than pollination and fertilization, such as competition among fruitlets within a cluster or hormone signaling, may be important. Stem clipping is required. It is susceptible to a physiological disorder named green spot (GS). Sheick et al., (2022) found that early season fruit bagging reduced GS appearance, but netting showed mixed results between years and rootstocks. Rootstock selection influenced GS incidence, especially in 2021. There were some differences of mineral composition between symptomatic and asymptomatic apples, but it is not clear that nutrient imbalance directly influences GS disorder incidence. Further research on the mechanisms behind GS will consider light, humidity, and wind. Anatomical features of 'WA 38' fruit, such as lenticel morphology and physiology will also be characterized. Musacchi et al. (2023) studied effects of multi-leader training systems and prohexadione-ca applications on 'WA 38'. Pro-Ca appeared to reduce fruit number and yield per tree in two seasons, yet this cultivar also sets mostly a single fruit per cluster and usually does not require thinning. Fifty-one % of the clusters set a single fruit under normal weather conditions. An interaction between Pro-Ca and training systems was found. The 3-axis-control trees produced 88% more than 1-axis control, while the same comparison was not significant in the Pro-Ca data set. 'WA 38' fruit size was positively affected by Pro-Ca application in 2019, with the untreated control producing 22% more apples in the extra-large size class (56 to 48 apples/box). Fruit pack out and defects did not reveal any negative effects of Pro-Ca treatment. More years of investigation will be needed to assess the physiological performance of 'WA 38' treated with Pro-Ca in top-worked trees.

'Crimson Crisp®' (Coop 39): (U.S. Plant Pat. No. 16,622) Scab resistant but susceptible to cedar apple rust, powdery mildew (of foliage and fruit) and to fire blight. Important to store in controlled atmosphere storage for post-December sales. Thinning is as difficult as 'Gala'. Coop 39 has low acidity for a scab resistant cultivar.

'Crimson Snow®' (MC38): This chance seedling from Australia, which ripens at the same time as 'Pink Lady' has been commercialized internationally in Italy, France, Switzerland, and Serbia. Managed by Kiku Variety Management of Braun's nursery. Not alternate bearing but needs special cultivation. The 700 hectares produce 12-24 tons. The productive trees bear apples larger than 'Fuji,' combined with high coloring, results in high pack-out. These sweet apples, with moderate aroma, store well.

'Cripps Red': See 'Joya®'.

'Dalinsweet®': Scab resistant**.** A good quality apple, but with poor fruit appearance ratings (www.dalicom.com). 6-month storage in CA (Klein et al. 2018). A red sport ('Red Dalinsweet') is being introduced. Good storage ability. White flesh. Juicy and sweet with a touch of acidity.

'Dazzle' (PremA129). USPP 29,214. Highly canker susceptible and not recommended for planting in the EU where disease pressure is high. Conic and may be slightly lopsided. Scired x A280 ('Sweetie®'). Good storage, texture, flavor, and appearance. Susceptible to scab and to powdery mildew.

'Enjoy®' ('Gradisca'): A sweet, attractive apple grown by the Melinda brand group. USPP 30,008, expires in 2037. Derived from open-pollination of 'Fuji', 'Gradisca' was discovered in 1994 in a 'Fuji' orchard in France. Sweet, perfumed and colors well in heat. Strong floral aromas. Harvests with 'Golden'. 'Gradisca' is characterized by its bright red fruit and good production. 'Gradisca' has more perfumed fruit and more intense red overcolor than it's 'Fuji' parent. 'Gradisca' is susceptible to apple scab.

'Envy® ('Scilate'): 'Envy®' is hybrid of 'Royal Gala' and 'Braeburn'. It was developed by HortResearch in New Zealand and patented in 2009. It ripens with 'Fuji' and is said to have consistent quality across production regions. 'Envy®' apples are mostly red with yellow specks. The peel is thick and tough. 'Envy®' can be susceptible to internal browning in storage due to ethylene and the use of Harvista (1-MCP) (James, 2022). 'Envy' is prone to russet, so early sprays should be under conditions suited to drying. Artificial spur extinction protocols are used to promote cropping. 'Envy' is susceptible to *Neonectria ditissima in NZ*, which colonizes picking wounds and leaf scars, with susceptibility like its 'Gala' parent (Smith et al., 2019). In some pictures 'Envy' looks like a poorly colored 'Gala', and its shape can vary from conic to squat. Fortunately, 'Envy' is less bitter pit susceptible than its 'Braeburn' parent. 'Envy®' is marketed by CMI Orchards, Rainier Fruit Co. and Oppy in the US (envyapple.com). 'Envy' is susceptible to scab; mildew and the leaves are susceptible to magnesium deficiency symptoms. Lenticel breakdown can be severe. In 2022, late rains and transport problems led to deterioration of 'Envy' apples grown in NZ, with reports of losses of ~$1 to 5 million dollars. Sidhu et al. (2022) examined crop load and thinning methods and their impact on 'Scilate' apples. Flesh firmness, total soluble solids, dry matter content, malic acid content, and fruit shape were improved under the Artificial Bud Extinction (ABE) regime, with positive effects most evident the second season. High-quality fruits were obtained from low and medium crop loads. Fruit quality was poor for high crop load trees. Low crop load fruit had a slightly higher incidence of internal flesh browning and fruit softening after regular atmosphere storage. Crop load also impacted fruit and leaf mineral nutrient content. Fruit N, Ca, Mn, and Zn, and leaf N, Fe, Zn, and Cu content increased, while fruit and leaf K declined with a higher crop load. High crop load, irrespective of the thinning regime, and hand thinning with a medium crop load, induced severe biennial bearing. Fruit yield was relatively consistent with ABE, even with a medium crop load. ABE with a medium crop load (around six fruit cm^{-2} LCSA) was an effective method of managing crop load and optimizing fruit quality. Singh et al. (2022) reported that despite some improvement in fruit quality parameters, delaying harvest of 'Scilate' fruit increased the risk of fruit softening (FS) and internal flesh browning (IFB).

'Evercrisp®' (MAIA-1): USPP#24, 579-Patent expires in 2032. Twenty years after the first seedling that would become MAIA1, the apple marketed as 'EverCrisp®', growers have planted more than 1.7 million trees in 728 orchards across the United States (April 5, 2021- GFG). Leaves are prone to Frogeye leaf spot-black rot. 'Evercrisp' trees are extremely susceptible to fire blight, and *Marssonina* susceptibility was noted in a Massachusetts planting. Fruits are also prone to water core. Northern growers need to realize that with climate change, the margin for proper maturation might change. Currently, 'Evercrisp' is harvested the first week of November in northern MI, so growers suggest extensive thinning to ensure a one-pick harvest, as two picks may not be possible due to timing. 'Evercrisp' can be a muddy, brown-red on younger trees and there is variation in both fruit size and appearance. Bitter pit increased on G.41rootstock. Recommendations from Penn State University (PSU) are to harvest for long term storage at a starch iodine reading of 4-6 and for direct market at 6-7. This cultivar has some sensitivity to CO_2 injury in longer storage, which may cause internal browning. This is a very firm cultivar that stores very well and can benefit from some storage time, which allows for a little softening and development of aromatic flavor compounds.

'Evelina®': see 'Pinova'/'Pinata' sport.

'Fräulein® (GS 66): USPP 30,862; 3 Sept. 2019. A chance seedling of 'Honeycrisp', perhaps by 'Braeburn'. https://www.fraeulein.de/en/apples/#. Dr. Gorgens of the Esteburg Center in Germany said 'Fraulein' is interesting, but as it is bicolor, it can be difficult to color, it harvests late and is susceptible to powdery mildew, bitter pit, and brown core, not unexpected given the presumed pedigree.

'Freya®' (WUR037): Scab resistant. USPP#28,397 P37 granted in 2017. A cross of 'Elise' x a scab resistant breeding selection from the Fresh Forward program, formerly Wageningen University and Research Apple Breeding (WUR). 'Freya' is comparable to 'Elstar' in taste and harvest time and can be stored the same as 'Elstar' in ultra-low oxygen (ULO) conditions until May. Recommended for northwestern and central Europe. Fruits have an average of 75% red color, are larger than 'Elstar' and are a balance of sweet and sour, good firmness and are marketed as "temptingly tart." Only slightly susceptible to apple canker and tolerant to powdery mildew. 'Freya' is unsuitable for long term storage due to rots and flesh browning (Klein et al., 2018) (2016). 'Freya'® is sold under an open access model.

'Galant®' (Lumaga A913) (SR): 'Galant' is a scab-resistant cultivar with sweet and very firm flesh. It has 50-80% red/pink coloration with some stripes on a greenish/yellow base and has pronounced lenticels. The fruit is medium in size and slightly elongated. 'Galant' resulted from a cross between 'Resi' (scab resistant cultivar from Germany) and 'Delbard Jubileè' (Switzerland). It is licensed to Fruture GmbH. Trees are low growth but high yield. It is harvested in mid-September and has a relatively long harvest period. The Melinda website mentions it is slightly astringent. Experiments at Fondazione Edmund Mach (FEM) by Angeli et al. (2021) showed 'Galant' was prone to superficial scald, flesh browning, browning of the skin and underlying flesh (soft scald and soggy breakdown). Angeli et al. (2021) applied initial low oxygen stress conditions (ILOS) and 1-methylcyclopropene (1-MCP). Superficial scald increased at early stages of maturity but the reduction of the respiratory metabolism by using ILOS technology allowed this to be under 4% in comparison with controlled atmosphere (CA) (35%) after 180 days storage. ILOS and CA storage did not affect the incidence of internal browning, which is often higher than 60% after 14 days shelf-life. Unfortunately, flesh browning limits the storability of 'Galant®' to 120 days (Neuwald et al., 2016). Superficial scald and flesh browning incidence were similar in 1-MCP treated and untreated apples.

'Gala' strains:

'Bl-14 Gala': USPP#22,867. 'BL-14 Gala' exhibits a distinct early maturity date from other Gala sports grown in proximity to 'BL-14'. This sport also has intense coloration and striping in comparison to the other sports, and has lower acid levels than 'Gale Gala', 'Banning Gala', and 'Simmons Gala'.

'Devil Gala': An early maturing, well coloring apple sport discovered by Zanzi nursery. It provides good color when grown in Southern Europe.

'Foxtrot Gala': US plant patent #25,664. This sport is said to have a 75% pack out of extra fancy in WA state and to be larger than 'Buckeye Gala' by a box size, but it should be noted that this report comes from the patent owners' orchard. It is said that the full color throughout the tree allows one-pick harvests. The budwood is highly managed.

'Galaval®': U.S. Plant Patent No. 19,909. 'Galaval®' originated in France and is popular in Europe. It is a sport of 'Galaxy Gala' overlaid with dark red stripes. In a study by Cishon et al. (2021) 'Galaval®' rated well, as did 'Gala Decarli-Fendeca' when grown in central Europe.

'Gale Gala' ('Malaga'): This sport develops 90-100 percent full red color with deep red striping, allowing harvest in one or two pickings. The finish is very clean. Fruit size, firmness and eating quality are equal to other Gala sports.

'Redridge Gala®': A sport of 'Brookfield Gala', which ripens about 5 days earlier and is almost 100% red blush.

'Temptation Gala®': USPP 31,443. A whole tree mutation of 'Foxtrot Gala' that is said to be large, intense red, early maturing with exceptional flavor and firmness.

'Galy®' ('Inobi' cv.): USPP# 31,287 in December 2019. Scab resistance (V_f gene). This cultivar is a cross of the German 'Pilot' apple (not patented) x 'X6398' (not patented), at Angers, France in 1995 by breeders at INRA and Novadi in France. 'Galy' ripens a week after 'Gala'. It is said to either have a balanced flavor or is described as slightly acidic and is crunchy (yet also described as having a fine, firm texture) and juicy. While described as attractive, with a uniform red (75%-100%) over yellow, pictures suggest that sun exposure is important, if not crucial for fruit coloration. Reports suggested that 'Galy®' may have good storage potential, but details on the length of storage were not provided. Available for testing in the US.

'Giga®' ('Ipador'): USPP# 32,392 granted on October 27, 2020. Better3Fruit N.V., a private breeding institute in Belgium, is the owner of the cultivar and brand. The International Pome Fruit Alliance Ltd. (IPA) owns the global master license for allocating growing rights. VOG is the first to introduce Giga® apples in Europe. The parentage is 'Goldrush®' (Coop 38) x 'Kanzi®' (Nicoter), which is a 'Gala' x 'Braeburn' hybrid. Resistant to scab, *Rvi6* (i.e., *Vf*), but susceptible to fire blight. The fruit is large, 75% dark red and has an extremely good storage ability (at least 7 months). Its taste is intense with a very balanced sweet/tangy taste. The taste is full-bodied with flavor notes ranging from banana to honey, cinnamon, and dried fruits. Apples have 16.1 °Brix and 8.2 g/L malic acid, which should appeal to many consumers. The flesh is very firm. 'Giga'® is stored for several

months prior to marketing, with 7 months of storage listed. The 'Giga'® brand name has a "mighty good" slogan. 'Giga' is said to be blessed with a fruity bouquet and a sweet-sour and firm bite that only gets better with time. Reports on ripening time vary from the first week of October, to others saying it ripens the last week of October in Belgium. It blooms early, with 'Idared'. Partly open calyx and calyx tube can be open. From pictures, leaves can be chlorotic with some lesions that resemble bitter rot. Fruit size can be variable within a tree.

'Gradisca®': See 'Enjoy®'.
GS62: See 'Sunspark®'.
GS 66: See 'Fräulein®'.
HC2-1: See 'Zingy®.'

'Heliodor™' (UEB3264/1 cv.). Heliodor™ is a cross between 'Golden Delicious' and 'Topaz', from the Institute of Experimental Botany in Prague, Czech Republic. 'Heliodor' is a medium to large apple with moderate ribbing. The bright yellow skin is smooth, shiny, and russet free, and typically without blush. The yellow flesh is moderately firm, crisp, and very juicy with a sweet-subacid flavor. This apple is resistant to scab and has very low susceptibility to powdery mildew. Harvest timing is like 'Golden Delicious', achieving eating maturity about 2 weeks after picking. It bears heavily and needs to be thinned annually to prevent biennial bearing. One report suggests Heliodor is most suited to home gardens rather than commercial orchards.

'Honeycrisp' sports:

'Premier®': Is an early ripening strain owned by Adams County Nursery. Reportedly it did not withstand heat well in 2022 in WA. Caution is urged in the east coast as this sport can often ripen from the inside out, accelerating ripening and increasing softening.

'Roseland Red Honeycrisp®' (SO 7): USPP# 33,113 (2021). International Plant Management has the rights. Discovered in Roseland, VA, by A.R. Alton. This is a 'Honeycrisp' whole tree mutation; discovered in 2009 and propagated in 2012. This sport is almost 80-90% red, with the same maturity and storage performance as standard 'Honeycrisp'. 'Roseland Red Honeycrisp®' colors exceptionally well in the heat and performs well in cooler climates. 'Roseland Red Honeycrisp®' has good pack-outs.

'Royal Red HoneycrispÒ': USPP #22,244. Discovered in Washington State, this sport is a blush type and has the crisp, juicy texture of its parent. Beyond the high color, initial tests indicate improved storage characteristics. The tree is low vigor and trees should not be allowed to bear a crop too soon.

'Honeymoon®': See 'Lemonade'.
HOT84A1-See 'Tuitti'.

'Hunnyz®': Mid-season red-yellow apple with a crunchy texture and a long storage life. Exclusive to Auvil Gee Whiz apples. A hybrid of 'Honeycrisp' x 'Crimson Crisp' (SR). Social media sites have had fun ridiculing the name, complete with a backwards n in the signs.

'Inobi'- see 'Galy®'.
'Inogo': See 'Lory®'.
'Inolov': See 'Mandy®'.
'Inored': See 'Story®'.
'Ipador': See 'Giga®'.

'Joly red' (Mored Joly red): Dark red, almost purple, very sweet apple. Crossed by Jean Moors. Club cultivar marketed by the (BFV) (Belgian Fruit Auction) and Fruit Auction Zuid-Limburg. The harvest season is early October. Apples are very typey in certain locations. Fruits cluster on the tree, are 14°Brix and low acid. Thick skin aids storage.

'Joya®' (CR Brisset, 'Cripps Red', 'Sundowner'): 'Joya®' is a sport of the originally named 'Sundowner' apple, a sister to 'Cripps Pink'/Pink Lady'®, re-branded. In France, Blue Whale has about 250 growers and ~250 acres devoted to 'Joya®'. 'Joya®' is interesting in that it requires a long growing season, later than it's 'Pink Lady' sister, but it does not require long chilling (needing only 300 chill units), so it is more of a warm climate apple best suited to regions that do not get below freezing. It is bitter pit susceptible. Water stress increased water use efficiency without impacting yield. 'Joya's susceptibility to bitter rot, *Colletotrichum fructicola,* was first reported by Nodet et al. (2019).

'Juici®': Bred in Washington State, in a cross of 'Honeycrisp' by 'Braeburn'. Very dense and great firmness (20 lbs) at harvest, that only drops a pound or two in controlled atmosphere storage. Good sugar acid balance. A vascular necrosis disorder was reported by Sallato (2021) on 'Juici', 'Honeycrisp' and 'Jazz' in WA State. The incidence of this disorder varied from about 45-70% on fruit of these cultivars that had been sorted and packed. An exclusive cultivar of Oneonta Starr Ranch Growers (OSRG). First US crop was in 2016 and projected to have 500,000 boxes from Washington State in 2022.

'Kanzi®' ('Nicoter'): This is the second most popular club cultivar behind 'Pink Lady. A hybrid of 'Gala' x 'Braeburn', it is bicolor, crisp, with a good sweet/acid balance. Canker sensitivity has necessitated the need for an interstem, resulting in a higher cost for trees. Trees can be biennial without proper management. With 'Kanzi®' the highest infection rates with *Nectria* were at full bloom to petal fall. Options to control blossom-end rot include timing of scab or powdery mildew fungicide sprays to full bloom, and canker pruning just ahead of flowering in orchards strongly affected by *N. ditissima* (Holthusen and Weber, 2021). 'Kanzi' is also susceptible to lenticel breakdown, seen in Western Australia and to *Colletotrichum* in storage. In research by Weber et al. (2019) the genus *Penicillium* was encountered most frequently on decayed 'Nicoter' apples, followed by *Fusarium*, *Botrytis*, *Neonectria* and *Monilinia*. There was a significant relationship between fruit mass and rot incidence, possibly due to a link with pre- and or postharvest factors that affect susceptibility and correlate with fruit mass. 'Nicoter' apples also appear to be sensitive to extremely low oxygen concentrations during storage, with a loss of acidity in most treatments (Neuwald et al, 2021).

