Editorial
So What Have You Done For Me Today?

That is a reasonable question for a member of the tree fruit industry or a taxpayer to ask of a publicly funded institution such as the USDA-ARS-Appalachian Fruit Research Station (AFRS). What we have done is to think and plan for the future. So what does that do to help you today? Well it’s what we did 29 years ago when our laboratory opened and the results are what we have today. When AFRS started its work in 1979, we looked to the future problems of the industry and asked, “What are the ‘inevitable’ problems to be addressed?” In 1979, labor was not a critical issue, in fact “Hard Tomatoes, Hard Times” was still resonating through the agricultural community. Labor-saving mechanization was neither politically correct nor a great industry need, but it was inevitable that labor would be a critical need sometime in the future so AFRS worked to develop technology that would be on the shelf when the time came for its need. Today that technology is coming off the shelf in the form of sweet cherry, citrus, and blueberry harvesting machinery, harvest-aid platforms, mechanical thinning machines and bin filling technology. Furthermore, the plant architecture and training systems to marry the machine with the tree were needed to accommodate mechanization. Since breeding programs have a 20-30 year timeline, plans were made to develop the cultivars of the future. Today, peach cultivars have been released with upright (‘Sweet-N-UP’) and pillar (‘Crimson Rocket’) architectures that have a narrow and exposed fruit-bearing surface that facilitates mechanical thinning and harvesting as well as ease of hand thinning and harvesting.

In 1979 Plum pox or Sharka virus (PPV) was not present in North America, it was a European problem, but it was inevitable that global trade would someday introduce it to the U.S. Before Plum Pox ever reached the shores of the U.S., AFRS scientists led an international team to developed genetic resistant plum germplasm in anticipation of this devastating disease. Since Plum pox entered the U.S., AFRS scientists have continued with the development of resistant germplasm and expect to have release approval within the year of a plum pox-resistant plum cultivar (‘HoneySweet’) developed through genetic engineering.

In 1979 the home or business computer was a rare fixture but it was inevitable that computers would play a key role in all aspects of agriculture. AFRS scientists teamed with the University of Maryland to take the accumulated knowledge of how and when fire blight infection occurs and to build a ‘computer program’ named MaryBlyt to predict infection periods. MaryBlyt has been a key tool in managing fire blight throughout the U.S. and the world.

In 1979 the ‘organic movement’ was a tiny, tiny blip on the radar screen of the American consumer and the commercial food production system of the U.S. However, with the increased interest of American consumer in food production systems with reduced or no dependence on toxic pesticides, AFRS scientists took-up the challenge of using natural organisms to control damaging disease microbes. AFRS developed the first bio-fungicides (Aspire, Bio-coat, Biocure and BioSave) for the commercial horticultural market and later generations of this technology are now commercially available throughout the world. Non-toxic insect repellants based on kaolin clay were developed (Surround WP) and are now used worldwide in both organic and traditional sustainable horticultural production systems.

In 1979, soil erosion with its nutrient and sediment pollution of waterways was a serious concern for agriculture, in general, but of minor concern in tree fruit production due to the small acreages and inherent design of orchards that reduced overland flow of runoff; yet recently there is interest in production systems that conserve soil organic matter and soil carbon because these are the backbone of soil fertility and the long-term sustainability of agriculture. Some of the first field studies at AFRS lead to the development of soil management and cover crop systems that not only preserved or increased soil organic matter, now termed carbon sequestration, but increased the

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COVER: Gala apple harvest at the Geneva Experiment Station of Cornell University. (Photo by Joe Ogrodnick)
biodiversity of habitats in the orchard to increase the populations of beneficial insects and organisms. This was, and always will be, simply good stewardship of the land. As the concepts of ‘carbon credits’ moves forward, these carbon sequestering technologies will have additional economic benefit for the tree fruit industry.

So what have we done for the industry today? Today, we look to the future and its problems through the lens of terms such as genomics, computer vision, global warming, genetic engineering, and water use efficiency. With the new technological tools that have been developed since 1979, we stand prepared to meet the needs of global competition, diminishing land resources, and increased demand for high quality, nutritious fruit. In another two decades we will look back and determine how well we anticipated the problems, but based on our track record, we will meet these challenges.

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NEW YORK Fruit Quarterly FALL 2008 • VOLUME 16 • NUMBER 3

This publication is a joint effort of the New York State Horticultural Society, Cornell University’s New York State Agricultural Experiment Station at Geneva, the New York State Apple Research and Development Program, and the NYSBGA.

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NEW YORK STATE HORTICULTURAL SOCIETY
Rapid Application of SmartFresh™ (1-MCP) to Apples After Harvest is More Important Than Rapid CA

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This work was supported in part by the New York Apple Research and Development Program.

In the last several years, we have accumulated a considerable body of information to help New York growers and storage operators exploit SmartFresh™ technology. This new technology has had a major effect in improving the quality of our fruit in the marketplace. This improvement has been especially valuable after the fruit leaves the storage facility since loss of quality during subsequent shipping and handling operations is out of the control of the storage operator and shipper, and sales are driven by quality at the point of consumption. Loss of quality is a problem for apples worldwide, but it has been a major issue for New York growers since many of our varieties soften rapidly after harvest.

