Editorial

George F. Lamont

George Frederick Lamont, 83, Saranac Lake, NY passed away peacefully on Friday March 13, 2020 at the Adirondack Medical Center, In Saranac Lake. George was predeceased by his second wife Ursula, and leaves behind a daughter Rebecca, son Stephen, their mother Jackie, his brother Roger and sisters Marjorie and Marcia.

I’ve always thought of George as an industry icon, I’m sure he would graciously decline the title. He was selfless, humble and always avoided the spotlight, but his place in our industry always makes me think of a favorite quote from John of Salisbury written in the 11th century;

“We are like dwarfs sitting on the shoulders of giants. We see more, and things that are more distant, than they did, not because our sight is superior or because we are taller than they, but because they raise us up, and by their great stature add to ours.”

Everyone who encountered George could benefit from his generosity, he would always share the latest information on any subject believing that a rising tide lifts all ships. George’s life and career involved a constant stream of help for others. Whether it be the multiple students from around the world invited to live in his house and intern on the farm. Or leading strategic planning for the NY State industry. Or that he initiated and led the formation and operation of the Premier Apple Cooperative. Most of the apple world knew George, but even those that didn’t know him, benefitted hugely from his full-time commitment to the entire industry. In the latter part of his career he led both the New York State Horticultural Society and the Apple Coop through the most challenging years. His leadership at Premier literally changed apple prices for an entire industry. Or that he initiated and led the formation and operation of the NY State Horticultural Society and the Apple Coop through the most challenging years. His leadership at Premier literally changed apple prices for an entire industry.

As a leader, George’s selflessness was never more evident than in the formation and operation of the Premier Apple Cooperative. In the early years of the Cooperative, George was the driving force behind the creation of a governance structure that allowed everyone to participate and share in the decision-making process. He was a leader who always put the needs of the group before his own desires.

George’s selflessness was also evident in his personal life. He was always willing to help others, whether it be by providing a place to stay or by sharing his knowledge and expertise. He was a man of great generosity, and he always avoided the spotlight, preferring to let his actions speak for themselves.

George’s life and career were marked by a constant commitment to improving the apple industry. He was a leader who was always looking for ways to improve the industry, whether it be through new technologies or by changing the way things were done. His legacy is one of innovation and dedication, and he will be remembered as one of the great leaders in the apple industry.

Everyone who knew George will miss him deeply. He was a man of great talent, dedication, and selflessness. He will be remembered as a giant in the apple industry, and his legacy will live on for many years to come.

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NEW YORK STATE HORTICULTURAL SOCIETY
Brown marmorated stink bug (Halyomorpha halys, Stal) (BMSB) is an invasive species which causes economically significant damage to tree fruit, vegetable, ornamental and field crops. This pest was first discovered in the US in eastern Pennsylvania in the late 1990s but has subsequently spread to over 40 states including many where fruit production is widespread (citation for BMSB first detection (Hoebeke and Carter 2003) “StopBMSB.org” 2020). Initially, stink bugs were primarily a nuisance for homeowners who combatted populations invading their homes each fall (Nielsen and Hamilton 2009). However, damage from BMSB feeding was soon observed in commercial orchards and by the late 2000s, this pest was a growing concern for fruit growers in the Mid-Atlantic states. Currently, BMSB is considered a serious pest of tree fruit within the US, causing major damage to apples, pears and especially peaches (Holtz and Kamininga 2010). In 2010, BMSB caused an estimated $37 million in losses to tree fruit growers in the Mid-Atlantic region (United States Apple Association 2011). Brown marmorated stink bug has proven to be a difficult insect to manage in commercial plantings, in part due to the inefficiency of current monitoring systems used to assess pest density and time control measures.

Considerable effort has been directed toward developing BMSB monitoring systems. At the time of its first discovery in the US, specific methods to trap BMSB did not exist and thus, early studies focused on black light traps to track populations (Nielsen et al. 2013). However, black light traps proved to be most effective during the early season and less capable of tracking populations during the critical period prior to apple harvest in the early Fall. Initial efforts to draw BMSB to traps using attractants was based on observations by Asian researchers that BMSB were frequently caught in traps baited with a pheromone known as EEZ-MDT used to monitor a different stink bug species, Plautia stali. BMSB were attracted to EEZ-MDT, despite not producing this or any closely related compounds (Weber et al. 2017). Unfortunately, EEZ-MDT is primarily attractive to BMSB during the later season after much of the growing season has elapsed thus negating its utility in early season predictive trapping (Funayama 2008, Leskey, Short, et al. 2012).

In 2014, the aggregation pheromone of BMSB was finally identified as a blend of two compounds (Khrimian et al. 2014) 10-bisaboladien-3-ol and 10,11-epoxy-1-bisabolen-3-ol via the rhodium-catalyzed asymmetric addition of trimethylaluminum to diastereomeric mixtures of cyclohex-2- enones 1 and 2. The detailed stereoisomeric structures of many natural sesquiterpenes with the bisabolane skeleton were previously unknown because of the absence of stereoselective syntheses of individual stereoisomers. Several of the bisabolols are pheromones of economically important pentatomid bug species. Single-crystal X-ray crystallography of underivatized triol 13 provided unequivocal proof of the relative and absolute configurations. Two of the epoxides, (3S,6S,7R,10S) 3-ol and 10,11-epoxy-1-bisabolen-3-ol via the rhodium-catalyzed asymmetric addition of trimethylaluminum to diastereomeric mixtures of cyclohex-2-enones 1 and 2. The detailed stereoisomeric structures of many natural sesquiterpenes with the bisabolane skeleton were previously unknown because of the absence of stereoselective syntheses of individual stereoisomers. Several of the bisabolols are pheromones of economically important pentatomid bug species. Single-crystal X-ray crystallography of underivatized triol 13 provided unequivocal proof of the relative and absolute configurations. Two of the epoxides, (3S,6S,7R,10S). Subsequent studies revealed that a 3.5:1 mixture of these compounds was more attractive to BMSB than either compound alone, but a combination of the BMSB pheromone mixture with EEZ-MDT, the Plautia stali pheromone, was more attractive than the individual pheromone components (Khrimian et al. 2014, Leskey, Agnello, et al. 2015, Leskey, Khrimian, et al. 2015, Weber et al. 2017) 10-bisaboladien-3-ol and 10,11-epoxy-1-bisabolen-3-ol via the rhodium-catalyzed asymmetric addition of trimethylaluminum to diastereomeric mixtures of cyclohex-2-enones 1 and 2. The detailed stereoisomeric structures of many natural sesquiterpenes with the bisabolane skeleton were previously unknown because of the absence of stereoselective syntheses of individual stereoisomers. Several of the bisabolols are pheromones of economically important pentatomid bug species. Single-crystal X-ray crystallography of underivatized triol 13 provided unequivocal proof of the relative and absolute configurations. Two of the epoxides, (3S,6S,7R,10S). Although the evolutionary basis for this cross-species attraction is unknown, the synergy between the BMSB aggregation pheromone and EEZ-MDT is now well established and most commercially available BMSB lures contain these components. Once attractive lures had been developed, designing effective and
accurate traps to capture BMSB in field settings took on increasing importance.

**BMSB Trap Designs**

Initial BMSB trap designs were essentially modifications of extant designs used to trap other tree fruit pests including the pyramid trap (Figure 1), a modification of the Tedders trap originally used to trap plum curculio and other stink bug species (Leskey and Hogmire 2005). Subsequent attempts to refine and optimize designs more appropriate for the biology of BMSB continued with the basic pyramid trap but included several size and color modifications, which provided some improvements in catch (Nielsen et al. 2011, Leskey, Wright, et al. 2012a, Leskey, Agnello, et al. 2015). Ultimately, a full-size (4’ tall) black chloroplast-constructed pyramid trap, baited with the two-part BMSB aggregation pheromone lure, has proven to be the most effective monitoring system for attracting and retaining BMSB in orchard settings across multiple studies (Leskey et al. 2012, Nielsen et al. 2013, Morrison et al. 2015, Weber et al. 2017, Rice et al. 2018).

Although widely adopted, pyramid traps are physically large traps which are cumbersome to install and easily damaged by weather and farm machinery, thus hampering their utility in field settings (Acebes-Doria et al. 2018) we compared standard pyramid traps to clear sticky cards attached atop wooden stakes and evaluated two commercially formulated lures (Trécé and AgBio. A smaller and easier to handle version of the pyramid trap, the Rescue* trap (Sterling International, Inc., Spokane, WA), also is available for monitoring BMSB. The Rescue trap is most effective when it is positioned such that one or more of the fins are in contact with a tree limb or trellis post as shown in Figure 2. Morrison et al (2015) tested this trap when hung from a branch without the fins contacting wood and found that it captured significantly fewer BMSB adults and nymphs than the pyramid trap. Our experience is that the Rescue trap is highly effective and a good choice for monitoring BMSB when it is correctly deployed.

Recent studies have revealed that monitoring for BMSB can be accomplished using smaller and simpler trap designs that may be easier to transport, install and inspect (Rice et al. 2018). In Asia, native stink bug pests are often monitored using chloroplast-constructed pyramid trap, baited with the two-part BMSB aggregation pheromone lure, has proven to be the most effective monitoring system for attracting and retaining BMSB in orchard settings across multiple studies (Leskey et al. 2012, Nielsen et al. 2013, Morrison et al. 2015, Weber et al. 2017, Rice et al. 2018).

Although attractant-baited pyramid and panel traps are the current industry standards for trapping BMSB, neither of these tools were designed de novo to suit the specific behaviors and biology of BMSB, rather they were adapted from trap designs used for other insects (Leskey and Hogmire 2005, Acebes-Doria et al. 2018, Rice et al. 2018). More robust systems that are tuned to the unique behavior of BMSB as they seek out hosts or mates are needed to increase reliance on traps for making management decisions. In addition, the potential of managing BMSB via mass deployment of traps would be greatly enhanced if the trapping systems captured a higher percentage of the attracted bugs than is currently achieved using the baited pyramid or panel trap.