'Karma®': Starr Ranch Growers in Washington State have exclusive rights to this apple. 'Karma®' apple has a vibrant bi-color skin, unique floral aromas, is very juicy and crisp, with high Brix.

The pedigree includes 'Fuji', 'Golden Delicious' and 'Honeycrisp', and the apple is naturally resistant to flesh browning after cutting.

'KinderKrisp' is a new apple cultivar developed by David MacGregor, a private apple breeder in Minnesota. Said to have exceptional flavor and crisp texture, like its 'Honeycrisp' parent, this early ripening apple features much smaller fruit, perhaps a perfect size for snacking or for a child's lunch. It may have a niche with homeowners. 'KinderKrisp' flowers early and ripens in late August. There was no discussion of disease susceptibility in the patent. David has released other apples including 'Crabby Crisp', 'Intensity' ('Haralson' x 'Honeycrisp'), 'Black Mac', and 'Shizam' ('Honeycrisp' x 'Shizuka').

Kirzuri: See 'Morgana®'.

'Kissabel®': A series of red fleshed apples. https://www.kissabel.com/. There are reports of susceptibility to flesh browning.

Kissabel® Jaune (Y102): Jaune is French for "yellow", and the skin is yellow with orange blush and sl. russeted lenticels. The flesh is pink.

Kissabel® Orange (Y101): The skin color is orange with yellow lenticels and the flesh color is pink and red. It is said to have balanced flavor and to ripen after 'Gala'.

Kissabel® Rouge (R201): USPP 28,218; 25 July 2017. Ripens with 'Braeburn' and said to have berry notes. Long stem may require clipping. Populin et al. (2022) found that ethylene release was earlier in 'Kissabel Rouge'.

'Lemonade®' (PremA153): See also 'HoneyMoon®'. 'Royal Gala' x 'Braeburn'. Acid but with sweetness, it does not exactly taste like lemon but has acidity.

'Lory®' ('Inogo'): A clean yellow apple that is a tip bearer and has some bare wood in pictures. Resistant to scab and to rosy apple aphids.

'Lucy Rose®', 'Lucy Glo®': These apples were bred by Bill Howell in Washington from crosses of 'Honeycrisp' apples with a red-flesh apple 'Aerlie Red', also known as 'Hidden Rose'. The most promising offspring were 'LucyRose®' with a red peel and 'LucyGlo®', which has a yellow skin. The first 'Lucy' apples were sold in 2018. Today, Washington State growers with Chelan Fresh and Stemilt are growing 'Lucy Rose®'.

'Luiza' (SCS425). An 'Imperatriz' x 'Pink Lady' hybrid from a Brazilian program. *Glomerella* leaf spot resistant, but not resistant to scab. Medium chill requirement. Cross compatible with 'Venice' apple from the same breeding program. These will be marketed as 2 of the 3 apples in the Samboa brand.

'Magic Star®': One of the names used for conventionally grown SQ159 ('Natyra®'). The clubbed stem suggests stem clipping may be required. Possible *Colletotrichum* may be evident in some photos.

'Majesty®': USPP#25,890 granted in 2015. Breeders at Consorzio Italiano Vivaisti (CIV) developed this hybrid of 'Scarlet O' Hara' (Co-op 25) by a breeding selection. Scab resistant, but susceptible to fire blight. Good storage. The flavor is aromatic, with a high sugar content (16 °Brix). Susceptibility to moldy core may be an issue, due to the 'Scarlet of Hara' parentage.

'Mandy®' ('Inolov'): USPP#28, 398 filed in 2014. A cross of 'Gala' by an advanced breeding selection. 'Mandy®' is 40 to 60% red, scab resistant (Vf), and matures between 'Golden Delicious' and 'Braeburn'. Fruits are flavorful, crunchy, juicy, and firm, with good storage potential. The shape is cylindrical, and the bi-color fruit require good sun exposure for coloration.

'Minneiska': See 'SweeTango®.'
MC38: See 'Crimson Snow®.'
MN80: See 'Triumph®'.

'Modi®' (CIVG198): Scab resistant, but susceptible to *Venturia asperata,* an atypical strain of apple scab. Grown in Italy, Australia, and one packer in California has done well with 'Modi' but stressed that he needs 3 sprays to reduce sunburn. 'Modi' was the scion cultivar in the NC 140 organic planting assessing rootstocks and it was abysmal in performance. 'Modi' is very prone to damage from plum curculio, and internal lepidoptera. It is also very susceptible to *Marssonina*.

'Morgana®' ('Kizuri'): This apple from Better3Fruits is a late cultivar with a wide window for picking. Due to its firmness, 'Morgana®' also has an excellent shelf life. This apple is a hybrid of 'Golden Delicious' by a Cornell unnamed breeding selection which is a hybrid of 'Delicious' x 'Liberty'. Being grown by the Melinda brand. 'Morgana®' is crisp, refreshing and very juicy**.** This apple cultivar was introduced at Fruit Attraction in Madrid. During the first phase, trees will be planted in Italy, The Netherlands, Germany, and Belgium. Trees are exclusively available from Carolus Trees under the name 'Kizuri'. Noted for its juiciness and slight anise flavor.

'Natyra®' (SQ159)**:** SQ159 grown by organic growers can by traded under the brand name 'Natyra®'. If grown conventionally, the name 'Magic Star®' is used. This apple is a hybrid of 'Elise' and a scab resistant WUR-selection. The bloom time is around that of 'Golden Delicious' and harvest is a little after or with 'Braeburn'. This cultivar is susceptible to canker and mildew. The apples have a great firmness and are rarely russeted. 'Natyra®' is a quality apple that consistently tops consumer polls with its sweetness, aroma, taste, and crunch. It has an extended shelf life in the store and at home, adding to 'Natyra®'s popularity. A description of the Natyra® apple is at www.natyra.bio. Neuwald et al. (2016) found that 'Natyra' maintained excellent fruit firmness (FF) during storage 7 months CA storage and showed no physiological disorders. The tough skin aids storage but is prone to skin flecking. 'Natyra' is a weak grower, so its use in crosses with 'Honeycrisp', may make tree vigor an issue in the resulting progenies. For rootstocks, G.11, G.16, or stronger M.9 clones were recommended. 'Natyra' is prone to sooty blotch, as with many organically grown varieties. Its tendency to retain mummies means that black rot control (*Diplodia*) must also be prioritized (Adolphi and Oeser, 2022).

'Nicoter'- See 'Kanzi®'.

NJ150: See 'RubyRush®'.

Opal' (UEB 3264/1): USPP #15, 963. Filed in 2004 and expires in 2024. A good quality 'Golden Delicious' x 'Topaz' hybrid. https://opal-apple.com/ Lenticels and stem cavity get russeted. Scab resistant (V_f gene) but reported by Prencipe et al. (2022) to be susceptible to the pathogen causing dry lenticel rot, *Ramularia mali.*

'Pazazz®': This 'Honeycrisp' offspring can produce very large apples, depending on crop load. Cultivars, such as 'Pazazz', that developed disorders related to CO_2 sensitivity, as well as those not typically associated with CO_2 (soft scald) could be distinguished using metabolic fingerprints (McTavish et al, 2021). Exclusive to Honeybear Brands, 'Pazazz' may have cuticle disorders when grown in NY.

'Pinova' (Called 'Pinata' in the US, was called 'Corail' and 'Sonata' in the past): Low susceptibility to scald, a plus in organic plantings. 'Pinova' is a slow softening cultivar and fruit firmness at the recommended storage temperature of 1°C did not differ from fruit stored at 3, 4 or 5°C. Neuwald and Kitteman (2015) suggested that higher storage temperatures might be an effective way to reduce the incidence of *Neofabraea* spp. storage rots while still maintaining fruit quality. Additionally, increased storage temperatures can provide a substantial reduction in energy consumption during storage. 'Pinova' is also susceptible to *Colletotricum* in storage. It is susceptible to canker. Full bloom is the most susceptible stage for infection by *N. ditissima* in 'Pinova'. Options to control blossom-end rot include timing of scab or powdery mildew fungicide sprays to full bloom, and canker pruning just ahead of flowering in orchards strongly affected by *N. ditissima* (Holthusen and Weber, 2021).

Pinova sports': 'Dalirail', 'Dalinip' and 'Daligris' (USPP) sports are not being planted.

'Alnova®' (K12586): An early ripening 'Pinova' sport (2-3 weeks earlier).

'Evelina®' ('Roho 3615'): "Surprisingly apple." Carneiro and Baric (2021) found two strains of *Colletotrichum* virulent on 'Evelina' which caused postharvest rots.

'Pink Lady®' ('Cripps Pink'): Climate change and changes in pathogen types appear to be impacting many major cultivars, including 'Pink Lady'. In 2019, a severe outbreak of fruit rot caused by *Colletotrichum fructicola* was noted in commercial 'Pink Lady' apple orchards (>20 ha in total) in Northern Italy. The symptoms were small circular red/brown lesions on the apple. Disease incidences of over 50% of the apples were observed (Wenneker et al., 2021). In 2021, Carneiro and Baric found an additional strain of *Colletotrichum* causing postharvest bitter rot. In 2022, the first report of a different *Colletotrichum* (*chrysophilum)* causing apple bitter rot on 'Pink Lady' was observed in Spain (Cabrefiga et al., 2022). Scald is reduced using 1-MCP. *Alternaria* rot and apple cracking were noted in Israel. Cracking at the calyx, up to 80% was attributed to high temperatures at the early cell division stage. Cracking was reduced by GA_{4+7} and BA treatment (Stern et al., 2015). *Alternaria* was controlled by fungicides (Gur et al., 2020)

'Pink Lady' sports: There are at least a dozen 'Cripps Pink' strains. These include earlier-maturing sports and better-colored sports with names such as 'Rosy Glow', 'Ruby Pink', and many others. The club concept and the provisions concerning "Essentially Derived Varieties" prevent the uncontrolled spread of these strains. 'Rosy Glow' and the New Zealand strain 'Sekzie' are grown in Italy. The differences between both strains are minimal.

'Lady in Red®': This high color mutation of 'Cripps Pink with high coverage of the same bright pink blush, gives exceptional pack outs. It matures one week before Cripps Pink.

'Barnsby' (PLBARB1): Ripens 3 to 4 weeks earlier than its 'Cripps Pink' parent, making it suited to northern growing regions. It is said to have good bud line stability.

'Pirouette®' ('Rubinstep'): A hybrid of 'Clivia' x 'Rubin' bred by Jan Blazek at the Research and Breeding Institute of Pomology in Holovousy, Czech Republic. Moderately vigorous. Upright with a tendency to spread. Keeps up to three months in storage. Somewhat susceptible to scab and powdery mildew. Medium size round flattened. Orange red blush surface with yellowish flesh. Juicy and sweet.

PremA17: See 'Smitten®.'
PremA34: See 'Cherish®'
PremA093- see 'Sassy.'
PremA153': See 'Lemonade®' and 'Honeymoon®.'
PremA280: See 'Sweetie®.'

'RedPop®' (CIVM49): Scab resistance. USPP#32,391 in 2020. 'CIVM49' originated from a cross of 'Crimson Crisp' by 'Mitchgala', a 'Gala' sport. The new cultivar was selected in 2006. The South Tyrolean Fruit Growers Cooperatives (VOG) and the Association of Val Venosta Producers of Fruit and Vegetables (VIP) own the master license for European cultivation rights. VOG was the first to introduce the apple. 'RedPop' has a good storage ability, the fruit is a manageable size, and is an intense red. The flesh is firm, has a very sweet taste and is both juicy and crisp. The flavors are said to range from plum to elderflower to dried fruit and honey. The 'RedPop®' brand slogan is: "Little big sweet." Fruits ripen in mid-August to mid-September but will be stored and marketed after the New Year. The tree is very precocious in bearing, non-biennial, of medium vigor with high and constant productivity. The fruits are very attractive with uniform brilliant deep purple red color which covers the 80% of the surface. However, the outer color bled into the flesh when an apple was sampled in November. It has a very high eating quality, the flesh is fine, crisp, juicy, and has high sweetness (14.5-15.0 °Brix) and medium-low acidity (4.9 g/L malic acid). Excellent storability, up to 6 months under controlled atmosphere, and shelf life up to two weeks. Ripens 10 to 15 days after 'Gala'. The open calyx seen in some apples raises concerns for the potential to develop moldy core.

'Rosalee®' (MAIA-11): USPP#29,146. This cultivar is a 'Honeycrisp' x 'Fuji' cross introduced by the Midwest Apple Improvement Association (MAIA) that harvests two weeks after 'Golden Delicious'. This apple has a clean floral flavor and a crisp texture. It was very susceptible to white rot and brown rot in studies by researchers at The Ohio State University. Graft union breakage with 'Rosalee®' on G.935 rootstock was reported in Indiana. The thin skin of 'Rosalee' prevents commercial packing. MAIA notes that 'Rosalee' is a medium vigor tree with some biennial bearing tendencies and susceptibility to fire blight. Young trees may also have skin cracking followed by susceptibility to summer and storage rots due to the cracking.

'Rubinstep': See 'Pirouette®'.

'Rubis Gold®' (Zouk 31): Zouk 31 is a is a unique golden-yellow apple with an orange-red blush. The orange-pink blush occurs in moderate climates with sufficient difference in temperature. The apple remains golden yellow in hot climates, but the taste and storage are not compromised with production in hot climates. It has a long storage capacity and good shelf life. The apple has a short stem, a thin skin yet it is easy to handle. Zouk 31 has a balanced sweet and sour taste with an intense aroma. The fruits can be stored in CA regime until the end of June, without 1-MCP. Zouk31 has tolerance to scab, a multi-genic trait from one parent. The tree has an open structure with strong apical dominance. The tree structure ensures good exposure of the apples. Most of the fruits get a blush, but this varies depending on the position within the tree. The blush can cover up to 50% of the surface. Harvest time is around 'Golden Delicious'.

'RubyRush™ (NJ150): USPP#33,546. A new release from the apple breeding program at Rutgers University. This 'GoldRush®' x 'Enterprise®' hybrid was selected for its scab-resistance. RubyRush™ also has resistance to fire blight and cedar apple rust. The fruit is said to be juicy and aromatic with a desirable crisp texture. The tree is vigorous and should be thinned to avoid biennial bearing.

'Sambóa® Brand apples: Referred to as the three sisters, Sambóa brand is featuring year- round availability of three apples from the Brazilian Epargi breeding program of Denardi, which targets resistance to *Glomerella* leaf spot and lower chill unit requirements. https://www.samboa.it/ **'**Luiza'-picks with Gala, 'Venice' (SCS426) harvest between 'Gala' and 'Fuji' and 'Isadora' is ripe in late October.

'Sassy': An exclusive of Next Generation apples in NZ. This hybrid from NZ has 'Jazz', 'Fuji', and 'Pacific Rose' in its pedigree. It is a tip bearer and has bare wood. The dark red color can extend into the flesh. Said to be sweet with a "zing."

'Scilate'; See 'Envy®'.
'Shinano Gold': See 'Yello®'.

'Sinfonia®' (YX-4): 'Sinfonia' is from the breeding program in S. Giuseppe di Comacchio (Ferrara), Italy. A hybrid of 'Co-op 25' ('Scarlet O'Hara'), by an unpatented selection ('CIVCP-142)'.'Sinfonia' was selected in 2000. Weak vigor, big fruit size, and good storage are key characteristics. 'Sinfonia' has a mid-season ripening time, high productivity, and precocious fruit bearing. The fruits have an elongated shape. The overcolor is light red over green. The flesh is very firm with fine texture and good juiciness. The flavor is slightly acidic with excellent eating quality. The fruit keeps very well on the tree and in cold storage.

'Smitten®' (PremA17): USPP# 22,356, granted in 2011, so the patent will likely expire in 2030. 'Gala' x 'Braeburn'. I find 'Smitten' to be rock-hard and many fruits resemble poorly colored 'Gala'. They are harvested 2 weeks before 'Tenroy Gala'. The thick club on the end of the stem suggests stem clipping is required. Two new sports are available 'Red Smitten®' Stripe (102543 cv.) and 'Red Smitten®' Blush (102543 s/2 cv.).

'Story®' (Inored cv.): Patent granted in 2012, filed in 2011 so expires in 2031. Created by the Novadi Company in France, this bi-colored apple features a smooth, shiny, dark red over-color on a yellow background. It is very firm and sweet with a well-balanced sugar to acid ratio. The medium vigor tree has fruit well distributed on the tree. It harvests ~15 to 25 days after 'Golden Delicious', or 10-15 days after 'Granny Smith', which eliminates it from consideration in most of NY. 'Story®' is a very productive, scab-resistant apple with an easy-to-grow tree. It is susceptible to powdery mildew and to the pathogen that caused dry lenticel rot (Prencipe et al., 2022). Not prone to preharvest drop. Good storage. 'Story®' may have secondary bloom and variability in fruit size. 'Story' is perceived by some as having low juiciness and very low acidity. The thick skin helps its storage life but can be offsetting to consumers. While 'Story' had smaller fruit size (69 mm) than Galiwa (79.1), it had a higher percentage of surface color (93% vs 43%) (Csihon et al., 2019). Tronel et al. (2015) stressed that 'Story' is an apple cultivar for the south, as a few results recorded in Val de Loire show varietal susceptibility to cool temperatures before harvest, which limits the development of this cultivar to the South of France. According to CEP Innovation - NOVADI, this cultivar is sensitive to low temperature storage (-0,5°C), but a descent in storage temperature from 2.5°C (for one month) to -0.5°C can limit scald. ' Story®' Inored from the same harvest sample stored directly at -0.5°C, showed soft scald linked to low temperatures storage.