SmartFresh™ technology is based on an inhibitor of ethylene perception known as 1-methylcyclopropene (1-MCP). Ethylene is the plant growth regulator that controls many aspects of ripening and senescence. In the case of apples, ethylene is closely linked with the rate of fruit softening. Thus a major benefit of SmartFresh™ is that it slows down softening of the fruit.

SmartFresh™ is usually applied to bins of fruit in air-tight storage rooms, and fruit are then stored in air or controlled atmosphere (CA) storages for periods that are appropriate for the variety and harvest date. Depending on the variety, the beneficial effects of SmartFresh™ can be reduced with extended storage.

Ethylene is produced naturally by the apple and its measurement is an important part of tracking fruit maturity during the harvest period. In general, fruit which produce lower levels of ethylene (i.e. early in the harvest window for any variety) tend to store longer with or without SmartFresh™. As a result, early harvested fruit are better candidates for long-term storage. SmartFresh™ also works best when fruit are not producing ethylene. Therefore, the internal ethylene concentration (IEC) of the fruit at the time of harvest is the first major factor that can affect the efficacy of SmartFresh™ application.

Figure 1. Internal ethylene concentration (ppm) of Jonagold apples at harvest and after storage in air for 1, 7, 14 and 21 days before treatment with 1-MCP (A) and flesh firmness (lb-f) after CA at 33°F storage for 5 months (B).

SmartFresh™ is a technology that has resulted in much better quality of fruit of some varieties in the marketplace, but we are still learning to use it to obtain maximum benefits for storage operators and consumers. In this article, we address the issue of whether it is better to apply SmartFresh™ as rapidly as possible after harvest and then be less concerned about rapid CA. This is an important question, especially for storage operators who cannot fill rooms quickly. Our results show that with rapid SmartFresh treatment, it is safe to delay CA storage application. However, if fruit are not cooled properly, and have not been treated with diphenylamine (DPA), there is increased potential for external carbon dioxide injury.
It is often not always recognized that ethylene continues to be produced by the fruit after harvest. Initially, rapid cooling helps to slow down ethylene production. However, ethylene production by the fruit increases in storage, the timing of which is affected by fruit maturity. Figure 1A shows data for an experiment with Jonagold apples. The IEC in the fruit was measured for up to 21 days after harvest while they were kept in cold air storage. After seven days, the IEC increase indicates that postharvest ripening has become less controllable. This type of change is also the basis for why rapid CA has been recognized as an important method to maintain fruit quality. Rapid CA, in which oxygen levels around the fruit are reduced to less than 5% in seven days, was rarely used 30 years ago. However, rapid CA now has become the industry standard, at least for large storage operations. The IEC of the fruit also affects the response of fruit to SmartFresh™ as illustrated in Figure 1B. A reduced SmartFresh™ firmness response in Jonagold was associated with increased IEC at the time of treatment.

The effects of both maturity and delays after harvest provide the basis for SmartFresh™ use recommendations provided by AgroFresh, Inc. The recommendations list maximum number of days between harvest and treatment, as well as other specific handling recommendations for important varieties. It is interesting to note that in Canada the maximum period between harvest and treatment is three days for all varieties, established by the federal Pest Management Regulatory Agency.

The AgroFresh recommendations are guidelines that necessarily average the interactions between maturity of fruit at harvest and subsequent changes in IEC during storage, but the situation in the field can be more complex. An apple harvested at the early part of the harvest window may take seven days or longer before ethylene production increases. As a result, the “degrees of freedom” for management of early picked apples may be quite high. However, an apple harvested at the end of the harvest window may take only a day or two to show increased ethylene production or, worse yet, may already be producing high amounts when harvested. In addition, commercial storage operators have to contend with a lot of variability in the maturity of fruit from different orchard blocks. These differences are likely to become greater and more critical with a later harvest date. Therefore, it is likely that a management protocol that emphasizes rapid SmartFresh™ treatment of fruit after harvest is desirable.

Also, as we have described in previous NY Fruit Quarterly articles (Razafimbelo et al., 2006; Watkins and Nock, 2007), rapid CA may make some storage disorders worse, especially external carbon dioxide injury in SmartFresh™ treated fruit. Strategies for reducing these risks may involve less emphasis on rapid CA as well as control of carbon dioxide levels in the storage.

The objective of the research presented here was to determine if rapid SmartFresh™ treatment (within two days of harvest) would then permit a more relaxed approach to the time taken to establish CA conditions. This research was carried out over two seasons. In the first year (Experiment 1), we examined the effect of delayed CA in McIntosh and Empire fruit grown in two regions. In the second year (Experiment 2), we addressed the issue of temperature effects if field heat were not removed quickly following harvest.

**Methods**

**Experiment 1**

McIntosh apples were harvested in the Champlain and Western New York region, while Empire fruit were harvested in the Hudson valley and Western New York during the normal window for CA storage (Table 1). Three orchard blocks were harvested for each variety in each region, transported back to the storage facility at the Cornell Orchards in Ithaca, cooled overnight to 36°F, and treated with 1 ppm 1-MCP, generated from SmartFresh™ powder, for 24 hours. Fruit were then either placed into CA storage conditions immediately (two days after harvest) or after 7 and 14 days after harvest. Rogers McIntosh from the Champlain were stored in 2% carbon dioxide for the first four weeks, and then 5%, in 2% oxygen at 38°F. Marshall McIntosh from western New York were stored under the same carbon dioxide regime, but in 4.5% oxygen. Empire apples from the Hudson Valley and Western New York were stored in 2% carbon dioxide and 2% oxygen at 36°F. Fruit were stored for six months and evaluated after one and seven days at 68°F.