Traps designed to capture insects that are attracted to sex pheromone or host plant volatile lures may be less effective for trapping insects attracted to aggregation pheromones due to fundamental differences in how insects respond to the various kinds of behavior-modifying chemicals (Aldrich 1988, Wertheim et al. 2005). Insects responding to sex-pheromone lures track the odor plume, reach the source, and are consequently captured in traps. In contrast, BMSB responding to their aggregation pheromone often are not captured due to their becoming arrested on foliage or other surfaces prior to reaching the trap. This aggregation behavior often results in host plants near a pheromone-baited trap sustaining higher rates of BMSB damage than those farther from traps (Sargent et al. 2014, Weber et al. 2017). The failure of current trap designs to capture a significant proportion of the bugs responding to the trap and lure is most likely due to small and inefficient retention mechanisms relative to the several meter area of arrestment created by the aggregation pheromone (Morrison et al. 2016). Improved designs for trapping BMSB need to provide a larger and more efficient means of retaining bugs that
have responded to the lure.

An especially promising approach for capturing a large percentage of responding bugs is the use of long-lasting insecticide netting (LLIN) as the retention mechanism. Originally designed for use as mosquito-preventing bed netting in regions affected by malaria, LLIN has recently been incorporated into the design of traps for agricultural pests (Martin et al. 2006, Kuhar et al. 2017). This deltamethrin-impregnated netting has been shown to be highly lethal to BMSB: 10 s of exposure resulted in >90% mortality for nymphs and >40% mortality against adults, with mortality increasing with longer exposure times (Kuhar et al. 2017) which have insecticide incorporated within the fibers, have been widely used for control of malaria and other insect-vectored diseases. Only recently have researchers begun exploring their use for control of agricultural pests. In this study, we evaluated the toxicity of a deltamethrin-incorporated LLIN, ZeroFly (Vestergaard–Frandsen, Washington, DC).

Over the past few years, we have been exploring the use of LLIN for trapping BMSB. The aim has been to improve trapping efficiency by increasing the area of retention. LLIN traps were constructed from deltamethrin-impregnated netting (ZeroFly, Vestergaard Frandsen) draped over a 6’ shepherd’s crook or wooden post driven 2’ into the ground (Figure 4). For the wooden post design, a 16 oz. plastic deli cup was nailed into the top of the post to increase the width of the silhouette of the netting as it hangs from the post. The netting was fastened to the post with cable ties to prevent wind-damage and to ensure that the netting hangs straight down, theoretically mimicking the appearance of a tree trunk. These LLIN traps were baited with high dose (100 mg) dual-component BMSB lures (AgBio) to maximize the attractiveness of each trap. Traps were placed in the center of a 1 m² piece of landscape fabric to inhibit the growth of weeds and make it easier to count the number of dead BMSB that fell to the ground.

Comparison of Pyramid or Fin-Style Versus Panel Style Traps

In 2018, we compared the efficacy of the pyramid or Rescue, fin-style traps, to the clear sticky panel trap for monitoring populations of BMSB at 30 sites in southern Michigan. The tested fin-style traps were the Dead-Inn Pyramid Trap® (AgBio Inc., Westminster, CO) and the Rescue® Reusable Stink Bug Trap (Sterling International Inc., Spokane, WA). These traps have performed similarly for us in terms of the average number of BMSB captured per trap per day and were used interchangeably in this study (data not shown). The panel trap was the Stinkbug STKY ™ Dual Panel Adhesive Trap (Trécé Inc., Adair, OK) clipped to a 2.5 cm x 2.5 cm x 1.2 m wooden post. All traps were baited with a Trécé dual-component BMSB aggregation pheromone lure. All but one of the sites monitored were orchards, most of which were being managed for commercial apple production. One was an urban wooded site where BMSB numbers have been consistently high for the last few years. A clear panel trap and one of the fin-style traps was placed along the orchard perimeter 30 meters apart at each of the 30 sites. Traps were deployed at some sites as early as mid-May, but for the purposes of this comparison, traps were set up and checked weekly beginning in mid-June, concluding by mid-October.

The fin-style traps consistently captured significantly more BMSB than the panel traps (Figure 5). Season-long cumulative trapping per site ranged from 2 to 1,004 for the fin traps (6,616 total, 220.5 average per site) and from 5 to 320 for the panel traps (1,717 total, 57.2 average per site). Weekly mean catch by trap type revealed there was a point in the season when the fin trap clearly outperformed the panel trap. There also was a weak relationship between captures in the two trap types (Figure 6).

Overall, our findings indicate that the panel trap is not the best option for monitoring BMSB. We agree that pyramid style traps are cumbersome to use and can sometimes interfere with orchard equipment, which is why it is good to note that another fin style trap, the Rescue trap, when installed properly with fins touching an orchard post or tree trunk, will perform just as well as pyramid traps and are far easier to deploy and assess.

Comparison of LLIN to Pyramid or Panel Style Traps

In 2018, we also conducted a field study at a subset of sites to compare the efficacy of the novel LLIN trap to that of the pyramid and panel traps. Sites were selected based on their history of high BMSB populations. Three of each kind of trap were set up 50 meters apart along the perimeter of each orchard, in one of three positions, in the orchard edge, in the wooded edge, or in the clearing between the orchard and wooded edge. For the LLIN trap, the netting was draped over a 2.5 cm x 2.5 cm x 1.2 m wooden post topped with a small plastic deli cup to increase the width of the visual silhouette. All traps were baited with a Trécé dual-component BMSB aggregation pheromone lure, which was changed every 12 weeks according to manufacturer’s specifications. Traps were first deployed and checked weekly beginning in May and ending in October. Captured BMSB adults and nymphs
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were counted weekly and removed from the traps or landscape fabric below LLIN traps. Upon each visit, the number of BMSB hanging around each trap but not captured in the trap, were also recorded.

On average, the LLIN caught the most BMSB adults or nymphs, with pyramid traps second and panel traps a distant third (Figure 7). Both LLIN and pyramid traps caught significantly more BMSB adults than panel traps (panel-LLIN: \( P < 0.001 \), panel-pyramid: \( P = 0.025 \)). Average BMSB nymphal capture was significantly affected by trap type (\( P = 0.0001 \)) as well (Figure 7). Thus, the newly developed and not yet optimized LLIN trap may be an improvement upon the pyramid trap. The panel trap again proved to be the poorest option for capturing BMSB. In addition, the number of BMSB found adjacent to traps was significantly affected by trap type (\( P < 0.001 \)). Our counts of BMSB hanging around the traps by type supports the idea that LLIN traps may be the best at both luring in and capturing BMSB (Figure 8). Further work is needed to determine if this will translate into less adjacent crop damage when using the LLIN trap.

**Optimizing trap placement**

Trap placement was investigated by deploying traps in 3 positions relative to the orchard perimeter. Three sets of LLIN, pyramid and panel traps, all baited with the Trécé dual-component lure were used in this study, as described earlier. Traps were placed along the perimeter and within the orchard row (“Orchard”), along the wooded edge (“Woods”), and in a clearing between the orchard and the wooded edge (“Mid”). Traps placed at the wood edge were deployed directly adjacent to deer fences, when present. At sites without deer fences, a 1 m² area of vegetation was cleared (via hand trimming and applications of glyphosate where needed) within the wood edge habitat and traps were positioned in this clearing. Traps in the orchard edge treatment were deployed within the drip line of fruit trees, but far enough from limbs, foliage and fruit to prevent any contact with the netting. Traps placed in the middle treatment were at least 1.5 m from any obstruction that may have obscured the silhouette of the trap.

The experiment was conducted as a 3 x 3 factorial with the three trap treatments and three placement treatments replicated five times across four Mid-Michigan commercial fruit orchards. Traps were deployed in blocks of three, with each trap type replicated once per block and each block corresponding to a different placement zone. Approximately once per week, traps within each block were rotated to avoid biasing the data based on variation in BMSB density and plant community between deployment spots. All captured BMSB and those within 1 meter of the trap were counted and removed weekly as previously described.

Average adult catch was significantly affected by trap placement (\( P < 0.001 \)) (Figure 9). Traps deployed in the middle of the crop-wood edge interface caught significantly more BMSB adults than those deployed at the wood edge (\( P = 0.0072 \)) or those within the crop perimeter (\( P < 0.001 \)) (Figure 9). Average adult catch did not vary significantly between traps deployed on the wood edge and those deployed on the orchard perimeter (\( P = 0.684 \)).

Average BMSB nymphal capture also was significantly affected by trap placement (\( P < 0.001 \)) (Figure 9). Traps deployed in the middle of the crop-wood edge interface caught significantly more BMSB nymphs than those deployed at the wood edge (\( P = 0.031 \)) or those at the orchard perimeter (\( P < 0.001 \)) (Fig. 6). The
number of BMSB nymphs caught in traps at the wood edge did not vary significantly from that of traps at the orchard edge ($P = 0.239$).

Results of this study show that trap placement has an important effect on resulting BMSB catch. All tested trap designs caught more BMSB when deployed in “middle” locations between the crop perimeter and wood edge, and LLIN traps in these middle locations caught, on average, almost twice the total BMSB of similarly placed pyramid traps.

**Conclusions and recommendations**

Fin-style traps baited with a commercial BMSB lure proved to be good options for trapping this problematic invasive species. The large pyramid trap can be cumbersome to use which is why we tested a smaller fin-style trap that is easier to deploy and maintain. This Rescue trap, when installed properly with fins touching an orchard post or tree trunk, will catch just as many BMSB as pyramid traps.

LLIN traps are a promising alternative to extant forms of BMSB trapping, but unlike pyramid and panel traps, the design takes into consideration the behavioral ecology of BMSB whereby individuals often land in the vicinity of a trap. LLIN traps were designed to maximize retention within the 2-3m zone of arrestment BMSB displays near aggregation pheromone lures. Interestingly, significantly fewer adjacent BMSB were found near LLIN traps than panel or pyramid traps. These data may serve as early evidence that LLIN traps are able to capture a greater proportion of responding BMSB than panel or pyramid traps. Future designs could incorporate modifications that increase the surface area of LLIN or increase the complexity of the netting allowing for more folds and niches where BMSB may be caught and in so doing, contact a lethal dose of insecticide. Behavioral studies examining BMSB activity near or on LLIN traps may be required to direct further enhancements of the initial trap design.