'Sugarbee®' (first designated as B-51, but patent name is CN121): Discovered in MN, Regal Fruits has the international rights, with Chelan Fresh growing it in the US. Fruits are firm, crisp, and very sweet.

'Sugar ringo' apples from Japan, present a unique way to market water-cored apples. The varieties 'Haruka', 'Sun Fuji', and 'Shinano Gold' sorted to confirm water core and grown in the Iwate province sold out in Canada in 2 days. Ringo means apple, but the sugar identifies these specific apples as having water core, that water-soaked center caused by a build-up of one specific apple sugar, sorbitol, is considered as a mark of quality by Japanese consumers.

'Summerset®' MAIA12): USPP #29, 213. A hybrid of 'Honeycrisp' x 'Fuji', MAIA12 harvests around the 2nd or 3rd pick of 'Honeycrisp'. MAIA12 apples that meet quality requirements will be sold as 'Summerset®'. The texture is much like 'Honeycrisp' with more tang. Skin flecking like its 'Fuji' parent is evident in some photos.

'SQ159: See 'Natyra®' if grown organically, and 'Magic Star®' if grown conventionally. The name 'Sprank' is used when it is marketed in the Netherlands. Low vigor tree.

'Sunrise Magic®' (WA2). This was also called 'Crimson De-

light': A 2011 release by WA State University that is a hybrid of 'Splendour' x 'Gala'. A low ethylene producer.

'SunSpark®' (GS62): USPP34,206 granted in March 2021. Discovered by Gerard Sundermeyer, in Ottbergen, Germany. The parents of 'SunSpark' were unknown, but DNA tests revealed that the parents are 'Nicoter' and 'Honeycrisp', but it is unclear which is the female or male parent. 'Nicoter is a hybrid of 'Gala' and 'Braeburn' and 'Honeycrisp' is a cross of 'Keepsake' and 'MN 1627'. Due to the weak vigor of both parents, trees may be of low vigor. 'SunSpark' was selected for its taste. The fruits have a crispy and juicy texture. The fruit flesh is cream colored and coarse in texture. The apples can be stored for a long time. Firmness is maintained during shelf life. The skin has 70-90% solid to mottled red coloration over a yellow background, with greater coloration with sun exposure. Lenticels are small but prominent. The fruit surface has shallow dimples and green/golden russeting at the stem end. Production is moderate to heavy with a tendency to alternate bearing, therefore fruit thinning is necessary. The harvest date is the end of September/early October

'Sweet Maia®' (MAIA-SM): This apple is a hybrid between 'Honeycrisp' and 'Winecrisp' (Co-op 31) distributed in 2001 and first fruiting in 2009. It is an early season apple with fall apple qualities. I'm surprised, based on the reported parentage, that it is said to ripen 7-12 days before 'Gala'. It has 80-100% bright attractive red color, and a long harvest window of 14 to 21 days. Not prone to pre-harvest drop, crisp, sweet. Good storage life of 90 days in common refrigerated storage, yet early apples are usually not known for their storage life. Reports from Reality Research on the MAIA website shows that 1-MCP formulations, Retain alone or with Harvista, improved storage performance in controlled atmosphere, but not common storage. The 'Winecrisp' parent is prone to scarfskin and russet, is productive, has small fruit (2.25- to 3-inch fruit) and has some tendency to fruit drop, but it stores well. Like 'Winesap', 'it is said to be more suited for processing. 'Sweet Maia®' can be managed as a 1 or 2 pick harvest. Challenges include potential overcropping with quality and size loss. Some water core is common. They suggest to not leave it on the tree too long, or the flavor suffers.

'SweeTango®' ('Minneiska'): New roadside growers can sell these apples, but not grow them. USPP filed in 2006, so it expires in 2026. 'SweeTango®' apple is grown in five states in the U.S. (Washington, Minnesota, Wisconsin, Michigan, and New York) and in two Canadian provinces (Quebec and Nova Scotia) by a cooperative of 45 members, called the Next Big Thing. They are also being grown internationally. 'Minneiska' growers in northern Germany are challenged by susceptibility to bruising and stem punctures during harvest. Coloring is another challenge, so a pack out of 66 % is said to be realistic, with pack out ranging from 20 to 80%. Japanese beetles: Pires and Koch (2020) looked at Japanese beetle feeding and survival on ST apple fruits and concluded that the adults are not primary pests of apple fruits; however, they may be secondary pests if the flesh of the fruits is exposed by some other agent. Moldy core: Canadian researchers reported on samples shipped from NZ to Canada with the first incidence of moderate to severe moldy core of 'Sweet Tango' caused by *Alternaria arborescens* (Ali et al., 2021). It would be interesting to know if the calyx is more open under NZ conditions, as the cultivar grown in other regions is not prone to moldy core. Postharvest: Tong et al. (2019) found that although stored fruit developed decay and shriveling, no or low incidences of soft scald and soggy breakdown were observed. In general, 'Minneiska' fruit maintained good firmness and soluble solids concentration for up to 3 months when stored in air and for 4 months in CA conditions of 1.5-2.5% O2 and 1.5-2.5% CO_2. Tong et al. (2013) used models to estimate the effect of harvest date and its interactions with post-harvest storage regime on apple fruit firmness. The models indicated that harvest date had little effect on fruit firmness at harvest, regardless of orchard location, and the variance due to year was small. Storage had a large effect on firmness, but the differences between air storage and controlled atmosphere storage were not significant. Simulations were performed to determine the effect of sample size on fixed effect estimates, especially harvest date. Lenticel disorders: Villani et al. (2014) said that varieties with "leaky" lenticels (such as 'Golden Delicious' and 'SweeTango'), act as sugar reservoirs for the epiphytic black yeast, *Aureobasidium pullans*. They advised growers to consider the brand of Captan being used as well as the adjuvants when treating russet-prone cultivars during conditions that are slow drying. Harvest: DeLong et al. (2020) developed an optimal harvest maturity model for 'Minneiska' apple fruit based on the delta-absorbance meter. As the I_{AD} values declined during fruit maturity, the upper boundary value of 0.26 was defined as when to begin harvest, while the lower boundary value of 0.12 was when to end harvest for longer-term storage. Fruit set: Francescatto et al. (2021) examined ethylene evolution of flowers of different apple cultivars and found that 'Minneiska' had a high and sustained level of ethylene just after bloom, which might reduce fruit set. Applications of aminoetoxyvinylglycine (AVG) reduced ethylene and increased fruit set and fruit number per tree. Pollination by drone (Dropcopter) improved fruit set Bruising. Sensitive to bruising and stem punctures. Sunburn threshold lower than 115°F. Mario Miranda Sazo (Cornell Cooperative Extension) reported that pneumatic defoliation in New York improved fruit color and quality on 'Gala', 'Fuji', 'Pink Lady', 'Minneiska' and 'Honeycrisp'. However, for 'Minneiska' and 'Honeycrisp', there was some fruit damage, and too many apples were knocked off the tree. Sazo emphasized the importance of using pneumatic defoliators with narrow (1-2 feet wide) and vertical canopies. Pneumatic defoliators are most effective up to 12 inches into the canopy.

'Sweetie®' (PremA280): The USPP# 19,762 expires July 2026. 'Sweetie' is grown in China under a license with the name 'Charlo'. This apple is a hybrid of 'Braeburn' x 'Royal Gala'. 'Sweetie' ripens about a week before 'Gala' and has larger fruit size. Sweet and very low acid. First Fruits in WA grows 'Sweetie' in the US. Elongated shape.

'Sweet Zinger®' (MAIA-Z). A weak vigor tree and a hybrid of 'Goldrush' x 'Sweet Sixteen'. Floral and extremely sweet. Crunchy, biting chunks of apple. Susceptibility to brown rot (*Monilinia*) was noted in a study by researchers at The Ohio State University.

'Swing' (Xeleven'): Scab resistant and good tolerance to other pathogens. Long storage life. Prone to water core which dissipates in storage. Ripens with 'Fuji'. A product of the Red Moon company. Fruit flesh is prone to browning after cutting.

'Tessa®' ('Fengapi'): 'Tessa' is a cross between 'Gala' and 'Pink Rose'. It is said to have a wonderfully firm bite and juicy, sweet pulp. Fresh Produce News reported that the 215 hectares (531 acres) have been planted in Europe for the 'Tessa' project and will expand to 800 hectares over the next five years. The club cultivar is marketed by many European fruit companies. The Middle East and Asia are potential markets.

'Topaz' is the most widely grown scab-resistant cultivar in the Czech Republic. It is very productive and of high quality. 'Topaz' is slightly susceptible to powdery mildew, but very susceptible to fire blight, *Phytophthora* trunk rot, canker, and *Gloeosporium* rot, which must be considered in the choice of orchard site and orchard management techniques.

'Triumph®'(MN80) (SR): A new apple from the University of Minnesota that is a cross of 'Honeycrisp' x 'Liberty'. MN80 ripens with 'Honeycrisp', to a week later. Scab resistant, dark red color, moderate vigor, thins easier than 'Honeycrisp', bears consistently, medium to large fruit, does not oversize, no signs of bitter pit. Stem bowl russetting may occur. Low to moderate susceptibility to cedar apple rust (CAR), which is a concern in the northeast.

'Tuitti®'(HOT84A1): A selection bred to be resistant to heat and to have a low chilling requirement. It is from the Hot Climate Program (HCP) of Turner and Growers**,** involving collaboration with NZ and Catalonia/Spain. The new apple's parents include two New Zealand varieties: 'Scilate' ('Envy®'), and 'Scired', a sibling of 'Pacific Rose', that is marketed in New Zealand as 'Pacific Queen' or 'New Zealand Queen'. This apple ripens about 2 weeks before 'Fuji'. Fruit Future will be planting trees of HOT84A1 in the next 6 years. 'Tuitti' is the first release from the New Zealand-Catalonia Spain collaborative Hot Climate Program (HCP).

UEB: Selections with this prefix are from the Institute of Experimental Botany of the Czech Academy of Sciences (IEB) that was founded in 1962.

Venice' (SC5426): From the breeding program at Santa Catarina, Brazil. 'Venice' is a hybrid of 'Imperatriz' ('Gala' x 'Mollie's Delicious') × 'Baronesa'('Fuji' x 'Princesca'). The cross was made in 2000. USPP 30,040; 1 Jan. 2019. 'Venice' has ~ 64% red color , 13 °Brix, acidity of 62 Meq L^1 and flesh firmness of 87 N. Susceptible to *penicillium* storage fruit rots. Its fruits are sweet, well balanced, firm, crisp and juicy. It is low chill and resistant to *Glomerella* leaf spot and is part of the 'Samboa' apple brand.

WA 2: See 'Sunrise Magic'. AKA 'Crimson Delight'.
WA 38: See 'Cosmic Crisp'.

'Wellant®' ('Fresco') CPRO47: A niche cultivar for farm shops. Full flavor, and a rustic appearance due to fruit skin russeting, prevalent at the calyx end. 'Wellant' is a hybrid of a Dutch breeding selection by 'Elise' from Wageningen. 'Wellant' has a classic red blush, with full-bodied flavor and size. Its intense flavor and fruity aroma are said to contribute to exceptional fruit quality. Harteveld et al. (2020) showed that it is susceptible to black rot (*Diplodia seriata)* as is the apple cultivars 'Elstar'. Adolphi and Oeser (2022) suggest that fruit mummy removal be considered. Low susceptibility to scab and a low thinning requirement. Susceptible to magnesium deficiency, powdery mildew, and canker susceptibility like 'Jonagold'.

'Wild Twist®' (formerly 'Sweet Cheeks®'. Regal 10-45): https://www.wildtwistapples.com/. A late ripening cultivar, that is a hybrid of 'Honeycrisp' x 'Cripps Pink' developed by Regal Fruit. It has been licensed to Hess Brothers of Lancaster County, PA who are partnering with Rainer in Washington State for a dual coast production which will be split 50/50 across production regions. Because of its late harvest growers need to be cautious in how they manage this cultivar to ensure a timely harvest.

WUR 29: See 'Wurtwinning®'.
WUR 37: See 'Freya®'.

'Wurtwinning®'(WUR 029): USPP# 34,086 granted April 5, 2022. A cross between SQ159 ('Natrya') by 'Honeycrisp'. Late ripening. It is characterized by its upright to outwardly spreading plant habit and its moderate vigorous growth habit, which is surprising given its two low vigor parents. Good yield of high-quality fruits with bright red skin and resistance to scab and powdery mildew. Slight susceptible to core flush caused by low temperatures.

'Yello®'('Shinano Gold') is a cross of 'Golden Delicious' by 'Senshu' made at the Nagano Fruit Tree Experiment Station in Japan, in 1983. The apple was registered and released in 1999. The fruit is sold in Europe, Australia, and parts of Asia under the brand name 'Yello'. In 2015, 10 metric tons of 'Yello' were sold in Europe as a test. 'Yello' is now grown in Italy, where it is purposely differentiated from 'Golden Delicious'. Bloom is early to mid-May and 150-160 days after full bloom are needed to ripen. Harvest is in the middle of October. The color is pale green to yellow. It has excellent storage for 4 months in cold storage. Balanced taste, crisper and more complex flavor than 'Golden Delicious'. However, 'Yello®' fruits may get stem end cracks, like it's 'Senshu' parent. Trees are moderately resistant to *Alternaria* blotch and mildew, but susceptible to scab.

Yx-4: See 'Sinfonia®.'

'Zingy' (HC2-1) is a new hybrid from IFO's breeding program. This attractive, bright red bicolored apple matures with 'Gala'. It has good sugar and acidity levels combined with high firmness and good storage for an early cultivar. HC2-1 is grower friendly, with high and regular yields, good fruit size, good ability to color and a clean skin finish.

Zouk 31: See 'Rubis Gold®'. ZOUK is a Belgian breeding program initiated by the Johan Nicolaï and his family.

Zouk 32: See 'Coryphée®'.

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Preliminary Observations on Storage of MAIA-1 (EverCrisp®)

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Keywords: fruit quality, storage quality, fruit greasiness, fruit crispness, fruit core browning

Storage of MAIA-1 apples at 33ºF resulted in firmer fruits and slower ripening than in fruits stored at 38ºF, but fruits at the lower storage temperature are susceptible to core browning development. 1-MCP at either storage temperature resulted in unacceptable development of physiological disorders. The use of 1-MCP is not recommended.

MAIA-1 (trademark name EverCrisp®) was developed by the Midwest Apple Improvement Association. The variety is a cross between Honeycrisp and Fuji. It is being planted rapidly and there are about three million trees in the ground throughout North America. However, no published information about the storage of MAIA-1 apples is available. Issues that have concerned the industry are water core at harvest and possible associations with breakdown, and flesh and core browning of fruits in storage. In this preliminary study, we have carried out a trial to compare the effects of storage temperature and 1-MCP on the quality and storage disorders of the variety.

Methods

MAIA-1 fruits were obtained from eight orchard blocks on October 30, 2019. The fruits were transported to the Cornell postharvest laboratory where 20 fruit per orchard block were used to assess internal ethylene concentration (IEC), flesh firmness, soluble solids concentration (SSC), titratable acidity (TA), starch pattern index (SPI), I_{AD} (index of difference of absorbance) values and water core incidence.

The remaining 260 fruits were divided into four groups. Two groups were cooled overnight at 33ºF or 38ºF, and 1-MCP applied to one group per treatment. Therefore, there were four independent treatments for each orchard block.

1. 33ºF, no 1-MCP treatment
2. 33ºF, 1-MCP treatment
3. 38ºF, no 1-MCP treatment
4. 38ºF, 1-MCP treatment

Fruits were stored in air for 4 or 7 months and quality was evaluated after 1 and 7 days at 68ºF.

Presentation of results: There was no replication within each orchard block. Therefore, both means for individual orchards and average means for treatments are provided when useful for interpretations of the results.

Results

At harvest The IECs, which reflect ethylene production of the fruits, were generally low (Table 1). The highest IECs were measured in the fruits of the orchard block with the highest water core incidence. Firmness, SSC, TA and SPIs ranged from 19.3-21.8 lb, 12.3-15.0%, 0.47-0.68% and 4.7-6.2, respectively. Fruits were generally of similar greenness, the higher the I_{AD} value, the higher the chlorophyll concentration. Fruits from most orchard blocks had water core but variable, the highest being 50% in block 3.

After storage: Internal ethylene concentration (IEC): The IECs of the fruit after storage for 4 and 7 months plus 7 days at 68ºF are shown in Figures 1A and B, respectively. The IECs indicate the rate of ethylene production, and therefore that ethylene production was lower at 33ºF than at 38ºF at both removal times; that the production was much greater at 7 months than 4 months without 1-MCP treatment; and that 1-MCP greatly suppressed ethylene production although the effects of 1-MCP started to decrease by 7 months. The means for the treatment effects including days 1 and 7 shelf-life results are shown in Table 2.

After storage: Flesh firmness: The flesh firmness of the fruit after storage for 4 and 7 months are shown in Figures 2A and B, respectively. After 4 months of storage, the fruits were about 1 lb softer if stored at 38ºF compared with storage at 33ºF (Table 3). An effect of 1-MCP was not detected 1 day after removal from storage, but 1-MCP treated fruit were firmer than untreated fruit after 7 days. After 7 months of storage, fruit treated with 1-MCP were sometimes higher than untreated fruit if stored at 33ºF, but not in 38ºF where 1-MCP treated fruit were actually softer at day 1 of shelf life.

Table 1. Maturity and quality indices of MAIA-1 fruits from eight orchard blocks in Western NY harvested on October 30, 2019. Indices measured were internal ethylene concentration (IEC), firmness, soluble solids concentration (SSC), titratable acidity (TA), starch pattern index (SPI), I_{AD} (index of difference of absorbance) values and water core (WC) incidence.

