What single trait drives research?

I wish today to challenge your opinion on a subject. If I asked you to tell me the single most important trait that drives all research, what would you select? I will not try to fill the page with potential answers. Each, I have no doubt, would be worthy of including. For the purpose of this discussion, I will submit that it is the ability to reduce or replace human labor. In earlier times, it was an effort to replace animal labor that was at the top of this list, as we moved away from “horsepower” and towards mechanically generated power.

Our ability to feed this planet, which seems not able to put a stop to population growth, has been a challenge ever since the first farm in the Garden of Eden. Man has toiled to feed his family first before any other need. Today is really no different. It is because we are so incredibly efficient that over 90% of the global population can tend to other needs. Today, the same challenge is how to produce more with fewer man hours.

So the single driving trait behind all new research is: how do we accomplish more with fewer man hours? Farm labor in current times is at an all-time critically low level. We have the same or greater need to feed this planet’s growing population, but fewer hands seem willing to participate in the task. This leads researchers to help us reduce hand labor. In apple production, we see this in efforts to chemically thin our crops and reduce hand thinning. One might suggest that the modern apple orchard is here only to increase production of high quality fruit. I would argue that it also goes to reduced handling of marginal fruit and reduces labor in orchard maintenance (pruning).

The Civil War, one might argue, was a result of man’s inability to replace hand labor in the cotton fields. One has to wonder, if the cotton gin and modern combine had been available, would our history books have been written differently? Modern fruit packing lines are able to replace many hands and increase accuracy of the finished pack. Technology has replaced labor. Equal improvements are being made outside of the packing houses. As the cost and difficulty in finding ready hands to work on our farms continues, we will rely on research to help us bridge this need.

The remarkable thing about researchers is that, given a problem, they seem to always find a solution. Today, most growers feel that farm labor is the limiting factor. I am certain that our researchers are attuned to this and are working behind closed doors to help us meet this challenge. It is interesting that we first must have a problem to inspire us to find a solution. As a researcher, you certainly have job security, because as farmers, we always seem to have a new problem to hand off to you.

Paul Baker
New York State Horticultural Society
Sanborn, New York
pbaker.hort@roadrunner.com
Pest management is a vital part of tree fruit production on Long Island, NY, where pesticides are used for the control of various pests including oriental fruit moth (OFM) and codling moth (CM). Analysis of recent (2012–2013) pesticide application records in tree fruit orchards reveals most insecticide applications were driven by these two insects. Improperly used pesticides are of great concern, for Long Island’s sole-source underground aquifer (over 3 million people depend on it), the L.I. Sound and the Peconic Estuary, and growers face other pressures to minimize use of pesticides in a highly populated region. According to the 2013 NY State Department of Environmental Conservation’s Long Island Pesticide Pollution Prevention Strategy (now called L.I. Pollution Prevention Strategy) (http://www.dec.ny.gov/chemical/87125.html) Report: “Water quality monitoring by Suffolk County and other entities shows that pesticides are among a number of contaminants detected in Long Island groundwater as a result of a wide range of human activities”. A 2011 NYS DEC study shows that shallow private wells in agricultural areas are vulnerable to pesticide contamination, with more than 50% of the samples taken from these wells containing detectable pesticide residues. L.I. fruit growers are also facing issues different from other fruit growing areas of the State. The majority of L.I. tree fruit production is marketed locally as U-pick (pick-your-own) or from farm stands for fresh consumption, as part of the growing interest in agro-tourism on eastern Long Island, which attracts over 1.2 million tourists each year from the metropolitan area. Although pesticides are generally not applied at or close to harvest, growers note that consumers frequently express concern about pesticide use on produce. Although not documented on Long Island, CM and OFM can develop resistance to organophosphate, carbamate and pyrethroid insecticides. Due to groundwater concerns, some newer pesticides are restricted from use on L.I. These issues have elevated interest in alternative management methods, including insect mating disruption (MD). The technology uses synthetically produced sex pheromone dispensers placed out in the orchard, to release a “cloud” of pheromone that prevents males from orienting to a particular female. Unmated females fail to reproduce; over time, the pest population and crop damage decrease, often to negligible levels.

Used in other states and regions of NY (Joshi 2008; Agnello 2009; Breth 2010), MD had been used only minimally in L.I. orchards until around 2013, when Lea Loizos, Technician with the Cornell Cooperative Extension of Suffolk County Agriculture Stewardship Program, began working with growers to expand IPM practices. In 2014, we initiated a 3-year participatory project to increase adoption of IPM in Long Island tree fruit orchards. The project engaged 10 growers in using non-insecticidal area-wide insect mating disruption for CM and OFM control in orchards by providing a 40% cost offset for pheromone dispensers, to encourage adoption of the proven technology. The program also included added support to assure growers the strategy was performing as expected, as well as in-season and at-harvest fruit quality evaluations to provide added feedback.

Methods

Grower participation: As participating partners, L.I. fruit growers agreed to include MD techniques initially on a trial ba-
Refrigerated and Ventilated Cooling Systems for Fruit and Vegetable Storages

- COMMERCIAL REFRIGERATION
- DESIGN, SALES AND SERVICE
- SERVING AGRICULTURE FOR OVER 65 YEARS

Free Consultation and Quote
Call Mike Mager at 585-343-2678

ARCTIC REFRIGERATION CO. OF BATAVIA
26 Cedar Street, Batavia, NY 14020
www.arcticrefrigeration.com

One Bushel Crates

Well built and reliable, these boxes will protect your produce. In bulk, $7.50 each

Hamlin Sawmill
1873 Redman Rd. Hamlin, NY 14464
585-964-3561
art@rochester.rr.com
www.OneBushelCrate.com


At Adams County Nursery we specialize in commercial fruit tree nursery stock for a diverse, eastern market using the latest in technology and innovation.

Adams County Nursery, Inc. • (800) 377-3106 • (717) 677-4124 fax
www.acnursery.com • email: acn@acnursery.com
sis, replacing the traditional insecticide-based management approach, despite the higher cost and perceived risk associated with new technology. Most L.I. orchards are mixed blocks of pome and stone fruits. Long Island has approximately 360 productive tree fruit acres, located mostly in eastern Suffolk Co., including 28 acres of new plantings since 2014 (Figure 1). About 288 (78% of the total acreage) are suitable for using MD. Insect populations are typically uneven across the landscape. Approximately 10% of the total acreage (about 33 acres) didn’t have significant OFM/CM infestations before 2014, and CM in particular was uncommon. Another 12% (about 40 acres) was not suitable for MD because of small planting size or fragmented shape. While we provided suggestions on target pests for each site, the project allowed growers to make their own decision about which MD product to use. Participating growers chose Isomate ties (CM/OFM-TT and OFM-TT) for codling moth and/or oriental fruit moth control in pome and stone fruits. Six growers, who own about 233 acres total, decided to use MD during the 2014–2016 seasons. Each year in late winter to early spring, the project investigators met individually with participating tree fruit growers to discuss pest management priorities for each block, details of the MD strategy, weekly monitoring by project staff, and other regular support the program would be providing throughout the season. Aspects covered included pheromone tie placement, durability, availability, verifying performance, and actual costs of the program for each orchard block. Four growers, who own about 70 acres total, decided not to use MD. These four orchards were included in the project for comparing outcomes between MD and non-MD approaches. Weekly trap data were provided to non-MD growers, and these orchards were managed under traditional insecticide based control.

**Deploying pheromone dispensers:** Orchard sizes of participating farms varied between 5–62 acres. A workshop on MD was organized by the project investigators to educate and train growers and workers on using MD in orchards, and a handout on MD describing the technique and illustrating proper use was distributed and also published in Suffolk County Agricultural News, reaching 300 subscribers, including fruit growers. Project staff worked with each grower to determine the appropriate amount of product needed for each block. Isomate CM/OFM-TT was used at 150–200 ties/A and Isomate OFM-TT was used at 100 ties/A. With on-site assistance from project staff, pheromone ties were deployed in trees during bloom for apples and at fruit set for peaches (Figure 2). To help growers with proper deployment, project staff met with workers at each site to demonstrate placement, and then followed up during mid-May to mid-June, to make sure ties were correctly located and distributed.

**Performance check:** Each season from May to September, over 60 monitoring traps (40 OFM, 20 CM) were set in project orchards and checked weekly to ensure the effectiveness of mating disruption. Traps were set in both MD and non-MD orchards to compare moth populations in both situations. CM L2 and OFM L2 lures (long-life standard lures) were used in traps hung 5 feet above ground. Weekly monitoring data were provided to the growers to help growers track insect population status in their orchards, as well as to assess whether MD was working properly. During the growing season, project investigators also made frequent visits to the participating orchards to conduct random fruit checks for signs of insect infestation or injury (Figure 3). Growers were also provided necessary recommendations, such as information on other insects not controlled by MD (such as plum curculio and European apple sawfly), reduced-risk insecticide options, and other periodical scouting data.

**Insecticide applications:** Insecticides for CM and OFM were applied in the MD orchards only if the trap catches were above the designated threshold (2 or more for CM, and 5 or more OFM per week). Orchards not using MD had a 1st insecticide application recommended according to the Michigan State University model (Rothwell 2013) at 200–250 degree-days (50°F) after biofix (first moth catch) for first generation, with a 2nd application 10–14 days later; then, successive treatments for the second generation were based on an action threshold of 5 and 15 moths trapped/week, respectively, for CM and OFM. L.I. growers are mostly limited to Assail and Delegate insecticides (Coragen, Altacor, Belt, Calypso, and Intrepid, are not approved for use on L.I.), with Assail preferred for 1st generation egg hatch targeting CM, OFM, and incidental control of European apple sawfly and plum curculio. Delegate was suggested for mid-season control targeting CM, OFM, and incidental control of leafrollers. Other pests such as European red mite, apple maggot, and aphids, were controlled as needed using reduced-risk or low environmental impact products where possible.
Pre-harvest evaluation: Prior to fruit harvest, an average of 18,000 apples and 4,000 peaches per year were visually inspected for insect-related fruit damage both in MD and non-MD orchards (Figure 4). A total of 500 fruits per sample were randomly checked from 10 interior and 10 border trees. Number of samples per orchard varied between 2 to 7 based on block size.

Results and Outcomes

Mating disruption use: During 2014–2016, the project implemented MD in 70% (233 acres) of L.I. tree fruit acreage, about 3.5 times the acreage under MD prior to the project in 2013 (<20% of total acreage).

Pest monitoring: Knowing the pest status and population trends are keys for a successful pest management operation in any agriculture production. Production of high quality fruit and economic sustainability of orchards largely depend on timely control. Over the project period, CM populations were noticeably lower in MD orchards, compared with orchards not using MD (Figure 5). An average of 1.08, 0.20, and 0.07 CM/trap/week were captured from the MD blocks compared with 2.47, 1.75, and 2.40 CM/trap/week from the non-MD blocks in 2014, 2015, and 2016, respectively (Table 1). Based on trap data, we saw a clear trend of decreasing CM populations in the MD area, but a steadily increasing population was found in non-MD orchards. A similar trend was found in the OFM populations. In 2014, the season began with a high OFM flight (as high as 60 moths/trap/week) in some orchards, but populations in MD orchards dropped to far below economically damaging levels in 2015 and 2016 (Figure 6). An average of 1.52, 0.21, and 0.28 OFM/trap/week were captured from the MD blocks, compared with 3.08, 1.37, and 1.83 OFM/trap/week from the non-MD blocks in 2014, 2015, and 2016, respectively (Table 1).

Table 1. Average numbers of codling moths and oriental fruit moths/trap/week in mating disruption and non-mating disruption orchards in 2014–2016. Numbers in parentheses are the number of traps checked each season.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Mating disruption</td>
<td>1.08 (8)</td>
<td>0.20 (9)</td>
<td>0.07 (9)</td>
<td>1.52 (25)</td>
<td>0.21 (19)</td>
<td>0.28 (20)</td>
</tr>
<tr>
<td>Non-mating disruption</td>
<td>2.47 (10)</td>
<td>1.75 (11)</td>
<td>2.40 (11)</td>
<td>3.08 (16)</td>
<td>1.37 (16)</td>
<td>1.83 (16)</td>
</tr>
</tbody>
</table>

Figure 4. Blemish-free apples ready to harvest protected by mating disruption ties. (Photo: Faruque Zaman)

Figure 5. Weekly codling moth trap captures using CM L2 lures in mating disruption (L) and non-mating disruption (R) tree fruit orchards on Long Island from 2014–2016. Number in parentheses are the number of traps checked each season.
Fruit damage evaluation: Codling moth, plum curculio, tarnished plant bug, European apple sawfly, oriental fruit moth, and stink bug were the most significant insect pests in pome and stone fruits on L.I. during the project period. On average, these insects were responsible for 5.0% of apple and 1.25% of peach damage. Over the past three years, while CM damage to apples was less than 0.5% in MD areas, up to 23% CM fruit damage was found (Figure 7) in one orchard where mating disruption was not used or properly executed. OFM damage was very low, just 0.25% in apples and 0.15% in peaches, in the MD area. However, in the non-MD blocks, nearly 2.0% fruit was found damaged by OFM.

Economic viability: From 2014–2016, growers using MD spent approximately $133–$259 per acre for CM and OFM control in apples and $81–207 for OFM control in peaches. This is based on current prices for MD dispensers (Isomate CM/OFM-TT and OFM-TT) plus 2 applications of either Assail or Delegate. Prior to the project, some non-MD orchards used up to 6–8 applications of insecticide per season (data collected from pre-project period application records) costing $379–$506 per acre (rotating application of Assail and Delegate). Although some orchards reduced costs by using organophosphate, pyrethroid or other products, efficacy of these products were not as expected. For orchards using MD, insecticide applications generally remained at around 0–2 per season for CM and OFM. We estimate growers saved about $212–$247 per year in pest management costs. For growers with already low CM and OFM populations, we feel the cost of using MD will compare favorably to existing pesticide expense, although there may be need for occasional supplemental insecticide applications. This additional cost can be reduced by regular monitoring and site-specific applications. Given the current CM and OFM population trend in L.I. non-MD orchards (Figures 5 & 6), we expect at least 4 insecticide applications per season will be needed in these blocks, which compares favorably to the cost of MD plus 2 insecticide applications (assuming blocks of sufficient size for MD use). All costs were calculated based on retail product prices. Labor, fuel or other associated application costs were not included, but would increase costs, especially for insecticide application.