The panel does not appear to be a viable tool for monitoring BMSB. Bug captures in the panel trap are typically low even in high pressure sites and do not correlate well with either the fin-style or LLIN style traps when BMSB becomes susceptible to the aggregation pheromone in late summer. Studies are needed to determine if these low catches can accurately predict BMSB infestation level and damage. Acebes-Doria et al. (2018) found that pyramid and panel catch rates were strongly correlated, opening the way for utilization of the easier to handle but lower catch rate panel trap. However, our results indicate a weak relationship. This is especially the case in the late summer into fall when BMSB populations are highest, and accurate monitoring is required for precise timing of chemical interventions prior to harvest. Similarly, we found that the ratio of BMSB catch between LLIN and either panel or pyramid traps was variable, further reinforcing the conclusion that data collected by relative trapping for BMSB using panel traps may not accurately reflect true levels of BMSB populations in the field.

From a practical standpoint, we have observed insects escaping from the adhesive especially when catch is high. In addition, handling the trap can leave the users fingers and clothing contaminated with adhesive, hampering the acceptance of the trapping system by both growers and scouts. Finally, we observed that the adhesive used on sticky panels loses effectiveness at lower temperatures, with BMSB nymphs capable of walking unhindered on the sticky cards during cooler autumnal weather near harvest.

Panel traps were introduced specifically because pyramid traps were considered too burdensome to carry and install and too easily damaged by farm equipment (Rice et al. 2018). Although LLIN traps are lighter and less easily damaged than pyramid traps, they require more effort to assess. Unlike pyramid traps which can be checked from a standing position, LLIN traps often require users to squat or kneel to accurately detect BMSB on the dark landscape fabric beneath the trap. This difference may be insignificant for younger operators, but the length of time one must squat or kneel to assess traps may serve as barrier for older or less physically able users. As a result, the protocol for assessing catch in LLIN traps may need further development if this new design is to be accepted by growers and scouts. During periods of particularly high catch, we tested alternative LLIN trap assessment methods including sweeping all fallen BMSB on the landscape fabric into a zip-top plastic bag. Once within the bags, the samples can be frozen for later counting which can be performed seated at a table or countertop. Additional refinements to the LLIN trap design are needed to help ameliorate this issue. However, insects captured in traps deployed as part of an attract and kill program (like that in Morrison et al. 2016) the brown marmorated stink bug, is an invasive, polyphagous insect that causes serious economic injury in particular to specialty crops in the United States. Growers have been forced to respond by increasing the frequency of broad-spectrum insecticide (e.g., neonicotinoid, pyrethroid, and carbamate) would not need to be counted, eliminating the problems encountered in assessing catch.

Current best practices for BMSB trapping recommend placing traps at or just inside of the crop perimeter (Weber et al. 2017), but our results show that all trap types catch fewer BMSB when deployed in this manner. Visual stimuli are critical in facilitating the BMSB response to monitoring traps (Leskey, Wright, et al. 2012b), thus catch may be hindered in locations which obscure the visual silhouette of traps. Unfortunately, it is often difficult to find appropriate spots which are free of vegetation and other visual obstructions without placing traps in drive rows or other farm access points. Placing traps in an optimal location may not be possible, and future research should focus on understanding the relationship between the catch rate of traps placed in various farm landscapes and resulting fruit injury.

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John Pote is a Post-doctoral Research Associate who works with Larry Gut; Julianna Wilson is a tree fruit integrator in the Department of Entomology, Michigan State University; Larry Gut is a Professor of Entomology at Michigan State University who leads MSU’s program of tree fruit arthropod management.
Potential Role of Root Traits of Rootstocks in Fire Blight Susceptibility

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Keywords: Erwinia amylovora, disease tolerance, root growth, root mass, root shoot interactions.

Genetic resistance to fire blight, caused by the bacterium Erwinia amylovora, exists in wild Malus species, but due to long juvenility periods, high heterozygosity, and self-incompatibility in apples, it can take several years for backcrossing to achieve commercially acceptable good fruit quality. Disease resistance in the host plant could, however, provide an alternate to chemical control measures to sustainably limit bacterial spread, especially if bacteria is already inside the plant. Apple rootstocks affect scion genotypes in many different ways and can be used to regulate growth, vigor, architecture, phenology, physiology, fruit quality and tolerance to diseases of grafted scion cultivars. Fire blight resistant rootstocks have also been used to acquire tolerance in susceptible scion cultivars for sustainable disease management in apple orchards (Zhu et al., 2014; Jensen et al., 2012; Jensen et al., 2010; Norelli, 2003).

Use of resistant rootstocks can provide a natural means to directly combat fire blight infection of rootstocks, but can also limit its internal spread in susceptible scions (Norelli et al., 2003; Russo et al., 2007). Fire blight susceptible scion cultivars grafted on rootstocks (G.16, G.30, and G.11) from the apple rootstock breeding program in Geneva have shown high to moderate resistance against fire blight (Norelli et al., 2003). It has been proposed that gene expression changes in disease related proteins, and pathways related to various cellular and metabolic responses, are partly responsible for rootstock-driven differential fire blight susceptibility of grafted scions (Jensen et al., 2012). However, rootstocks can potentially use various mechanisms to provide resistance, and the exact cause of rootstock-derived scion resistance or tolerance to fire blight is yet unknown.

Roots of the apple rootstocks, the hidden half of an apple tree, are critical for their interaction with the soil microbial communities and physical environment. However, due to technical challenges to visualizing and studying below-ground plant organs, roots are under-researched, compared to above-ground plant organs. Roots can trigger physiological and genetic responses that lead to the activation of inter-organ signaling, and molecular pathways for recognizing and initiating the systemic defense against pathogen infection (Nalam et al., 2012). Some root traits also hinder penetration of soil-borne pathogens into living tissue and act as physical barriers (Bani et al., 2018).

Root system architecture (RSA), which includes root length, diameter, density, angle, and branching pattern, impacts uptake of water and nutrients from the soil (Rogers & Benfey, 2015). RSA traits can help plants survive under stressful conditions e.g., wounding, flooding, drought, and nutrient deficiency (Khan et al., 2016; Steffens and Rasmussen, 2016). The root systems of apple rootstocks, which mainly consist of adventitious roots originating from the nodal junctions of stem cuttings, are understudied and need further research to understand their potential role in enhancing tolerance to various biotic and abiotic stresses.

We have carried out several experiments to understand the effect of root traits on the fire blight susceptibility of grafted scions and non-grafted rootstock plants. Root traits of apple rootstocks were evaluated to explore their interactions with scion genotypes, and to measure scion susceptibility to fire blight infection. Results of this research have been also published as a peer-reviewed research article “Singh J, Fabrizio J, Desnoues E, Pereira Silva J, Busch W, Khan MA. 2019. Root system traits impact early fire blight susceptibility in apple (Malus domestica). BMC Plant Biology 19 (1): 1-14”.

Materials and Methods

We conducted two experiments to characterize the phenotypic variation in the root traits of apple rootstocks, and to study the role of root traits on fire blight susceptibility. Fire blight inoculations in both experiments were done using a highly virulent E. amylovora strain (Ea2002A) by cutting the youngest unfolded leaf of an actively growing shoot using scissors dipped in the bacterial inoculum, as described earlier (Singh et al., 2019). Total leaf length (cm), total shoot length (cm), and length of fire blight necrosis of a leaf (cm) were measured using a ruler 8 days after
Root surface area and fire blight susceptibility in non-grafted 1-year-old 'M.7' rootstocks. In the second experiment, 21 non-grafted 1-year-old scions. These results suggest that root traits of rootstock play a role in regulating fire blight susceptibility in the grafted scions. The root system of each young tree was separated into coarse (diameter > 1 mm) and fine (diameter < 1 mm) roots, dried in an oven, and then used to determine fine root dry mass (g), coarse root dry mass (g), and total root dry mass (g). All data collected for root and for fire blight disease severity was used for statistical analysis including ANOVA, Pearson correlation coefficients, hierarchical clustering and principal component analysis (PCA) in R statistical software (http://www.R-project.org/).

Results and Discussion

Root dry mass of rootstock and fire blight susceptibility of grafted scions. In the first experiment, fire blight susceptibility data for 45 different scion genotypes grafted on 1-year-old 'Malling 7' ('M.7') rootstocks were used to evaluate the relationship between root traits and fire blight infection severity. 'M.7', a moderately fire blight-susceptible rootstock, was originally selected from traditional French rootstocks, at East Malling Research Station (UK). These grafted plants were grown in a greenhouse facility at Cornell AgriTech (Geneva, NY) in D40H deepots (Stuewe and Sons, Tangent, OR) containing a standard Cornell soil mix (50 peatmoss:50 vermiculite with 6.2 kg.m⁻³ lime, 1.25 kg.m⁻³ superphosphate, and 0.62 kg.m⁻³ calcium nitrate) at 25°C, 50% RH, and 16 h light/8 h dark photoperiod for a period of 8 weeks. For each scion genotype, three replications were maintained in the greenhouse and arranged in a completely randomized block design.

We found significant (p < 0.05) variation for fire blight infection (%), and root dry mass (g) in 'M.7' rootstocks obtained from the same nursery (Figure 2; Figure 3). The root dry mass of 'M.7' rootstocks varied from 0.7 grams (g) to approximately 6.0 g. Percent fire blight lesion length showed significant (p < 0.05) variation and ranged from 1.2 to 93%. Overall, root dry mass (g) had significant (p < 0.05) negative correlation (-0.48) with fire blight percent lesion length (%), suggesting that a greater root dry mass of the rootstock reduces fire blight susceptibility of grafted scions. These results suggest that root traits of rootstock play a role in regulating fire blight susceptibility in the grafted scions.