Orchard block	IEC (ppm)	Firmness (lb-f)	SSC (%)	TA (%)	SPI (1- 8)	I_{AD} value	WC (%)
1	0.54	20.9	15.0	0.52	5.6	0.91	5
2	0.69	21.8	13.7	0.63	5.9	0.96	0
3	1.13	21.6	15.5	0.68	5.9	1.01	50
4	0.40	19.9	13.2	0.51	6.1	1.21	10
5	0.46	19.3	12.3	0.50	5.1	0.78	20
6	0.57	19.6	13.0	0.50	5.3	1.09	5
7	0.48	19.7	13.8	0.54	6.2	0.85	20
8	0.88	20.3	14.2	0.47	4.7	1.08	25
Average	0.64	20.4	13.8	0.54	5.6	0.99	17

Table 2. Internal ethylene concentrations (ppm) of MAIA-1 fruits untreated or treated with 1 ppm 1-MCP at harvest and stored at 33ºF or 38ºF for 4 or 7 months and evaluated after 1 and 7 days at 68ºF. Different small letters indicate significant differences between means.

Storage temperature (ºF)	1-MCP	4 months		7 months	
		1 d	7 d	1 d	7 d
33	No	3.0b	14.2b	0.16b	24.3b
	Yes	0.4b	0.3b	0.26a	0.3b
38	No	166.1a	193.5a	0.21a	372.5a
	Yes	2.9b	1.5b	0.25a	52.1b

After storage: Soluble solids concentration: No effects of storage temperature or 1-MCP on the SSC was found at 4 months of storage (data not shown). After 7 months of storage, the SSC was lower in fruit stored at 38ºF after 1 and 7 days at 68ºF; 14.7% and 13.7% in untreated and treated, respectively, on day 1, and 14.9% and 14.0% in untreated and treated, respectively, on day 7.

After storage: Titratable acidity: The titratable acidity of the fruits was consistently higher with 1-MCP treatment (Table 4). However, no consistent effect of storage temperature was detected.

After storage: I_{AD} values: The fruits were greener (higher I_{AD} values) at 33ºF than at 38ºF, and after 1-MCP treatment compared with untreated fruits (Table 5).

After storage: Core browning: After four months of storage, the disorder was found only in fruits that had been treated with 1-MCP (Figure 3, 4A). Although more orchard blocks were free of browning at 38ºF than at 33ºF, no statistical effect of tempera-

Figure 3. Core browning of MAIA-1 apples.

Table 3. Flesh firmness (lb) of MAIA-1 fruits untreated or treated with 1 ppm 1-MCP at harvest and stored at 33ºF or 38ºF for 4 or 7months and evaluated after 1 and 7 days at 68ºF. Different small letters indicate significant differences between means.

Storage temperature (ºF)	1-MCP	4 months		7 months	
		1 d	7 d	1 d	7 d
33	No	20.5a	19.8b	19.2b	18.6ab
	Yes	20.8a	20.7a	20.7a	20.1a
38	No	19.5b	19.1c	19.0b	18.5ab
	Yes	19.8b	19.7b	18.5c	18.0b

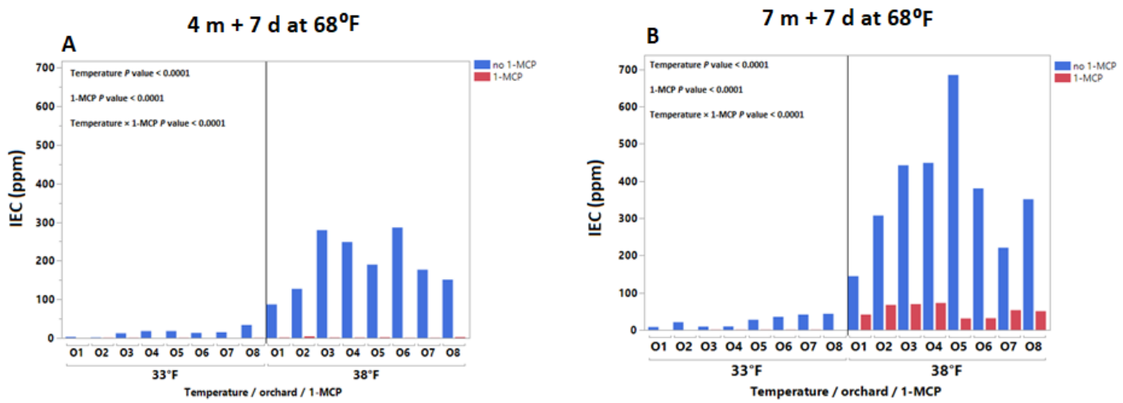

Figure 1. Internal ethylene concentration (ppm) of MAIA-1 fruits untreated or treated with 1 ppm 1-MCP at harvest and stored at 33ºF or 38ºF for 4 or 7

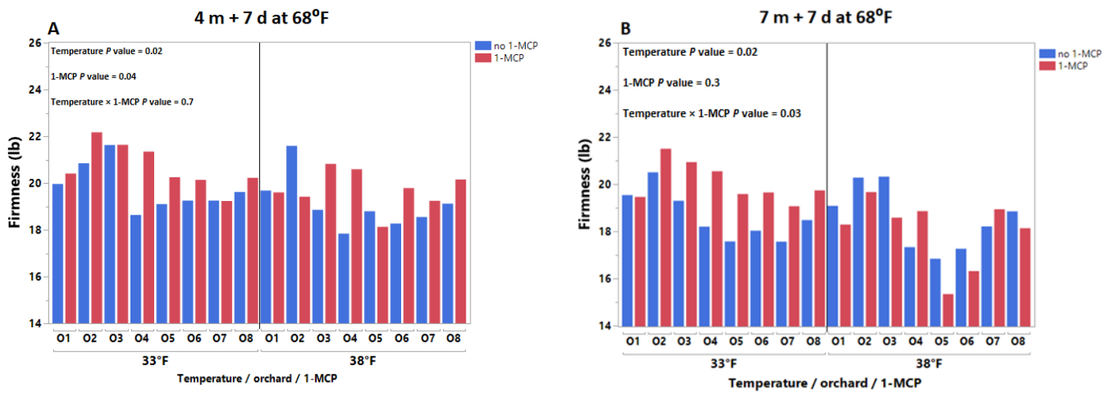

Figure 2. Flesh firmness (lb) of MAIA-1 fruits untreated or treated with 1 ppm 1-MCP at harvest and stored at 33ºF or 38ºF for 4 or 7 months and evaluated after 7 days at 68ºF.

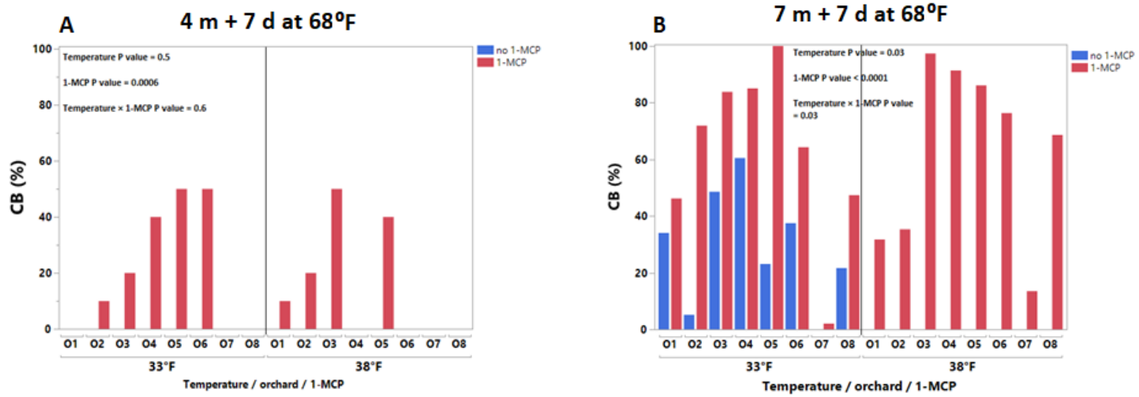

Figure 4. Core browning incidence of MAIA-1 fruits untreated or treated with 1 ppm 1-MCP at harvest and stored at 33ºF or 38ºF for 4 or 7 months and evaluated after 7 days at 68ºF.

Figure 5. Flesh browning of MAIA-1 apples

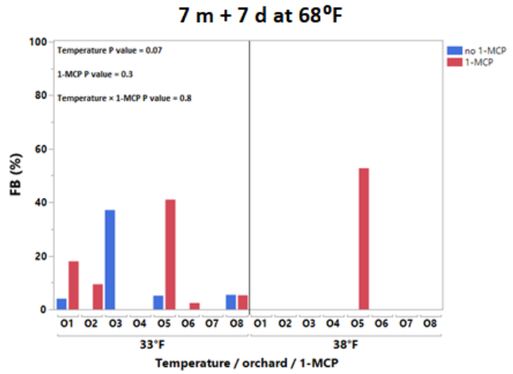

Figure 6. Flesh browning incidence of MAIA-1 fruits untreated or treated with 1 ppm 1-MCP at harvest and stored at 33ºF or 38ºF for 7 months and evaluated after 1 and 7 days at 68ºF.

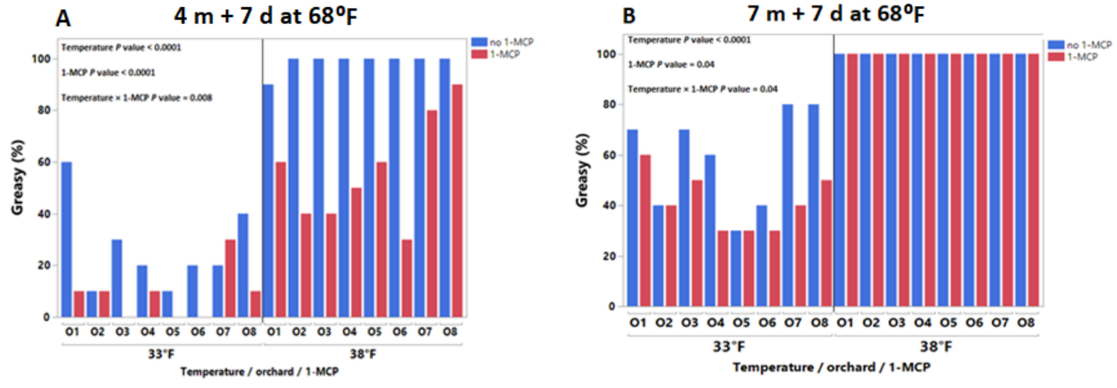

Figure 7. Greasiness incidence of MAIA-1 fruits untreated or treated with 1 ppm 1-MCP at harvest and stored at 33ºF or 38ºF for 4 or 7 months and evaluated after 7 days at 68ºF.

Table 4. Titratable acidity (%) of MAIA-1 fruits untreated or treated with 1 ppm 1-MCP at harvest and stored at 33°F or 38°F for 4 or 7 months and evaluated after 1 and 7 days at 68°F. Different small letters indicate significant differences between means.

Storage temperature (°F)	1-MCP	4 months		7 months	
		1 d	7 d	1 d	7 d
33	No	0.29b	0.24b	0.16b	0.15c
	Yes	0.34a	0.28a	0.26a	0.22b
38	No	0.29b	0.23b	0.21b	0.21b
	Yes	0.34a	0.29a	0.25a	0.24a

Table 5 I_{AD} values of MAIA-1 fruits untreated or treated with 1 ppm 1-MCP at harvest and stored at 33°F or 38°F for 4 or 7 months and evaluated after 1 and 7 days at 68°F. Higher I_{AD} values indicate greener fruits. Different small letters indicate significant differences between means.

Storage temperature (°F)	1-MCP	4 months		7 months	
		1 d	7 d	1 d	7 d
33	No	0.66a	0.53b	0.56b	0.46b
	Yes	0.74a	0.74a	0.65a	0.65a
38	No	0.46b	0.37c	0.31d	0.24d
	Yes	0.52b	0.50b	0.43c	0.42b

ture was detected. After seven months of storage, core browning incidence was very high in the 1-MCP treated fruits, averaging 65% at both temperatures (Figure 4B). In contrast, no core browning was detected in untreated fruits stored at 38°F, while the fruits stored at 33°F had an average of 25% core browning. These results indicate that 1-MCP treatment results in a high risk of core browning development regardless of storage temperature, but storage at 33°F increases the risk of disorder development in untreated fruits. Therefore, 38°F is the appropriate storage temperature for MAIA-1 and 1-MCP treatment should be avoided.

After storage: Flesh browning: No flesh browning was detected after 4 months of storage but was found in fruits from several orchard blocks after 7 months of storage at 33°F and 1-MCP treated fruits from one orchard block stored at 38°F (Figure 5, 6). No significant effects of treatment were detected because of the high variation among fruits from the different orchard blocks. However, the results suggest that 1-MCP treatment of MAIA-1 is unwise and that 38°F is the appropriate storage temperature.

After storage: Greasiness: After four months of storage, greasiness incidence was higher at 38°F than at 33°F, and was lower in 1-MCP treated than untreated fruits (Figure 7A). The incidence of greasiness averaged 18% and 1% in untreated and 1-MCP treated fruits, respectively, at 33°F, and 97% and 71% in untreated and 1-MCP treated fruits, respectively, at 38°F. Greasiness was more pronounced after 7 months of storage (Figure 7B) being 100% regardless of 1-MCP treatment at 38°F, while averaging 41% in 1-MCP treated fruits and 59% in the 1-MCP treated fruits. This difference was significantly different, but this difference is likely commercially irrelevant. Nevertheless, without the concerns about core and flesh browning in fruits stored at 33°F, the benefit of the lower storage temperature would be useful, especially for storage times such as 38°F.

Discussion

MAIA-1 is a remarkably long storability apple, even after 7 months in air storage. The greatest limiting factor to long term storage of MAIA-1 appears to be core browning and to a lesser extent flesh browning at 33°F and at both 33°F and 38°F if fruits are treated with 1-MCP. These results strongly suggest that MAIA-1 is highly sensitive to injuries if stored at low temperatures (as is one of its parents, Honeycrisp). One explanation for the effects of 33°F and 1-MCP at either storage temperature is that ethylene is necessary as part of the defense system that is necessary to protect the cells against free radicals that damage the plant cells. Both 33°F and 1-MCP markedly reduce ethylene production by the fruits.

Unfortunately, the lower storage temperature of 33°F and/or use of 1-MCP does have benefits on fruit quality that are lost at 38°F, most markedly reduced control of greasiness. Greasiness is a problem that is of concern to the industry as it makes removing the skin coating in order to apply wax more difficult. The storage temperature of 38°F can also result in lower flesh firmness and greenness but TA was maintained. However, the firmness of the fruit under storage conditions of 38°F for 7 months is acceptable even without 1-MCP, and certainly higher than would be expected with any of the 'traditional' varieties. Acceptable fruit quality is likely if high quality storages are used.

In conclusion, we recommend a storage temperature of 38°F for MAIA-1 without 1-MCP. However, more research on the storage of the variety is needed, especially to find controlled atmosphere regimes that will maintain quality of the fruit without development of core browning and flesh browning. Brown core is associated with rapid cooling, usually to 32°F, but as with Honeycrisp, may benefit from slower cooling protocols.

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Digital Technologies for Precision Apple Crop Load Management (PACMAN) Part II: An Overview of Digital Technologies Currently Available for PACMAN

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Computer vision and deep learning algorithms are allowing the application of digital technologies to crop load management. We are working with several technology companies to evaluate and guide the development of useful applications that will help growers optimize crop load and crop value.

Precision Apple Crop load MANagement (PACMAN) has been demonstrated as an extremely effective method for optimizing crop load. Adoption has been slow, primarily due to the time and labor constraints required for tedious, repetitive counting and measuring buds, flowers, and fruitlets. We are developing digital solutions to increase the adoption of PACMAN, as part of a 4-year national project, funded by the USDA-NIFA SCRI. This article is a follow-up to our previous articles summarizing earlier work on this project (Robinson et al., 2022; Wallis et al., 2023).

Imaging sensors (e.g., high resolution RGB cameras) have become widely available in our daily life, allowing us to collect numerous images and videos for analysis. Recent breakthroughs in ***artificial intelligence (AI)***, or specifically ***deep learning (DL)***, enable harnessing such image and video data for accurate information extraction such as crop load estimation (Jiang et al., 2020). This article provides explanations of underpinning technologies that are used as partial solutions in PACMAN.

In addition, numerous companies have emerged providing digital technologies including computer vision and other AI-based solutions to PACMAN. In 2021 and 2022, we began identifying these companies and their technologies. The landscape of this industry is rapidly evolving. In this article, we provide a description of several companies and technologies currently available to assist with PACMAN for the 2023 season, based on our experiences with them over the past two years.

For the latest updates, please visit the PACMAN website: pacman.extension.org

Overview of Digital and Computer Vision Technologies for PACMAN

AI-based crop load estimation can be classified into two categories: (1) crop counting of still images and (2) crop counting of image sequences and videos (Figure 1).

Still Image Analysis for Fruit Counting

Regression is the simplest and most straightforward method of fruit/organ counting, from the technical development viewpoint. Deep learning (DL)-based regression models can directly use a still image as input to predict the number of fruits in that image. For example, taking an apple tree image using a smartphone, such a regression model could infer the number of apple fruits in the image. The advantage of this approach is that data annotation is less costly, enabling fast annotation of a large dataset for model training. The major drawback is that fruit location information will not be available for further analysis and operations (such as robotic thinning and picking).

Object detection is an intuitive approach to count fruit and other reproductive organs (e.g., buds and blooms) in still images. Compared with the regression-based approach, object detection identifies and localizes each fruit by drawing a rectangle box in an image, and subsequently, the number of detected boxes is used as the fruit count. The key improvement is that users can easily interpret model inference results because the object detection-based approach mimics human counting behavior from *detection to counting (i.e., see and count)*. Currently, the majority of commercial imaging-based technologies for crop load estimation rely on the object detection-based approach.

Segmentation-based approach has also been investigated for crop load estimation. The key difference compared to the object detection-based approach is that segmentation-based approach identifies individual pixels of a fruit, which is the most accurate

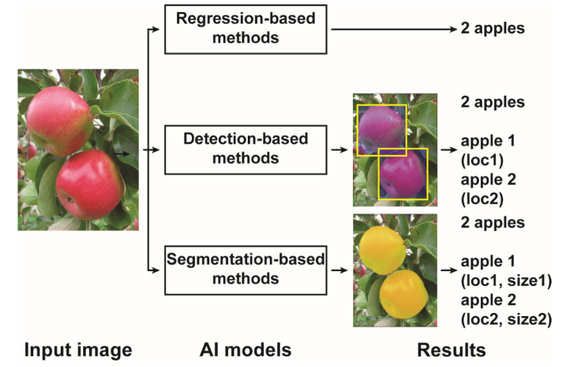

Figure 1. Examples of various techniques for AI-based computer vision solutions to PACMAN. Regression-based models predict only the number of fruits in an input image, detection-based models are capable of providing location information, and segmentation-based models further estimate fruit size information.

approach in terms of characterizing a fruit (e.g., for size estimation). Annotating data for model training, however, is at the pixel level and costly for many agricultural applications and Digital Agriculture (DA) products.