Impacts and beneficiaries: Under the cost-sharing agreement, project fruit growers were provided 40% reimbursement of the mating disruption tie purchase costs to offset the additional expenditure of trialing MD. Cost-sharing support has motivated and encouraged growers to incorporate MD as a standard practice beyond the project period. We feel that growers, orchard workers, consumers, and the environment all benefit from use of this technology through reduction in unnecessary insecticide use. The program has also promoted adoption of reduced-risk insecticides over older more broad-spectrum products: currently 75% of insecticides used in L.I. fruit orchards are EPA-designated reduced-risk.
materials. L.I. agriculture, and orchards in particular, are important to the local economy and an increasing attraction for tourism.

Conclusions
Pesticide application timing and the choice of materials are the most critical issues for L.I. tree fruit growers because of mixed-cultivar blocks, variable harvest periods, the demand for high-quality fruit, tourist-centered marketing, and restrictions on product use. The mating disruption technology is highly appropriate for L.I. growers, but also benefits from a strong support system to assist implementation. This project has increased MD use in L.I. orchards from less than 20% to over 70% of total acreage within the last three years. The project was also successful in reducing CM and OFM populations in some orchards to far below economic threshold levels, with fruit damage at a minimum. While the early season investment for MD ties may seem initially high, the overall seasonal costs for CM and OFM control favorably compares to solely insecticide-based management. In some cases, use of MD is much less expensive, depending on pest pressure and history of insecticide use. We believe with mating disruption alone (for orchards with low insect pressure) or in combination with effective insecticides and timely applications (for orchards with moderate to high insect pressure), fruit damage can be significantly reduced and maintained at a low level. The long term use of MD with careful monitoring can help maintain target insect populations in the orchard at low levels. With MD, regular monitoring is vital for timely decision making and determining strategic pest control applications. Based on our current fruit damage assessments (very low CM/OFM-related fruit damage in MD orchards; see Table 2) in MD and non-MD orchards, it was difficult to measure the economic value of using MD or a combination of MD and insecticides in all orchards, but we expect MD to minimize risk of developing resistant populations in orchards. Marketing decisions (as fresh fruit, in cider, or processed in other ways) may also influence use of MD and tolerance for fruit damage.

Literature Cited

Acknowledgements
We thankfully acknowledge the technical help from the Cornell University Entomologists Art Agnello and Peter Jentsch. Many thanks to the Agriculture Stewardship Program of Cornell Cooperative Extension of Suffolk County (CCESC). We appreciate the support of the participating Long Island tree fruit growers. This project was supported by the NYS Department of Agriculture and Markets through a program funded by the USDA Specialty Crops Block Grant program. Also thanks to The Friends of Long Island Horticulture for their support.

<table>
<thead>
<tr>
<th>ID</th>
<th>Farm ID</th>
<th>MD use</th>
<th>% damage by CM/OFM</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pome</td>
<td>Stone</td>
<td># fruit checked</td>
</tr>
<tr>
<td>1</td>
<td>yes</td>
<td>yes</td>
<td>3000</td>
</tr>
<tr>
<td>2</td>
<td>yes</td>
<td>yes</td>
<td>1500</td>
</tr>
<tr>
<td>3</td>
<td>no</td>
<td>no</td>
<td>4500</td>
</tr>
<tr>
<td>4</td>
<td>no</td>
<td>yes</td>
<td>2000</td>
</tr>
<tr>
<td>5</td>
<td>yes</td>
<td>yes</td>
<td>5000</td>
</tr>
<tr>
<td>6</td>
<td>yes</td>
<td>yes</td>
<td>1000</td>
</tr>
<tr>
<td>7</td>
<td>no</td>
<td>yes</td>
<td>1000</td>
</tr>
<tr>
<td>8</td>
<td>no</td>
<td>yes</td>
<td>1500</td>
</tr>
<tr>
<td>9</td>
<td>no</td>
<td>yes</td>
<td>1500</td>
</tr>
<tr>
<td>10</td>
<td>no</td>
<td>yes</td>
<td>3000</td>
</tr>
</tbody>
</table>

* - MD ties not properly placed

Table 2. Percent codling moth and oriental fruit moth damage in apples (CM and OFM) and peaches (OFM only) in mating disruption and non-mating disruption orchards on Long Island, 2014–2016.
Fire blight, a bacterial disease of pome fruits caused by the pathogen *Erwinia amylovora*, should be constantly on the minds of growers. Under the right conditions, this disease is known for spreading quickly and devastating an orchard with reverberating effects for years. Two of the reasons that this pathogen is so successful in seemingly being everywhere at once are the abilities of the organism to grow very quickly and to disseminate readily within and between trees. Once fire blight bacteria find their way onto apple flower stigmas, populations can undergo as many as ten cell doublings a day when temperatures are in the upper 70s to 80s F, leading to upwards of 1,000,000 bacterial cells on one flower. From there, pollinators and weather events can spread bacteria quickly to new flowers. Once those large populations build up on stigmas, as little as 0.01” of rain or even a heavy dew can provide the moisture needed for the fire blight pathogen to swim from the stigma tip down the style to the nectaries, where the bacteria infect flowers through natural openings.

Once the bacteria have moved into the flower nectary and initiated blossom blight infection, they will begin to spread systemically through the tree. Similarly, when fire blight bacteria initiate shoot blight infections at shoot tips, the bacteria also will begin spreading systemically. It is during this systemic spread inside trees that the fire blight pathogen also initiates a second method of dispersal, dissemination via the emergence of ooze droplets onto the plant surface. Though flower to flower dissemination is important, ooze droplets are the major dispersal factor for fire blight. Ooze droplets emerge onto the surfaces of cankers in the spring and represent the source of primary disease inoculum that can be disseminated to flowers by insects including flies (Norelli et al. 2003). Ooze emergence and pathogen dissemination from blossom blight and shoot blight infections drive the occurrence of fire blight into the summer. In addition, severe storms that both spread pathogen cells from ooze droplets and provide entry wounds in trees result in major epidemics that can ultimately cause significant tree losses in affected orchards.

**Physical and biological characteristics of fire blight ooze droplets**

Ooze droplets are colorful, ranging in color from white to dark red hues, and are mostly comprised of exopolysaccharide sugars and bacterial cells (Figure 1). Darker colored ooze tends to harbor larger populations of bacterial cells (Slack et al. 2017). Ooze droplets can emerge from any infected tissue, including immature fruit (Figure 1A), flower pedicels (Figure 1B), shoots (Figure 1C), and leaf petioles (Figure 1D). There is seemingly no pattern to the colors, as ooze droplets of several different colors can appear close together on the same stem or the same fruit. We’ve done some preliminary chemical analyses of different-colored ooze droplets, and darker-colored ooze contained higher levels of flavonoids, which are plant-derived compounds that could be released in response to pathogen activity inside the host (Slack and Sundin, unpublished data).

---

**Figure 1.** The range of ooze droplet colors and sizes on various host organs. (A) Ooze forming on immature apple fruit. (B) Ooze emerging on a flower pedicel (arrows) in a flower cluster exhibiting blossom blight symptoms. (C) Display of various-colored ooze droplets on apple shoots ahead of shoot blight symptoms. (D) Ooze droplets forming along the mid-vein of a leaf as well as on the petiole.
Ooze droplets are small, with a typical volume between 1 to 20 μl (0.001 to 0.02 ml). To put this into perspective, Figure 2 shows drops of colored dye of various volumes compared to a penny (Figure 2). Though they are quite tiny, these colorful ooze droplets are perfectly packaged to spread *E. amylovora* bacteria that will infect new apple trees. The exopolysaccharide sugars protect the bacterial cells inside the ooze droplet; these cells can survive within a dried ooze droplet for over one year (Hildebrand 1939). When ooze droplets first emerge from a tree, they are highly viscous and sticky. When disturbed, ooze droplets can produce bacterial strands, due to the droplet’s viscous nature, that can stick to insects or to other animals. These strands, with or without insect aide, can enable further spread through an orchard (Keil and van der Zwet 1972). If ooze droplets get wet, such as through rain events or from spraying activities, they can dissolve and the bacteria within the ooze can spread. We equate this method of spreading as wetting events releasing a “cloud” of bacteria from the ooze droplet that will then spread with water and wind. If any of these bacteria are deposited on shoot tips and can invade through microscopic wounds, a new shoot infection will occur. The “cloud” concept also explains how significant and widespread fire blight outbreaks can occur following strong storms and strong wind events. The storm and wind activity generates wounds and simultaneously moves very large populations of bacteria that can ultimately settle onto shoot tips and cause new infections.

Ooze droplets are the main dissemination factor for fire blight. This means that without ooze droplets, there would be less spread of fire blight from tree to tree. Figure 3 shows a modified disease cycle of fire blight highlighting the effects of ooze droplets. Ooze droplets enable the bacteria to spread and infect multiple plant organs as well as multiple trees throughout the growing season. In the spring, cankers that were missed during winter pruning can start oozing. Bacteria from these ooze droplets on cankers are thought to be disseminated to flowers and young shoots by various insects, including flies, as well as by weather events. If blossom blight infection occurs, ooze droplets can emerge on flower pedicels (Figure 1B) which can then enable pathogen cells to be disseminated to the young, growing shoots. When the shoots become blighted, ooze droplets can emerge, enabling inoculum spread for further infection of new shoots. Thus, the earlier in the season that shoots become blighted, the more significant are disease issues, because bacterial inoculum from ooze drives further secondary cycles of shoot blight. In many cases, ooze emergence from shoot blight infection occurs

---

**Figure 2.** Comparison of representative ooze droplet volumes to a standard United States penny. Droplets of dye in the image range from 1μl (0.001 ml) to 20 μl (0.02 ml). Ooze droplet volumes emerging on apple shoots in orchards can range from 1 – 20 μl, with an average volume of close to 5 μl.

**Figure 3.** Fire blight disease cycle depicting when ooze droplets are important for disease spread. Solid lines indicate the spread of bacteria from ooze droplets via insects or weather events; dashed lines indicate disease progression. Starting from the bottom left, *Erwinia amylovora* bacterial cells emerge from overwintering cankers within ooze droplets; these bacteria can be disseminated to open flowers via insects and weather events. When the flowers start to succumb to blossom blight, ooze again emerges facilitating pathogen dispersal to shoots. The cankers can also ooze post bloom, providing inoculum to infect young shoots. When the bacteria move into the trunk, they can form a canker and overwinter, resulting in a continuation of the cycle the following year.

**Figure 4.** Emergence of white ooze droplets on an apple shoot well below the appearance of fire blight disease symptoms, which are just showing up at the shoot tip.
but still a significant number of bacterial cells. For example, even if the fly only removes 1/1000th of the ooze droplet, it could still be removing as many as 1 million cells. If it then flies off and lands on a nearby shoot (Figure 5C), it is possible that enough cells could be deposited to cause a new shoot infection. We hypothesize that the concentrated cell numbers and their protective sugar matrix facilitate insect transmission of fire blight by providing the numbers component necessary for infection and an ability to survive the time component needed for the fly to land on a new shoot tip.

**Ooze emergence from infected apple tissue**

We were interested in determining the mechanism of egress from plant tissue of fire blight bacteria emerging as ooze. In some situations, for example in pears, ooze emerges from the host through natural openings such as lenticels (Zamski et al. 2006). We examined apple tissue under ooze droplets using scanning electron microscopy to determine how the *E. amylovora* pathogen was escaping the host. In these studies, we never observed *E. amylovora* escaping through natural openings. Instead, we observed bacteria emerging from the host through wounds or tears in tissue, and in some cases, we observed erumpent mounds of tissue underneath ooze droplets (Figure 6A and 6B, and additional figures in Slack et al. 2017). We interpreted these results as indicating that internal proliferation of fire blight pathogen cells in the confined spaces inside apple stems, fruit, petals, and pedicels, results in a buildup of pressure that ultimately causes a wound, opening a microscopic hole that enables the bacteria to spill out onto the surface. At this point, the viscosity of the exopolysaccharide sugars holds the cells within a droplet (Figure 6C).

**Controlling ooze in orchards**

Since ooze emerges after fire blight infection, the best method to control the amount of ooze present in orchards is to control fire blight infections. The best materials available for blossom blight control are streptomycin and kasumir. Use of fire blight prediction models to time spray applications, maintaining excellent spray coverage, and maintaining focus and diligence in fire blight control during bloom are all keys to success. The shoot blight phase of fire blight is best managed using prohexadione calcium (Apogee; BASF Corp.), a shoot growth inhibitor that also provides excellent control of shoot blight (Sundin 2014).

A second method of managing ooze emergence is through pruning. Winter pruning of cankers is critical for the removal of cankers and removal of the primary inoculum that oozing cankers provide for flower infection in the spring. In-season removal of active shoot blight infections is possible, but must be done very carefully. As stated above, when pruning infected shoots (strikes), it is always suggested to remove the shoot at least 18–24” below visible symptoms. In high-density trees, if this is not possible due to shorter branch lengths, branches should be pruned back to the central leader. As we determined from sampling studies, when ooze is present, even higher populations of bacteria are present in the infected shoot (Slack et al. 2017), and these bacteria are capable of moving very quickly, especially through branches of young trees of highly susceptible cultivars. Pruned cuttings should be dropped into orchard row middles and allowed to dry thoroughly over a period of weeks before removal. This will reduce the potential for further spreading of fire blight bacteria within an affected block. Always be careful to not touch any ooze droplets during pruning activities, as this could also result in unintentional spreading of fire blight.
Conclusions
Ooze droplets represent the most important mechanism enabling the spread of fire blight through an orchard and between orchards. Incredibly large bacterial populations, densely packed into ooze droplets, spread as a “cloud” with wetting and wind. Intense weather events that result in tree injury, including hail storms or storms with high winds, can effectively move these “bacterial clouds” through orchards. Because of the large population sizes in even one ooze droplet, storm events can trigger fire blight epidemics, even when the amount of existing infection prior to the storm was relatively low. The microbiological characteristics of ooze, large bacterial populations environmentally protected in a viscous sugar matrix, along with inevitable storm events, enable the fire blight pathogen to seemingly be everywhere at once. Effective management of fire blight infections, and in particular blossom blight and early shoot blight infections, will give the best prevention of devastating fire blight outbreaks.