Root surface area and fire blight susceptibility in non-grafted rootstocks. In the second experiment, 21 non-grafted 1-year-old 'M.7' rootstocks were used to identify role of root traits in regulation of fire blight in non-grafted plants, and to evaluate the extent to which roots can influence levels of fire blight susceptibility of shoot. First, we created four distinct root area classes (RACs) of 'M.7' rootstocks by altering the numbers of adventitious root nodes through pruning, from the bottom up, using Fiskars hedge shears. Afterwards, rootstocks were photo-imaged, and then grown in plastic pots (26 cm diameter x 22.5 cm depth) in a completely randomized block design for 106 days as described in the first experiment (Figure 1).

The average root surface areas (cm²) varied between approximately 1,700 (lowest RAC-1) to 4,500 cm² (highest RAC-4). There was significant (p < 0.05) variation in fire blight infection, measured as percent lesion length (%), between different RACs over time (Figure 3; Figure 4). Total fire blight infection was less in root classes with high root surface areas (cm²) at the start of the experiment, and vice versa. The rates of fire blight infection progress were about 41% to 75% in RAC-4 and RAC-3 from 2-8 days after fire blight inoculation and used to calculate the percent leaf and shoot lesion length (%). At the end of each experiment, roots were shaved off each of the rootstocks, and dried in an oven to determine dry root mass (g).

For the second experiment, additional root trait data were digitally collected both at the beginning and at the end of the experiment. The root system from each 'M.7' rootstock was photographed by rotating it 360 degrees to capture the three-dimensional root surface area using a Canon EOS Rebel T5 Digital SLR camera (Cannon USA Inc., Melville, NY, USA) as shown in Figure 1. Raw images were analyzed to calculate the total root surface area (cm²) using ImageJ (https://imagej.nih.gov/ij/). Afterwards, rootstocks were categorized into four classes (RACs), from lowest to highest root surface area (cm²). At the end of the experiment, roots were carefully dug out, and washed using a detergent and water. Roots were then spread on a flat surface, and photographed using a Canon EOS Rebel T5 Digital SLR camera. Photo-images were processed using an ImageJ software to calculate pre- and post-experiment root surface areas (cm²). Based on digital root diameter classifications, the root system of each young tree was separated into coarse (diameter > 1 mm) and fine (diameter < 1 mm) roots, dried in an oven, and then used to determine fine root dry mass (g), coarse root dry mass (g), and total root dry mass (g). All data collected for root and for fire blight susceptibility (%) in an experiment with 45 scion cultivars grafted on 1-year-old 'M.7' rootstocks obtained from the same nursery.
greater root surface area does not bring greater fire blight tolerance.

In addition, there was a significant ($p < 0.05$) positive correlation between root traits evaluated pre- and post-planting, for a total duration of 106 days of plant growth, indicating that initial root traits (root area, root dry mass) could be used as a predictor of root traits at later stages of root development. Pre-plant root area (cm$^2$) and fine root dry mass (g) had significant negative correlations with fire blight susceptibility. Negative correlations between percent lesion length (%) against post-planting root area (cm$^2$), coarse root dry mass (g), and total dry mass (g) were not significant.

Conclusions

Our results showed great variation in root traits for ‘M.7’ rootstock obtained from the same nursery. A significant negative relationship was found between root surface area, root dry mass and fire blight susceptibility of grafted and non-grafted young apple plants. These results suggest that an optimum root area is required to achieve the maximum tolerance against fire blight. However, more studies should be carried out to identify the exact mechanisms, genes, and management practices that can impact root traits and rootstock-derived tolerance/resistance. These can then be used to provide recommendations to nursery growers and in breeding programs for developing rootstocks with optimal productivity.

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Awais Khan is a research and extension professor of plant pathology at Cornell AgriTech in Geneva and his program focuses on genetics of host disease resistance and disease management in fruit crops.
Describing Pest Communities on Low Tunnel vs. Open Field Grown Strawberry in New York

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Keywords: protected culture, IPM, strawberry, pest monitoring

Most major strawberry producing countries in the world, excluding the U.S., grow most of their crop under high and plastic low tunnels (Castilho et al. 2015). These tunnels can greatly extend the growing season in cold climates, and protect fruit against rain, wind and frost damage (Anderson et al. 2019). Although an increasing number of strawberry growers are, or are interested in producing under plastic, the majority have not adopted this production technique. This may be due to high initial costs of implementation and maintenance, variable yield, and risks of increased pest pressure.

Few studies have evaluated the effects of tunnel environments on pests, but it is clear that these plastics influence primary abiotic conditions, namely temperature, humidity and exposure to ultraviolet radiation, that pests experience (Anderson et al. 2019, Orde and Sideman 2019). These plastics transmit, block or partially block UV and infrared radiation, and can diffuse passing light to varying degrees. In general, low tunnels can provide a UV-limited, warmer and drier environment that is buffered against outside elements, ultimately leading to improved plant growth.

Key strawberry pests include generalist insects and mites, perennial weeds, and a diverse suite of pathogens. Some pests may respond positively to the warm, dry and UV-limited environment provided by plastic tunnels, while others respond negatively to these conditions. Few studies have evaluated the strawberry pest community present under low tunnels, and none have included invertebrates, weeds and pathogens in a single comprehensive study. The purpose of this research was to address this lack of information that is necessary for developing IPM programs for this new production system.

Materials and Methods

During the summers of 2018 and 2019, 24 plots of bare-root ‘Albion’ were planted in rows at Cornell AgriTech in Geneva, NY. All plots were on raised beds, covered with white plastic mulch, and fertilized once per week. Half were assigned as low tunnel, and the remaining half as open (Fig 1). Once plants were established, sheets of Dubois plastic (1.5-mil film; Trioplast AB, distributed by Dubois Agrinovations) were fitted to metal hoops over tunnel-assigned plots. A similar approach was taken in 2019, but multiple plastics were used. Plastics were chosen to have similar clarity and light diffusion, but to be variable in their transmission of UV radiation. Treatments included a no plastic open-field control, a UV-B transmitting plastic (Dubois [Dubois Agrinovation], a partially UV-B blocking plastic (Tufflite IV [Berry Global Inc.], and a UV-B blocking plastic (Warps 4 yr UV-Clear [Warps Bros.]).

Yield damage and infestation by Drosophila suzukii Strawberry harvests occurred from June-July to early November in 2018 and 2019. Partially ripe to fully ripe berries were collected during harvest, weighed, and scanned for damage caused by invertebrates (namely tarnished plant bug and slugs) and for various fruit rots. Marketable fruit was identified as berries with undetectable or minimal damage caused by disease or arthropods/slugs, and those that weighed > 5 grams. A random set of berries were set aside to assess infestation by Drosophila suzukii Matsumura (spotted wing drosophila, “SWD”). Adults of SWD reared from berries were counted every two days for three weeks. Sampling occurred several times during peak infestation in 2018, and twice per month in 2019.

Arthropods. General arthropod abundance was surveyed using standard pitfall traps (Carolina’s) and clear sticky card traps (Catchmaster®). Pitfall traps were installed within plastic mulch in the center of each plot (Fig 2A). Traps were loaded with 50% propylene glycol and collected weekly in 2018, and twice per month in 2019. Clear sticky cards (12 x 10 cm) were deployed and collected once per week in 2018, and twice per month in 2019 (Fig 2B). Individual herbivores were counted and identified to order, family, or species.

Targeted sampling occurred for TPB and foliar herbivores (i.e., mites, aphids and thrips). Density of TPB was assessed weekly in 2018 and twice per month in 2019 by tapping flower clusters on to white plastic plates and counting the number of adults and nymphs present. Ten strawberry leaflets were collected from each plot weekly (2018) or twice per month (2019) and observed for the presence of foliar herbivores.

Pathogens. To determine disease incidence and severity on strawberry fruit, harvests were conducted as described above and individual berries were rated for disease. Fruit diseases of interest included anthracnose (Colletotrichum acutatum Simmonds) and botrytis or “gray mold” (Botrytis cinerea Pers), but other diseases including Rhizopus stolonifer Vuillemin were recorded if present. Foliar leaf pathogens common leaf spot (Mycosphaerella fragariae Tul.) and phomopsis leaf blight (Phomopsis obscurans Sutton) were assessed using a presence/absence survey on strawberry leaflets. This survey took place on September 21, 2018 and October 14, 2019. Leaflets were also scored for damage by mites, thrips and other foliar feeding arthropods.

Weeds. Weed harvests were collected every 2-3 weeks in 2018, and once per month in 2019. All weeds rooted within plastic beds within open-field or low tunnel plots were collected. After collection, weeds were immediately identified to species.
then placed in brown paper bags and dried for 24 hours at 70°C to determine dry weight.

Results

Yield damage and infestation by SWD The proportion of marketable fruit of total yield was 50% higher under Dubois-covered plots and 35-57% higher under all plastics compared to uncovered plots in 2018 and 2019. Marketable yields appeared to increase under plastics increasing in UV-limitation in 2019. Damage by TPB was similar across all covering treatments in both years, but slightly decreased under plastics increasing in UV-limitation in 2019 (Fig 3). There was also little effect of covering treatment on slug damage. The proportion of fruit attacked by anthracnose (Botrytis fruit rot) and botrytis was higher on open plots compared to those with plastic covering during both years (Fig 3). SWD was first detected in late August and reached peak densities in September–October during the summers of 2018 and 2019. Significantly more SWD adults were reared from berries collected on open vs. Dubois-covered plots in 2018, and marginally higher counts were observed on open plots in 2019. Pest surveys Pitfall traps and sticky cards. Common pests recovered from pitfall traps included crickets (Gryllus spp.), click beetles, seedcorn maggot (Delia platura), aphids, leaf beetles (mostly flea beetles), leafhoppers, long-necked seed bugs, moths (mostly those in Noctuidae), scarab beetles (Japanese beetle and Cyclolophaga spp.) and slugs (Fig 4). Common pests recovered from sticky cards included seedcorn maggot, aphids, flea beetles, leafhoppers, SWD, TPB, sap beetles and thrips (Fig 4). The overall total number of herbivores recovered from pitfall traps did not vary between covering treatments in both years, although catch was higher under low tunnels on most days during both seasons. The opposite trend was observed for catch on sticky cards, where abundance was higher on open plots on most days during both seasons, and this difference was most apparent between open and UV-limiting plastics. Crickets, flea beetles, leafhoppers, thrips, seedcorn maggots, SWD and TPB were the only groups that varied in their capture between covering treatments in one or both years (Fig 4).