**Experiment 2**

McIntosh apples from Apple Acres Orchard and Empire apples from Cornell Orchards were harvested, and stored overnight at 36, 45 or 55°F. Fruit were then treated with 1 ppm 1-MCP at each respective temperature for 24 hours and kept at these temperatures for 2, 7 or 14 days. All fruit were then held at 36°F overnight before CA storage regimes were established. Fruit were stored for 4.5 and 8.5 months and evaluated after one and seven days at 68°F.

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**Table 1. Maturity and quality factors in the McIntosh and Empire apple fruit used in Experiment 1.**

<table>
<thead>
<tr>
<th>Variety</th>
<th>Region</th>
<th>IEC (ppm)</th>
<th>Starch index</th>
<th>Firmness (lb-f)</th>
<th>Soluble solids (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>McIntosh</td>
<td>Champlain</td>
<td>14.95#</td>
<td>5.6</td>
<td>15.2</td>
<td>12.0</td>
</tr>
<tr>
<td></td>
<td>Western NY</td>
<td>42.80</td>
<td>5.7</td>
<td>14.8</td>
<td>12.1</td>
</tr>
<tr>
<td>Empire</td>
<td>Hudson Valley</td>
<td>1.62</td>
<td>4.4</td>
<td>16.9</td>
<td>11.5</td>
</tr>
<tr>
<td></td>
<td>Western NY</td>
<td>0.83</td>
<td>5.2</td>
<td>15.8</td>
<td>11.1</td>
</tr>
</tbody>
</table>

# Each mean is the average of 3 orchard blocks in each region.
Results and Discussion

Experiment 1

Although fruit were evaluated after one and seven days at 68°F, only the results for a seven-day shelf life are shown here (Figure 2). For both varieties and growing regions:

1. Fruit treated with SmartFresh™ were firmer than untreated fruit.
2. Fruit without SmartFresh™ treatment (untreated) typically were softer with increasing delays after harvest before CA storage.
3. SmartFresh™-treated fruit did not show greater softening with increasing delays between harvest and CA storage.

No major effects of treatments on storage disorders or decay were found in this experiment. These results strongly suggest that the application of SmartFresh™ within a couple days of harvest reduces the need to apply rapid CA. This means that if it is more appropriate for some operations to fill rooms over longer periods of time, then it is possible to achieve this if facilities for quick treatment of small volumes of fruit are available. Concern has been expressed that quality of some fruit lots may be compromised if there are variable fruit maturities and therefore variable responses of fruit to SmartFresh™. For example, if a given orchard lot of fruit did not respond to SmartFresh™, then that fruit will be much softer if CA application is delayed. This is a factor that should be considered in a storage operation, especially towards the end of the harvest window. The risk of quality loss in non-responsive fruit will be greater with longer storage periods, and therefore it is likely that large storage operations that are trying to maximize storage potential will apply both rapid SmartFresh™ treatment and rapid CA. Interestingly, rapid SmartFresh™ treatment and more relaxed CA application seems ideally suited to smaller size operations with a goal of short to medium term CA storage length.

These results also highlight the importance of rapid CA after harvest for maintaining fruit quality for fruit that are not treated with SmartFresh™. Although delays between two and seven days were not examined, clear loss of firmness was found between these two times. Delays of CA application beyond a few days after harvest can result in significant loss of firmness.

Experiment 2

McIntosh apples were already producing climacteric levels, with internal ethylene concentrations (IECs) of...
6

Figure 3. Internal ethylene concentrations of McIntosh and Empire apples either untreated or treated with 1ppm 1-MCP and kept at 36, 45 or 55°F.

Figure 4. Flesh firmness (lb-f) of McIntosh apples treated with 1-MCP after overnight cooling to 36, 45 or 55°F and then maintained at these temperatures for 2, 7 or 14 days before storage in CA at 36°F for 4.5 or 8.5 months plus 7 days at 68°F.

Figure 5. Flesh firmness (lb-f) of Empire apples treated with 1-MCP after overnight cooling to 36, 45 or 55°F and then maintained at these temperatures for 2, 7 or 14 days before storage in CA at 36°F for 4.5 or 8.5 months plus 7 days at 68°F.

116 ppm, at the time of harvest, while Empire apples were producing relatively low ethylene levels as indicated by IECs of 7 ppm.

SmartFresh™ markedly inhibited the IEC of McIntosh apples despite the high levels at harvest (Figure 3 A). However, for this variety higher IECs were found in both untreated and treated fruit with higher delay temperatures and delays. In Empire, application of SmartFresh™ within a day of harvest completely stopped increases in ethylene production at all temperatures (Figure 3 B). However, the IEC of untreated fruit increased and was stimulated further by increased holding temperatures. Fruit also softened at the higher storage temperatures on day 14 (data not shown).