Acknowledgements
We thank the Michigan Apple Committee, Michigan Tree Fruit Commission, Michigan State Horticultural Society, Project GREEEN, a Michigan plant agriculture initiative at Michigan State University, Michigan AgBioResearch, and the U.S. Department of Agriculture for supporting fire blight research projects in the Sundin lab. We thank Cory Outwater and Quan Zeng for performing some of the experiments described in this article.

Literature Cited

Figure 6. (A) Scanning electron micrograph (SEM) of the surface of an immature apple fruit surrounding two ooze droplets that had emerged on the surface (30X). (B) Close-up SEM image of the two ooze droplets showing surface tear wounds where the droplets (denoted by arrows) have emerged (200X). (C) Emergence of a yellow ooze droplet on an apple shoot from a small wound site (denoted by arrow). As the ooze emerges onto the stem surface, it forms a droplet through the actions of gravity and viscosity.

Suzanne Slack is currently a Ph.D. student in plant pathology at Michigan State University. She was previously a horticulture extension agent with Virginia Cooperative Extension. George Sundin is a professor of plant pathology and leads Michigan State Universities program on applied disease control for tree fruits. [Email: sundin@msu.edu]
Bitter Pit is a physiological disorder that is associated with low calcium levels in apple fruit (Ferguson and Watkins 1989). In Honeycrisp, bitter pit is expressed as discolored, generally brown, sunken necrotic lesions on the skin, commonly at the calyx or blossom end of the apple (Figure 1), but can be found in the stem half of the fruit as well when incidence is severe. The lesions will vary in shape and shade of brown, and are defined by irregular, faceted borders, with the affected tissue remaining firm to the touch. Over time, small lesions can coalesce into larger lesions of irregular shapes. In other cases, larger, more rounded lesions are observed, but still with faceted borders and firm texture, helping to distinguish them from cases of lenticel breakdown and secondary attacks by opportunistic fungal pathogens. Under the peel, cortex tissue can become “corky” in texture and brown in color (Figure 2). Bitter pit can occur without peel symptoms, although this appears uncommon in Honeycrisp.

While bitter pit can often be seen on Honeycrisp fruit at harvest, the disorder can also occur within the first month of refrigerated storage (Al Shoffe et al. 2016), or while transiting in the retail supply chain. Conditioning of fruit for 7 days at 50°F prior to 38°F storage for soft scald mitigation is known to increase bitter pit expression. Growers can face the Faustian dilemma of choosing between storage regimes that favor one problem over the other. The economic loss to the grower can be severe, since a single bitter pit lesion is enough to downgrade an apple from fresh market grade to juice, with a loss in value of 75% or more.

The incidence and severity of bitter pit will vary by variety, orchard block, farm, region, season, and storage regime, but continues to defy prediction. While calcium deficiency of some form is generally considered to be the cause of bitter pit, the exact biological process(es) is not known. Calcium ions (Ca$^{2+}$) are important structural components in cell membranes, also in cell walls, and they serve to help regulate water within cells, as well as playing a role in hormonal signaling (De Freitas and Mitcham 2012). The concentration of “free” calcium in an apple tree is very tightly regulated, and the ions are known to move around locally in the plant via the spaces between cells (the apoplast), through the cells themselves (the symplast), and from the roots to leaves and fruit via the xylem. The transpiration (water) stream serves as a sort of “engine” that moves calcium ions upward to the growing points of shoots and fruits. Excess calcium in the system is stored within cell organs called vacuoles. The amount of calcium stored in vacuoles can reach 40% (Bangerth 1979) of total plant calcium. It is commonly understood by growers that calcium ions do not move readily in the soil profile, hence the importance of adjusting soil calcium and pH levels through incorporation during the pre-plant phase of new orchard development. The case is similar in plant tissue, where calcium ions demonstrate only limited mobility. Calcium transport does not occur to any significant degree via the phloem, so calcium will not transfer from leaf tissue to growing fruit in the photosynthate stream.

As the fruit increases in size during the cell expansion phase of development, xylem tissue in the fruit end begins to lose transport effectiveness (Lazar et al. 2001), especially in the calyx end.

Research continues at Cornell University, and elsewhere around the world, focusing on bitter pit causation, prediction, and mitigation. One school of thought considers the expression of the disorder to be directly related to calcium status in the tree, as discussed above. An alternative hypothesis is to consider calcium status as an indirect factor, with some other factor(s) triggering the expression of the disorder, such as environmental conditions or plant hormones (Saure 1996). Apple rootstocks have been observed to influence elemental mineral status in leaves (Fallahi 2012; Fazio et al. 2013),
with rootstock effects on the elemental mineral status of leaves and fruit being a focus of research being conducted by a team lead by Dr. Lailiang Cheng, Professor of Horticulture at Cornell University in Ithaca, New York. Dr. Cheng recently discussed his research on rootstocks and mineral nutrition at a stop on the 2016 International Fruit Tree Association Summer Tour of Western New York and the New York State Agricultural Experiment Station in Geneva. During Dr. Cheng’s presentation, he stated that Budagovsky 9 (Bud 9) and some of the Geneva series rootstocks show less potassium uptake and lower bitter pit incidence. Dr. Cheng’s presentation can be found on YouTube at http://fruitgrowersnews.com/video/rootstock-selection-impacts-bitter-pit-honeycrisp/ (or simply use the search terms “Rootstock Selection Bitter Pit” and you will see the link to the Fruit Grower News article.).

It is interesting to note that Bud 9 has a good, if anecdotal, reputation in the Hudson Valley for producing Honeycrisp with less bitter pit incidence. Such claims are difficult to confirm scientifically in the commercial orchard, as growers are not in the habit of planting different rootstocks in what scientists describe as “randomized complete blocks” that allow for sophisticated statistical analysis. There exists a growing body of evidence that indicates rootstocks can play a role in improving the elemental nutrition status of the scion variety. As this body of knowledge develops, it may eventually become possible for growers to factor a particular rootstock’s nutritional performance profile into their selection decision. For example, soil tests indicate a potential for calcium deficiency, so choose a rootstock known for its efficiency in calcium uptake. Such characteristics can be capitalized on in breeding programs to develop rootstocks more finely tuned to address issues such as susceptibility of fruit to bitter pit. However, actual field data from grower orchards documenting the relationship of the rootstock selection to incidence and severity of bitter pit is not well represented in the scientific literature. This should not be a surprise, as the overwhelming variability associated with bitter pit makes it difficult to design and site the long-term studies needed to accurately document this issue under commercial conditions.

As (bad) luck would have it, in addition to significant yield losses due to the early April freeze, the 2016 season proved to be a banner year for bitter pit in the Hudson Valley of New York State. Survey data from twenty Honeycrisp blocks located in Ulster, Dutchess, and Columbia Counties described a bleak picture of bitter pit incidence this past season (Figure 3).

With bitter pit incidence in the field reaching 63.3% on 9 September in an unrelated research trial, it was not surprising to get a call from a Columbia County apple grower the next day who had observed a serious case of bitter pit in his 3rd leaf Honeycrisp orchard. The grower was concerned that while it was all bad, one Honeycrisp/rootstock combination appeared to be worse than the other. The orchard was planted as two adjacent blocks, but seamless in appearance, on a consistent soil type, trickle-irrigated, trees sourced from the same nursery, and of comparable (high) quality, planted at the same time, and trained per the tall spindle system at 4’ x 13’. The only difference was that half of the planting was G-41, and the other half was M.9 NAKBT337 (M9-337). Upon visual inspection, the fruit on the G-41 side was more severely afflicted with bitter pit. While not absolutely ideal for statistical analysis, it was clear that this was still an opportunity to compare the performance of two popular rootstock choices under commercial conditions. An experiment was immediately set up to document horticultural and environmental factors that might explain through data analysis what the eye could see in practice.

### Materials & Methods

The experiment was initiated on 10 September, with the grower planning for harvest two days later. Six trees were selected in each block, with the only selection criteria being the presence of a nursery tag confirming the identity of the rootstock. Each tree was strip-picked, the number of drops recorded, and the trunk circumference was measured at 30 cm above the soil line. Harvested fruit were returned to the Cornell Hudson Valley Research Laboratory for bitter pit evaluation. Two separate 15-apple samples, from trees adjacent to the test trees, one sample from each rootstock/block, were taken for destructive evaluation of fruit firmness, soluble solids, and starch pattern index. Several days later, following harvest, 10 randomly selected terminal shoots were measured on each tree, a foliar sample was taken from each block (10 leaves/tree, one per terminal shoot taken 1/3 down from the shoot tip, from each tagged tree), along with a soil sample from each block, one core per tagged tree. Foliar and soil samples were sent to a commercial laboratory for analysis. Individual apples were rated for bitter pit lesion quantity and incidence, the peel surface area affected by bitter pit was visually estimated in 10% increments, and fruit diameter (mm) and fruit weight (grams) was measured. Data were analyzed using JMP statistical analysis software.

### Results

#### Observations of orchard condition and fruit quality

Tree vigor throughout the block was very uniform, with trees appear-
ing to be in good health (Figures 4 and 5). Irrigation water was applied generously through the growing season, compensating for the relatively dry summer and fall. The crop load appeared to be reasonable for a 3rd leaf Honeycrisp orchard, especially considering the early season freeze losses. Fruit flesh firmness and soluble solids content were identical between the two blocks (Table 1), while the starch pattern index (SPI) differed only slightly.

Incidence and severity of Bitter Pit. The total numbers of apples evaluated were 144 (average 24 apples/tree-rep) in the M9-337 block, and 171 (average 28.5 apples/tree-rep) in the G-41 block (Table 2). Differing lower case letters following the numbers indicate statistical significance was found. The first rating is the most common technique – incidence, or does the apple express symptoms of the disorder, yes or no? The G-41 side of the block showed 81.9% BP incidence compared with 59.7% for the M9-337 side.

The second technique involved counting bitter pit lesions on the surface of each apple. Again, the G-41 block was found to have more bitter pit, with an average of 49 lesions per sampled apple compared with 18 lesions per sampled apple in the M9-337 side. The third method involved relating the spot counts to the actual size of the apple. Surface area (SA) was estimated by a calculation based on the geometric formula for a sphere. Honeycrisp apples are not actually spherical in shape, but are most often flattened vertically, and can have an irregular form. Cursory measurement checks on other Honeycrisp fruit indicated that the formula for a sphere would likely overestimate the actual surface area of the apple by approximately 5%. For the purposes of this field study, it would be reasonable to expect this error to remain a constant across all the sampled apples, and therefore would not adversely impact the comparative results presented in Table 2. In terms of lesion density, Honeycrisp on G-41 at 2.3 lesions/cm² SA in this orchard was more severely afflicted with bitter pit than the fruit grown on M9-337 at 0.8 lesions/cm² SA.

Soil and foliar nutrient status. The orchard soil is classified as a Knickerbocker Fine Sandy Loam 3-8% slope, with a deep profile. The actual slope of the site was mild, closer to the 3% side of the range. I would expect this site to be droughty in the absence of irrigation. Soil test parameters (Table 3) indicated a pH above 6.5, optimum availability of magnesium (Mg), near-optimum availability of phosphorus (P), near-optimum availability of potassium (K), and low availability of calcium (Ca). Percent organic matter (OM) in the bottom 2% range is rather low, and the capacity of this soil to provide nitrogen (N, as nitrate) is also low. Considering the excellent soil water drainage, low water holding capacity, and low capability to supply nitrate nitrogen, this orchard would likely benefit from split calcium nitrate applications in the spring. The levels of nutritional elements present in the foliage generally reflects the soil weaknesses (Table 3). Foliar calcium levels are well below optimum overall, with G-41 at 1.10%

Table 1. Harvest indices in Honeycrisp apples from two rootstocks.