Foliar feeding arthropods: Mites, thrips and aphids. Higher density of foliar herbivores (mites, thrips and aphids combined) were found under all low tunnel plastic in 2018, and no effect was observed for thrips during both years. Damage on leaflets by arthropods generally support above results, with mite damage occurring at higher proportions under tunnels and no differences occurring for general insect damage (i.e. by flea beetles, Japanese beetles and thrips).

Flower tapping for TPB. There was little difference in TPB density on flowers between open and low tunnel plots during both years, although there were higher counts of TPB on sticky cards from open plots in 2018. In addition, the proportion of fruit damaged by TPB of total yield was very similar between all covering treatments, with a season average of 48 ± 2% occurring in 2018 and 38 ± 3% in 2019.

Foliar pathogens. The two major pathogens identified on strawberry leaflets were common leaf spot (“CLS”) and Phomopsis leaf blight (“LB”). The proportion of leaflets infested by common leaf spot was nearly double on open plots compared to those under Dubois tunnels in 2018, and was similarly high on open plots compared to UV-limiting plastics in 2019 (Fig 5). Curiously, infestation was similar between open and Dubois (UV-transparent) tunnels in 2019. Although LB was present during both seasons, there was no difference in the infestation rate between covering treatments during both years.

Weeds. In total, over thirty weed species were identified from strawberry plots. Most were present in tears or openings of plastic mulch that exposed bare soil. Covering treatment had little impact on total weed biomass (i.e. dry weight) when combining all weed species and pooling across dates in 2018 and 2019. However, when considering each date separately, weed biomass was higher under low tunnels for the majority of dates during the 2018, but this was not observed for 2019. The only significant effect on a weed species was observed for dandelion (Taraxacum officinale L.) in 2018, which reached a higher biomass under low tunnels, and for ragweed (Ambrosia artemesiifolia L) in 2019 which reached highest biomass under Tufflite plastics.

Discussion

Plastic tunnels can provide an optimal environment for growing strawberries. In our study, we found marketable yield to be 35-57% higher under low tunnels compared to open-field conditions in both years, and there was a slight positive effect of increasing UV-limitation on yield in 2019. These results are consistent with past studies on low tunnel strawberry production (Lewers et al. 2017), and may be explained by the benefits of shading (Tang et al. 2020) or limiting exposure to UV that can reduce photosynthesis, biomass and yield for many crops (Cervantes et al. 2019).

Invertebrate presence General herbivore activity described from pitfall traps was
higher under low tunnels compared to open plots during 2018 and 2019. In addition, density of *T. urticae* was profoundly higher under low tunnels during both years. Direct observations of pests on high tunnel vs. open field caneberry in Michigan found similar results (Leach and Isaacs 2018). We suggest that many of these pests respond favorably to the warm and dry environment present under the tunnels by increasing rates of growth and reproduction. Select herbivores may additionally benefit from the UV limitation provided by Tufflite and Warps plastics. Exposure to UV-B can directly harm pests, as observed for *T. urticae* (Suzuki et al. 2009), but can also harm pests indirectly by inducing plant defenses (Izaguirre et al. 2007)280-315 nm.

On the other hand, herbivore capture on sticky cards was higher on open plots for most days in 2018, and highest on open and Dubois-covered (i.e., UV-transmitting) plots in 2019. This was especially true for seedcorn maggots, aphids, and SWD in this study. Many flying pests, including drosophilids, aphids, thrips, whiteflies and Japanese beetles rely to some extent on the presence of UV-A to navigate their environment (Antignus et al. 2001, Doukas and Payne 2007, Cramer et al. 2019). Thus, a UV limited environment may lead to reduced host finding and aggregation. However, we found high SWD infestation under Dubois, a UV-transmitting plastic in 2019. In this case, plastics may provide a physical barrier against invasion (Leach et al. 2016).

Plastics appeared to provide little protection against TPB, a key pest causing severe yield loss in 2018 and 2019. Between 31-48% of fruit exhibited clear TPB damage throughout both seasons, and there was a slight trend of less damage occurring under UV-limiting plastics. Direct counts of nymphs and adults, however, were very similar across covering treatments. These results are similar to observations made in Minnesota (Anderson et al. 2019).

**Pathogens and weeds** Tunnels of all plastic types appeared to reduce the presence of most foliar and fruit pathogens in our study, and this result is consistent with past observations (Kumar et al. 2011, Orde and Sideman 2019, Pritts and McDermott n.d.). Low pathogen infestation could be the result of reduced spore germination (which relies on UV exposure for some species), or reduced transmission between hosts by limiting standing water (Wharton and Diéguez-Uribeondo 2004). We found reductions of common leaf spot, *Rhizopus*, and *Botrytis* under UV-transmitting and UV-blocking plastics, indicating that reduced standing water is the most likely mechanisms reducing infection of foliage and fruit under low tunnels in our study.

Dry weight of weeds was similar between all covering treatments in 2018 and 2019, although in 2018 weed biomass was higher on most dates. Weeds typically germinate and grow more quickly under warm air and soil temperatures. Air temperatures are generally higher under low tunnels relative to open plots, but there is little evidence that soil temperatures are higher (Anderson et al. 2019, Orde and Sideman 2019). To further elucidate tunnel effects on weeds, more research is needed.

**Conclusions**

Plastic tunnels can provide a UV-limited and warmer environment for growing strawberries, and these conditions resulted in higher marketable yield in our study. Tunnels had varied impacts on the incidence and severity of pests, with many but not all pests reaching higher densities under low tunnels of any plastic type. This included *T. urticae*, crickets, thrips, leafhoppers, flea beetles, and possibly weeds, with *T. urticae* being the most economically significant. Higher density or presence of SWD, seedcorn maggots, aphids, fruit rots, and common leaf spot were found on open-field plots compared to those under any plastic tunnel type. Plastics transmitting or blocking UV-B had little effect on the presence of most pests, with crickets being the primary exception. Plastics may therefore provide a physical or UV-barrier for some pests, while also providing favorable conditions for the growth and reproduction of others. Finally, TPB populations and fruit injury were high on both open and plastic covered strawberries and represent a significant management challenge for low tunnel strawberry production.

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Samantha A. Willden is a graduate student who works with Dr. Gregory M. Loeb who leads Cornell’s berry and insect management program.

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Managed pollinator protection plans (MP3s) are local guides designed to reduce pesticide exposure to bees by increasing communication between growers, beekeepers, and other stakeholders. The Environmental Protection Agency released its Proposal to Mitigate Exposure to Bees from Acutely Toxic Pesticide Products in May 2015, which encouraged states and tribes to develop MP3s.

Michigan’s MP3, Communication Strategies for Reducing Pesticide Risk for Managed Pollinators in Michigan, outlines pesticide risk and assessment as well as strategies to reduce pesticide exposure from managed pollinators, especially honey bees. The plan encourages communication between growers, land managers, beekeepers, and pesticide applicators to reduce pesticide exposure. It promotes pollinator health through the development of best management practices and pollinator education. Michigan State University received funding from the Michigan Department of Agriculture and Rural Development, which acquired funding from the Environmental Protection Agency, to support writing and implementing strategies in the MP3 plan.

Michigan State University also received funding from the North Central IPM Center to lead a national working group of people who work on MP3s and related projects. The group currently includes representatives from 10 different states. The MP3 working group is creating shared resources and supporting efforts in other states to protect managed pollinators.

Michigan State University provided information about pollinators to pesticide applicators by authoring a section about pollinators for the Michigan Private and Commercial Applicator Core Manual, the book that many people in Michigan study before taking an exam to become certified pesticide applicators. The section about pollinators has been shared with other states that are interested in including a similar section in their study materials for pesticide applicators. MSU has also spoken to hundreds of certified pesticide applicators about managed pollinators at over a dozen pesticide recertification credit clinics.

In order to provide pollinator education to a wide range of stakeholders, Michigan State University developed an online Pollinator Champions course. The free course is interactive and takes about 6 hours to complete. Pollinator Champions is the fastest growing online course in terms of enrollment within MSU Extension and has a high completion rate. The Pollinator Champions course received MSU Extension’s 2019 Innovative Technology Award. Students who complete the free Pollinator Champions course can choose to pay a small amount to become certified so that they can give presentations about pollinators to public groups.

With input from growers, beekeepers, and Extension experts, Michigan State University is developing crop-specific pollinator stewardship guides on how growers can support pollinator health.
Increasing Juice Extraction and Drying Efficiency in Apple Products by Pulsed Electric Fields Treatment

Kate Pinsley, Shuang Qiu, Kyle Kriner, Carmen I. Moraru and Olga I. Padilla-Zakour

Keywords: Apple, hard cider, apple juice, tannins, polyphenols, Pulsed Electric Fields

New York State is the second largest apple-producing state in the US and, most importantly, grows more apple varieties than any other state. The diversity of apples contributes to the unique quality and attributes of each apple product. “Dessert” or “culinary” apples are mainly used for fresh consumption or baking. These apples are usually sweet or sharp tasting, with tannin concentrations between 0.02-0.2% (Valois, 2007). “Bittersweet” and “bittersharp” apples are those high in acid and contain up to 1% tannin, both of which are valued in fermented (hard) cider production.