Both McIntosh and Empire apples were softer after 8.5 months of CA storage than after 4.5 months, irrespective of treatment (Figures 4 and 5). Empire fruit without SmartFresh™ and with delays softened more than McIntosh, but SmartFresh™ treated fruit were always firmer than untreated fruit. The benefits of SmartFresh™ in maintaining firmness were also apparent even in fruit that had been kept at warmer temperatures prior to CA storage.

However, major effects of SmartFresh™ and delay at the different temperatures were found in this experiment.
In McIntosh, the incidence of external carbon dioxide injury was low but increased with higher temperatures before CA storage after both 4.5 and 8.5 months (Figure 6). Senescent breakdown and superficial scald were highest in untreated fruit kept at 55°F, and to a lesser extent at 45°F.

In Empire, SmartFresh™ treatment resulted in lower levels of senescent breakdown and decay, but higher levels of flesh browning (Figure 7). An effect of delay that was spectacular and unexpected was the increased external carbon dioxide incidence in MCP treated apples kept at warmer temperatures prior to CA storage. This effect was surprising as the fruit in the Empire orchard block that we used have a history of low susceptibility to carbon dioxide injury, as was shown by fruit kept at 36°F before CA storage.

Increased risk of carbon dioxide injury would not be a problem for fruit treated with diphenylamine (DPA) to avoid storage scald. However, the results demonstrate that proper cooling is critical for fruit that has not received DPA treatment. It is possible that this observation explains why some Empire apples have had high instances of carbon dioxide injury.
dioxide injury, even when the levels of the gas in the storage atmosphere have been kept at 1% or lower. Although carbon dioxide injury in McIntosh was not high in this experiment, the variety is also susceptible to this disorder. Therefore, we urge that care be taken to manage cooling after SmartFresh™ treatment if fruit have not been treated with DPA.

A feature of this experiment was the observation that flesh-browning levels started to decline with increasing delays before CA storage. As part of a New York Farm Viability Institute grant to find solutions for flesh browning issues in Empire apples, we included a three week delay at 35°F before CA storage. Unfortunately the results (Figure 8) showed that while the incidence of flesh browning was markedly reduced in untreated fruit, fruit treated with SmartFresh™ had high levels similar to those found

Figure 7. External carbon dioxide injury, senescent breakdown and flesh browning incidence in Empire apples treated with 1-MCP after overnight cooling to 36, 45 or 59°F and then maintained at these temperatures for 2, 7 or 14 days before storage in CA at 36°F for 4.5 or 8.5 months plus 7 days at 68°F.
without a delay treatment. Fruit with delay treatments were also unacceptably soft, even with SmartFresh treatment. Delayed treatments also resulted in higher levels of senescent breakdown, although these levels were lower in SmartFresh™-treated fruit. External carbon dioxide injury was, as expected by previous results, much lower in delayed treatments.

Aside from increased susceptibility to carbon dioxide injury if fruit were not cooled properly before CA application, the experiments did not reveal any additional risks associated with the strategy of delaying application of CA conditions in fruit treated with SmartFresh™. However, it is important to recognize that CA delay strategies could have a downside in lots of fruit that did not respond well to SmartFresh™. In that case, a severe penalty in terms of fruit condition should be expected for such fruit. Although we do not know the actual risk in commercial practice, we suggest that delays be avoided in fruit harvested late in the harvest window, especially if considerable block-to-block variability in fruit condition is observed.

Summary and Conclusions

This study illustrates some important messages for New York storage operators, both small and large scale.

1. For storage operators who are not using SmartFresh™, the importance of rapid CA after harvest for maintaining fruit quality is reinforced. Delays of CA application beyond a few days after harvest can result in significant loss of firmness. The loss of fruit quality will be greater with increasing length of CA storage.

2. Rapid application of SmartFresh™ technology maximizes the positive responses of fruit to treatment. The effect is likely to be true for fruit stored in air as well as in CA. Rapid SmartFresh™ treatment allows later application of CA storage atmosphere without loss of quality, but note point 4 below.

3. Strategies for applying SmartFresh™ to smaller quantities of fruit have, and will continue to be devised by storage operators around the state. Decisions about the investment involved should take into account the length of expected storage. For example, a storage that is operating for only four months may not need to utilize faster SmartFresh™ application than recommended by AgroFresh, whereas an operation planning an eight month storage period or longer should actively consider rapid SmartFresh application.

4. Our results show that delayed CA storage after 1-MCP application can greatly aggravate the risk of external carbon dioxide injury if temperatures of the fruit after treatment remain high. It would be nice to think that temperatures of 45, and especially 55 °F, are excessive and would never occur for extended time periods in commercial practice. Unfortunately, they are not unreasonable for rapidly filled rooms with inadequate cooling capacity. However, remember that the risk of external carbon dioxide injury is eliminated if fruit have been treated with DPA for control of storage scald.

Acknowledgements

This research was supported by the New York Apple Research and Development program, AgroFresh, Inc., The New York Farm Viability Institute, and Cornell University’s Experiment Station federal formula funds project NE-1018. We are very grateful to the many growers who contributed fruit for these trials.