<table>
<thead>
<tr>
<th>Rootstock</th>
<th>Firmness (lbs./in.²)</th>
<th>Soluble Solids (%)</th>
<th>Starch Pattern Index *</th>
</tr>
</thead>
<tbody>
<tr>
<td>M9-337</td>
<td>17.1</td>
<td>14.2</td>
<td>6.9</td>
</tr>
<tr>
<td>G-41</td>
<td>17.1</td>
<td>14.2</td>
<td>6.5</td>
</tr>
</tbody>
</table>

* Cornell 1-8 step rating scale

Table 2. Incidence, Severity, and Density of Bitter Pit: Honeycrisp on G-41 vs. M9-337

<table>
<thead>
<tr>
<th></th>
<th>Incidence of Bitter Pit *</th>
<th>Average Number of Bitter Pit Lesions per Apple **</th>
<th>Average # BP Lesions per CM² of Apple Surface **</th>
</tr>
</thead>
<tbody>
<tr>
<td>HC/M9-337</td>
<td>59.7% a</td>
<td>18 a</td>
<td>0.8 a</td>
</tr>
<tr>
<td>HC/G-41</td>
<td>81.9% b</td>
<td>49 b</td>
<td>2.3 b</td>
</tr>
</tbody>
</table>

** JMP LSM/Student’s t-Test  p ≤ 0.05
* JMP Contingency Analysis of Means by Treatment, w/Chi-Square and Analysis of Means by Proportion
Soil Organic Matter (%) 2.4 2.1 Low
Soil Magnesium (lbs./A) 219 219 Optimum
Foliar Magnesium (%) 0.21 0.27 0.35-0.50
Soil Calcium (lbs./A) 1,563 1,455 Low
Foliar Calcium (%) 1.10 0.95 1.3-2.0
Soil Phosphorous (lbs./A) 4.0 2.0 Low - Good
Foliar Phosphorous (%) 0.15 0.14 0.13-0.33
Soil Potassium (lbs./A) 202 158 Near Optimum
Foliar Potassium (%) 1.54 1.47 1.35-1.80
Soil Nitrogen (ppm) 23.5 7.2 Low

bitter pit overall, but not the statistically significant difference between the two rootstocks and may help explain the severe calcium, in the context of adequate potassium, was consistent block, incurring thousands of dollars in losses. Low soil and leaf was striking. The grower had no option but to “juice” the entire

Discussion

The seriousness of the bitter pit problem in this orchard was striking. The grower had no option but to “juice” the entire block, incurring thousands of dollars in losses. Low soil and leaf calcium, in the context of adequate potassium, was consistent between the two rootstocks and may help explain the severe bitter pit overall, but not the statistically significant difference between performance of the two rootstocks. The results of horticultural parameter measurements were not always statistically significant, but the trends were consistent. The data collected from this site consistently suggested that Honeycrisp on G-41 are slightly less vigorous, and represented a more productive rootstock/scion combination than M9-337. Even so, with a slightly higher crop load, less apparent tree vigor and being grown under similar conditions, plus seemingly better foliar nutrient status, the Honeycrisp/G-41 combination still produced fruit with significantly more bitter pit expression. Fruit workers often equate higher vigor, and lower crop load, as factors contributing to a higher potential for bitter pit, not vice-versa, as was observed here.

In summary, the numbers supported what the eyes could see. Causation of, and a solution for the bitter pit issue is not at all clear. Topdressing with high-calcium lime may help in this particular example, but not in the short term. Foliar calcium applications have been known to produce inconsistent results. One takeaway from this modest field exercise is that rootstock selection can have serious consequences beyond our usual concerns about tree size, burr knots, woolly apple aphid and fire blight resistance, replant issues, and Phytophthora tolerance. On paper, it would have been reasonable to expect G-41 to perform better than M9-337, but the reality was not so, and it is difficult to explain why. In the case of Honeycrisp, as a grower, it would be prudent to factor in your experience with bitter pit in your own orchards when deciding on what rootstock to select for new plantings. In recent years, the supply of size-controlling rootstocks has been tight, and planting decisions are too often driven by availability, not necessarily by the best horticultural match to the situation at hand. Please review pack out data carefully and look closely at the performance of your own orchards and others in your region when making rootstock decisions.

Acknowledgements

I’d like to express my appreciation for the project assistance provided by Sarah Rohwer and Dr. Gemma Reig, and the editorial review of this manuscript by Dr. Reig and Dr. Chris Watkins. Financial support for this work was provided by Cornell Cooperative Extension – Eastern New York Commercial Horticulture Program.

References


Dan Donahue is a member of the Cornell Cooperative Extension Eastern New York Commercial Horticulture regional team and an Extension Associate-Area Tree Fruit Specialist based at the Cornell University Hudson Valley Research Laboratory in Highland, NY.

Columbia Tractor, Inc. Serving the Hudson Valley & Western New England with these quality lines of tractors & equipment:
— Case IH — Kubota — Bush Hog — Woods — Kinze —
— Unverferth — Brillion — Monosem — Unverferth —
— Ag-Tec Sprayers — Aerway Aerators — Husqvarna —
— Kawasaki Mule — Befco — Echo — Great Plains Drills —

Call us for Parts - Service - New & Used Tractors & Equipment

PO Box 660, 841 Route 9H, Claverack, NY 12513
Approx. 40 miles south of Albany, NY, in the Hudson Valley
Phone: 518-828-1781 • 800-352-3621 • Fax: 518-828-2173
Email: Skinne@columbiatractor.com • Web: www@columbiatractor.com
**Wafler Nursery**

Producing Quality Apple and Pear Trees for Over 55 years

Select from inventory of budded trees or Custom Order
- Orchard Supplies  - Wildlife Packages

Wafler Nursery  10748 Slaght Rd.  Wolcott, NY 14590
Phone: 315-594-2399  Toll Free: 877-397-0874  Fax: 315-594-8829
www.waflernursery.com  Email: info@waflernursery.com

---

**MUNCKHOF**

3-row Orchard & Vineyard/Berry Sprayer

Now available in the USA!

- Do your spraying job in 1/3 rd of the time!
- Savings on labour, fuel and tractor hours: -66%!
- Low power requirement: Only 80 HP at axle on pump!

LaGasse Works
5 Old State Route 31
Lyons, NY 14489
Phone: 315-946-9202

WWW.LAGASSEORCHARD.COM

---

NEW YORK STATE HORTICULTURAL SOCIETY
The Network for Environment and Weather Applications (NEWA) provides web-based apps supporting digital agriculture at http://newa.cornell.edu/. The tools on NEWA give open-access, real-time decision support to end users for integrated pest management (IPM) and crop production. NEWA builds tools from plant phenology, insect phenology, and plant disease epidemiology models that land grant university researchers have developed by correlating weather data to plant and pest development in laboratory, growth chamber, greenhouse, and field experiments. Field validation occurs before implementation into NEWA tools that include the current, historic, and 5-day forecast outlook. Today, over 40 tools in NEWA, from growing degree days to apple thinning, support agriculturally relevant decisions on the farm. We are pleased to announce a full-time NEWA coordinator in the New York State IPM Program, Dan Olmstead (dlo6@cornell.edu), who started in January 2017.

**History.** In 1996, NEWA started in NY with about 40 weather stations supported by the NYS IPM Program. As of 2017, NEWA serves 12 member states with five additional farms in outlying states (Figure 1). Land grant universities and apple grower associations in North Carolina and Minnesota partner with NEWA (Figure 2) and each state designates a NEWA coordinator to manage their network. Since 2008, the Northeast Regional Climate Center (NRCC) has provided database, programming, and meteorological expertise. In 2016, over 400 weather stations (150 in NY) were included in NEWA’s network and with the addition of the Michigan mesonet, there will be...
over 500 in 2017. Producers host most weather stations in NEWA, which uses Rainwise AgroMet weather stations. The State Climatologists in New Jersey at Rutgers and in Michigan at Michigan State University maintain independent mesonets in their states, providing those data to NEWA. Michigan has Enviro-Weather, which is a similar system to NEWA. National Weather Service (NWS) stations, provided through the NRCC and served on NEWA, show as airport icons on the map. These data have a relative humidity correction factor and leaf wetness data based on a humidity threshold (Table 1).

**Fruit tools.** Many tools in NEWA address apple and grape decision support. Fourteen for apples (fire blight, apple scab, sooty blotch & flyspeck, spotted tentiform leafminer, oriental fruit moth, codling moth, plum curculio, obliquebanded leafroller, apple maggot, San Jose scale, apple carbohydrate thinning, apple irrigation, apple evapotranspiration, and apple frost risk) and five for grapes (Phomopsis cane and leaf spot, powdery mildew, black rot, downy mildew, and grape berry moth). Over the next year, we will develop and validate eight tools for berry crops (strawberry and blueberry downy mildew, and grape berry moth) and five for grapes (Phomopsis cane and leaf spot, powdery mildew, black rot, downy mildew, and grape berry moth). Next year, we will expand and validate eight tools for berry crops (strawberry and blueberry gray mold, strawberry and blueberry anthracnose, mummyberry, cranberry fruitworm, blueberry maggot, and strawberry root weevil), readying these for full implementation in 2018. In addition, eNEWA for grapes, a daily email sent to subscribers, provides a summary of grape tool results. An apple eNEWA, successfully beta tested, requires further development. A data product developed in 2016 sends station weather data from NEWA into RIMpro, a third party software program purchased separately, which has an apple scab simulation model among other tools.

**Outreach & Impact.** NEWA is the topic of many presentations and workshops throughout the coverage areas. For instance, 22 presentations and workshops tracked by the NYS IPM Program in 2015 reached over 1300 people. The results from NEWA's tools frequently appear as topics in extension newsletters with regional and statewide reach, informing producers about upcoming risks and the potential need for intervention to protect or grow the crop. In recent years, NEWA's website has enjoyed over 1.5 million page views per year (defined as when the user spends at least a half hour on the page). NEWA also supports field research and secondary and undergraduate education.

NEWA significantly improves IPM practice and adoption. In a survey of primarily apple and grape growers using NEWA, given in 2007 before the current website launched, the majority agreed that NEWA improved their IPM practices (Figure 3) and 99.2% of NEWA users said they would recommend NEWA to farmers. In a recent stakeholder evaluation of the University of Vermont’s outreach programming, 93% of growers identified access to NEWA as beneficial to their pest management programs, with 86% indicating a decrease in pesticide use and 71% reporting increased profitability resulting from use of NEWA (T. Bradshaw, personal communication). Some representative grower comments about NEWA: “The orchard was largely scab-free for the first time in several years. The orchard manager depended heavily on NEWA and could see significant differences between the on-site station and the one we had been using”; and “I use the NEWA site almost every day early in the season.”

![Table 1. Comparison of five models to estimate leaf wetness. Best estimates have “fraction of correct estimates” closest to one; “correct success index” closest to one; “false alarm ratio” closest to zero. The “bias” measure < 1 is an underestimate and > 1 is an overestimate. Highlighted in dark blue are the best estimate scores, in brown the worst. NEWA uses an average RH ≥ 90% to estimate an hour of leaf wetness.](image)

![Figure 3. NEWA has positive impact on farm IPM practices as evaluated by The Survey Research Institute (SRI), Cornell University in 2007. This was before our current, app-based, website launch in 2009.](image)

**Skill in Weather Station Maintenance**

In NY, about a fifth of all weather stations are on apple farms. To improve the accuracy and reliability of the weather stations in NY NEWA, we investigated the status of the majority of weather stations located on apple farms. This project contributed significantly to the reliability and accuracy of the weather station data by building grower expertise.

We exceeded our target by 33%, reaching 32 apple farmers in NY who own NEWA weather stations and performing field analyses. Owners and farm managers learned about station maintenance and calibration methods during field visits. Field visit analyses on 32 of the 38 Rainwise weather stations located on NY apple farms skipped two that were no longer connected to the network, two maintained by NEWA, and two on Long Island, outside the reach of the project. Based on analysis of the data reported on the NEWA website, we determined that 18 of the 32 instruments were not working correctly before the field visit: 10 with relative humidity (RH) sensor errors, 2 with rain gauge problems, and 11 with data transmission outages. Nine of the 18 stations were repaired either during the field visit or afterwards by the grower. Six needed the RH sensor replaced. Three had data transmission problems – one dry-off if RH ≥ 87%; dry-off if ≤ 90%; dry-off if RH decreases more than 41% in an hour. RH threshold (≥ 90%).

Prior to farm visits, we wrote a Troubleshooting and Maintenance Guide, distributed during field visits. A blog, You’re NEWA, blogs.cornell.edu/yourenewa/, was created, and all NEWA contacts...
subscribed to it. Several blog posts covered troubleshooting and maintenance, pointing to the troubleshooting and maintenance guides. The NEWA website now points to the guides in the main menu, under About Weather Stations:


Two workshops on weather station maintenance, troubleshooting and calibration techniques, *Improving the Reliability of your Weather Station*, were held in February 2015 in Geneva and Highland, NY. An actual weather station for hands-on use allowed attendees to learn how to troubleshoot weather station issues. Rainwise Inc., the weather station manufacturer, participated via Skype link during a question and answer segment. Based on Qualtrics survey evaluations, the workshops were successful in informing attendees about weather station maintenance and troubleshooting. In Geneva, 21 attended, and 9 in Highland. Eighteen (60%) responded to the workshop evaluation. We found considerable change in knowledge after the workshop. Most attendees were already planning how to utilize the information they had learned about weather stations. After attending the workshop, participants are now doing the following:

- (84%) Routinely, at least once per year, clean the rain gauge, inspect all sensors and connections on the weather instrument and on the IP-100.
- (72%) Periodically check the weather station battery voltage on RainwiseNet.
- (56%) Check weather data on RainwiseNet and NEWA for data gaps.
- (56%) Have the weather station calibrated by Rainwise every two years.

One person reported that the 2015 season had the best weather station performance in the Wayne County area they had seen, underscoring the value of routine maintenance.

Favorite portions of the workshop were the Skype session with Rainwise Tech Support; the slide presentation about common maintenance issues, data transmission, and RainwiseNet settings; and the demonstration of dismantling the weather station. Based on requests from attendees, two workshops during the 2016 Hudson Valley Winter Fruit School gave attending apple and grape growers the opportunity to learn about using NEWA’s tools. Presentations and hands-on demos on NEWA were given at New York State Berry Growers Association-sponsored Workshops in January and February 2017.

**New tools and upgrades**

As with weather stations, improving the accuracy and user experience of the models on NEWA is a priority. One top priority was to reinstate the degree day calculator in 2016. We implemented improvements to the apple tools on NEWA. We built forecasts into six apple insect tools for enhanced decision support. A new tool for the emergent pest, San Jose scale, was also implemented in NEWA in 2016.

The **NEWA Degree Day Calculator**, [newa.cornell.edu/index.php?page=degree-day-calculator](newa.cornell.edu/index.php?page=degree-day-calculator), provides an easy way to calculate the accumulated degree days for a desired date range for any base temperature used in NEWA tools. The results show the degree day value for each day in the 5-day forecast window and a chart of degree day progression for the chosen date range, which includes the forecasted data. This degree day calculator allows apple growers and others to determine specific degree day accumulations between dates of their choosing (Figure 4).

We improved the apple insect tools in NEWA that inform IPM intervention for codling moth, oriental fruit moth, oblique-banded leafroller, plum curculio, spotted tentiform leafminer, and apple maggot, improving these with degree day forecasts for five days into the future. The insect tools now include a table of the insect’s daily degree day accumulation that is forecasted for its developmental base temperature five days into the future. Enhanced IPM messages accompany the new forecast-inclusive apple insect tools. These improvements allow end users to know if IPM action thresholds for key insect pests are looming and to take steps to prepare for suggested management tactics.