Apple juice is one of the most popular fruit juices, with significant nutritional value. Apple cider, the pressed and unfiltered refrigerated juice, is more flavorful than juice due to increased amounts of components derived from the original fruit. Apple cider also has higher nutritive value than juice due to higher polyphenolic and soluble fiber contents. Tannins, a type of phenolic compounds present at higher concentrations in apple skins and at lower amounts in the flesh, contribute to bitterness and astringency, which are important sensory characteristics of both cider and hard cider. Fermentation “softens” the bitterness of tannins, while the remaining astringency provides mouthfeel and body to the cider. In addition, the oxidation of tannins contributes to the cider’s typical golden-brown color.

High quality cider is typically made from a blend of apples selected to balance sugar, acid, and tannin contents. High tannin cider apples are scarce and expensive in the United States, and the efficiency of tannin extraction into juice is low. Depending on the apple variety, processing conditions and method of measurement, 40-90% of an apple’s total tannins are lost during standard processing, hence the need to maximize the efficiency of extraction of the polyphenolic components. Researchers have tried with varying degrees of success to extract polyphenols out of apple mash or pomace with maceration (Cristina-Gabriel et al., 2012; Valois, 2007), heating prior to pressing (Martin, 2017), ultrasound-assisted extraction (Pingret et al., 2012), pressure-assisted extraction (Wijingaard & Brunton, 2009), or water, methanol, and/or acetate assisted extraction (Martin, 2017). The final goal of these studies was to produce cider with significantly higher tannin content or to manufacture a concentrated source of apple polyphenolics from pomace that can be added to the cider to increase its final tannin content.

The current consumers’ demand for fresh-like products is driving the development and application of nonthermal process-

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

Pulsed Electric Fields (PEF), a novel nonthermal process, during production of apple cider, hard cider and dried apple slices resulted in higher extraction of phenolic compounds (12-34%), slight improvements in juice yield (0-7%), and faster drying rates. The application of PEF in hard cider production can improve the polyphenol and tannin levels in the final product allowing cidermakers to reduce the percentage of expensive, high tannin apple varieties in the final blend.

Figure 1. Flowchart for the preparation of apple cider, dried apple slices and hard cider with and without PEF treatment.

This short communication presents work we are doing to protect pollinators of various horticultural crops.
ing technologies to manufacture high quality fruit products. High Pressure Processing has become a popular technology that can be used to ensure the safety and extend the shelf-life of refrigerated juices and beverages. Another emerging non-thermal technology that has an increasing number of applications in the food industry is Pulsed Electric Fields (PEF) treatment. High intensity PEF uses short, high intensity pulses of electricity (tens of kilovolts/cm) that create pores in bacterial cells’ membranes by electroporation; after this treatment bacterial cells die, and this process can replace thermal pasteurization. In case of low intensity PEF, pulses of a few kilovolts/cm can be applied to a food matrix in order to quickly and non-thermally open the cell tissue via electroporation. This process can facilitate slicing, enhance mass transfer that speeds up frying and decreases oil absorption in potato fries, or lead to faster drying rates and improved extraction of bioactive compounds from fruits and vegetables.

Previous research has shown PEF to outperform enzymatic maceration for polyphenolic compounds extraction from crushed grapes or grape skins, but for the treatment of apple mash, contradictory results have been reported. For example, 80% increase in total polyphenols was found by Schilling et al. (2008), while only about 20% increase was found by Grimi et al. (2011). The research on PEF-assisted extraction is limited, and confounded by equipment differences and process parameters. Yet, PEF offers clear opportunities for simpler and more environmentally friendly methods to enhance juice yield and extraction of biologically important components, such as tannins. Additionally, PEF has been shown to increase the air drying efficiency in potatoes (Lebovka, et al., 2007), and consequently it may offer the same benefits for apple drying.

Therefore, the objectives of this study were to: 1) investigate the feasibility of applying PEF as a nonthermal technology for producing apple cider and hard cider with increased phenolic content; and 2) assess the effect of PEF on juice yield and apple slices drying efficiency.

**Materials and Methods**

**Apples:** McIntosh, Red Delicious, Granny Smith, Honeycrisp, Empire, Fuji, Jonagold, Goldrush and Mutsu apples were purchased from a local supermarket and Cornell Orchards (Ithaca, NY) to prepare apple cider and dried slices.

**Apple cider preparation:** Apples were cored and sliced to produce apple cider as shown in Figure 1. The mixture of apple slices (500 g) and tap water (1000 g) was processed in the CellCrack UL Batch Pulsed Electric Field System (Elea, Quackenbruck, Germany). The voltage PEF treatment applied was 25–30 kV in a 30-cm width chamber (~1 kV/cm). The pulse duration and frequency were 40 μs and 1kHz respectively. The PEF treatment was conducted on apple slices or on apple mash for 400 pulses. Slices were shredded and the mash pressed using a GoodNature X1 mini juicer (GoodNature, Buffalo, NY) to prepare apple cider.

**Dried apple slices preparation:** Apple slices with or without PEF treatment were loaded into the Food Dehydrator (EXC10EL, Excalibur, Sacramento, CA) to evaluate the hot air drying process at 135°F.

**Hard cider preparation:** A blend of Porter’s Perfection and Golden Russet (courtesy of Ian Merwin, Black Diamond Farm, Trumansburg, NY) was used as the source of tannins. Apples were milled, the mash treated by PEF or left untreated (control), followed by pressing and fermentation at 12°C to dryness (14–17 days) according to established protocols. DV10 yeast was used at 25 g/hL previously rehydrated with 30 g/hL GoFerm. A blend of dessert apples was used to prepare a fermented neutral cider comprised of McIntosh, Mutsu and Gold Rush. For sensory evaluation, the final hard ciders were blended at 30% high tannin blend (control and PEF treated) with 70% neutral blend and adjusted to 3% sugar by the addition of sucrose.

**Physicochemical analysis:** Juice yield was calculated based on juice weight against apple mash weight (%w/w). The cider samples were analyzed for color components (L, a, b) using a Hunter Lab colorimeter (UltraScan VIS, HunterLab, VA). Turbidity was measured with a Hatch Portable Turbidimeter (Loveland, CO). Total Polyphenol Content was determined using the Folin-Ciocalteu colorimetric assay. Tannins were measured following the methyl cellulose precipitation method using the 10 mL assay format.

**Sensory Evaluation:** Sensory evaluation of hard cider was conducted at the Cornell Sensory Center (Ithaca, NY) with 100 untrained panelists recruited from the alcoholic beverage panel, all of whom reported consumption of hard cider at least once a month. The tests were carried out following the guidelines and policies of the Cornell Institutional Review Board for Human Participants.

**Results and Discussion**

**Apple cider extraction.** The effect of PEF on apple slices is shown in Figure 2. The pictures of the five apple varieties tested
clearly indicated that the electroporation caused by the PEF applied (400 pulses at 1 kV/cm for 40 μs) was able to increase cell permeability, resulting in fast browning of the apple slices due to the reaction of the polyphenol oxidase enzyme and the apple phenolic compounds in the presence of air. The electroporation process was expected to increase the juice yield, but a small increment was observed only for 3 varieties: Red Delicious (+7.4%), Empire (+2.5%) and Granny Smith (+1.1%). As the PEF treatment was applied to apple slices submerged in water instead of apple mash, it is possible that higher yield could have been achieved if the process was applied directly to the mash. Further results based on the extraction of phenolic compounds seem to substantiate this approach. It is also possible that the applied energy was not sufficient to create enough electroporation to increase juice yield.

When the PEF was applied to the five different apple mashes prior to juice pressing, marked improvements in total phenolics extractions were obtained, as seen in Table 1. Increases of over 30% were observed for Red Delicious and Fuji, followed by less than 20% for the other 3 varieties tested. This extraction improvement fits within the published range for PEF-treated apple mash, with an approximately 20% increase found by Grimi et al., (2011) in the treatment of Golden Delicious apples, and the 80% increase in total polyphenols found by Schilling et al. (2008) in the treatment of a high-tannin cider apple blend.

Apple drying. The effect of PEF on the drying behavior of apple slices is shown in Figure 3, which shows moisture loss over time. All five varieties, with or without PEF treatment, reached the dried stage after 160 minutes using a dehydrator with forced hot air at 135°F. PEF treated Red Delicious, Granny Smith, Honey Crisp and Empire apples showed better drying efficiency with drying completed within 100 to 120 min. The only variety that did not benefit from PEF was McIntosh, which is consistent with the lack of effect on juice yield discussed previously. These results agree with a previous study that evaluated the effect of

Figure 3. Moisture content of apple slices with or without Pulsed Electric Fields (PEF) pre-treatment during hot air drying at 135°F.
Table 1. Increase in total phenolic content of apple cider by variety due to the application of Pulsed Electric Fields (PEF) to apple mash prior to juice pressing.

<table>
<thead>
<tr>
<th>Variety</th>
<th>Fuji</th>
<th>Jonagold</th>
<th>McIntosh</th>
<th>Mutsu</th>
<th>Red Delicious</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increase compared to untreated control</td>
<td>30%</td>
<td>12%</td>
<td>18%</td>
<td>19%</td>
<td>34%</td>
</tr>
</tbody>
</table>

PEF pretreatment on drying efficiency of potato tissue (Lebovka, et al., 2007).

**Hard cider quality.** The application of PEF resulted in minor changes to the physical attributes of the fermented product, but significant increases in total phenolics (Table 2). The PEF treated hard cider was less turbid, slightly darker (lower L), and redder (higher a) than the control. These effects have been documented in previous studies, and these color changes were associated with greater anthocyanin extraction from the skins (Valois, 2007). The total phenolic content further corroborates the higher extraction efficiency by PEF calculated to be about 30% higher than the control (Table 2). The extraction of tannins was not as effective, with only a modest increase of about 4%. Tannins were measured by the methyl cellulose precipitation test, which is known to correlate better with the sensorial perception of astringency in hard ciders. Additional testing will be needed to assess the phenolic profile of the treated cider.

To investigate the effect of PEF on cider acceptability by consumers, we conducted a sensory evaluation of hard ciders blended following common practices used by the industry.