Image Sequence and Video Analysis for Fruit Counting

Although the aforementioned techniques have demonstrated that the detection and counting of plants and plant organs can be fairly accurate in still images, a single image is usually not adequate to cover the plant of tree crops (e.g., an apple tree) or an entire plot of trees. Thus, image sequences and videos need to be acquired, and processing these data requires expanding detection and counting methods. The key challenge of object detection in image sequences or videos is to associate the same object over different images. There are currently two types of methods that address this issue: tracking-based methods and reconstruction-based methods.

The key to ***tracking-based methods*** is to associate detections of the same fruit (a.k.a. correspondence estimation) over consecutive image sequences or video frames so that individual fruits can be tracked to avoid repeated counts.

The key concept of ***reconstruction-based methods*** is the reconstruction of a global coordinate system to which objects detected in individual images can be projected. For 2D reconstruction, global orthoimages (a panoramic view of an entire tree or row) have been reconstructed by mosaicking image sequences or video frames such that sub-images of an entire apple tree could be extracted from the orthoimages. Subsequently, detection-based methods are used to detect and count fruits in the extracted sub-images. For 3D reconstruction (Figure 2), point clouds, a common data format of 3D representation, are obtained using either image sequences or video frames through photogrammetric algorithms or additional optical sensors (e.g., LiDARs). A transformation relationship is established between the 2D images and the obtained 3D point clouds, so that objects detected in 2D images could be projected to the 3D space or vice versa. As detections of the same object would significantly overlap in the 3D space, redundant detections could be eliminated to obtain accurate object quantity. Additionally, 3D reconstruction-based methods enable the extraction of additional information such as 3D location and fruit morphology (e.g., diameter or volume), providing great potential for comprehensive evaluation of fruit development. The 3D reconstruction-based methods are considerably computationally expensive and may not always be necessary for PACMAN.

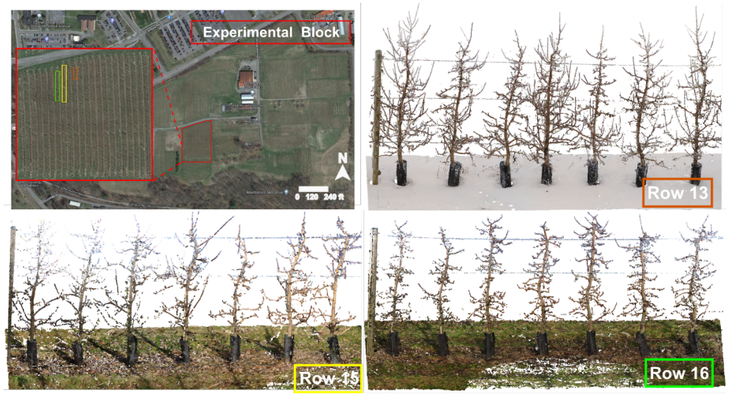

Figure 2. 3D point cloud data collected on different days from an experimental orchard in Cornell AgriTech.

Common Challenges

Many techniques are available for crop load estimation with unique pros and cons, but there are some common challenges affecting all the technologies. Image quality consistency is one of the most important factors to achieving a high counting accuracy. If images collected in your orchards have a comparable quality (e.g., brightness) to the images used for model training, the counting accuracy is likely to be guaranteed. The most commonly used method to improve image quality consistency is the use of active illumination, so that image quality variation due to environmental factors (e.g., sunlight) could be minimized.

Training data size and variation is another important factor for accurate image analysis. Deep learning (DL) models favor using a large dataset for training, so the processing accuracy during model training can be guaranteed to new, unseen images collected from any given orchard. Data annotation can be expensive, however, which could be a barrier for DA products from startups who cannot afford many data annotations. Transfer learning is a model training technique that allows efficient knowledge transfer from one task to a related task. With investments and efforts from large technology giants, large image datasets of common objects in daily life have been freely available for pretraining models with sufficient basic image features or knowledge (e.g., how to detect a circular object). This would considerably reduce the cost of data annotation for apple fruit detection. The latest model can even accurately detect various fruits without any annotation or transfer learning (Meta AI 2023).

Finally, calibration between raw image counts and actual counts is typically required to achieve the best counting accuracy. This calibration considerably addresses miscellaneous issues that cannot be directly modeled such as fruit occlusion. It should be noted that the calibration sometimes can be laborious and time-consuming, but it may provide the needed analysis accuracy for optimizing profits.

Description of Commercial Companies Currently Offering DA Solutions for PACMAN

Numerous companies have emerged in the past several years, offering AI-based computer vision solutions for PACMAN (Table 1). Many of these companies offer additional services. On the next page we provide a brief description of the companies we are currently aware of, currently offering commercial services in the United States. Many were featured in the PACMAN Briefings webinar series in 2023. The recordings of these webinars are available at the following link https://www.youtube.com/playlist?list=PLajA3BBVyv1zc9xkiCSPqj3rEjW2vJ4Yb. These technologies (software and hardware), as well as the companies involved, continue to evolve. Many are in the early stages of development and we expect significant change and growth in this area in the future.

AgerPix Company based in Spain, with representatives in North America. Tractor or ATV-mounted camera system utilizing RGB imaging, deep learning-based data analysis, and LiDAR for crop load/harvest estimations.

Aurea Imaging Company based in the Netherlands, providing orchard variability mapping on a per tree basis, including blossom and vigor maps. These maps are used to direct custom or "prescription" applications, to improve orchard uniformity. Applications include blossom mapping to guide thinning, vigor mapping to inform Apogee applications, root pruning, and variable rate fertilization. Scans are made using drone flights, in collaboration with local aerial agriculture companies or drone pilots.

Fruit Scout Washington-based company with presence in the Eastern US. Uses a handheld smartphone-based application, accompanied by small (2") handheld QR codes for scans. Turnkey solution from bud counting and trunk measurements to yield estimation for continuous adjustment(s) to achieve the target crop load, on a per tree basis.

Green Atlas Green Atlas is an Australian-based company dedicated to assisting tree-crop growers in managing the life-cycle of each and every fruit, on every tree, across their entire orchard. Their latest product, Green Atlas Cartographer, is the innovative combination of hardware and software that allows flower, fruit, weed, pest counts and tree structure to be quickly and accurately mapped over entire orchards.

LaGasse Fabrication and Machining (North American Distributor for Aurea Imaging and Munckhof) A machining company based out of Lyons, NY, and the North American distributor of Aurea Imaging & Munckhof services and equipment.

Munckhof Fruit Tech Innovators Equipment manufacturing company based in the Netherlands, specializing in tools for spraying, harvesting, and bin filling. Precision sprayers utilize drone-based maps to apply custom or prescription applications, on a tree-by-tree basis. Applications include targeted bloom thinning, fruitlet thinning, Apogee applications, etc.

Orchard Robotics Cornell-based start-up located in Western NY. Tractor or ATV-mounted stereo cameras for detecting, counting, and measuring buds, flowers and fruitlets to provide guidance for chemical thinning, using custom stereo camera and deep learning-based data analysis. Data on a per tree basis. No additional in-field equipment is required.

Outfield Company based out of the United Kingdom. Self-flying drone is purchased by the user. Drone flights are programmed and then drone deployed to collect imaging used to map orchard variation, including blossom density, tree vigor and yield variation. Maps illustrate relative variation for an orchard block, rather than per-tree counts. Data may be used by the orchard to make decisions related to thinning, fertilization, and harvest.

Pometa (formerly known as Farm Vision), a company founded by University of Minnesota graduate. Handheld smartphone-based application to detect, count, and measure fruitlets on a per tree basis using video images. Used for thinning applications utilizing fruit growth rate model for fruit set predictions. Also used to make yield predictions near harvest. Markers placed in canopy for geo-locating scans. Now compatible with iPhone Pro (13 or 14 with built in GPS and Lidar) with no external hardware required.

Vivid Machines Company based in Ontario, Canada. ATV or tractor mounted camera system utilizing multi-spectral imaging and deep learning-based data analysis. Provides real-time data on bud, blossom, fruitlet, and crop load information.

Virtual SCRI Educational Extension Activities

This past winter we interviewed three vision system companies for precision crop load management in apples in 2023 and in the future. Our main goal was to learn how these technologies can help NY growers to evaluate their fruit thinning decisions and yield estimations in high density orchards. Here we summarize the responses provided by Dr. Dave Brown and Dr. Patrick Plonski, both from Pometa (formerly known Farm Vision), Jenny Lemieux from Vivid Machines, and Charles Wu from Orchard Robotics.

What are the main applications we can use in 2023? In the next two years?

Pometa: Crop load management (BETA blossom cluster counting, fruitlet counting, growth and predicted abscission, and the Fruit Growth Rate Model); Irrigation (fruit growth rates); Harvest (fruit color, size, and growth, hand scans or ATV mapping (> 1 inch), Harvest forecast by bins/acre and size distribution; Post-harvest (bin scanning); Weather services (frost, heat and dew alerts, station specific forecast).

Vivid Machines: In 2023 blossom counts, fruitlet and fruit sizes, counts to help with thinning and yield prediction, BETA Fruit Growth Rate Model; in 2024-2025 disease detection and pruning insights.

Table 1. Technologies currently available for PACMAN.

Company	Contact Information	Target Applications	Target Growth Stage	Technique Category
Agerpix	Karina Lau | Karina.lau@agrotraction.com | www.agerpix.com	Crop load management / Yield estimation	mature fruit	Proximal Sensing/Rover
Aurea Imaging	https://aureaimaging.com/ | Distributed by LaGasse | https://lagassefab.com/	Variability mapping	growing season	Near-surface Remote Sensing / Drone
Fruit Scout	Chris Hall | chris@fruitscout.ai | https://fruitscout.ai/	Crop load management / Yield estimation	growing season	Proximal Sensing/ Handheld
Green Atlas	https://greenatlas.com/ | info@greenatlas.com US service provider: innov8.ag (WA) | https://www.innov8.ag/ FarmCloud (WA, NY, CA) | https://myfarmcloud.com/	Crop load management / Yield estimation	bloom, small fruit (>20 mm) to preharvest	Proximal Sensing/Rover
Munckhof Fruit Tech Innovators	https://www.munckhof.com/ | Distributed by LaGasse | https://lagassefab.com/	Spraying	growing season	Spraying unit/Ground
Orchard Robotics	Charlie Wu | charlie@orchard-robotics.com | https://www.orchard-robotics.com/	Cropload management / yield estimation	bloom, small fruit to preharvest	Proximal Sensing/Rover
Outfield	Oli Hilbourne | oli@outfield.xyz | https://outfield.xyz/	Crop load management / Yield estimation	bloom and mature fruit	Near-surface Remote Sensing / Drone
Pometa (formerly Farm Vision)	Dave Brown | Dave.brown@metergroup.com | https://pometa.io/	Cropload management / yield estimation	bloom and small fruit to mature	Proximal Sensing/ Handheld
Vivid Machines Inc	Jenny Lemieux | jenny@vivid-machines.com | https://www.vivid-machines.com/	Crop load management / Yield estimation	bloom, small fruit (>10 mm) to preharvest	Proximal Sensing/Rover

Orchard Robotics: In 2023 bud counting, blossom counting, fruitlet counting and sizing from early-stage all the way up until harvest, the size distribution model for precision thinning; in the future we will be looking at expanding into disease detection and early-warning of fire blight.

How accurate have your numbers been?

Pometa: Final crop load is as accurate as hand measurements with the fruit growth rate model; yield estimations for harvest have been within +/- 5% (within ~3 weeks of harvest).

Vivid Machines: 90% accuracy, with variation between farms and varieties.

Orchard Robotics: For full block yields we have demonstrated 93% accuracy. For fruitlets, we are within +/- 10% sizing accuracy at the earliest growth stages, and this accuracy improves throughout the season.

How early can fruitlet size be assessed?

Pometa: 5 mm, 25mm for ATV scans.

Vivid Machines: 10mm.

Orchard Robotics: About 5 mm, accuracy within 10% at 10mm.

What is the set up and ground-truthing process?

Pometa: Install iPhone app. Must use an iPhone 12, 13, or 14 Pro or Pro Max. To reach the top of trees, mount phone on a 3' to 6' long pole. ATV scans require mounting iPhone ~6 ft off ground on a fixed pole attached to the front of an ATV. We recommend a quadlock motorcycle mounting. Install plastic markers (~3 inches) on two trellis posts for reference row segments. For common training systems, ground truth data not required. Detailed vertical scans of reference segments are used to predict occlusion for ATV driving (30 to 60 seconds/scan). For an unfamiliar training system, six individual tree high quality ground truth measurements should be collected throughout the season.

Vivid Machines: Our team conducts the initial farm mapping and software set-up. We also provide a mounting system to attach the camera for scanning that can be left on overnight. The amount of ground truthing is dependent on the amount of an orchard scanned. The person operating the camera can do the ground truthing as it takes as long to count a tree and size a sample of what is on the tree. For 2023, Vivid Machines will be helping by providing ground-truthing as much as possible, as part of the service.

Orchard Robotics: A few minutes to mount the camera to a tractor, gator, or UTV. No additional infrastructure is necessary to start scanning. The system requires a one-time setup of your orchard structure for reference (telling it the name, variety, and location of each block). For accurate absolute data, we highly recommend calibration counts to inform our system's occlusion models. Calibration counts are done by the grower, and the time varies depending on the number of calibration counts and blocks, but calibrating a single block should not take more than an hour of counting.

What is your pricing structure?

Pometa: $100/acre starting price for a minimum 100 acres (unlimited use for the season, per acre price declines substantially with volume); $1000/orchard one-time setup cost.

Vivid Machines: $5000 per year hardware lease and a $80 per acre subscription fee. Talk to us about our 2023 new customer pricing.

Orchard Robotics: Camera system at-cost for $10,000, option to lease a system for $4,000 / year. Free camera upgrades. Software subscription at $96/acre/year. Risk mitigation pricing strategy for first year users.

What is the data collection process and how much of the data collection and processing is automated?

Pometa: Scans are uploaded and processed automatically when iPhone connects to wifi. Hand-held scans of reference segments between two marked trellis posts. Growers set up ~10 of these per block. Scanning takes 30-60 seconds depending on fruit size and post distance. Scans are used to measure fruit growth rates, and to build occlusion models for ATV scanning. During the fruitlet phase, growers scan reference segments every 3-4 days in order to predict fruitlet drop. Ideally, growers scan blocks with an ATV mounting after fruit set to provide the first harvest forecast, then again, an additional 1-2 times before harvest to dial in that forecast. In bin-scanning mode, post-harvest, growers can pass the iPhone over a bin to obtain size and color distributions for their harvest.

Vivid Machines: The user needs to hit 'start/stop' on the recording. Once the sensor is plugged in – all data upload and visualization is automatic. Camera sensor updates are done automatically.

Orchard Robotics: The entire process is automated. Doing an orchard scan is a simple, two-click process: one click to start the scan, and one click to stop the scan. All of the processing is handled automatically after the conclusion of the scan and does not require any additional work from a grower (other than plugging the camera in at the end of the day to recharge!) After the couple of hours of processing time, growers can then view the data on either our provided tablet, or on our website. We supply everything you need to start scanning (tablet to control the camera, the camera system itself, and an external battery + charger).

How long does it take data to be processed into an actionable report?

Pometa: An hour for the reference segment, overnight for ATV full block scans.

Vivid Machines: Immediate data to growers in the orchard on a tablet/phone as soon as they stop recording. The app provides immediate fruit counts, average fruit size/tree, and tree counts. Once the grower connects to the internet, the data gets uploaded to the cloud, and the predictions display on a dashboard by 9am the next morning. This interactive dashboard provides all of the data insights collected to date throughout the season.

Orchard Robotics: We have a very powerful computer inside the camera system that processes all the data on-device, which means that you do not need a fast internet connection to upload tons of data. This also means that data can be returned as an actionable report quickly, usually within 2x the scan time. (i.e., for a 5-hour scan, you will have the data back within 10 hours, and this is something you can leave running overnight).

Can I integrate your hardware/software over my existing equipment?

Pometa: Yes. iPhone can be mounted on ATV or gator.

Vivid Machines: Yes, we have built a mounting system that can be adapted for different farm equipment allowing our sensor to be attached to a variety of vehicles.

Orchard Robotics: No additional infrastructure is necessary to start scanning.

How do we view the data?

Pometa: Web application for data display; iPhone app for data collection.

Vivid Machines: We have an app and a dashboard. The app runs on any phone or tablet. The data is aggregated at a row level at the moment, but individual trees can also be selected. The cloud-based dashboard can be viewed in a website browser and allows growers to get a more extensive view of their orchard. You can filter by date, variety, block etc. The dashboard provides information such as growth curves and size and count distribution.

Orchard Robotics: Scans are run on a tablet app we have developed. This tablet interface lets growers start, stop, and view orchard scans + the status of the camera system. We have a mobile/tablet app to view processed data immediately in the field, as well as a cloud-based website where growers can access, interact with, and export data.

What do you offer in terms of tech support?

Pometa: Remote support for east coast and Midwest growers. Targeted in-field training and support for larger Pacific Northwest producers.

Vivid Machines: We provide field staff to scan and collect ground truth points for growers. Field staff are available to email, call, or message for quick answers. More technical support available should product suggestions or more complicated issues arise. Currently, our field staff communicates with the technical team on behalf of growers.

Orchard Robotics: Full on-site support and servicing whenever a grower needs it – just give us a call and we'll be there!

Future Directions: The DATA Initiative

Despite the development of new digital agriculture (DA) tools, such as crop load estimation systems, the adoption of these technologies has been slow. This hinders the potential environmental and socioeconomic benefits of DA and creates a major obstacle for further innovation in the field. Through the PACMAN extension activities and other efforts, three key barriers to technology adoption have been identified: 1) a lack of objective product evaluation and local performance validation, 2) insufficient strategic planning for technology and business development, and 3) limited educational materials and events for establishing DA literacy and adoption.