The new tool for San Jose scale operates similarly, with forecasts and graphs charting the insect’s developmental degree day accumulations (Figure 5). All NEWA tools have an easy-to-use selection dashboard on the left with results displayed on the right. These insect tools’ results have location-specific, real time estimates for insect development status with appropriate IPM messages that change as the degree days accumulate from biofix. The improved and new apple insect tools are now available at [newa.cornell.edu/index.php?page=apple-insects](newa.cornell.edu/index.php?page=apple-insects) easily accessed from the NEWA main menu under Pest Forecasts/Apple Insects.

**Future directions**

NEWA’s end users and state coordinators provide guidance and advice on future development. Grower-based support of NEWA continues to increase, with new weather stations being added routinely. A grower cache for crop growth stage and first trap catch dates to inform the model biofix (start date) would enhance user experience. Virtual stations built from the NWS gridded forecast database could create station locations anywhere on the map. A developer sandbox would revolutionize the ability of scientists to create, validate, and implement new tools in NEWA. These are just a few of the ideas put forth by our stakeholders. Our new partner states, Ohio and Michigan, and our nascent collaboration with the NYS Mesonet will bring more minds to the table for advances in digital agriculture applications that will benefit producers.

**New tools.** While not new, the apple scab and fire blight tools need enhancements. Calculating ascospore depletion with the apple scab tool will improve the estimation of the end of the primary scab season. The epiphytic infection potential algorithm from Maryblt software, courtesy of developer Alan Biggs, will be woven into the fabric of the fire blight tool along with humidity forecasts, an improved user interface and disease management messages. We plan to refine the apple phenology calculations for use in all the apple tools, and ultimately implement a green tip date predictor. Eight tools for berry crops are slated for full implementation in 2018, following validation in 2017. Our partners to the south have requested tools for tufted apple bud moth, brown marmorated stink bug, oriental fruit moth in peaches, and bacterial spot of peach. An additional model for apple thinning, the pollen tube growth model, would provide thinning options for organic production.

**Development.** Look for our NEWA survey, which will inform a ten-year perspective on NEWA, its impact on agriculture and requirements for a successful future. The website will become
mobile-friendly, working on a smart phone more like an app than a website. NEWA’s stakeholders will contribute ideas for this vision in a technology strategy workshop in 2017. Along with the responsive website will be development of virtual weather stations, growers’ cache, and a premium interface. With more than forty models on our current wish list, from sectors as diverse as Christmas trees and dairy farms, the future demands a developer sandbox just to keep pace.

**New partnerships.** The strength of NEWA is its partnerships. We will embark on a collaboration with the NYS Mesonet, a network of 125 state-of-the-art weather stations built by the University at Albany to inform NY citizens about weather as our climate becomes more volatile and weather events extreme. The Ohio State University (OSU) and the USDA Agricultural Research Service at The OSU look forward to building a NEWA network in Ohio where extension scientists will work primarily with apple and grape growers. Our partnership with Michigan and the Enviro-Weather network was sparked by their interest in the Cornell apple irrigation and Cornell apple carbohydrate thinning tools. This partnership bodes well for a future where NEWA and Enviro-Weather build ever greater excellence in digital agriculture.

NEWA, newa.cornell.edu, has a proven track record for providing grower benefits and outcomes that include improved IPM practice, reduced environmental impact, and improved crop yield and quality. This is particularly true for apple production, as there are now 14 apple-specific IPM and crop production forecast models implemented in NEWA. Our ARDP-funded project built grower expertise in weather station maintenance for NEWA and achieved improvements to the apple insect and degree day tools on NEWA. These outcomes will ultimately contribute to the economic success and IPM practices of apple growers using the NEWA tools.

**Literature cited**

**Acknowledgements**

Crowd-sourced, open access NEWA can’t exist without the

---

**Figure 4.** NEWA’s degree day calculator gives location-specific degree day accumulations for several base temperatures. Choose a date range and results show in a table and chart. Scroll over the line to get specific degree days for each point.
Figure 5. The San Jose scale tool in NEWA is typical of the apple insect tools and many other insect tools in NEWA. Degree days are tabulated and a chart is generated showing degree day accumulations. Below the table and chart, messages about pest status and pest management specific to the pest, date and location of interest inform the end user. New in 2016, the apple insect tools include forecasted degree days in the results.
shoulders of many to stand on. The authors would very much like to acknowledge the support of growers, extension faculty, educators, programmers, researchers and professors across the Northeast, Southeast and Midwest who are too numerous to mention by name. We want to especially acknowledge our state coordinators, essential to NEWA’s growth and impact: Terence Bradshaw, University of Vermont; Jon Clements, University of Massachusetts Extension; Peter Oudemans, Rutgers The State University; Robert Crassweller, Pennsylvania State University; Mary Concklin, University of Connecticut; JP Jacobson, Pine Tree Apple Orchard, Minnesota Apple Growers Association; Michael Parker, North Carolina State University; Cheryl A. Smith, University of New Hampshire Extension; Mizuho Nita, Virginia Polytechnic Institute and State University; Matthew Wallhead, USDA-ARS-ATRU, The Ohio State University; Beth Bishop, Michigan State University.

Juliet Carroll has led the New York State IPM Program’s weather network, NEWA, the Network for Environment & Weather Applications, since 2005. She is the Fruit IPM Coordinator for the New York State IPM Program at Cornell University. Julie recognizes the importance of weather in driving disease and insect development in orchards and vineyards. She and colleagues in the New York State IPM Program and the Northeast Regional Climate Center have developed NEWA into a user-friendly suite of apps to assist growers in their IPM and crop management decisions.

THE PICKIN’ IS EASY WITH THESE MACHINES

The Munckhof Pluk-O-Trak

- Increase Fruit Quality up to 60%
- Bin filler ensures that large bins are filled evenly, without bruising fruit
- Compressor
- Onboard air compressor for pneumatic tools
- Conveyors
- Remove to use for pruning
- Automatic Sensor Steering
- Leveling & Stability
- Hydraulic leveling suspension

The REVO Pluma 4WD Harvester

- Increase Efficiency
  - Four hydraulic adjustable platforms - pick at all levels
- Compressor
  - Onboard air compressor for pneumatic tools
- Bin Trailer
  - Trailer holds up to 16 bins.
- Two Sizes of Pluk-O-Trak!
  - Senior (shown) and Junior models available.

Call OESCO, Inc. for a demonstration
800-634-5557
www.oescoinc.com

Scan to see the Pluma in action!
Tannin Additions to Improve the Quality of Hard Cider Made from Dessert Apples

Micah Martin, Olga I. Padilla-Zakour, Christopher Gerling
Department of Food Science, Cornell University, New York State Agricultural Experiment Station, Geneva, NY

This research was supported by the New York Apple Research and Development Program

With a recent revival in the hard cider industry, New York State is uniquely poised to take advantage of this growing trend. Since the cider industry still represents a very small percentage of the total market, consumer expectations for cider are mostly unknown or driven by a few key market players. The craft cider market in particular has been responsible for much of the innovation in this sector, and there is renewed interest in high-quality imported ciders from the United Kingdom, Spain, and elsewhere, that tend to be less sweet and more astringent.

Most ciders are a result of blending several different apple varieties, since unlike wine grapes, very few apple varieties have the perfect balance of sensory characteristics. The astringency of cider is a reflection of the apples used to produce it, which in the case of mass-market cider, utilizes primarily two types of apples: sharps (tart) and sweets (also known as “desserts”). Both of these types are low in tannin and thus impart little to no astringency in the final cider product. The two other types, bitter-sharps and bitter-sweets, are high in tannins and are blended along with sharps and sweets to make a final product that is more astringent and higher in total phenolics (TP).

Bittersharp and bittersweet apples (“cider apples”) are infrequently found in the open market due to their high levels of astringency, which make them unpalatable as an out-of-hand apple. Their use in traditional ciders, however, is indispensable, as they contribute to the structure, preservation, finish, and perceived complexity of the cider. Dessert apples, the ones commonly found in supermarkets, have a long history of steady demand from both consumers and processors and are the primary apples that New York State produces. As a result, there was a strong tendency towards sweet ciders, familiar apple varieties, and an emphasis on price when making purchasing decisions. These results are consistent with observed market trends of transparency in labeling for all age groups and more adventurous purchasing in millennials, the largest generational group of individuals born between 1980–2000. All age groups valued local production highly when purchasing cider, second only to the recommendation of a friend, which further emphasizes the role of consumer education and communication to promote cider purchases.

Sensory Evaluation of Cider Blends with Added Tannins

We were interested in assessing the acceptability of the addition of endogenous and exogenous tannins to cider made from dessert apples, to increase the astringency and complexity of the final cider. This sector, and there is renewed interest in high-quality imported ciders from the United Kingdom, Spain, and elsewhere, that tend to be less sweet and more astringent.

Consumer Expectations for Cider

Due to the evolving nature of the cider market in the United States, it is likely that consumer preferences are evolving in tandem. To evaluate this hypothesis, a consumer survey was conducted in the tasting room of a winery that sells both wine and cider. A majority of the participants (n = 50) had consumed cider no more frequently than a couple of times a year (64%). The results showed that the average consumer preferred sweet cider to dry cider (56%), and preferred wine to other alcoholic beverages (52%). As anticipated, the majority of participants were not familiar with hard cider apple varieties. When asked which apple would be of most interest if made into hard cider, Honeycrisp ranked highest among a group of more exotic or lesser known varieties such as Kingston Black, Tremlett’s Bitter, or Orange Pippin. Finally, those tested emphasized the price, place of production (specifically local production) and the recommendation of friends when making purchasing decisions about cider. The results show the need and the opportunity to educate consumers regarding apple varieties for cider production and the range of styles available to meet different consumer expectations.

Those in the age group 21 to 34 (n = 15) were the most likely to read the back information panel and the most willing to try unknown apple varieties. This age group also had a balanced preference for sweet and dry ciders and placed very little importance on the brand of the cider. For participants older than 35, there was a strong tendency towards sweet ciders, familiar apple varieties, and an emphasis on price when making purchasing decisions. These results are consistent with observed market trends of transparency in labeling for all age groups and more adventurous purchasing in millennials, the largest generational group of individuals born between 1980–2000. All age groups valued local production highly when purchasing cider, second only to the recommendation of a friend, which further emphasizes the role of consumer education and communication to promote cider purchases.
Ida Red, and MacIntosh. Fermentation was carried out with Lallemand DV-10 yeast supplemented with a mixture of organic (Go-Ferm, Fermaid-K) and inorganic nitrogen (diammonium phosphate) at ambient temperature of 16°C for about 21–28 days, until no sugar remained. Sulfite levels were kept at 30–50 ppm. This base blend (first control sample) was then tannin-enriched with 150 ppm total phenolics as mg gallic acid equivalent (GAE)/L using 3 treatments: addition of 20% fermented cider made from high-tannin cider apples (endogenous), and two commercially available exogenous powdered tannins: grape tannin UVA Soft from Scott Labs at 278 ppm (54% calculated retention), which is recommended for white wines; and gall nut from Scott Labs at 179 ppm (84% calculated retention) recommended for cider and white wines. The two powdered tannins were selected as the best options after evaluating several commercial products for suitability in ciders. The cider apples chosen, Harry Masters Jersey and Dabinett, are being used by many NY state cider producers due to their medium to high levels of tannins. In previous studies, we had identified a commercial cider that received high consumer acceptability and thus was used as an additional control to be evaluated against our four treatments. The four prepared samples were normalized to conditions we had optimized for residual sugar at 3%, pH 3.5–3.6, and carbonation at 1.5–2.5 volumes of carbon dioxide. Prepared ciders (Figure 1) were bottled and kept refrigerated until the sensory trial.

We recruited 193 participants from the Cornell Sensory Center database by promoting the study and offering a small payment reward. The sensory studies were conducted following all the requirements of the Institutional Review Board of Cornell University regarding beverage samples for consumption. For each sample, the participants evaluated appearance, color, aroma, flavor, carbonation, and overall liking on a 9-point hedonic scale (from “Dislike extremely” to “Like extremely”). They also evaluated the qualities of sweetness, acidity, astringency, carbonation, and apple flavor on the 5-point Just-About-Right (JAR) scale (1, “Not Enough”; 3, “Just-about-right”; 5, “Too Much”). The JAR scale is useful in determining which attributes of a product are not optimal and that their alteration would potentially have a large impact on liking of the product in question. The research was conducted over 3 days at the Sensory Evaluation Center at Cornell University.

No significant differences in overall liking were observed between the four samples with endogenous and exogenous tannins; however, all received positive hedonic ratings, significantly higher than the commercial cider (Figure 2). Astringency was just-about-right for all prepared samples, demonstrating a wide range of astringency acceptability, and that the three different sources of tannins were equally acceptable (Table 2). The penalty analysis also revealed that the blend with high-tannin cider apples was penalized heavily for its appearance among non-cider drinkers. Subsequent analysis revealed the sample to be

---

**Figure 1.** Bottled ciders prepared at the New York Experiment Station in Geneva. A base cider “control” tannin enriched with three treatments: 20% cider from high tannin apples “cider”, and two commercial tannins “Ft” and “Uva Tan”

**Figure 2.** Hedonic results of sensory evaluation of cider blends with added tannins.
significantly more turbid than the other 4 samples (Table 1).

Among non-cider drinkers, the expectation appears to be for a perfectly clear product, whereas experienced drinkers are accustomed to some sediment in some high-quality ciders. The positive acceptability of these ciders confirms our previous work on an “ideal” cider that balances consumer expectations with regard to sweetness, level of tannins, acidity, and carbonation. These results are very encouraging, as they demonstrate the capacity to make quality ciders with dessert apples and that different styles can be developed just by adding tannins to the cider. Commercially available powdered tannins that are carefully selected and added at optimal concentrations to cider can be successfully used to reach the same level of complexity and astringency obtained from using a blend of dessert apples and hard cider apples. The only exception was for “apple flavor.” In all five samples, more than 1/3 of panelists felt the samples were not sufficiently apple-flavored. An option to increase the apple character of the final cider is to add apple juice or concentrate to reach the optimal 3% residual sugars.