Table 2. Physicochemical properties of hard cider with or without Pulsed Electric Fields (PEF) pre-treatment.

<table>
<thead>
<tr>
<th></th>
<th>Total Phenols as Gallic Acid Equivalents (mg/L)</th>
<th>Tannins as Epicatechin Equivalents (mg/L)</th>
<th>L</th>
<th>a</th>
<th>b</th>
<th>Turbidity (NTU)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control hard cider</td>
<td>1100</td>
<td>770</td>
<td>39.5</td>
<td>2.1</td>
<td>20.4</td>
<td>32</td>
</tr>
<tr>
<td>Hard cider with PEF pretreatment</td>
<td>1450</td>
<td>800</td>
<td>38.2</td>
<td>4.9</td>
<td>20.2</td>
<td>23</td>
</tr>
</tbody>
</table>

Table 3. Sensory Evaluation and Just-About-Right Rankings of final hard cider blend made of 30% PEF treated high tannin cider (control untreated) and 70% neutral cider.

<table>
<thead>
<tr>
<th></th>
<th>Appearance</th>
<th>Aroma</th>
<th>Taste</th>
<th>Texture</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control Hard Cider</td>
<td>6.3</td>
<td>6.4</td>
<td>6.1</td>
<td>6.3</td>
<td>6.2</td>
</tr>
<tr>
<td>Hard Cider with PEF pretreatment</td>
<td>6.6</td>
<td>6.6</td>
<td>6.2</td>
<td>6.3</td>
<td>6.3</td>
</tr>
</tbody>
</table>

Typically, the blend would have 20-30% high tannin varieties and 70-80% neutral varieties to balance the flavor, astringency, bitterness, and cost, as high tannin cider is expensive. Therefore, a blend of 30% high tannin (PEF treated and untreated control) was used for the sensory evaluation, adjusted to 3% sugar by addition of sucrose. Control and PEF hard ciders had the same acidity (6 g/L) and alcohol level (7.6% ABV). After blending, the difference in total phenolic and tannins content was small, less than 10%, indicating that panelists might not be able to perceive the difference.

For the test, 100 panelists were asked to rate the hard cider samples using a 9-point Hedonic liking scale and the Just-About-Right (JAR) 5-point scale. As seen in Table 3, the panelists rated both samples favorably for appearance, aroma, taste, texture and overall liking, with no statistically significant differences between the two. Results based on the JAR scale showed that the ciders were well balanced in important attributes such as tartness, bitterness and astringency. The PEF sample was rated slightly better at sweetness and cloudiness, with both samples perceived as needing more apple flavor. These results confirm that the sensorial attributes of hard cider prepared using PEF treated apple mash were very similar to the control, and that quality was not negatively affected by the PEF treatment. Bitterness and astringency, which would normally be associated with the total phenolic and tannin contents, were not perceived differently even though the PEF samples had slightly higher concentrations of these compounds. This suggests that when the final phenolic and tannin concentrations are within a certain range, they are not differentiated by panelists. An economically important implication of these results is that the final blend of hard cider would require less of the more expensive PEF treated high tannin cider to match the phenolic content of the untreated control. For example, instead of blending the PEF treated high tannin cider at 30%, it could be reduced to 20-25%.

**Summary**

This study demonstrates some possible applications of Pulsed Electric Fields (PEF), a novel non-thermal process, during production of apple cider, hard cider and dried apple slices. We investigated treating apple slices and apple mash with low energy PEF to partially electroporate the apple tissue (flesh and skin), without the application of heat or enzymes, which resulted in higher extraction of phenolic compounds (12-34%), slight improvements in juice yield (0-7%), and faster drying rates. Varietal effect was significant, indicating that PEF conditions need to be further optimized to achieve better results. The application of PEF in hard cider production can improve polyphenol and tannin levels in the final product while maintaining the product’s physicochemical attributes.
and sensorial quality, and allowing cidermakers to reduce the percentage of expensive, high tannin apple varieties in the final blend. Further studies will focus on optimization of PEF conditions and economic analysis to determine best approaches for the apple industry.

Acknowledgements
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Literature Cited


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Evaluation of Modern Communication Technologies for Certified Pesticide Applicators to Communicate with Non-Certified Sprayer Operators

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Keywords: Technology, Communication, Certified Pesticide Applicator, Pesticide, DEC

The Special Permit Training (SPT) Program certification enables non-certified applicators in New York State to apply a specific list of federal restricted use pesticides (FRUP) without the direct, on-site supervision of a NYS certified pesticide applicator. The New York State Department of Environmental Conservation (NYS DEC) defines the term onsite direct supervision as where a certified applicator is physically present at the application site and can use their natural voice to reach the unassisted ear of the non-certified sprayer operator. The definition of direct supervision in NYS excludes the use of electronic forms of communication between the supervising certified applicator (SCA) and the non-certified applicator (NCA). Agricultural pesticide applications occur within a noisy environment, especially for airblast applications, and such direct voice communication in the field is both physically impossible and unsafe. Special Permit Training, sometimes also known as “Handler Training” was first developed and implemented in 2000 in collaboration with the NYS DEC. NYS DEC agreed to remove the requirement for on-site direct supervision if the applicator was trained to understand the risks of the restricted use pesticides, and how to take steps to prevent the risk of injury to the environmental, the applicator, or other living things. Following the completion of a 3-hour annual training program developed by Cornell Cooperative Extension educators, the Special Permit trainee was authorized to apply a specific list of federally restricted use pesticides (FRUP) under the supervision of the farm’s SCA, but without having to comply with the “on-site” and “voice to ear” communication requirements.

SPT continued relatively unchanged through 2015 with the list of approved FRUP’s growing to 155 registered products. The growth of the FRUP list was primarily attributable to the inclusion of generic formulations of brand name products with concurrent benefit of cost savings to the producer. Products were included in the approved list based on their EPA product registration number, not by active ingredient. For example, for products containing the active ingredient chlorpyrifos, there may have been a half-dozen actual name brand and generic formulations on the approved FRUP list. In 2015, as part of a general review of NYS pesticide applicator regulations in anticipation of changes in the federal certification and training (C&T) regulations, NYS DEC conducted a review of the long-standing SPT program. The regulator concluded that SPT, as then implemented, was not in compliance with federal regulations in place at the time. As such, cancellation of SPT was proposed for the 2016 season.

By 2016, SPT had grown in size and scope across NYS, with over 100 apple and processing vegetable farms and 500+ employees participating in the annual training sessions. Returning to specific compliance with the on-site, voice communications-only definition of direct supervision would seriously impact apple and processing vegetable production in NYS. Cornell Cooperative Extension specialists in collaboration with the Cornell Pesticide Management Education Program (PMEP) and the Office of the Dean at the Cornell College of Agriculture and Life Sciences (CALS) worked with NYS DEC officials in Albany to bring SPT into compliance with federal regulations for the 2016 season. A major concern of the regulator was the growth of the approved FRUP list to 155 registered products when federal regulations could be interpreted to allow only a single product for the whole program, not 155. NYS DEC was also concerned about the growth of the program when the regulatory goal was to increase the number of certified applicators, not non-certified SP holders. Finally, the intent of the federal regulations pertaining to FRUP application by NCAs under the supervision of SCAs was that NCAs be trained to a level approximating that of certified applicators. In order to meet these goals, 80% of SPT educational materials were revised, an exam was implemented, certified applicator exam preparation courses were emphasized statewide, and the list of approved FRUP’s was reduced from 155 to 11. The FRUP reduction was a challenge, achieved through the elimination of generic formulations in favor of brand name but more widely available products, and the input of Cornell faculty, private consultants, and pesticide distributor field personnel. A consequence of this FRUP reduction process was an increase in spray chemical costs for the producer. CCE extension specialists accomplished the re-vamp of the SPT program through a concerted effort in March of 2016, with a successful implementation in early April.

A new challenge will come in 2021 as we expect the current SPT program to be eliminated after the 2020 season. Why? The legal basis for SPT was eliminated as part of the 2017 federal revision of the C&T regulations. SPT has been legally allowed to continue here while NYS DEC pursues the implementation of the federal C&T regulations in NYS, a multi-year process. The NYS implementation process is expected to be completed before the 2021 spray season, and without a suitable replacement being found, SPT will have to be cancelled and the industry will...
revert to operations compliant with the original NYS definition of on-site direct supervision. For the 2020 season, we are expecting 95 NYS farms with 453 NCA's to participate in SPT, the loss of these skilled employees in 2021 to farm pest management programs will be serious. A justification for the original federal SPT regulations was that not all farm employees are sufficiently skilled in the English language to be able pass state’s pesticide applicator certification exams. NYS SPT is a bilingual program, with attendance roughly equally divided between Spanish and English speakers. Since all pesticide certification exam training materials, NYS DEC exam itself, and pesticide labels are only offered in English, farm employees whose first language is not English face a daunting challenge to become fully certified.

A possible solution to the impending loss of SPT is allowing the voice contact requirement of onsite direct supervision to be met using modern communication technology. Natural voice contact is impossible when operating an airblast sprayer or using a self-propelled sprayer that has a cab and a single seat as the supervising applicator must be in the cab or on the operator station so their voice can be heard. Reliable radio or cellular communication, perhaps with the use of emergency smartphone apps, may be a suitable substitute for natural voice communication. It is interesting to note that electronic devices are allowed for offsite direct supervision of non-certified applicators applying NY restricted-use pesticides. While this is a fine point, it does indicate there is precedence in NYS for the use of electronic communication devices.

**Experimental Design**

In order to evaluate the use of technology in effective communication between a non-certified spray rig operator and a certified supervisor we compared the following methods of verbal supervision using modern communication technology.