Literature Cited


Chris Watkins is a professor in the Department of Horticulture and leads Cornell’s postharvest physiology program. Jackie Nock is a research support specialist who works with Dr. Watkins. Hannah James has a postdoctoral position in the Watkins laboratory supported by the New York Farm Viability Institute to help develop solutions for flesh browning in McIntosh and Empire apples.
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Currant Cane Dieback in NY: Preliminary Data From the Hudson Valley Trial

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From 1891-1913, a destructive blight of currants swept through the Hudson Valley and the Northeastern United States. During this time, Cornell scientists conducted extensive investigations into cause and management of this epidemic. Extension publications from the period estimated that between 25-50% of North American currants were lost to the disease, which was eventually dubbed currant cane dieback. Unfortunately, no effective means of managing the disease were discovered at the time. As early as April 1917, Ribes quarantine and eradication legislation was beginning to be put into effect in an effort to manage white pine blister rust. In 1998, Ribes planting restrictions for New York were discussed and eventually relaxed in 2003. Prior to 2003, the disease was not likely to have been a problem due to planting restrictions on currants. In 2005-2006, a destructive blight of red currants re-emerged in the Hudson Valley. The blight was present at all of the largest currant production sites in the Hudson Valley. Soon after reports of the 2005 Hudson Valley epidemic were made public, we were informed that the disease was also present in Connecticut at one of the largest currant growers in the Northeast. One of the more disturbing observations from the ongoing epidemic was the fact that the dieback was particularly devastating to the white pine blister rust resistant cultivar ‘Titania’ to which most of the currant acreage in the Northeastern US is planted. The currant cane dieback causes young shoots, entire canes, and even whole bushes to suddenly wilt and die from spring to late summer/early fall (Figure 1A-C). The current season’s growth on canes often becomes infected at the shoot tips. Leaves of infected canes become chlorotic and completely wilt after final elongation and fruit set. Eventually, leaves may turn brown and necrotic as the young shoot tip begins to die (Figure 1D). The cortex and pith of young infected shoots/canes is often discolored (light tan) as the fungus kills the tissues (Figure 2A). In mature infected canes, the pith becomes completely necrotic (dark brown to black), which often completely decays (Figure 2B) leaving hollow canes that easily snap off when handled or during strong winds. The pathogen of the cane dieback epidemics of the 1890s and early 1900s was proven to be Botryosphaeria ribis. Botryosphaeria species are common pathogens of woody perennials causing limb and cane death in many bushberry, tree fruit, and woody vine crops. This fungus produces fairly diagnostic stroma (clusters of small, black, warty bumps) on mature canes from the previous season’s infections (Figure 3A-B). Prior to the extensive investigation on the disease in 1911, another fungus, Nectria cinnabarina, was thought to cause the disease. This fungus is weakly pathogenic on woody perennials and some sources consider this fungus to be a true cause of disease on currants. At the turn of the 20th century, N. cinnabarina was often found on currants already declining from dieback. The presence of coral-colored stromata on dead canes is diagnostic of Nectria (Figure 3C), and some sources consider its presence an indicator of Botryosphaeria infection.

From 2005 to present, we have made extensive observations, collected numerous samples, isolated fungi from the margin of dieback cankers, and subjected them to genomic DNA sequence analysis to determine the identity of isolated fungi. Moreover, we attempted to inoculate healthy currants in the Geneva research planting with isolated fungi. In short, our observations of the ongoing epidemic and signs and symptoms of the disease were consistent with the reports from the early extension bulletins. Our fungal isolations were consistent in morphology, sporulation, and ribosomal DNA homology with the pathogen, B. ribis, identified in the older literature. We were also able to infect healthy plants by inoculating young buds with homogenized mycelium of B. ribis.

Unfortunately, no reliable means of managing the disease were discovered in all of the experimentation conducted at the turn of the 20th century. Moreover, being a new
disease to the 21st century, little to no pesticides are specifically labeled for this disease in NY. Our goal was to reinvestigate the potential of cultural practices and widely labeled copper and sulfur pesticides to manage this disease at a commercial grower with natural infection. Specifically, we endeavored to: 1) determine differences in dieback resistance in a red, a pink, and a white currant cultivar; 2) evaluate effect of sanitation on the development of dead or dying shoots; and 3) ascertain whether or not extended season applications of copper and sulfur pesticides reduce the progression of dieback.

**Field Trial Design**

A field trial was setup to evaluate the effect of cultivar, fungicides and sanitation on the intensity of dieback and cane death. The experiment was first conducted in the summer of 2007 and is now being repeated in the summer of 2008.
The Field Site  The trial site, located in Germantown, NY, has a 7-acre hillside planting of mature 6-year-old red ('Rovada'), pink ('Pink Champaign'), and white ('Blanca') currants. The site has a naturally high level of currant cane dieback, and the Germantown area is where several of the 20th century observations about the disease were made. The planting is laid in rows of 100-150 bushes in blocks by cultivar with six rows for each cultivar. Additional blocks of ‘Rovada,’ gooseberries, brambles, and cherries are planted nearby. Within the cultivar blocks, the six rows were divided into sub-plots of two rows randomly selected for different fungicide treatments. The two rows within the sub-plots were randomly designated as sub-sub-plots for sanitation treatments.