After completing the survey, sensory panelists were asked to assess their willingness to pay for a 750-mL bottle of the cider they selected as being the most liked now, knowing that it was locally produced from a blend of NY apples (Figure 3). A 750-mL bottle was chosen due to its popularity among local craft ciders. In contrast to wine and beer, which come in predictable volumes of a 12-oz can or a 750-mL bottle, cost comparisons for cider can be challenging due to its variable packaging options. As such, a picture of a 750-mL bottle and its equivalent in ounces was provided to assist in making this comparison.

The initial bid given to participants was $11.00 followed by a second bid of $13.00 if the initial bid was affirmed and $9.00 if it was denied. This partitioned the total willingness to pay into four intervals: (1) less than $9.00 (8% of panelists), (2) between $9.00 and $11.00 (15% of panelists), (3) between $11.00 and $13.00 (32% of panelists), (4) at least $13.00 (45% of panelists). From this information, the average willingness to pay was calculated at $12.74, which for a bottle of craft cider in New York State is very typical. This number may be underestimated for two reasons. First, a plurality of respondents was in the highest bid category, suggesting that an even higher bid range may have been suitable. Secondly, a majority of the panelists indicated that they were students (76%) and as such, had below average incomes (Table 3), thereby depressing their ability and possibly willingness to pay.

Table 3 summarizes the demographics of the panelists. Noticeably, 85% were millennials who tend to be more open to new products. This was confirmed when panelists were asked whether they would be likely to purchase a bottle of cider they had never purchased before, and 42% stated they would be likely or very likely to do so. Brand familiarity was also assessed by inquiring about individual commercial and local brands. While, as anticipated, many of the commercial brands were recognized, several local brands that have distribution only in New York or the Northeast had similar recognition scores.
Future Work

Based on the positive results obtained from our studies on tannin addition to cider, we are now focused on producing a tannin-rich extract from apple pomace to increase astringency and overall quality of ciders made from dessert apples. Our aim is to have an extract that would be comparable or superior in quality to other commercial products being offered for alcoholic beverages. We are evaluating using the pomace from both dessert and hard cider apples as the source of apple tannins. The production process will be designed with sustainable and affordable technologies.

Summary

As competition continues to grow in the cider industry, innovation and sustainability are a must. The continued rising demand for local and craft products will continue to buoy the New York cider industry. Understanding customer expectations for transparency, variety, and local production will help to meet those demands. Tannin fortification of ciders made from dessert apples increases complexity and quality of the final ciders. Successful options to achieve higher levels of tannins include blending with ciders made from high tannin varieties, or adding commercially available tannins currently used for other alcoholic beverages. Ongoing research on production of tannin-rich extracts from apple pomace will provide a new alternative for the cider industry.

Acknowledgements

We would like to thank Cortni McGregor Stahl at the New York State Agricultural Experiment Station in Geneva for her technical assistance in preparing the ciders for sensory analysis. We would like to thank Alina Stelick, Research Support Specialist at the Sensory Evaluation Center, for technical support and use of the facilities for conducting consumer sensory panels. This project was supported by the NY Apple Research and Development Program.

Table 3. Summary of sensory panel demographics (n = 193).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
<th>Frequency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td>Male</td>
<td>29</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>71</td>
</tr>
<tr>
<td>Age</td>
<td>21-34</td>
<td>85</td>
</tr>
<tr>
<td></td>
<td>35-44</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>45-54</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>55+</td>
<td>2</td>
</tr>
<tr>
<td>Income</td>
<td>&lt;$20,000</td>
<td>24</td>
</tr>
<tr>
<td></td>
<td>$20,000-$29,999</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>$30,000-$39,999</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>$40,000-$60,000</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>$60,000-$100,000</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>&gt;$100,000</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Prefer not to answer</td>
<td>17</td>
</tr>
</tbody>
</table>

Micah Martin is a graduate Food Science student in Cornell’s College of Agriculture and Life Sciences. Olga Padilla-Zakour is professor and chair of Cornell’s Food Science department. Chris Gerling is the Enology Extension Associate who manages the Vinification & Brewing Laboratory in Geneva.

*99% of recent survey respondents would recommend our tax service... it must be LOVE!

A recent survey asked Farm Credit East tax clients to rate their satisfaction with our tax service. The results were so positive, we can’t help but share them: • 98% reported their expectations were met or exceeded • 92% of the participants valued our tax preparation service • And 99% said they would recommend Farm Credit East tax service to a friend!

Call today to find out how Farm Credit East can help you with tax planning and preparation. Talk to an expert like Lindsay Eckman. She just loves guiding her clients through the entire tax process.

What do you love? Send us your selfie at FarmCreditEast.com/WeAreYou.

Farm Credit East
800.562.2235
FarmCreditEast.com/TaxPrep

* Based on a six month survey of Farm Credit East 2018 tax preparation clients. For complete survey results, visit FarmCreditEast.com/taxsurvey.
Stress-Induced Watercore in ‘NY2’ Fruit: Causes and Mitigation

Mario Miranda Sazo¹ and Lailiang Cheng²
¹ Cornell Cooperative Extension, Lake Ontario Fruit Program, Newark, NY
² Horticulture Section, School of Integrative Plant Science, Cornell University, Ithaca, NY

This research was supported by the New York Apple Research and Development Program

Production of ‘NY2’ apples (a cultivar developed by the Cornell apple breeding program and first available to US consumers in 2014 and 2015) has rapidly increased in New York State and it is now an important and profitable cultivar for several NY apple growers. However, during the past three seasons, we have observed various degrees of stress-induced watercore (SIWC) on some ‘NY2’ apple orchards in western New York (WNY). The disorder has also been reported in the Champlain and Hudson Valley regions with different levels of incidence and severity in different orchards and growing seasons (Wallis and Donahue 2015). The disorder has never been reported across several dwarfing rootstocks at the New York State Agricultural Experiment Station (NYSAES) in Geneva. This type of watercore differs from the traditional watercore in ‘Fuji’ or ‘Delicious’, in that water-soaked symptoms show up in the outer cortex tissue rather than in the core area. High temperature and high light conditions followed by cool nights often lead to SIWC development on susceptible varieties like ‘NY2’ fruit. The leading theory is that high temperature and high light makes the cell membranes leaky and cool nights slow down the uptake of sorbitol from the cell wall space into the parenchyma cells (Figure 1). This appears to be consistent with the unseasonably warm weather conditions we had in WNY during the months of August in 2014 and 2015 (approximately two weeks both years) followed by low night temperatures in September (more cool nights were registered in 2015 than in 2014).

This past summer, we had one of the warmest and driest growing seasons on record in WNY. In the first four months (April-July), we recorded a total average of 6.43” rainfall, and only 1.66” and 1.03” rainfall in the months of June and July, respectively. There were 22 days with temperatures above 85˚F in July and August. The first 15 days of September were warmer in 2016 than in 2015 or 2014. Marlow and Loescher (1984) have indicated that a wide range of environmental and physiological factors can influence the development of traditional watercore on susceptible cultivars. Of these, we believe that similar patterns of temperatures, rainfall, and seasonality in 2014 and 2015 were more conducive to SIWC development in WNY than those in 2016. Based on our observations and industry reports, SIWC on ‘NY2’ fruit was more widely spread in 2015 (60 to 70% incidence in the worst case at one site) than in 2014 (45 to 50% incidence at one site) or 2016 (14% incidence as an average from 20 ‘NY2’ sites evaluated for this project) (Table 1). In 2015, the effect of higher temperatures in August followed by low temperatures in September may have accelerated SIWC development partly through advancing the maturity of ‘NY2’ fruit. Moreover, precipitation in the month of September 2015 was higher compared with 2014 and 2016 (5.21” in 2015 versus 1.04” in 2014 and 2.02” in 2016). Rainfall could have also played a negative role and may have delayed harvest and allowed the fruit to mature and become more prone to SIWC development.

Our results show that stress-induced watercore (SIWC) development is strongly linked to light crop load in 4- or 5-year old ‘NY2’ trees on dwarfing rootstocks. Lime treatments in an established orchard with a very low soil pH (4.77) have only significantly decreased SIWC incidence in one of the two years, and it may take longer for a consistent effect to be detected on the ‘NY2’ fruit.

Figure 1. Schematic route of sorbitol transport form source (leaf) to sink (‘NY2’ fruit) and its contribution to stress-induced watercore (SIWC); authors modified original explanation and drawing for traditional watercore, from Marlow and Loescher (1984).
The NYS HS now has a Facebook page.

Get updates, plus links, to other agricultural organizations!

Follow Us On Facebook:
www.facebook.com/NYSHorticulturalSociety

Join Now To Support The Fruit Growing Community

Farm Bureau members are eligible for $500 off the purchase or lease of qualified 2015 and 2016 Chevrolet, Buick or GMC vehicles, from Silverado to Encore to Terrain and more!

1.800.342.4143 NYFB.org
Download your member verification certificate at FBAdvantage.com/GM
Must be a member for at least 30 days to be eligible.
Water-soaked symptoms begin just beneath the peel and expand towards the core as fruit ripening continues (Figure 2). Mild SIWC with just a few flecks in a small section or two should dissipate in storage. However, more advanced SIWC symptoms can lead to internal breakdown or other forms of internal browning following lengthy storage. A nutritional imbalance (such as low soil pH) or other stress factors may contribute to SIWC. The worst SIWC seen in ‘NY2’ fruit seems to be in young trees with a light crop load. The only external indicator of a problem is very dark red skin color on the side exposed to the sun. In some cases we have also noticed the presence of ants on the fruit – attracted by the accumulation of sorbitol just beneath the peel (Figure 1).

The objectives of this project were: 1) to determine if ‘NY2’ fruit is more sensitive to stress-induced watercore when Ca supply is low, such as on low pH soils and/or under a low crop load situation, and 2) to understand why stress-induced watercore is more severe in some blocks than others by conducting a survey of ‘NY2’ orchards.

**Materials and Methods**

**Experiment 1 (two-year liming study).** In the fall of 2014, when the SIWC problem was first observed in a 4-row tall spindle non-irrigated block of 4-year old ‘NY2’ trees on B.9, we took leaf, fruit and soil samples for nutrient analysis. The following year on April 15, 2015, we set up a liming trial where two rates of lime (2.5 and 5 tons/acre) were applied with a spreader tractor (Figure 3) to increase soil pH. Each treatment was replicated 5 times, but no foliar calcium sprays were made in 2015. Leaf samples were taken on August 13 for nutrient analysis, and fruit samples were taken at harvest on October 14, 2015 for SIWC evaluation. The trees were also evaluated in 2016, but the plots were not limed again and did not receive any foliar calcium. A random 80-fruit sample of normal and SIWC fruit was taken from each of the five untreated plots (not limed in 2016) for complete nutrient analysis at fruit harvest on October 12, 2016. Additionally, a 50-fruit sample was taken from each replicate to evaluate SIWC incidence and severity. Fruit samples were cut open at the equator and were categorized into none, light, medium, or severe water-soaked symptoms.

**Experiment 2 (crop load/calcium study).** In 2016, we initiated a field trial on crop load manipulation in combination with foliar Ca sprays in a 4-year old, non-irrigated ‘NY2’ orchard on M.9 rootstock. The study site had a soil pH of 6.57 and showed a 60 to 70% incidence of SIWC in 2015. During the first week in April, a freeze occurred at the site that resulted in significant damage to flower buds. The trees were not chemically thinned at petal fall or 8–10 mm fruit stage. When fruit size reached 30–32 mm, crop load was adjusted manually. Ten uniform trees were selected per plot based on trunk cross-sectional area (TCA) at 1 ft above ground level. There were two levels of crop load imposed to trees on June 29, 2016. A normal crop load at 5 fruits/cm² TCA or a low crop load at 2 fruits/cm² TCA, in combination with two levels of foliar Ca sprays (no Ca spray or 5 sprays of calcium chloride). The following foliar Ca spray treatment was used for ‘NY2’ trees: 3 sprays of 2 lbs of calcium chloride/100 gal water at two-week intervals starting from 10 days after petal fall, followed by 2 additional sprays at 4 lbs of calcium chloride/100 gal starting from 4 weeks before fruit harvest at two-week intervals. Calcium sprays were applied with an airblast sprayer by a grower cooperator on June 13, 27, July 11, September 13, and 27. There were a total of 4 treatments with each treatment replicated 5 times, with 10 trees per replicate in a completely randomized design. At harvest, a random 50-fruit sample was taken from each replicate for complete nutrient analysis on October 12, 2016. Additionally, a 50-fruit sample was taken to evaluate SIWC incidence and severity as described above for Experiment 1. Fruit flesh samples were taken and freeze-dried for complete nutrient analysis at Cornell’s Nutrient Analysis Lab. Nitrogen

---

**Table 1. Effects of temperatures, rainfall, and seasonality on SIWC incidence (%) of ‘NY2’ fruit before harvest in Western NY the last three years.**

<table>
<thead>
<tr>
<th>Season</th>
<th>August</th>
<th>September (first 15 days)</th>
<th>SIWC incidence (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2014</td>
<td>Warm</td>
<td>Cool nights</td>
<td>High 45-50%</td>
</tr>
<tr>
<td>2015</td>
<td>Warm</td>
<td>Cool nights</td>
<td>Severe 60-70%</td>
</tr>
<tr>
<td>2016</td>
<td>Hot</td>
<td>Warm nights</td>
<td>Medium 14%</td>
</tr>
</tbody>
</table>

---

**Figure 2. SIWC disorder as observed in ‘NY2’ apple (a), (b), and (c). SIWC as shown in another ‘NY2’ apple from the Champlain Valley (d). (Photo by Anna Wallis).**
was analyzed with a C/N analyzer and all the other nutrients were measured via inductively coupled plasma atomic emission spectrometry.