Dr. Yu Jiang, Cornell AgriTech, has initiated and is leading a new Digital Agriculture Trials for Adoption (DATA) program that aims to lower these barriers to adoption by 1) building standardized test beds and protocols for DA solution validation; 2) forming communication groups through the current extension channels to engage strategic planning and discussion among DA parties including researchers, developers, entrepreneurs, investors, growers, and stakeholders; and 3) training producers and extension educators with needed knowledge to guide DA adoption with optimal return-on-investment. In 2023, DATA will work closely with the PACMAN SCRI team to set up a trial orchard at Cornell AgriTech, Geneva, NY and conduct performance validation of selected DA solutions to crop load estimation. Currently, DATA in collaboration with the PACMAN team has communicated with eight technology providers. We will periodically update the progress of the product trial evaluation and report a consumer report-style summary via the PACMAN extension events and media channels. We anticipate growers could use the summary to better understand commercial solutions and adopt the suitable one for farm management and operations. Meanwhile, we will organize listening sessions between growers and DA innovators to facilitate the technology adaptation in different geographical locations.

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Fall Pre-emergent Herbicide Timing Results and Takeaways

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Fall applications of either Chateau + Prowl or Alion control weeds as well or better than applications made during the spring when integrated into a season-long weed management program. In addition fall application of herbicides has the potential to relieve time sensitive work in the spring.

In recent years, warmer temperatures late into the fall have given orchard managers good opportunities to apply herbicides after harvest before the ground freezes up. Since spring tends to be a labor-intensive time of year, taking advantage of these warmer fall conditions for pre-emergent herbicide applications is becoming increasingly appealing. The critical time of year for good weed control in both high- and low-density apple plantings occurs from May through July, as this is when weed competition is most likely to reduce tree growth and yield potential (Merwin, 1994: Breth 2014, Breth 2015). Previous research (Breth et al. 2016) found very good efficacy of several pre-emergent herbicide products applied in the fall, with control lasting through the critical weed free period, when used in an integrated weed management program. Products that worked particularly well in fall applications in those trials included Alion, Goaltender, Chateau + Prowl, Sandea + Prowl, Casoron, and Simazine + Diuron.

Building off Breth's 2016 study, our team was interested in comparing the performance of fall- versus spring-residual herbicide programs. Additionally, we wanted to see how much weed control could be achieved using an herbicide program based solely on post-emergence applications of contact and systemic herbicide products.

Materials and Methods

2020 Field trials were established in 2020 at Everett Orchards in Peru, NY, and at Kast Farms in Albion, NY. Both field sites consisted of two rows of NY-1. The Peru site was planted in 2018 on G.935 at 4 by 12ft. The Albion site was planted in 2017 on M.26 rootstock at 3 by 12ft. In 2020, our cooperating growers applied a conventional herbicide program across the full field site. The Peru site was treated on April 21 with 4 oz per acre Grapple (rimsulfuron), 8 oz per acre Sinbar (terbacil), and 2 qt per acre Glystar Plus (glyphosate). On June 2, the Peru site received 3 pt per acre of Gramoxone (paraquat). On August 6, the Peru site received 48 fl oz per acre of Forfeit (glufosinate). Additives (e.g., NIS, water conditioners) were included in spray mixes, as needed, according to label recommendations. On October 27, the Peru plot was hand-weeded to remove well established weed cover to ensure a clean herbicide strip ahead of the first fall applied treatment.

In Albion in 2020, a similar conventional herbicide program was applied across the full field site. The Albion site was treated in April with 2.5 pt per acre Poast (sethoxydim) and 4 oz per acre Matrix (rimsulfuron). Additives (e.g., NIS, water conditioners) were included in spray mixes, as needed, according to label recommendations. The herbicide strip was 4 feet wide at both field sites.

We conducted regular weed scouting throughout the first growing season to better define the Weed species present at each field site. The Peru field site was heavily populated with perennial weeds like quackgrass, perennial sowthistle, milkweed, and white campion. The site also had annuals, such as shepherd's purse, common lambsquarters, and green amaranth. Our Albion field site had much lower weed pressure overall. The strips were mostly populated with winter annual species, such as annual bluegrass, hairy bittercress, common chickweed, common mallow, and common groundsel.

2021Treatments were laid out in a randomized complete block design, and were applied to a block of 12 trees, with five replicates per treatment. Our first fall treatment, which was applied in 2020, consisted of 12 oz per acre Chateau SW (flumioxazin) + 4 qt per acre Prowl H_2O (pendimethalin); applications were made to the Albion field site on October 23 and to the Peru field site on November 6. These treatments also included 48 fl oz per acre of Forfeit or Interline (glufosinate) to burn down existing vegetation. The spring treatments contained the same herbicide mixes and were applied to both sites on March 22, 2021. The post-emergent only treatment received an application of 48 fl oz per acre Interline or Rely 280 (glufosinate) on May 6 in Albion and May 14 in Peru. The Peru fall and spring treatments received an additional application of 48 fl oz per acre Rely 280 on May 26. In Albion, all treatment plots received an application of Mad Dog Plus (glyphosate) at 2.5 qt per acre on July 11. Those products were applied with CO_2 backpack sprayers at each site. Both sites were treated with additional post-emergent herbicides in the late summer, applied across all treatments by the growers using a boom sprayer, to control perennial weeds. Additives (e.g., NIS, water conditioners) were included in spray mixes, as needed, according to label recommendations. Detailed information on all experimental treatments and rates from 2021 and 2022 can be found in Tables 1 and 3 (Peru) and Tables 2 and 4 (Albion).

2022 The fall treatment of 5 fl oz per acre Alion (indaziflam) plus 48 fl oz Interline was applied at our Albion field site on October 22, 2021. In Peru, we applied 5 fl oz per acre Alion plus 48 fl oz Rely 280 on November 4, 2021. Our spring applied treatment of the same materials was applied on April 30, 2022, at both field sites. Our post-emergent only treatment of 48 fl oz of Rely 280 or Interline was applied on May 11 in Peru and on June 25 in Albion. In Peru, our fall applied treatment received an additional application of 48 fl oz of Rely 280 on May 20. In Albion, one follow up application of Interline at 48 fl oz per acre was applied to the spring treatment on July 29. Follow up treatments of 48 fl oz per acre of Interline were applied to the post-emergent only treatment on June 25 and August 18. Additionally, an application of Select Max (clethodim) was applied across all three treatments on June 8. These treatments were applied with a CO_2 backpack sprayer. Additional applications were made in Peru by the grower using a boom sprayer throughout the growing season to control perennial weeds across the field site. These included two applications of 16 fl oz per acre of Select Max on April 26 and May 31. 3 qts per acre of Glystar Plus was applied on July 7, and 3 pts per acre of Gramoxone was applied on August 16. Additives (e.g., NIS, water conditioners) were included in spray mixes, as needed, according to label recommendations.

Cumulative rainfall amounts over the four-week period following each experimental pre-emergent application are detailed in Table 5.

Weed cover, which is defined as the percent (%) area within the tree row occupied by weedy vegetation, was visually estimated for each plot at multiple points during the growing season in each year. In Peru, weed cover was estimated on the following dates:

- 2021: March 16, April 13, May 6, May 17, June 1, June 16, June 28, July 15, July 28, August 10, October 12, and November 15.
- 2022: April 11, May 5, May 18, June 3, June 16, June 28, July 13, July 25, August 12, September 1, and October 12.

In Albion, weed cover was estimated on the following dates:

- 2021: March 10, April 2, April 16, April 26, May 20, June 3, June 16, July 1, July 21, August 3, October 12, and November 19
- 2022: April 9, April 25, May 13, May 28, June 19, June 27, July 11, July 25, August 15, August 30, September 21, and October 14.

Data describing weed cover were analyzed separately for each date at each site using the ANOVA ($p \leq .05$) feature on the Fit Model command on JMP Statistical software. Where significant differences occurred, we assessed treatment differences using the Tukey HSD means separation test ($a = 0.05$). To better describe the suppressive effects of herbicide treatment during the critical weed free period, we then also averaged all weed cover estimates from May through July for each individual plot and analyzed the summary parameters.

Table 1. Applications made to the treatment plots at our Peru field site in 2021. Peach colored applications were applied via CO2 backpack sprayer, while blue treatments were applied across the full plot by the grower with his boom sprayer. Additives (e.g., NIS, water conditioners) were included in spray mixes, as needed, according to label recommendations.

2021 Peru Treatment Calendar			
Date	**Treatment 1: Fall Applied**	**Treatment 2: Spring Applied**	**Treatment 3: Posts Only**
11/6/2020	Prowl 4qt/Acre + Chateau 12oz/Acre + Forfeit 48 fl oz/Acre		
3/22/2021		Prowl 4qt/Acre + Chateau 12oz/Acre + Forfeit 48 fl oz/Acre	
4/27/2021	Poast at 1.5pt/Acre	Poast at 1.5pt/Acre	Poast at 1.5pt/Acre
5/14/2021			Rely 280 48 fl oz/Acre
5/24/2021	Milkweed hand cut	Milkweed hand cut	Milkweed hand cut
5/26/2021	Rely 280 48 fl oz/Acre	Rely 280 48 fl oz/Acre	
6/8/2021	Milkweed hand cut	Milkweed hand cut	Milkweed hand cut
6/16/2021	Poast at 1pt/Acre	Poast at 1pt/Acre	Poast at 1pt/Acre
6/22/2021	Milkweed and rootsucker hand cut	Milkweed and rootsucker hand cut	Milkweed and rootsucker hand cut
6/29/2021	Glystar Plus 2.5qt/Acre + Stinger at 1/3 pt/Acre	Glystar Plus 2.5qt/Acre + Stinger at 1/3 pt/Acre	Glystar Plus 2.5qt/Acre + Stinger at 1/3 pt/Acre
8/6/2021	Milkweed and rootsucker hand cut	Milkweed and rootsucker hand cut	Milkweed and rootsucker hand cut
8/10/2021	Rely 280 70 fl oz/Acre	Rely 280 70 fl oz/Acre	Rely 280 70 fl oz/Acre
10/12/2021	Hand cut	Hand cut	Hand cut
10/28/2021	Gramoxone 2.5pt/Acre	Gramoxone 2.5pt/Acre	Gramoxone 2.5pt/Acre
11/4/2021	Alion 5 fl oz/Acre + Rely 48 fl oz/Acre		

Table 2. Applications made to the treatment plots at our Albion field site in 2021. Peach colored applications were applied via CO2 backpack sprayer, while blue treatments were applied across the full plot by the grower with his boom sprayer. Additives (e.g., NIS, water conditioners) were included in spray mixes, as needed, according to label recommendations.

2021 Albion Treatment Calendar			
Date	**Treatment 1: Fall Applied**	**Treatment 2: Spring Applied**	**Treatment 3: Posts Only**
10/23/2020	Prowl 4qt/Acre + Chateau 12oz /Acre + Interline 48 fl oz/Acre		
3/22/2021		Prowl 4qt/Acre + Chateau 12oz /Acre + Interline 48 fl oz/Acre	
5/6/2021			Interline 48 fl oz/Acre
7/11/2021	Mad Dog Plus 2.5qt/Acre	Mad Dog Plus 2.5qt/Acre	Mad Dog Plus 2.5qt/Acre
8/19/2021	Interline 80oz/Acre	Interline 80oz/Acre	Interline 80oz/Acre
10/22/2021	Alion 5oz/Acre + Interline 48 fl oz/Acre		

Table 3. Applications made to the treatment plots at our Peru field site in 2022. Peach colored applications were applied via CO2 backpack sprayer, while blue treatments were applied across the full plot by the grower with his boom sprayer. Additives (e.g., NIS, water conditioners) were included in spray mixes, as needed, according to label recommendations.

2022 Peru Treatment Calendar			
Date	**Treatment 1: Fall Applied**	**Treatment 2: Spring Applied**	**Treatment 3: Posts Only**
11/4/2021	Alion 5 fl oz /Acre + Rely 280 48 fl oz/Acre		
4/26/2022	Select Max 16 fl oz / Acre	Select Max 16 fl oz / Acre	Select Max 16 fl oz / Acre
4/30/2022		Alion 5 fl oz /Acre + Rely 280 48 fl oz/Acre	
5/11/2022			Rely 280 48 fl oz/Acre
5/20/2022	Rely 280 48oz/Acre		
5/31/2022	Select Max 16 fl oz / Acre	Select Max 16 fl oz / Acre	Select Max 16 fl oz / Acre
6/3/2022	Milkweed hand cut	Milkweed hand cut	Milkweed hand cut
6/16/2022	Milkweed hand cut	Milkweed hand cut	Milkweed hand cut
6/28/2022	Milkweed hand cut	Milkweed hand cut	Milkweed hand cut
7/7/2022	Glystar Plus 3qt/Acre	Glystar Plus 3qt/Acre	Glystar Plus 3qt/Acre
8/12/2022	Milkweed and rootsucker hand cut	Milkweed and rootsucker hand cut	Milkweed and rootsucker hand cut
8/16/2022	Gramoxone 3pt/Acre	Gramoxone 3pt/Acre	Gramoxone 3pt/Acre

Results and Discussion

2021 Overall, the weedy vegetation cover at the Peru site was variable throughout the growing season, and consistent differences were not observed among herbicide treatments (Figure 1, Table 6). The number of perennial weeds present at the site obscured possible differences that would have resulted from suppression in annual weed emergence and establishment. All programs in Peru required multiple follow up applications of post-emergent materials, as perennial weed species emerging from vegetative below ground weed structures were not controlled by either our fall or spring pre-emergent applications to target germinating weed seedlings.

In Albion, weed cover was significantly lower in the fall applied treatment on our first spring sampling date of March 10, showing that the fall application was effective at preventing the establishment of weeds, particularly winter annual species (Figure 2, Table 7). These residual effects from the fall treatment extended into summer. The spring application (applied on March 21) took a few weeks to take effect; by April 16, there was no difference between spring or fall applied treatments, and both had lower weed cover than the post-emergent only treatment. Spring-applied residual herbicide efficacy broke down more rapidly compared to the fall treatment. On average across the weed free period the fall applied treatment had the least weed cover, while the spring applied and post-emergent only treatments were equivalent.

2022 In Peru, average weed cover in fall pre-emergent treatment plots was less than 10% for all observation dates (Figure 3, Table 8). Fall-applied Alion appeared to do a very good job at preventing winter annuals from germinating in the early spring and continued to control seedling emergence throughout the majority of the 2022 growing season better than, or as well as, the spring application. Weed cover in the spring-applied herbicide plots was significantly reduced compared to the post-emergent

Table 4. Applications made to the treatment plots at our Albion field site in 2022. Additives (e.g., NIS, water conditioners) were included in spray mixes, as needed, according to label recommendations.

2022 Albion Treatment Calendar			
Date	Treatment 1: Fall Applied	Treatment 2: Spring Applied	Treatment 3: Posts Only
10/22/2021	Alion 5 fl oz /Acre + Interline 48 fl oz/Acre		
4/30/2022		Alion 5 fl oz /Acre + Interline 48 fl oz/Acre	
6/8/2022	Select Max 16 fl oz / Acre	Select Max 16 fl oz / Acre	Select Max 16 fl oz / Acre
6/25/2022			Interline 48 fl oz/Acre
7/29/2022		Interline 48 fl oz/Acre	
8/18/2022			Interline 48 fl oz/Acre

Table 5. Weekly cumulative rainfall amounts following each pre-emergent application.

Cumulative Rainfall Following Applications (Inches)					
Treatment	Application Date	1 Week	2 Weeks	3 Weeks	4 Weeks
Albion Fall 2020	11/6/2020	0.57	0.83	1.02	1.95
Albion Spring 2021	3/22/2021	0.95	1.23	2.84	3.52
Albion Fall 2021	10/22/2021	2.35	3.55	3.74	4.66
Albion Spring 2022	4/30/2022	0.38	0.38	0.60	1.19
Peru Fall 2020	11/6/2020	0.00	0.44	0.90	1.42
Peru Spring 2021	4/27/2021	4.07	4.78	4.93	4.95
Peru Fall 2021	11/4/2021	0.06	0.61	0.69	1.09
Peru Spring 2022	4/30/2022	0.36	0.36	1.32	1.57

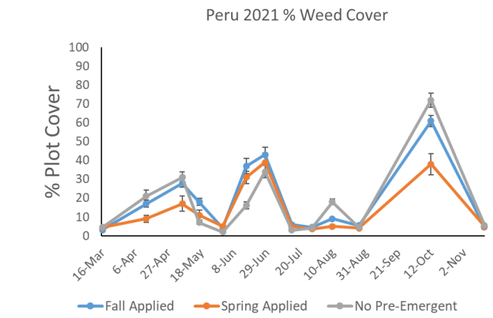

Figure 1. 2021 weed cover in Peru following fall applied Chateau + Prowl, spring applied Chateau + Prowl, and a post-emergent only program. Additional post-emergent applications were made on each plot as needed.

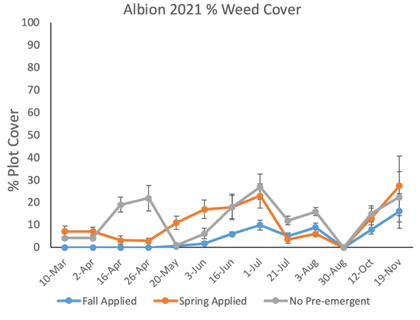

Figure 2. 2021 weed cover in Albion following fall applied Chateau + Prowl, spring applied Chateau + Prowl, and a post-emergent only program. Additional post-emergent applications were made on each plot as needed.

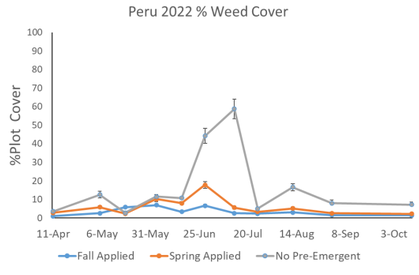

Figure 3. 2022 weed cover in Peru following fall applied Alion, spring applied Alion, and a post-emergent only program. Additional post-emergent applications were made on each plot as needed.