Fungicide programs  A copper, sulfur, and untreated fungicide program was implemented within the cultivar main plots. Copper hydroxide (Kocide DF: 40% metallic copper equivalent) and sulfur (Sulfur 6L Microflo) was applied to subplot treatments at 10 lbs./A and 2.5 gal./A, respectively. Fungicide applications were made at dormant to bud break, and again at full green tip to leaf burst. Applications were made using a small tractor-pulled 30-gallon vegetable sprayer with booms angled and nozzles calibrated for spraying small fruit crops. The ‘untreated’ treatment was sprayed with water at both timings.

Sanitation Treatments  Within sub-plot fungicide treatments, sub-sub-plots were either sanitized or left non-sanitized. Sanitization consisted of pruning out the dead shoots and dieback infected (fruiting with fungal stromata) shoots with loppers. Such shoots were pruned to the crown and removed from the planting. In the non-sanitized sub-sub-plots, the dead shoots and shoots with dieback inoculum were left intact.

Dieback Assessment Strategy  Ten bushes each were selected from the beginning, the middle, and the end of the row for a total of 30 bushes rated per sub-sub-plot. Each of these 10 bush ‘micro plots’ were considered replicates in the experimental design. On each bush, the number of total shoots per bush was counted along with the number of dying shoots, and the number of dead shoots or canes. Currant cane dieback disease intensity was expressed as the percentage of dead or dying shoots out of the total number of shoots. The bushes were rated for dieback intensity during the ‘Rovada’ harvest on 16 July 2008.

Results and Discussion  Prior to experimentation, the level of disease appeared to be evenly distributed within cultivar blocks. At ‘Rovada’ harvest, currant cane dieback symptoms and Botryosphaeria stromata were observed in all cultivars and treatment plots. Across all cultivars and treatments the percent of dying and dead canes per bush ranged from 0.0 to 79.6% and 0.7 to 17.0%, respectively.

Dying shoots or canes most likely represent within-season infections and as such would be the most reasonable indicator of treatment success. Within the design, pruning, cultivar and all interaction terms among pruning, cultivar, and fungicide treatment were not significant (P >0.05). Fungicide treatments of copper hydroxide and sulfur were effective, reducing the percentage of dying canes (in season infections) compared to untreated bushes (Figure 4). Of the two fungicides, sulfur applications reduced the percentage of dying shoots to a greater extent than copper hydroxide applications. Moreover, the level of control provided by sulfur across all variables was significantly greater than the control provided by copper hydroxide. However, it is uncertain whether a 3% reduction in shoot infection would translate into a noticeable improvement in planting life.

The general consensus of extension publications and fruit pathology literature is that Botryosphaeria canker diseases aren’t really manageable using chemical control. Certainly, it stands to reason that the fungus is protected from fungicides by the woody tissues in which it resides. However, most pest management guidelines including Cornell’s 2008 Pest Management Guidelines for Berry Crops affirm that applications of Bordeaux mixture, lime sulfur, and fixed copper to dormant bushes in the early spring to late fall may prevent initial infection and reduce overwintering inoculum of fungal shoot and cane diseases. It is known that Botryosphaeria fungi sporulate most heavily in the spring. Hence, the efficacy of our protective applications of copper hydroxide and sulfur is not surprising as the fungicides would be present on young currant buds where initial infections are known to take place.

It has also come to our attention that currant growers in New Zealand apply a fungicide called Amistar® (Syngenta Crop Protection) at 400ml/ha immediately after harvest for control of this disease. Amistar® applications are reported to be effective for reducing the disease and also promote green leaf retention and, in turn, increased bud size. In the
US we don’t have an Amistar® label for currants. However, the US formulation of Abound® (Syngenta Crop Protection) is analogous to the NZ Amistar® in formulation and concentration of the active ingredient Azoxystrobin. In fact, this product is actually labeled in NY (EPA Reg. 100-1098, NYSDEC Acceptance 9/16/04) for use on Botryosphaeria canker diseases of bushberries (including currants and gooseberries) at a rate of 6.2 to 15.4floz per acre. Abound may be applied the day of harvest and has no other restrictions that would prevent immediate post harvest application. Applications of Abound would have the advantage of being less phytotoxic to the crop and could be used to protect the young shoot growth from infection for much longer periods than copper or sulfur. This season, we have a large trial in Connecticut investigating the potential of currant cane dieback management using QoI (Strobilurin) fungicides.