NY2 survey: Over a three-day period in mid-October of 2016, we conducted a survey on soil pH, leaf nutrient status, tree age/rootstock, and average crop load of 20 ‘NY2’ blocks in Wayne, Niagara, Orleans, and Ontario Counties. A random 50-fruit sample was taken from 10 uniform trees at each of the 20 sites to evaluate SIWC incidence and severity as described above for Experiments 1 and 2. We correlated the incidence and severity (none, low, medium, high) of SIWC with the surveyed parameters, especially soil pH, and crop load level.

Results and Discussion

The 2014 data in Experiment 1 showed that soil pH was very low (4.77) and that ‘NY2’ fruit with SIWC had lower calcium than normal fruit, which was consistent with the original idea that SIWC development is associated with low fruit calcium (Figure 4). The low fruit calcium was also consistent with low soil pH. In 2015, the evaluation of SIWC showed a 20–25% reduction in the incidence of SIWC in the two lime treatments, as compared with the untreated control (Figure 5), but no significant differences in leaf or fruit nutrient levels were detected (data not shown). In 2016, there was no significant difference in SIWC incidence between the lime treatments and the control (Table 2), and no difference in leaf or fruit nutrient levels were found (data not shown). Compared with 2015, 2016 had much lower SIWC incidence.

Maintaining optimal soil pH is key for all apple cultivars grown under NY soil conditions. Liming brings multiple benefits to soil nutrient availability and tree growth and development on acid soils (Stiles and Reid 1991; Cheng and Stiles 2004). These include: (1) increasing the availability of calcium, magnesium and phosphorous, (2) reducing the availability of aluminum, manganese and iron to avoid toxicity problems, (3) promoting microbial activity in the soil and improving soil structure, and (4) improving root growth and soil retention of nitrogen and potassium and other nutrients for better uptake efficiency. Under the conditions of our liming study, we only observed a significant reduction in SIWC incidence by lime treatments at 2.5 and 5.0 tons/acre in one of the two years. As tree response to liming is often slow on established orchards, it may take longer for a consistent positive effect to be detected at this site. Alternatively, the liming effect may be only detectable in a year when the weather conditions are very conducive to SIWC development.

In our Experiment 2, ‘NY2’ trees with a low crop load (2 fruits/cm² TCA or just 27 fruits per tree after hand thinning) had higher incidence of SIWC at harvest than those with a normal crop load regardless of foliar Ca sprays, and foliar Ca sprays did not alter the incidence of SIWC (Table 2). These findings suggest that low crop load has made ‘NY2’ fruit more prone to SIWC and foliar Ca sprays did not seem to help. Nutrient analysis indicated that fruit flesh K concentration was higher in the low crop load treatment, but concentrations of other nutrients were not affected. Foliar Ca sprays did not affect fruit flesh Ca concentration, but somehow increased concentrations of K and P in the fruit flesh of the low crop load treatment (Figure 6).

The association of high SIWC incidence with low crop load was also found in the ‘NY2’ orchard survey in 2016. Crop load was calculated as the number of fruits per unit of trunk cross-sectional area (fruits/cm² TCA), and the crop load data from 20 ‘NY2’ sites were compared with a normal crop load of 5 fruits/cm² TCA. In most cases, the highest incidence of SIWC was observed on sites with a light crop load (Table 3). The most severe incidence of SIWC (27%) occurred at the site 3 with a very light crop and very large-sized fruit (data not shown), followed by site 6 (16%), site 13 (9%), and site 5 (7%). In general, low crop load situations (imposed
in Experiment 2 and evaluated through the ‘NY2’ orchard survey) exacerbated the occurrence and severity of SIWC. The severity of SIWC appeared more pronounced in the orchards surveyed on the east side than on the west side of Rochester. Finally, only 5 out of the 20 sites surveyed had a soil pH value of 5.6 or less, with 5.15 and 7.43 the lowest and highest soil pH, respectively. NY2’s susceptibility to SIWC appears to be more related to low crop load than low soil pH.

**Summary**

Although liming at 2.5 or 5 tons/acre in an established ‘NY2’ orchard with a very low soil pH (4.77) has only significantly decreased SIWC incidence in one of the two years for the duration of our field trial, we strongly recommend that NY growers incorporate an adequate amount of lime prior to planting a new ‘NY2’ orchard. The topsoil (0–8 inch depth) should be adjusted to pH 7 and subsoil (8–16 inch depth) to pH 6.5. An adequate liming program based on soil tests should be the first consideration in developing orchard fertilization plans (Stiles and Reid 1991; Cheng and Stiles 2004; Cheng 2015). Lime is the most economical source of calcium and magnesium. Regulation of soil pH through liming is also necessary to achieve optimal response to other nutrient elements. Once a ‘NY2’ orchard is established, soil pH should be maintained in the range of 6.0 to 6.5 throughout the soil profile to optimize tree growth and nutrient availability by doing soil analysis every 2 to 3 years and making a maintenance lime application of 1 to 2 tons of lime every 2 to 3 years. This is because the high annual precipitation in NY gradually leaches out calcium, magnesium, and potassium in the soil, leading to an increase in active hydrogen and aluminum and a decrease in soil pH. In addition, application of ammonium or ammonium-forming fertilizers (such as ammonium nitrate, ammonium sulfate and urea) acidifies soil by releasing hydrogen ion in the process of its conversion to nitrate. This acidifying effect is more pronounced when the fertilizers are applied in a concentrated area, such as under the drip emitters of the fertigation system.

Our crop load experiment and the

**Table 2. Effect of crop load (CL), calcium, and lime on incidence of stress-induced watercore “SIWC” in ‘NY2’ apple fruit grown at two sites in the western NY fruit region, USA.**

<table>
<thead>
<tr>
<th>Exp.</th>
<th>Cultivar</th>
<th>Trt. #</th>
<th>Lime (ton/A) applied in May 2015</th>
<th>Calcium program</th>
<th>SIWC incidence (%) evaluated in October 21**, 2016</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>None</td>
<td>Light</td>
</tr>
<tr>
<td>1</td>
<td>NY2</td>
<td>1</td>
<td>None</td>
<td>2.5 TCA</td>
<td>Without Calcium</td>
</tr>
<tr>
<td></td>
<td>NY2</td>
<td>2</td>
<td>2.5 ton/A</td>
<td>Normal (5 TCA)</td>
<td>Without Calcium</td>
</tr>
<tr>
<td></td>
<td>NY2</td>
<td>3</td>
<td>5.0 ton/A</td>
<td>Low (2 TCA)</td>
<td>Without Calcium</td>
</tr>
<tr>
<td>2</td>
<td>NY2</td>
<td>CL5</td>
<td>Normal (5 TCA)</td>
<td>Without Calcium</td>
<td>96</td>
</tr>
<tr>
<td></td>
<td>NY2</td>
<td>CL5+Ca</td>
<td>Normal (5 TCA)</td>
<td>5 foliar sprays</td>
<td>93.4</td>
</tr>
<tr>
<td></td>
<td>NY2</td>
<td>CL2</td>
<td>Low (2 TCA)</td>
<td>Without Calcium</td>
<td>82.2</td>
</tr>
<tr>
<td></td>
<td>NY2</td>
<td>CL2+Ca</td>
<td>Low (2 TCA)</td>
<td>5 foliar sprays</td>
<td>81.8</td>
</tr>
</tbody>
</table>

**Figure 4.** Comparison of fruit calcium level in fruits with and without stress-induced watercore of 4th leaf ‘NY2’ on B.9 rootstock on a site with a pH of 4.77 in October of 2014 (Soil and fruit sampling conducted by Kevin Maloney, Cornell Univ.).

**Figure 5.** Effect of two liming treatments (2.5 and 5 ton lime/acre) on incidence of stress-induced watercore (SIWC) in ‘NY2’ apple fruit harvested in 2015.

**Figure 6.** Effects of crop load and foliar Ca spray on concentrations of Ca, K, Mg and P in the fruit flesh of ‘NY2’. Different letters indicate significant difference at P<0.05, Duncan’s Multiple Range Test.
survey in WNY clearly indicate that SIWC development is closely associated with low crop load in 4 to 5 year-old ‘NY2’ trees. Therefore, properly controlling cropload of ‘NY2’ trees from year 2 to 5 is important for minimizing the risk of SIWC development as well as for optimizing early tree growth and cropping. Growers need to spend the extra money and time for precision hand thinning, especially when establishing and training the trees the first 2–3 years. Do not purposely under-crop or over-fertilize/fertigate the trees in order to achieve additional seasonal growth. Fortunately, this cultivar is more vigorous than ‘NY1’. The Cornell thinning gauge will help you measure trunk cross-sectional area (use 5 fruit/cm² TCA for ‘NY2’) and more precisely determine the final crop load for young ‘NY2’ trees.

It appears that weather patterns for a given growing season is the biggest factor affecting the incidence of SIWC. For example, higher than average temperatures in August followed by lower than average temperatures in September may accelerate SIWC development partly through their effects on fruit maturity and ripening of the ‘NY2’ fruit. Rainfall in September could also play a role by delaying harvest, which allows the fruit to mature and become more prone to SIWC development. Under these conditions, the likelihood of SIWC development in orchards with a light crop load could be increased. Although there is not much we can do about weather patterns, it might be useful to develop a model for predicting SIWC incidence and severity for ‘NY2’ based on weather data.

### Literature Cited


### Acknowledgements

Financial support from the Apple Research and Development Program is gratefully acknowledged. We also thank Ned Morgan (Morgan’s Farms, Marion, NY) and Matt Wells (The Apple Shed, Newark, NY) for helping us set up and maintain the research plots and for applying the lime and Ca foliar treatments. Craig Kahlke and Elizabeth Tee from CCE LOF and Suelen Uber, a visiting scholar and Ph.D. student from Brazil, helped with SIWC orchard

---

**Table 3.** Effect of different levels of soil pH and crop load (based on 5 fruits/cm² TCA) on incidence of stress-induced watercore “SIWC” for mature 4 or 5-year old “NY2” trees grown at 20 sites in the Western New York fruit region, USA.

<table>
<thead>
<tr>
<th>Site</th>
<th>County</th>
<th>Crop Load Measured (’NY2’/tree)</th>
<th>Ideal Crop Load (5 TCA)</th>
<th>Level of cropping before harvest in 2016</th>
<th>SIWC Incidence/severity (%)</th>
<th>pH</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Wayne</td>
<td>105/57</td>
<td>Right cropped</td>
<td>68</td>
<td>None 8</td>
<td>6.86</td>
</tr>
<tr>
<td>2</td>
<td>Wayne</td>
<td>132/129</td>
<td>Right cropped</td>
<td>96</td>
<td>None 4</td>
<td>7.43</td>
</tr>
<tr>
<td>3</td>
<td>Wayne</td>
<td>8/5</td>
<td>Over-cropped</td>
<td>88</td>
<td>Light 2</td>
<td>5.61</td>
</tr>
<tr>
<td>4</td>
<td>Wayne</td>
<td>28/32</td>
<td>Over-cropped</td>
<td>91</td>
<td>Medium 9</td>
<td>6.66</td>
</tr>
<tr>
<td>5</td>
<td>Wayne</td>
<td>42/90</td>
<td>Under-cropped</td>
<td>91</td>
<td>Severe 10</td>
<td>6.33</td>
</tr>
<tr>
<td>6</td>
<td>Wayne</td>
<td>39/67</td>
<td>Under-cropped</td>
<td>88</td>
<td>Over-cropped 10</td>
<td>6.24</td>
</tr>
<tr>
<td>7</td>
<td>Wayne</td>
<td>55/40</td>
<td>Slightly over-cropped</td>
<td>88</td>
<td>Light 2</td>
<td>6.88</td>
</tr>
<tr>
<td>8</td>
<td>Ontario</td>
<td>121/90</td>
<td>Slightly over-cropped</td>
<td>88</td>
<td>Medium 2</td>
<td>7.06</td>
</tr>
<tr>
<td>9</td>
<td>Wayne</td>
<td>114/67</td>
<td>Over-cropped</td>
<td>91</td>
<td>Over-cropped 10</td>
<td>7.06</td>
</tr>
<tr>
<td>10</td>
<td>Orleans</td>
<td>16/32</td>
<td>Under-cropped</td>
<td>88</td>
<td>Light 2</td>
<td>5.16</td>
</tr>
<tr>
<td>11</td>
<td>Orleans</td>
<td>30/44</td>
<td>Under-cropped</td>
<td>88</td>
<td>Medium 2</td>
<td>6.79</td>
</tr>
<tr>
<td>12</td>
<td>Orleans</td>
<td>77/53</td>
<td>Over-cropped</td>
<td>88</td>
<td>Over-cropped 10</td>
<td>6.79</td>
</tr>
<tr>
<td>13</td>
<td>Orleans</td>
<td>58/78</td>
<td>Under-cropped</td>
<td>88</td>
<td>Over-cropped 10</td>
<td>6.79</td>
</tr>
<tr>
<td>14</td>
<td>Orleans</td>
<td>34/40</td>
<td>Under-cropped</td>
<td>88</td>
<td>Over-cropped 10</td>
<td>6.79</td>
</tr>
<tr>
<td>15</td>
<td>Orleans</td>
<td>68/44</td>
<td>Over-cropped</td>
<td>88</td>
<td>Over-cropped 10</td>
<td>6.79</td>
</tr>
<tr>
<td>16</td>
<td>Niagara</td>
<td>82/62</td>
<td>Over-cropped</td>
<td>88</td>
<td>Over-cropped 10</td>
<td>6.79</td>
</tr>
<tr>
<td>17</td>
<td>Niagara</td>
<td>100/44</td>
<td>Over-cropped</td>
<td>88</td>
<td>Over-cropped 10</td>
<td>6.79</td>
</tr>
<tr>
<td>18</td>
<td>Niagara</td>
<td>122/78</td>
<td>Over-cropped</td>
<td>88</td>
<td>Over-cropped 10</td>
<td>6.79</td>
</tr>
<tr>
<td>19</td>
<td>Niagara</td>
<td>53/53</td>
<td>Right crop load</td>
<td>88</td>
<td>Over-cropped 10</td>
<td>6.79</td>
</tr>
</tbody>
</table>

---

Mario Miranda Sazo is an Extension Associate who specializes in orchard management and orchard mechanization with the Lake Ontario Fruit Program, Cornell Cooperative Extension. Lailiang Cheng is a research and extension professor in the School of Integrative Plant Science, specializing in apple nutrition physiology and nutrient management.
Apple Harvest Platforms: Quantifying Efficiency and Determining Economic Benefits

Matt Wells¹, Jennifer Ifft², Jacob Marc Freedland²
¹Cornell Cooperative Extension, Lake Ontario Fruit Program, Newark, NY
²Cornell University, Charles H. Dyson School of Applied Economics and Management

This research was supported by the New York Apple Research and Development Program

T
oday, many NY apple farms have a portion of their farm planted to high-density systems, and increasingly, most new plantings are high-density. These high-density systems have more than 1,200 trees/acre and are grown in the tall spindle format or another form of a “fruiting” wall system. The primary reasons to plant these types of systems are to return the investment quickly and to increase the rate of return by way of high early yields, greater cumulative yields over the life of the investment and improved fruit quality.