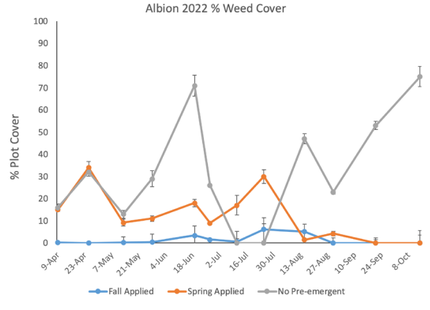

Figure 4. 2022 weed cover in Albion following fall applied Alion, spring applied Alion, and a post-emergent only program. Additional post-emergent applications were made on each plot as needed.

Figure 5. The Peru field site on August 12, 2022. The plot on the left is the post-emergent only treatment covered with green amaranth, while the plot on the right is the fall-applied Alion treatment with only a few quackgrass present.

Table 6. The percent weed cover of the three herbicide treatments in Peru, NY in 2021. Statistics were analyzed using the Standard Least Squares with Restricted Maximum Likelihood options in the Fit Model feature in JMP Statistical Software. Data were log transformed where appropriate. Means with different letters are significantly different according to Tukey's Honestly Significant Difference (HSD) Test.

% Weed Cover															
Treatment	Nov 20 2020	16-Mar	13-Apr	6-May	17-May	1-Jun	16-Jun	28-Jun	15-Jul	28-Jul	Weed Free Period Avg	10-Aug	27-Aug	12-Oct	15-Nov
Fall Applied	6	3	17 AB	28 AB	18 A	4 A	37 A	43	6 A	5	23	9 B	5	61 A	5
Spring Applied	6	4	9 B	17 B	11 AB	5 A	31 A	39	5 AB	4	17	5 C	4	38 B	5
No Pre-Emergent	6	5	21 A	31 A	7 B	2 B	16 B	34	3 B	4	16	18 A	5	72 A	6
P-Value	0.9285		0.0345	0.0155	0.0069	0.0147		0.4759	0.0047		0.0583		0.293	0.0036	0.338
Log P-Value		0.416					0.0081			0.3166		.0005			

Table 7. The percent weed cover of the three herbicide treatments in Albion, NY in 2021. Statistics were analyzed using the Standard Least Squares with Restricted Maximum Likelihood options in the Fit Model feature in JMP Statistical Software. Data were log transformed. Means with different letters are significantly different according to Tukey's Honestly Significant Difference (HSD) Test.

% Weed Cover													
Treatment	10-Mar	2-Apr	16-Apr	26-Apr	20-May	3-Jun	16-Jun	1-Jul	21-Jul	Weed Free Period Average	3-Aug	30-Aug	12-Oct	19-Nov
Fall Applied	0 B	0 B	0 B	0 B	0.6 B	1.8 B	6A	10 B	5.2 AB	4.6 B	9 AB	0	8	16.25
Spring Applied	7.2 A	7.2 A	3.2 B	3 B	11A	17 A	18 A	23 AB	3.6 B	14.4 A	6 B	0	13	27.5
No Pre-Emergent	4.2 A	4.2 A	19 A	22 A	1 B	6.2 B	18 A	27 A	12A	12.6 A	16 A	0	15	22.5
P-Value	0.001	0.0001	0.0003	0.0003	<0.0001	0.0022	0.0414	0.0242	0.0489	0.0173	0.0085		0.488	0.9785

Table 8. The percent weed cover of the three herbicide treatments in Peru, NY in 2022. Statistics were analyzed using the Standard Least Squares with Restricted Maximum Likelihood options in the Fit Model feature in JMP Statistical Software. Data were log transformed where appropriate. Means with different letters are significantly different according to Tukey's Honestly Significant Difference (HSD) Test.

% Weed Cover													
Treat	15-Nov	11-Apr	5-May	18-May	3-Jun	16-Jun	28-Jun	13-Jul	25-Jul	Weed Free Average	12-Aug	1-Sep	12-Oct
Fall Applied	5	1 B	2.6 C	5.8 A	7 B	3.4 C	6.6 C	2.6 C	2.4 B	4.3 C	3 C	1.6 B	1.4 B
Spring Applied	5	2.8 A	5.8 B	2.4 B	10.2 AB	8 B	17.8 B	5.6 B	3.4 B	7.6 B	5.2 B	2.6 AB	2.2 B
No Pre-Emergent	6	3.6 A	12.6 A	2.8 B	11.6 A	10.8 A	44.2 A	58.8 A	5.0 A	20.8 A	16.6 A	8.0 A	7.2 A
P-Value	0.338			0.0026	0.0174	<.0001			0.0048				
Log P-Value		<.0001	<.0001				<.0001	<.0001		<.0001	<.0001	0.0131	<.0001

Table 9. The percent weed cover of the three herbicide treatments in Albion, NY in 2022. Statistics were analyzed using the Standard Least Squares with Restricted Maximum Likelihood options in the Fit Model feature in JMP Statistical Software. Means with different letters are significantly different according to Tukey's Honestly Significant Difference (HSD) Test.

% Weed Cover													
Treatment	9-Apr	25-Apr	13-May	28-May	19-Jun	27-Jun	11-Jul	25-Jul	Weed Free Period Average	15-Aug	30-Aug	21-Sep	14-Oct
Fall Applied	0.2 A	0 A	0.2 A	0.4 A	3.4 A	1.6 A	0.6 A	6.2 A	2.07 A	5.2 A	14 AB	17 A	16 A
Spring Applied	15 B	34 B	9.2 AB	11 AB	18 B	9 B	17 B	30 B	15.7 B	1.4 A	4.2 A	7 A	11 A
No Pre-Emergent	16 B	32 B	13 B	29 B	71 C	26 C	1 A	11 A	25.2 C	47 B	23 B	53 B	75 B
P-Value	0.0271	0.0007	0.0107	0.0078	<0.0001	<0.0001	0.0018	0.0024	0.0002	0.0017	0.0496	0.0014	<0.0001

only treatments on May 5, June 16 through August 12, and October 12. Averaged across the weed free period, greater reductions in weed cover were observed in the fall-applied treatment. In this trial, fall-applied Alion appeared to do a very good job at preventing winter annuals from germinating in the early spring and continued to control seedling emergence throughout the majority of the 2022 growing season better than or as well as the spring application (Figure 5).

In Albion, weed cover was significantly lower in the fall applied treatment relative to the other treatments for most of the growing season (Figure 5, Table 9). With respect to the critical weed free period, the fall applied treatment had the least amount of weed cover, followed by the spring applied treatment. Similar to 2021, the fall pre-emergent herbicide application timing was best for suppressing weed ground cover in this location, where winter annuals were the predominant weed species.

Conclusions and Considerations

Given these results, we conclude fall applications of either Chateau + Prowl or Alion control weeds as well or better than applications made during the spring when integrated into a season-long weed management program. We recommend making fall applications of pre-emergent herbicides where your herbicide strips are clean enough and weather conditions are favorable. If your strips are weedy heading into the fall, you could apply a post-emergent material a week or two ahead of your pre-emergent application, but you will need to weigh the time and labor costs associated with two separate fall herbicide applications. Applications should be made prior to ground freeze up, which may be difficult in years with an early winter, particularly now as more late season varieties keep us harvesting some blocks into early November.

Previous work by Deborah Breth, Dan Donahue, and Anna Wallis also found good efficacy from fall applications with the following materials/combination of materials.

- Chateau (mostly annual broadleaves and some grasses) + Prowl (mostly annual grasses)
- Alion (annual broadleaves and grasses)
- Sandea (annual broadleaves and sedges) + Prowl (mostly annual grasses)
- Goaltender (annual broadleaves and some grasses)
- Simazine (mostly broadleaves) + Diuron (broadleaves and grasses)
- Sinbar (annual broadleaves)
- Casoron (annual broadleaves and grasses)
- Matrix (annual broadleaves and grasses)

Here are a few suggestions if you would like to apply pre-emergent herbicides this fall:

- **Choose materials that fit your weed species composition** – different materials work better on different weed species. Scout your orchards and see what your most problematic weeds are when deciding on which materials to apply. Our herbicide lookup table can help you select which materials to use.
- **Tank mix materials** to get the full spectrum of control that you need, as few products will likely control all your weed species present**.**
- **Adjust your rates by your soil textures –** product efficacy is going to be impacted by your soil textures. Many products contain a range of rates by soil texture, follow this closely to maximize efficacy and to reduce the risk of negative impacts to your trees.
- **Apply to as clean of a strip as possible –** Many pre-emergent materials need to reach the soil surface, so applying them on top of a weedy strip is going to greatly reduce your control. In Peru, we went through two weeks ahead of our Alion application with paraquat to burn down the vegetation that had come up during harvest. We applied the Alion two weeks later, after the vegetation had time to burn back and expose the soil surface.
- **Pay close attention to weather requirements –** Pre-emergent herbicides are finicky materials. Most need to go on prior to soil freeze up. Treatments should receive enough water (at least 0.5") within 7 to 10 days after application so that herbicide can be "activated" (penetrate into the ground and dissolved into the soil solution) and protected from photo-degradation or volatilization. Check the labels closely to make sure you are applying them under (as close to) ideal conditions as possible.
- **Apply with a "conventional" fixed-boom sprayer** calibrated to accurately deliver 40 to 60 gals. of water/A using flat fan nozzles and 30 to 40 psi, unless otherwise stated.
- **Don't rely on one application to give season long control** – Like any IPM program, the best control is going to be gained by using multiple tools from the toolbox. Use a variety of tactics (pre-emergent materials, timely burndown applications, well-timed systemic materials) to manage your weeds season-long.

Fall weed control has the potential to relieve time sensitive work in the spring, while providing similar levels of weed control to applications made in the spring. Like many chemical applications though, the best efficacy will be from following the label closely, paying close attention to the weather ahead of the application, and applying them to a clean herbicide strip in the fall. Rather than relying on the fewest applications possible, manage your weeds throughout the growing season with multiple tactics to keep your problematic weeds in check.

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High-Tannin Apple Supply and Demand in North America: Results from a 2021 Cider Industry Survey

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The current supply chain for high-tannin cider apple cultivars is fragmented and not well quantified. Our survey work showed that high-tannin apples account for a small percentage of the total fruit or juice used in ciders. Problems with the supply of high-tannin apples include limited acreage, recency of plantings, and biennial bearing.

As the North American hard cider industry has grown rapidly in the last decade, producers have been seeking specialized cider apple cultivars that contain high tannin concentrations. Many of these cider cultivars originated in England and France but are now grown in North America. Tannins are phenolic compounds that add bitterness and astringency, and thus complexity, to cider (Merwin et al. 2008; Valois et al. 2006). Several reports suggest that demand for these high-tannin apples among cider producers greatly exceeds supply (Pashow 2018; Raboin 2017; Weinstock 2016). Supply chain challenges are likely due to the limited number of acres of high-tannin cider apples planted in the North America. Additionally, cider cultivars are often prone to extreme biennial bearing, meaning that the trees over-produce in one year and have little to no crop the following year (Bradshaw et al. 2020; Green 1987; Hedden et al. 1993; Hoad 1978; Merwin 2015; Wood 1979). The impact of biennial bearing on cider apple supply, and thus commercial cidermaking practices in North America, has not been documented.

Cider supply chains have been explored on a state or regional basis (Becot et al. 2016; Pashow 2018), but the larger picture in North America has not (Peck and Miles 2015). How cider producers source these apples (growing their own or buying from grower partners), and geography, likely have different effects on profitability, and perhaps cider style, from region to region. To gain a better understanding of the supply and demand for high-tannin (i.e., bitter) cider apples in North America, we conducted phone interviews and an online survey with both apple growers and cider producers.

Methods

In May 2019, a random selection of North American commercial cider producers and orchardists listed on Cydermarket.com (now defunct) were interviewed by phone about a wide range of topics, including what apple cultivars they grow and/or use in their ciders, annual production volume and sales, prices they pay or charge for apples and/or juice, and how they respond to inconsistent apple availability. Thirty phone interviews were conducted with commercial cidermakers and grower partners in 2019, using a standardized script, occasionally asking clarifying questions. A set of recurring issues were then identified and compiled into a standardized questionnaire using Google Forms.

The Google Form questionnaire was distributed beginning on 31 March 2021, and was closed on 15 May 2021. Commercial cideries across the U.S. and Canada were identified via the American Cider Association (ACA) website, as well as various state and province association websites and sent a standard email. At least one follow-up email was sent to producers who did not respond within 7 days. The American Cider Association further advertised the survey on its website on 30 April 2021, also promoting the notice via their Facebook, Twitter, and Instagram accounts. Of those emailed (372), there was a 49% response rate.

In the survey, the term "bitter" was used rather than "high-tannin" because commercial cidermakers and growers may not think of tannins in numeric terms or use lab testing services. We use "bitter" and "high-tannin" interchangeably in this article.

Demographic data was not collected systematically, but interviewees and respondents skewed male, though many head cidermakers and orchardists were female. Grower interviewees who sell high-tannin fruit to cidermaker partners were overwhelmingly male. Some respondents did not identify themselves over email, and a few filled out the survey without identifying their company.

Table 1. Total number of survey responses by state and province

State/Province	Responses per state/province
California, New York, Oregon	15
Pennsylvania	13
Massachusetts, Virginia	12
Ontario	10
Michigan, Minnesota	9
Washington	7
Wisconsin	6
Colorado	5
British Columbia, Montana, New Hampshire, North Carolina, Nova Scotia	4
Arizona, Connecticut, Iowa, Maine, Ohio	3
Georgia, Illinois, Indiana, Kentucky, Maryland, Nebraska, New Mexico, Utah	2
Alabama, Delaware, Idaho, Louisiana, Manitoba, New Brunswick, New Jersey, North Dakota, Rhode Island, South Dakota, Tennessee, Texas, Vermont	1
No answer	6
Total (43 States and Provinces)	**198**

Percentages were calculated by Google Forms for questions that did not include a written response. Written responses were exported to Microsoft Excel to be standardized, particularly for cultivar name spelling, prior to analysis. In such cases, percentages were calculated in Excel.

Results and Discussion

Cidery Location, Production, and Distribution There were 198 responses from 37 states and six provinces (Table 1). The most represented states were California, New York, and Oregon (15 each); Pennsylvania (13); and Virginia and Massachusetts (12 each). Ontario had the most respondents (10) for Canada. A majority of respondents (83.7%) were primarily cideries, and 11 (5.6%) were primarily wineries. The remainder were breweries, meaderies, or distilleries who also produce cider. About two-thirds (64%) of respondents self-reported being located in "rural" locations, the rest identified their location as "urban".

Annual scale of production varied widely (Table 2). Of 195 respondents (three did not answer), nearly two-thirds reported producing 10,000 gal/year or less, and one-quarter (24.6%) reported producing between 10,000–50,000 gal/year. Large-scale producers represented a small minority of respondents, even though they produce the majority of cider in North America (Beverage Industry Magazine 2023).

Of 195 respondents (three did not answer), 74% reported having a tasting room or taproom, and 15% reported they were building one or planning to do so. These figures are similar to those reported by Pullman (2015) and Snyder (2016). In the mid-Atlantic region, a mere 16% of consumers reported purchasing cider at tasting rooms (Snyder 2016). Taprooms in North America can often be a venue to introduce consumers to a product and build a relationship, but the majority of cider is sold off-premises in retail stores.

Use of High-Tannin Apples Sixty-nine percent of all respondents reported using some "bitter" apples, including juice or concentrate, in their cider; an additional 16.7% said they plan to do so in the future (Table 3). Of those currently using "bitter" apples (137 responding), 55.5% reported growing their own, with another 17.8% planning to in the future. Approximately one-fourth (27%) said they do not grow their own "bitter" apples. Almost half (46.2%) reported that these represent 10% or less of all their apple-based inputs (including juice and concentrate). Only 6% stated that "bitter" fruit/juice constituted the majority (>50%) of their raw material (Table 4). This agrees with Pashow (2018), who reported that among New York State cideries, bittersharp and bittersweet cultivars represented 9% and 10%, respectively, of apples used, the rest being split between "sweet" and "sharp." Though consumers may be receptive to more tannic ciders (Tozer et al. 2015), ciders made solely from high-tannin cultivars may also be perceived as excessively bitter or astringent (Dawson et al. 2019). Thus, relatively low proportion of high-tannin apples being used may not be entirely due to supply, but also to consumer preferences.

Among those who reported they do not use "bitter" fruit, juice, or concentrate (61), the leading reason was lack of availability (60%), while cost was one of the least-cited reasons. Only eleven respondents reported lack of interest. About one-third reported they intend to source or plant "bitter" apples in the future, with three reporting that their trees were planted but weren't bearing fruit yet. Previous surveys in New York, Vermont, and the Midwest also found lack of availability to be a leading concern for cidermakers working with high-tannin cultivars (Becot et al. 2016; Pashow 2018; Raboin 2017).

Size and Age of High-Tannin Apple Orchard Plantings The reported size of high-tannin cider apple plantings ranged from 0.2 to 20 acres (65 responding), though 89% or respondents reported having 5 acres or less of these cultivars (Figure 1). When asked if their "bitter" cultivars have come into production (89 responding), one-third (32.6%) said "Yes", and 47.2% said "Some". When asked if their plantings of "bitter" apples were currently experimental (90 responses), 50% answered "Yes", with another 15.6% saying their plantings started out that way; only one-third (34.4%) chose "No". The recency of most "bitter" cider apple plantings agrees with other surveys (Miller et al. 2020; Pashow 2018) and underscores the need for research-based cultivar recommendations, as well as more extension-based resources on best management practices for cider apple orchards.

Table 2. Annual scale of production (gal/year or L/year) reported by survey respondents.

Scale of Production (gal/year)	Scale of Production (L/year)	Percentage of Respondents (n=195)
<1,000	<3,800	10.3%
1,000-5,000	3,800-19,000	36.9%
5,000-10,000	19,000-38,000	17.9%
10,000-50,000	38,000-190,000	24.6%
50,000-250,000	190,000-950,000	7.7%
250,000-500,000	950,000-1.9 million	0.5%
500,000-1 million	1.9-3.8 million	0.5%
>1 million	>3.8 million	1.5%

Table 3. Percentage of respondents who do, or do not, report using some high-tannin apples in their cider.