Dead shoots and canes most likely represent infections that occurred over the last few seasons including the season in which the trial occurred. In this case, in-season fungicide applications would have little impact on the percentage of dead canes per bush. Similarly, the pruning treatments are more likely to reduce inoculum pressure for the following season. Indeed, they will reduce the number of dead shoots within a season, but because of this, counting dead shoots isn’t a good indicator of pruning treatment success. By comparison, the cultivar treatments were in place for many seasons and dead shoots would be a valid indicator of cultivar resistance to dieback. Within the design, pruning, cultivar, and fungicide were significant ($P < 0.05$) factors influencing the percentage of dead shoots per bush. There were also significant ($P < 0.05$) interactions between cultivar × fungicide and pruning × fungicide meaning that fungicides affected the level of shoot death differently for different cultivars, and that pruning was more effective for different fungicide treatments. Due to significant interactions between factors we must present treatment effects (pruning and fungicide) separately for each cultivar. Across all treatments, the cultivar ‘Blanca’ had a mean percentage of (31.8 ± 3.5%) dead shoots per bush. Of the treatments, sulfur applications with pruning and copper hydroxide applications with pruning were improved over the non-fungicide treatments and fungicide treatments alone (Figure 5A). Across all treatments, the cultivar ‘Pink Champaign’ had the lowest mean percentage (15.3 ± 1.8%) of dead shoots per bush. Similar to ‘Blanca’, sulfur applications with pruning and copper hydroxide applications with pruning were improved over the non-fungicide treatment and fungicide treatments alone (Figure 5B). Across all treatments, the cultivar ‘Rovada’ had the highest mean percentage (34.1 ± 3.7%) of dead shoots per bush. (Figure 5C).

Aside from the fact that dead shoots were not a good assessment of fungicide performance, there appears to be an overriding trend that sulfur applications are helpful in managing disease. This is especially supported by our shoot infection data. In regards to cultivar, there do appear to be differences in the levels of resistance to this pathogen.

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**Figure 5.** Mean percentage of dead canes/shoots per bush resulting from currant cane dieback infections for fungicide and pruning programs in Germantown, NY. Shoot death data is present for cultivars ‘Blanca’ (A), ‘Pink Champaign’ (B), and ‘Rovada’ (C) Values are means and standard errors for individual bushes across replicate 10 bush blocks.
However, resistance to this pathogen is likely to be due to anatomical or chemical features of the variety as opposed to gene for gene interactions. Moreover, it is hard to ascertain if these differences are durable without additional years of data. In regards to pruning, we are unable to see potential effects of pruning in the first year. Because of this, we have chosen to repeat the treatments in the same blocks for a second season. Although we will sacrifice our ability to truly replicate the experiment, we may be able to shed light on the effects of pruning. The disease is a slow progressing disease, and as such, may take several seasons to completely kill the large canes. Because of this phenomenon, progress towards managing currant cane dieback in NY may not be accomplished in a single season.

**Bibliography**


**Acknowledgements**

This work was possible due to funding support provided by the New York Berry Growers Association.

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Blossom Blight Epidemiology

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This work supported in part by the New York Apple Research and Development Program.

Apple producers in New York have been plagued by fire blight for 200 years. The disease was first recognized as a problem in the late 1700’s in the Hudson Valley. Fire blight, caused by the bacterium Erwinia amylovora, affects many rosaceous plants although the impact is greatest on apple and pear. Fire blight does not occur consistently each year; one year there might be no disease, the next year severe disease, and the following year mild disease. The sporadic nature of the disease depends on the weather during a particular season. For instance, warm weather and rain need to occur at just the right time for apple blossoms to become infected. Fire blight epidemics have become more frequent and severe over the last few decades because of the switch to new high quality, but very susceptible varieties. Use of susceptible dwarfing rootstocks, especially M.9, in modern high-density orchards makes the situation even worse. Considerable economic hardship from tree loss and subsequent orchard rehabilitation is a result of fire blight epidemics. Recovering from these unforeseen costs is especially difficult now that other input costs have increased dramatically. These factors have renewed the interest of researchers to understand how fire blight epidemics are caused, and how the relationship between the bacterium and the apple affects epidemics with greater detail.

There are several distinct phases of fire blight: canker blight, blossom blight, shoot blight, trauma blight and rootstock blight. These phases contribute to making fire blight difficult to manage or predict because they act like separate diseases that are related to one another. This phenomenon has presented some difficulty for researchers because what is learned about how one phase of the disease works is not always applicable to another. Currently, the phase that is most effectively controlled is blossom blight. The most effective control of blossom blight is the application of preventive antibiotic sprays in the spring in combination with a blossom blight forecaster to time applications most effectively and not wastefully. Blossom blight control is essential to reduce the number of bacteria present in the orchard that can contribute to epidemics later in the season. Blossom blight infections can also lead directly to rootstock blight, which directly causes tree death. Because blossom blight control is critical to slow the late season phases of fire blight, it is important to have accurate forecasts of the blossom infection periods so that infection periods are not missed and there are no unnecessary antibiotic applications.

Blossom blight does not occur every year because several events need to happen in combination for infection to take place. Blossoms cannot be colonized by E. amylovora when they are closed, so if all of the conditions are otherwise favorable for a blossom blight outbreak, it will not happen because the bacteria will not reach the stigma surface. The exact source of bacteria in the very early spring has never been conclusively identified but there is good evidence that small cankers with difficult-to-see borders are an important source. It is likely that the bacteria are moved from the cankers to the stigma surface of the blossom by insects, such as flies, beetles or ants that are attracted by sugar sources. Bees are not involved in the initial movement of E. amylovora to blossoms but are effective at moving bacteria from one blossom to the next during pollination. Once on the stigma surface, E. amylovora needs to establish
a colony and multiply exponentially to a high population. Curiously, *E. amylovora* does not cause disease when on the stigma surface. In fact if nothing further occurs, the blossom would proceed to petal fall with no ill effects. All of the events described above, from the opening of the flowers to the multiplication of *E. amylovora* are temperature dependent. The ambient air temperature greatly affects the speed at which each process takes place. The final event that is necessary for blossom blight is a rain event or heavy dew. The rain or dew wets the surfaces of the blossoms so that the bacteria are able to travel from the stigma to the floral cup where the nectaries are located. It is through the nectaries that *E. amylovora* actually enters the blossom and causes an infection. The bacteria are unable to multiply in the floral cup and it is thought that this is because the sugar concentrations are too high for them to survive. The rain may also dilute the nectar, allowing the bacteria to survive and enter the blossom to cause the infection. Blossom blight is a very unusual disease because the part of the blossom where *E. amylovora* populations multiply is separate from where the infection takes place. It also means that the environmental factors that allow *E. amylovora* to multiply and spread may be different from those needed for an infection, but this must still be confirmed.