With increased tree density and more precocious dwarfing rootstocks comes trellis systems, tree training, and increased labor costs compared with low density free standing systems. However, many farms have purchased or made platforms to improve the labor efficiency of tasks like pruning, hand thinning, trellising and tree training (Miranda Sazo et al. 2010). Today’s modern high-density systems lend themselves to platforms or mechanization, due to narrow canopies and a more uniform production or work area, not only from the bottom to the top of the tree but from tree to tree.

Platforms improve efficiencies, primarily by eliminating ladder work. Workers are positioned at various heights on a platform and positioned to reach the work area while standing in place. Another key benefit to platforms is that a “steady” pace can be established that creates a more constant and efficient work flow. Lastly, after using platforms, most employees do not want to go back to using ladders, as they experience less fatigue from working on a platform and more work is accomplished.

Up until a few years ago, platforms were used exclusively for dormant pruning and growing season tasks, but not for harvest. However, there are now several commercial platforms available that can accommodate harvest and there are a small number of NY growers using them. This project was designed to investigate and trial commercial platforms during the western NY harvests of 2015 and 2016, to determine the potential efficiency gains and economic benefits.

Methods

Platform efficiency trials were conducted at four farms during the 2015 and 2016 seasons using three commercial harvest platforms (Figures 1–3). At each trial, a platform was compared with the traditional picking method for each farm. To ensure comparable picking scenarios for the two methods, orchards were chosen that were uniform (variety, spacing, age, yield), the same pickers were used for both methods, and the trial duration was the same. The key metric that was used to compare efficiency was bushels per man-hour. As an example, if a six-person team picked 50 twenty-bushel bins in eight hours, their picking rate would be 20.8 bushels per man-hour (50 bins x 20 bushels ÷ 6 pickers ÷ 8 hours). To establish this metric, the trials were timed to the minute (excluding breaks) and the bins were counted to the bushel.

In 2015, three trials were conducted, and in each case the apple quality on the trees was good enough to strip pick or one-pick the orchards. In 2016, the plan was to conduct trials in which the orchards were spot or multi-picked. From speaking with growers who had platform experience, the efficiency gains are much higher when spot picking. Spot picking with the traditional method using ladders has more inefficient ladder use, hence better efficiencies result when using platforms. Unfortunately, due to the challenging growing season in 2016, we were unable to conduct a spot pick trial, but conducted additional one-pick trials similar to 2015.

Platform Types and Features

The purpose of the trials was to determine if platforms increased picking efficiency. There was no objective to determine which platforms were the “best” or to recommend a specific platform to the industry based on the results. The three chosen for the trials were simply available and in use on local farms. There are several commercial platforms available in the marketplace, having some differences in functionality and features. The following is a list of major harvest platform functions and features:

Picking Zone: The picking zone is the area that is picked from the platform. There are two types that include “top-only” and “bottom to top”. In the case of top-only, the picking crew typically picks the bottoms first, from the ground and without a platform. After the bottoms are picked, a team on the harvest platform will finish by picking the tops. Note that for very narrow canopies, the pickers can pick both sides of the tree and the platform would progress through the orchard in every other
row. For deeper/wider canopies, pickers will pick to the center of the tree and the platform would progress through the orchard in every row. The maximum row spacing for most platforms is 13–14 feet, depending on canopy structure.

**Bin Flow:** Bin flow describes how the bin is placed in the orchard and how it is utilized by the platform. “Flow through” platforms require bins placed in the row and in front of the advancing platform. The bins are picked up/conveyed into the platform, they are filled and the bins exit out of the rear of the machine and onto the ground. “Bin exchange” platforms typically have trailers that are filled with bins behind the machine and the platform pulls bins from the trailers and deposits the filled bins on to the ground.

**Bin Fill:** Bin fill simply refers to how the bins are filled. “Picker filled” means the picker directly deposits the apples into the bins just as is done for traditional picking. The other style uses a “bin filler”, similar to what can be found in packing sheds. Apples are placed on a conveyor (belt or suction tube) and the apples flow to a bin filler.

**Drive:** Most platforms are self-propelled using low horsepower engines and hydraulic pumps.

**Steering:** There are two types: “auto steering” or “manual steering” by the picking team.

Table 1 lists the commercial platforms that were used in the trials and their major functions and features.

### Platform Efficiency Results

There were three trials conducted in 2015 and two in 2016. Three of the five trials showed efficiency gains of 13–16.8%, while two trials in 2015 showed no efficiency gains. It should be noted that the trials with efficiency gains had pickers with experience using the machines and working as a team. With the two trials that demonstrated no gains, the pickers had very little prior experience on the platforms. A key finding from the trials was that it takes time for the pickers to become familiar with the platform and, more importantly, learn to work effectively as a team. It could take several days for a team to learn to work well as a unit and to maximize their picking efficiency.

### Economic Analysis Results

**[NOTE:** The following results are based on trial results and hypothetical farm operations and practices. Due to a large number of variables that may be different from farm to farm, a tool has been developed to assist farm operations with calculating the potential savings for their own operations. This customizable tool to evaluate potential returns from investing in harvest platforms is available on the Lake Ontario Fruit Program website (lof.cce.cornell.edu).]

Based on the timed trials, we conducted an economic analysis assuming an efficiency increase for harvest activities of 13%. Since the platforms have applications in non-harvest activities as well, we assumed a 30% labor efficiency increase in pruning and a 40% increase in hand thinning (Miranda Sazo et al. 2010). Our calculations used an hourly wage (plus employer taxes) of $14.80, based on the average wage from the Cornell Fruit Farm Business Summary. Our model also worked with the assumption that there are 16 weeks available per season to prune, 8 weeks available to hand thin, and 8.5 weeks available to harvest.

Based on our model, a 150-acre farm purchasing one platform would save nearly $43,000 annually while completing 100% of its pruning, 100% of its thinning, and 27% of its harvest activi-
ties with platform equipped teams (Table 2). This translates into a payback period of around 1.5 years for a $65,000 platform at sticker price (Table 3). A 300-acre farm purchasing 3 platforms would save $91,348 a year, with a payback period of 2.1 years. They would complete 100% of their pruning requirements, 100% of their thinning requirements as well as about 41% of their harvest needs.

The majority of savings come from the purchase of the first platform. Subsequent platforms bring with them additional savings, but because the first one or two platforms are often enough to cover thinning and pruning needs, the additional savings come exclusively from harvest labor savings. For example, a 150-acre farm saves $42,822 annually with its first platform, an additional $5,583 with its second and third platforms, and then only an additional $3,454 if it were to purchase a fourth platform. These progressively lower additional savings result in longer payback periods for purchases involving more than one or two platforms (Figure 4).

Purchasing a platform exclusively for harvest generates labor savings, but has a long payback period, due to the lower efficiency gains versus other platform activities and the fact that it is only utilized for 8–9 weeks per season. As mentioned, no trials were conducted for spot picking but it is estimated that efficiencies would be in the range of 25–50%. As a hypothetical scenario, if a platform was used on 50% of the acreage for one pick and 50% of the acreage for spot picking, the annual savings could range from $18,000 to $43,000 per year with a 1.5–3.6 year payback range. Another way to pay for the investment more quickly would be to use the harvest platform over two shifts, which has been successfully tried by some growers. Two shifts doubles the hours and number of pickers using the machine in a season, thereby increasing the savings and reducing the payback period.

**Discussion**

More platforms are required for harvest than pruning, thinning and other seasonal tasks. The economic analysis indicated high returns from seasonal tasks that in theory could cover the costs of purchasing additional platforms for full harvest coverage. However, these additional platform purchases by themselves have a longer payback period. From this perspective, additional factors may be needed to justify the additional investment, especially for more leveraged operations. Farms with a portion of their farm requiring spot picking would see much improved savings or payback. There may also be benefits to spot picking more often in varieties like Honeycrisp. Some farms may see additional returns from platforms if they are able to do second-shift picking.
which would allow for more use of the platform and a quicker repayment period. Lower injury rates such as decreased falls from ladders could have large benefits for farms and farmworkers.

Some of the benefits might be considered less tangible, but are by no means less important. “Getting the job done” on time is something that can have a variety of benefits for a business. Satisfied workers can decrease labor turnover as well as improve recruitment. Harvest platforms may increase the pool of workers available to apple farms, as platforms are less physically demanding than ladders. These benefits can impact a farm’s bottom line and are an interesting topic for future research, especially as labor markets become tighter and costs continue to increase under NY’s new minimum wage legislation.

Conclusions

For farm operations that do not own a platform yet have a portion of the farm with row spacings at 14’ or less and intend to plant high-density orchards in the future, there is a quick payback when platforms are used for pruning (dormant/summer), hand thinning, tree training and trellising. If the vision for the farm is to have narrower systems (<13’) grown in a fruiting wall format, a platform that can accommodate harvest should be considered, as it will improve the payback on the investment and provide other operational and human resource benefits.

Our analysis indicates that most farms growing high-density systems should at a minimum evaluate their options for using harvest platforms. While the payoff may be lower than for pruning and thinning, there may be additional gains beyond labor efficiency. Given the importance of managing labor costs and supply in the current labor market and policy environment, the use of harvest platforms is one strategy to consider for remaining competitive in a global marketplace.

Literature Cited


Acknowledgements

Mark Hermenet (Hermenet Fruit Farms, Williamson, NY), Eric and Bobby Brown (Orchard Dale Fruit Farm, Waterport, NY), José Iniguez (Lamont Fruit Farms, Waterport, NY), Patrick Woodworth (Sandy Knoll Farms, Lyndonville, NY).

**AviGard® Bird Netting**

**Harvest Math 101**

RUINED FRUIT FLAVOR AND LOST TONNAGE ◄ LOST PROFITS

Protect blueberries, grapes, cherries, raspberries, blackberries and other crops 24/7 with **AviGard® Bird Netting from Plantra!**

Professional Grower Supplies for Vineyards, Orchards, Nurseries and Wildlife Habitat

Grow Tubes • Bark Protectors • Weed Mats • Fertilizer Packets • Deer Repellent

www.plantra.com 651-686-6688

©2017 Plantra, Inc.
NYSHS MEMBERSHIP INVOICE

Yes! I will support the NYSHS and its mission to Educate, Promote and Protect the New York Fruit Industry.

Yearly membership includes Hort Flash Newsletter, and the New York Fruit Quarterly. Dues are paid once a year, good from July 1st until June 30th. Please enclose check or cash.

Growers Membership ....................................................... $225
Per Each Multiple Membership after 1st ................................ $100
Growers w/50 Acres or Less .............................................. $100
Industry Professional ...................................................... $225
Academic Professional ................................................... $100

Sponsors:
Bronze level ......................................................................... $300
Silver level ........................................................................... $500
Gold level ............................................................................ $1000
Platinum .............................................................................. $2500 and up

ADDITIONAL SUPPORT:
AREAS YOU’D LIKE NYSHS TO SPEND MORE EFFORT ON:
H2A Reform .......................................................................... $100
Speaker Programs ............................................................... $100
Your Thought ______________________________________________ $____________

TOTAL AMOUNT .................................................................... $____________

Name_________________________________________________

Company______________________________________________

Mailing address_________________________________________

City_____________________________State_____ Zip__________

County __________________________

Phone______________________Fax________________________

E-mail __________________________

Thank You for Your Support!!! Membership dues are not deducti-
ble for Federal Income Tax Purposes. They may be tax-deductible
under other provisions of the IRS Code. Please check with your
tax advisor.

Please remit to:
NYSHS
630 W. North Street
Hedrick Hall
Geneva, NY 14456

www.NYSHS.org
Founded in 1855, the mission of the New York State Horticultural Society is to foster the growth, development and profitability of the fruit industry in New York State.

NYS HS accomplishes this by:
• Supporting educational opportunities for members
• Promoting the industry
• Representing the industry in matters of public policy

OBJECTIVES

Education - providing education programs for members that include:
• obtaining and disseminating information to the fruit industry
• sponsor and/or cooperate with other groups to provide and support tours
• sponsor trade shows
• cooperate with and encourage others to provide educational opportunities

Promoting the Fruit Industry by:
• promoting ideas which will benefit the economic health of the fruit industry
• educate the general public about the New York fruit industry

Representing the New York fruit industry by:
• Have cemented our role as legislative voice in both Albany and Washington, DC for the fruit industry
• representing the industry’s interest as well as other agencies and institutions

NYS HS ISSUES
• Pesticide Registrations
• Food Quality Protection Act
• Integrated Pest Management
• Agricultural Labor and Immigration
• Fruit Industry Economic Development
• Cornell Research and Extension
• Education Public Officials
• Educating Industry
• Food Safety