Response	Percentage of Respondents (n=198)
Yes	68.7%
No	14.6%
Plan to use	16.7%

Table 4. Proportion of respondents' total raw material (fruit, juice, or concentrate) that comes from high-tannin cider apple cultivars.

Response	Percentage of Respondents (n=132)
10% or less	46.2%
11-25%	27.3%
26-50%	20.5%
51-75%	4.5%
76-100%	1.5%

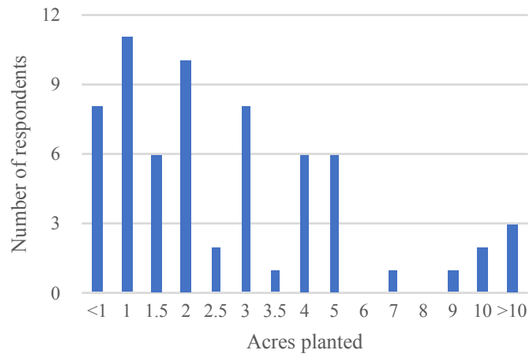

Figure 1. Reported size (in acres) of bitter apple plantings reported by survey respondents (n=65 responses).

High-Tannin Apple Cultivars Being Grown When asked how many bittersweet or bittersharp cultivars they grow (87 responding), 23% did not give a number; the rest gave an exact number or estimate. Most reported having many planted, often between eleven and twenty; a mere five respondents reported growing only one or two "bitter" cultivars (Figure 2). There was no clear trend between how many years a respondent had been growing these cultivars and how many cultivars they reported. Nor was

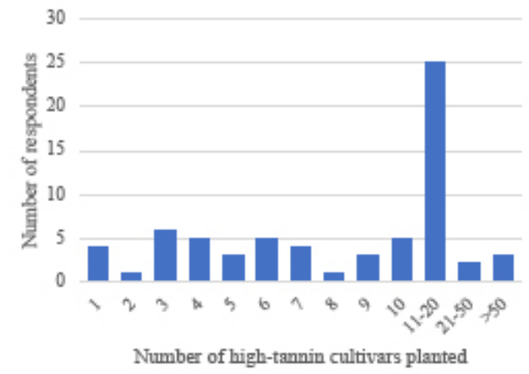

Figure 2. Number of different high-tannin ("bitter") cultivars being grown by survey respondents (n=65 responses).

there a clear trend between number of acres planted and number of cultivars: both large- and small-scale cider apple orchards have diversified plantings. Growing many different cultivars can allow new growers to identify those best suited to their site, and help growers at all levels of experience reduce the risk of crop failure from frost, disease, biennial bearing, etc. Diversification also enables cidermakers to make more "complex" or "balanced" cider blends (Lea 1978; Merwin et al. 2008; Villière et al. 2015).

Of the many high-tannin cultivars reported by growers, a dozen stood out as being mentioned most frequently (Table 5). 'Dabinett' was the most mentioned—it is also among the most widely grown in England. The highly prized but notoriously biennial 'Kingston Black' (Bradshaw et al. 2020; Merwin 2015) was second. Surveys conducted in New York and Vermont also found these two cultivars to be the most often planted by cider apple producers (Becot et al. 2016; Pashow 2018). Nine of the top dozen cultivars were low-acid bittersweets. Given the abundance of subacid or acid "cull" apples from the fresh-market and processing apple industries, sourcing high-acid bittersharps may not be a major focus for growers of cider-specific cultivars.

Most "bitter" cultivars being grown in North America originated in England (21), France (18), or the U.S. (17). Of the top dozen, nine were English, two were French, and one was American. The lack of domestically developed cultivars poses a risk to North American growers in climates with hotter summers or colder winters than Western Europe. The susceptibility of 'Dabinett' to cold damage was mentioned by several interviewees, and also reported in a previous Fruit Quarterly article (Peck et al. 2021). Additionally, the later flowering time for many European cider apple cultivars can greatly increase the risk of fire blight (*Erwinia amylovora*) (Byrde et al. 1986; Gwynne 1984; Locke et al. 1993; Miller et al. 2020).

"Bitter" cultivars originating in the US were a mix of a few predating Prohibition, some introduced in the 1960s to 1980s, and many introduced in the last decade. Three respondents simply reported growing "crabapples" without specifying species or cultivar(s). Five reported testing fruit from young seedlings and mature "wild" trees, sometimes propagating these in their orchards by grafting, a practice that is starting to gain popularity (Courtney and Mullinax 2018; Shirvell 2020; Krueger 2022).

Non-growers reported a less diverse array of "bitter" cultivars (21 total, Table 6). The most commonly mentioned were

Table 5. Cultivars most frequently mentioned by respondents who grow their own high-tannin cider apples.

Cultivar	Number of Growers (n=67)
Dabinett	49
Kingston Black	44
Yarlington Mill*	35
Porter's Perfection	22
Ellis Bitter	17
Chisel Jersey	17
Harry Masters Jersey	17
Michelin	15
Bulmer Norman	15
Brown Snout	15
Hewes Virginia Crab	13
Binet Rouge	12
Tremlett's Bitter*	12
*These cultivars may not always be true-to-type in North America.	

Table 6. High-tannin apple cultivars reported by non-grower cider producers who purchase from grower partners. Cultivars most frequently mentioned by respondents who purchase high-tannin apples from growers.

Cultivar	Number of Respondents (n=30)
Dabinett	8
Porter's Perfection	5
Kingston Black	5
Harrison	5
Hewes Virginia Crab*	5
Yarlington Mill*	4
Dolgo Crab*	2
Redfield	2
Tremlett's Bitter*	2
Chisel Jersey, Columbia Crab, Franklin, Frequin Rouge, Geneva, Harry Masters Jersey, Major, Manchurian Crab, Marie Menard, Muscadet de Dieppe, Muscadet de Lense	1 each
*These cultivars may not always be true-to-type in North America.	

Table 7. Percentage of respondents (growers and non-growers) asked if alternate/biennial yields affect their high-tannin apple supply.

Response	Percentage of Growers (n=96)	Percentage of non-growers (n=32)
Yes	84.4%	25.0%
No	15.6%	75.0%

'Dabinett' (8), 'Kingston Black' (5), 'Porter's Perfection' (5), 'Hewes Virginia Crab' (5), and 'Yarlington Mill' (4). Of these top five, the four English cultivars were also the four most mentioned by cidermakers who grow their own fruit. Mildly tannic 'Harrison' was also frequently mentioned. Some respondents did not know what cultivars go into the "bitter" juice blends they purchased.

Biennial Bearing and Crop Load Management Growers and non-growers were asked if biennial yields affected their apple supply (Table 7). Among growers (96 responding), a large majority (84.4%) chose "Yes" while among non-growers (32 responding), a large majority (75%) said "No". Both growers (73 responding) and non-growers (10 responding) were asked how they respond to the unavailability of bitter cultivars (Tables 8 and 9, respectively). Growers most commonly (65.8%) reported using whatever is available that year; 37% reported saving fermented cider to blend across multiple years, and 34.2% cited orchard practices such as thinning or plant growth regulator applications. Very few growers (9.6%) reported storing fruit or juice long-term. Cold storage can be expensive and can result in the loss of juice quality; it is also difficult to prevent fermentation and microbial contamination when storing juice. Strategies to manage the irregular supply of apples due to biennial bearing among non-growers (10 responding), strategies included trying to source from another grower or supplier (5), fermenting and blending across multiple years (3), freezing juice for subsequent years (2), using tannin supplements (2), or simply forgoing the use of bitter fruit or juice (1).

Growers (78 responding) were asked if they physically or chemically thin flowers or fruit on their "bitter" apple trees. Thirty-six (46%) reported they do not, and four (5%) reported having tried and stopped. Six said trees were too young to consider thinning yet. Of those reporting that they do thin their "bitter" cultivars, many reasons were given. Improvement of sugar content (10), tannin content (6), and acid content (3); as well as reduction of physiological stress on trees (9), were cited. Eight said they thin to mitigate biennial bearing or promote return bloom, with several others citing "harvest volume" or "overcropping". When asked if they would accept lower cumulative yields if they could guarantee more consistent yields from year to year (75 responding), 29% said "Yes", 56% said "Maybe", and 14.7% said "No". Given the potential for thinning to improve multi-year yields (Zakalik 2021), research into effective crop load management for these cultivars is needed.

Fruit size and crop number, though not a primary consideration for cider quality, can affect the cost of hand-harvesting, which is currently the norm in North America. Growers (78 responding) were asked if they pay pickers a different rate per bin to harvest small-fruited cultivars. About one-fifth (19.2%) said they do; 15.4% preferred not to say, and the rest said they do not. Some reported picking fruit themselves and not employing a picking crew. Several stated that the time required was greater for smaller fruit, thus increasing harvest cost for those paying pickers by the hour. One respondent reported paying pickers $5 per bushel for larger-fruited cider apples and $25 per bushel for smaller-fruited ones. Machine-harvesting costs for cider apples, as is done in much of Europe, are unlikely to be affected by smaller fruit size.

Buying and Selling Cider Apples and Juice Cider producers who do not grow their own "bitter" apples (32 responding) mostly reported purchasing from either one source (47%) or two sources (22%), though a few reported buying from more than five sources. Most (70%) reported buying from in-state or -province, 38% reported out-of-state or -province; 12% reported buying from out-of-country, namely, France and the UK. This partly explains why non-growers were less likely to say biennial yields affect their high-tannin apple supply: if one source falls through, they can find another.

Among growers of high-tannin apples asked if they sell "bitter" apples or juice to other producers (88 responding), 81.8% said "No", and two reported doing so in the past; 6.9% reported being open to do so. Only 9.1% said they currently do. Yet when asked if they buy "bitter" fruit or juice from fellow growers (92 responding), 48% answered "Yes" and 8.7% said they had done so in the past. Only three growers reported having both sold and bought "bitter" fruit or juice. Thus, either a few larger-scale growers are selling to many buyers, or not all sales are captured in this survey.

Prices paid for bitter apple fruit or juice were difficult to compare given that dollars per bushel, gallon, pound, and bin were all reported. Bin size, rarely specified by respondents, can range from 690 to 900 lbs in the apple industry. Growers reported paying other growers from $2–6 per gallon, but one reported paying $30 per gallon for specific crabapple juice, with shipping across-country nearly doubling the final cost. Prices per pound ranged from $0.25–0.90, and prices per bushel ranged from $8–30. Prices per bin could be as low as $100, but as high as $1,800. Growers who sell to other cidermakers (10 responding)

Table 8. Practices reported by grower respondents to deal with biennial bearing in high-tannin cider cultivars.

Response	Percentage of Respondents* (n=73)
Ferment what you have and save some for subsequent years	37.0%
Use whatever you have for that year's blend	65.8%
In-orchard horticultural means (thinning, plant growth regulator applications, etc.)	34.2%
Store fruit/juice longer	9.6%
*Many respondents chose more than one response	

Table 9. Practices reported by non-grower respondents to deal with lack of availability of high-tannin cider cultivars.

Response	Percentage of Respondents (n=10)
Ferment what you have and save some to blend the next year	30%
Not use bitter fruit/juice that year	10%
Freeze juice	20%
Use tannin supplements	20%

reported charging anywhere from $4–12 per gallon, $0.50–0.60 per pound, or $25–28 per bushel; one respondent reported charging $400 per bin. Non-growers who volunteered price data (12) reported paying a similar range for bitter fruit or juice: $2.50–12 per gallon, $0.25–0.75 per pound, $18–35 per bushel, or ~US$336 per bin. Per-pound prices are similar to those reported by Peck et al. (2018) in New York State, namely, $0.35–0.71 per pound.

The inconsistent, even confusing nature of reported price data reflects the decentralized, case-by-case nature of cider apple supply chain. Not all sellers have cider presses, while some buyers do. Shipping juice can also run the risk of fermentation or spoilage *en route*, while fruit are much bulkier, and thus more costly to transport. Some buyers operate on such a small scale (including having small-scale grinders and presses) that buying by the bin may be impractical from a processing and storage standpoint. For others, the opposite may be the case.

By contrast, reported costs of low-tannin juice were much lower. Canadian respondents reported prices of CAN$0.85–1.50 per liter (~US$2.38–4.19 per gallon), while American respondents reported US$1.20–6.00 per gallon. At the low end, costs for low-tannin and high-tannin juice in the U.S. were comparable, but top prices for "bitter" juice were much higher than top prices for low-tannin juice, likely due to regional scarcity and shipping costs.

Growers and non-growers were asked if they use formal contracts to buy or sell high-tannin fruit/juice. Among growers (59 responding), only 5% reported using a formal contract to guarantee a price, buyer, or seller; 10% said they planned to in future, and 73% said they would be open to doing so. Few (12%) said that they neither use a contract nor were they interested in doing so. Among those buying but not growing "bitter" apples (34 responding), 20.6% reported using a contract with a grower; 55.9% reported they would if possible; 20.6% said they do not, and one said definitively they would not. This further suggests a few large growers are selling to many buyers. It also demonstrates that growers are less likely to prefer a formal contract than non-growers. A few interviewees (both growers and buyers) noted that informal "handshake agreements" are popular among older or multi-generation growers. Several growers noted that these agreements are self-enforcing by word-of-mouth: if a buyer reneges on an agreement, other growers find out and become less willing to do business with that buyer. Growers' preference for

"handshake agreements" over formal contracts was also reported in New England (Fabien-Ouellet & Conner 2018). Still, a minority of both buyers and sellers reported using contracts, which reflects the relatively undeveloped nature of the cider apple supply chain.

Of non-growers who use bitter cultivars (34 responding), most reported buying juice (58.8%), or fruit (47.1%); some reporting purchasing in more than one form. Only six reported buying high-tannin apple concentrate; these tended to operate on a larger scale of production (>1 million gallons per year) and distribute at a regional or national scale.

Several interviewees who do not grow their own high-tannin apples reported partnering with nearby growers to establish plantings. These buyers reported encountering skepticism from growers, due both to unfamiliarity with growing these cultivars, and uncertainty as to whether young commercial cideries would remain long-term, reliable buyers for bitter fruit which are only useful for hard-cider production.

Conclusion

The current cider supply chain is vastly different from the U.S. wine industry. Almost 80% of grape acreage in the U.S. is devoted to wine grapes (Karlsson 2018), whereas the total acreage of high-tannin cider apple cultivars is small and not well quantified; a similar situation is true for Canada. High-tannin apples account for a small percentage of the total fruit or juice that most respondents use in their ciders, unlike wineries, which typically market single-varietal wines made from well-known grape cultivars. Most consumers are probably unfamiliar with what a "cider apple" is, let alone their names or cider quality attributes. This gives producers latitude to craft a cider by blending whatever cultivars (high- or low-tannin) are available, but also poses a marketing challenge and perhaps a niche marketing opportunity for those using and paying greater costs for high-tannin cider apples.

Survey and interview responses indicate that the North American cider industry is unsure how to work with cider cultivars, both from a supply chain and from a marketing perspective. Shortages, due to limited acreage and recency of planting, have led some producers to forgo trying to source high-tannin apples, a phenomenon sometimes called "supply elasticity of demand". Biennial bearing is also a significant issue, especially for vertically integrated operations.

The marketing challenges are also considerable for producers using high-tannin apples, and even those making dry ciders with low-tannin apples. A handful of large-scale producers, whose products tend to be low-tannin and often quite sweet, dominate the market in sales volume (Beverage Industry Magazine 2023). These "big players" have undoubtedly influenced consumer perceptions of, and expectations for, cider in North America. Though a majority of survey respondents use high-tannin apples, these cultivars are usually used in small proportion compared to low-tannin subacid and sharp apple cultivars.

Yet despite these headwinds, many cider producers, and industry associations, are working to educate and enthuse consumers ciders made from high-tannin apples cultivars, often at tasting rooms, farmers' markets, and festivals. As the cider market evolves and matures,, and more high-tannin cider apple orchards start producing fruit, it will be important to continue to survey the cider industry for their current practices, as well as their research and outreach needs.

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David Zakalik completed his Master's research on biennial bearing in cider apple orchards with **Dr. Greg Peck** who is a research and teaching professor specializing in cider apple production..

Special Feature:
2023 NYSHS Scholarship Winners

May 2023

The New York State Horticultural Society has announced the 2023 award recipients for the Paul Baker Memorial Scholarship. The scholarship awardees receive $500 scholarship each to be used towards their college/trade school expenses. Each year there is the opportunity for two students to receive this award from four different school districts in Niagara County.

Paul Baker worked in the Agricultural industry in one capacity or another his whole life. Before he passed, he had been the Executor Director of the NYS Horticultural Society for over 16 years. Paul Baker was an outstanding spokesperson for the fruit and vegetable farmers of NY. He was loved and respected by all who knew him. The NYSHS BOD, and Paul's family, are so proud to be able to continue his legacy through this scholarship.

The Paul Baker Memorial Scholarship winners for 2023 are Emily Milleville from Lockport, NY, and Amanda Huang from Youngstown, NY.

Emily Milleville will be graduating from Starpoint High School in Lockport, NY. She will be attending Clarkson University in the fall to pursue a degree in Civil Engineering. After college Emily plans to take up an occupation using her civil engineering degree to help design environmentally friendly structures. Her goal is to be able to create ways to build in such a manner that is sustainable and enhances the quality of air, water, and soil. Emily hopes to be diligent in her work and use the knowledge and values she has gained from growing up on her family farm.

Amanda Huang will be graduating from Lewiston-Porter Senior High School in Youngstown, NY. She will be attending Yale University in the fall to study Chemical Engineering and possibly pursue graduate school or medical school to continue her explorations in science overall. In her future, Amanda is interested in pursuing how engineering can help better the public health of our community. Whether this is designing structures to use renewable energy, or studying the impact of pollution on populations, she is excited to make a greener world.

NYSHS would like to congratulate Emily and Amanda for all their hard work throughout their High School careers and to wish them all the best in their future educational and work careers.

For more information about the Paul Baker Memorial Scholarship, please visit NYSHS.org for eligibility requirements and an application form or by contacting Karen Wilson, Business Manager at NYSHS@hotmail.com

Emily Milleville

Amanda Huang