1. Apple iPhone connected to Android Phone: The “Sprayer” used an iPhone 8 with noise cancellation enabled. The “Supervisor” used a Samsung Galaxy S8 Active.
2. Android phone connected to iPhone: The “Sprayer” used a Samsung Galaxy S8 Active. The “Supervisor” used an iPhone 8 with noise cancellation enabled.
3. Wired Earbuds connected to cell phone: Standard Apple earbuds that were compatible with the iPhone 8 were used during testing.
4. Consumer-Grade Wired Headset connected to cell phone: The wired Bose headset, model QC35, had active noise cancellation.
5. Bluetooth earbud connected to cell phone: Single earbud style with boom microphone, made by NPow.
6. Commercial-Grade Bluetooth Headset connected to cell phone: The Senear SM1P headset (headband style) is an industrial headset that has the ability to enhance speech and filter out background noise. It has Bluetooth connectivity and can also be used with two-way radios or for face to face communication. It limits in-ear exposure to 82 dB(A) to prevent damage to eardrums.
7. Consumer-Grade Bluetooth Headset connected to cell phone: Parrot Zik (Gen 1) Bluetooth noise canceling headphones have active noise cancellation technology for the wearer but not for the microphone.
8. Two-way radios: The two-way radios used for testing were the Motorola Mu 350 that have a range of up to 35 miles.

**Methods and Materials**

A script was prepared for both the supervisor and the sprayer consisting of 5 individual and unique sentences for each type of technology. A copy of the sprayer script and supervisor script was given to both individuals so that the sprayer could confirm that they heard the sentence correctly once the transmission ended, and vice versa.

The communications equipment was tested by reading a written sentence and having the other individual verify if they heard it correctly by checking a copy of the “script.” The quality of the transmission of the message was rated in the field and notes were made about how intelligible the sentence was.

The communications technology was tested against the noise of a John Deere Tractor Model 5525n with cab closed. The throttle was set at 2400rpm and noise in the tractor cab measured ~94 decibels. The “sprayer operator” sat in a stationary tractor with the engine at PTO speed. The “supervisor” was in a car moving around to 5 different locations in the orchard at a distance ranging from 118m to 489m.

**Rating Scale for effectiveness of communication:**

- 0 = no communication possible
- 1 = message was unintelligible
- 2 = message was mostly intelligible
- 3 = message was completely understood

**Results**

**Apple iPhone connected to Android Phone.** For the sprayer Audio communication was slightly garbled at times but clear enough to comprehend despite background noise. It required the use of both hands to place and receive a call which would be difficult while operating the tractor. At least one hand would need to continue the conversation unless the sprayer had a phone holder in the cab of the tractor. Connecting cell phone to cell phone had a very clear call quality for the supervisor. The cell phone of the sprayer filtered out the background noise and the message could be heard very clearly.

**Android Phone connected to iPhone.** For the sprayer Audio communication was hard to understand at times due to background noise. It required the use of both hands to place and receive a call which would be difficult while operating the tractor. At least one hand would need to continue the conversation unless the sprayer had a phone holder in the cab of the tractor. Connecting cell phone to cell phone had a good quality.

![Figure 1](http://example.com/figure1.png)

*Figure 1. Communication quality between a sprayer operator and a certified applicator supervisor using various technologies for communicating, rated on a 0-3 scale.*
quality for the supervisor. The cell phone of the sprayer filtered out some of the background noise however it was not as clear as the iPhone.

**Wired Earbuds connected to cell phone.** Audio was more garbled than cell to cell but still intelligible. Both hands are required to place a call, but in order to receive a call one hand would be needed to click the inline button on the microphone of the earbuds and no hands would be needed to continue the conversation. The sprayer could also easily adjust the call volume with the inline microphone button. When the sprayer used earbuds connected to their cell phone the background noise of the tractor was no longer filtered and it was more difficult to hear for the supervisor, but they could still communicate a message effectively.

**Consumer-Grade Bluetooth Headset connected to cell phone.** The noise cancelation was helpful but did not improve audio quality as much as expected. Audio was muffled yet comprehensible. Headset was comfortable. Placing a call required both hands to access the phone, but it is easy to receive calls and adjust volume with having to touch cell by using the touch panel on the headset. For the supervisor, the use of a consumer level noise-canceling Bluetooth headset connected to the cell phone did not improve call quality. The message coming from the sprayer was garbled with a high background noise level.

**Commercial-Grade Bluetooth Headset connected to cell phone.** Audio was clear and easily understood. Easy to hook up to Bluetooth. Noise cancelation provided good audio quality. Receiving calls and adjusting volume seemed effortless. Making calls required using cell. Headset is comfortable to wear and boom mic provides a hands free communication. The professional grade headset had an extremely clear quality and the message from the sprayer was easily understandable.

**Consumer-Grade Wired Headset connected to cell phone.** Call quality was muffled and could not be understood all of the time. The wire connection between the cell phone and the headset made for a reliable connection, but the wire can impede movement. Both hands are required to place and receive a call.

**Two Way Radio Connected to Two Way Radio** Very difficult to hear with tractor running. Lots of static. The further the distance the more communication was broken up. Least effective treatment. When using the two way radios the quality varied depending on the distance from the sprayer. There was background noise from the tractor that made it more challenging to understand everything. A few messages from the sprayer were only partially understandable.

**Bluetooth earbud connected to cell phone.** There is only one earbud on this device, made by NPow, that has a boom microphone extending towards the wearers jaw. It connects via Bluetooth to a cell phone. The sprayer reported very good clarity using this device for communication. Both hands are required to place a call, but in order to receive a call one hand would be needed to click the button on the earbud and no hands would be needed to continue the conversation.

**GPS Locator Test.** A separate investigation was performed on the effectiveness of emergency notifications with GPS coordinates in text-message format. A cell phone-app and a wearable button using Bluetooth were tested to see how much they helped to find a sprayer operator in an orchard as compared with having no GPS coordinates. An air blast sprayer and its operator went to a random location in an orchard and we timed how long it took to find the spray rig, as if there was an emergency we needed to assist with. For one example we had to search, driving in a pickup truck, looking down each row to find the sprayer rig. It was not as clear as the call volume, but it was 10 times quicker to find the sprayer and operator.

When using the two way radios the quality varied depending on the distance from the sprayer. There was background noise from the tractor that made it more challenging to understand everything. A few messages from the sprayer were only partially understandable.

<table>
<thead>
<tr>
<th>Time it took to find a Sprayer Operator in the Orchard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minutes</td>
</tr>
<tr>
<td>Red Panic Button</td>
</tr>
<tr>
<td>12:00</td>
</tr>
<tr>
<td>10:48</td>
</tr>
<tr>
<td>0:00</td>
</tr>
<tr>
<td>1:12</td>
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<tr>
<td>2:24</td>
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<td>3:36</td>
</tr>
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</tr>
<tr>
<td>5:56</td>
</tr>
<tr>
<td>6:00</td>
</tr>
<tr>
<td>6:12</td>
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**Figure 2. Time to locate a sprayer operator and air blast sprayer rig at a random location in an orchard (searching via pickup truck) using a cell phone app “Red Panic Button” as compared to the time to find the person without assistance.”**

**Figure 3. Grower responses to the survey question “What forms of technology do supervisors use to communicate with sprayer operators while they are spraying?”**

**Figure 4. Grower responses to the survey question “Are there of opportunities to improve emergency communication using technology?”**

**Results of Communication Survey of Growers.**

<table>
<thead>
<tr>
<th>Time it took to find a Sprayer Operator in the Orchard</th>
<th>[PERCENTAGE]</th>
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<tbody>
<tr>
<td>Red Panic Button</td>
<td>9.06%</td>
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<tr>
<td>Two-Way Radio</td>
<td>39.48%</td>
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<tr>
<td>In Person</td>
<td>20.97%</td>
</tr>
<tr>
<td>Cell Phone</td>
<td>33.87%</td>
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</table>

**New York State Horticultural Society**
This option is available built in on many cell phones as well.

Results of Communication Survey of Growers. A digital survey was distributed to growers in our program to ask questions regarding the current uses of technology to communicate with their sprayer operators, and their attitudes towards future developments. Below is a summary of the results of some of the answers we received.

- When growers were asked if there was an opportunity to improve emergency communications through technology 55% said yes, and 35% were unsure. Only 9% through there was probably not an opportunity to improve communications in an emergency situation.
- Of those who use cell phones to communicate with sprayer operators, all preferer phone calls over texting
- Phone calls were the most popular method of communication during emergency situations (88%)
- Respondents report that it would take an average of 6 minutes for them to respond to an emergency during spraying
- 80% of respondents report at all or some of their sprayer operators use a type of headset or earbud to communicate while spraying.
- Average amount that the supervisor spends on communications equipment for each spray rig is $143
- The average that they would be willing to budget is $219

Discussion

In 2018, 84% of growers surveyed were using either cell phones or 2-way radios to stay in regular contact with their sprayer operators. Phone calls were the most popular method of communication during emergency situations. Headphones or earbuds were utilized by a vast majority of respondents to facilitate electronic communication. 100% of those who have implemented electronic means of communication favored voice communications over texting. Respondents report that it would take an average of 6 minutes for them to respond to an emergency during spraying. A majority of growers believe that there is an opportunity to improve emergency communications through technology, which demonstrates that growers support the exploration of innovative methods of emergency communication such as GPS coordinate messages to locate the sprayer during an emergency. In a blind test of a commonly available no-cost smartphone “emergency button” app, we found that using the app in an emergency could reduce the SCA’s response time by 91%.

Our research results suggest that commonly used 2-way radios as well as Android and Apple smartphones perform adequately under field conditions. The noise-cancelling technology of recent Apple iPhones offer improved performance in noisy conditions. Smartphone “emergency button” apps are an economical and easily implemented tool to increase sprayer operator safety. Wireless noise-cancelling headsets can offer excellent performance, however commercial-grade sets that are built to survive the dusty environment of a farm can cost over $400+ per unit, greatly exceeding our survey-reported farmer cost tolerance of $219 per spray rig for communications gear.

Summary

Most sprayer operators are currently using electronic communications technology safely and effectively on a regular basis, and our research results indicate that 2-way radios and cell phones provide reliable levels of communication with supervisors. Emergency button apps provide an extra degree of safety with little to no additional expense.

Acknowledgements

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