**Blossom Blight Forecasting Models**

Two blossom blight forecasting systems are commonly used in the U.S. apple industry: *MARYBLYT* and *Cougarblight*. *MARYBLYT* historically has been most commonly used in the northeastern states of the USA but the use of *Cougarblight*, developed in Washington State, is becoming more widespread in the Northeast. The forecasting systems have tried to account for the effect of temperature and rainfall in their predictions of infection. To determine how well the two forecast systems really perform, their forecast accuracy was compared by analyzing historical data from British Columbia, England, Michigan, New York, Québec, Vermont, Washington State and West Virginia spanning the period from 1976 to 2002. The data were looked at as a whole and then split into geographic regions and cultivar susceptibility groups. The geographic regions were Eastern North America, England, and west coast North America and the cultivars were grouped as moderately susceptible and very susceptible. The overall accuracy of *MARYBLYT* and *Cougarblight* were equivalent, and both forecasters successfully predicted blossom blight infections 60-70% of the time. When accuracy of the forecasters was determined, both the number of correct infection predictions and the correct non-infection predictions were important. It is as important to know when an infection is not occurring as when one is occurring. Over-prediction leads to the expense of unnecessary antibiotic applications and could potentially lead to antibiotic resistance. The forecasting systems performed equally in the geographic regions of the east and west coasts of North America and on moderately susceptible cultivars. *Cougarblight* was significantly more accurate (*p* < 0.05) than *MARYBLYT* in England but *MARYBLYT* was significantly more accurate than *Cougarblight* with the very susceptible cultivars. Although the two forecasting systems were equally accurate overall, they did not always correctly predict the same infection periods. Ideally, to minimize the limitations of both forecasting systems, *MARYBLYT* and *Cougarblight* should be used together to insure that all infection periods are predicted.

Plant disease epidemiology is the study of factors, such as weather or characteristics of the host plant, that contribute to or influence the beginning, development, and spread of plant diseases. One of the reasons to study epidemiology is to be able to better predict when an infection event or the beginning of an epidemic occurs. As stated above, the predictions of blossom blight infection events by both *MARYBLYT* and *Cougarblight* were accurate 60-70% of the

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**Figure 1.** The epiphytic inoculum potential (% EIP) and frequency of blossoms with *E. amylovora*. A. EIP and frequency of blossoms with *E. amylovora* on the surface in 2004. A EIP and frequency of blossoms with *E. amylovora* by date showing the delay between EIP and frequency. The solid line is the threshold level for EIP. B. Frequency of blossoms with *E. amylovora* plotted as a function of EIP without a lag period. C. Frequency of blossoms with *E. amylovora* plotted as a function of EIP with a 1-lag period which improves the relationship between the two variables.
time. While this accuracy rate is certainly better than flipping a coin to decide whether a blossom infection is likely to occur, there is clearly room to improve forecasts. The work outlined in this article was aimed to understand the epidemiology of blossom blight so that improvements can eventually be made in blossom blight forecasting. Since the accuracy of the two blossom blight forecasters was statistically equivalent, it was decided to concentrate on MARYBLYT, the most commonly used forecaster in the Northeast United States. In the current version of MARYBLYT, blossom infection is predicted to be imminent when the minimum values of all four of the following thresholds occur: 1) Open blossoms with stigmas and petals intact; 2) Epiphytic inoculum potential (EIP) ≥ 100%, which is 110 degree-hours (198 DH) at base 18.3°C (65°F) accumulated in the last 44.4 degree-days (80 DD) at base 4.4°C (40°F); 3) Precipitation event of either dew, ≥ 0.25mm (0.01 inch) on the current day, or previous day rainfall (≥ 2.5mm; 0.10 inch); and 4) Mean daily temperature ≥ 15.6°C (60°F). One of the results from the analysis of forecaster accuracy was that the EIP threshold, an estimate based on temperature of how many E. amylovora cells may be present in an orchard, was not working as effectively as possible. An initial investigation of how well the EIP was performing in relation to how many bacteria were found on blossoms in an orchard was undertaken. Blossoms were sampled for the presence of E. amylovora over three years. In 2004, it was found that the EIP correctly predicted how frequently blossoms had E. amylovora on their surface 68% of the time. When EIP and the frequency of blossoms with E. amylovora

![Figure 2. The population of Erwinia amylovora per stigma (lines) and proportion of samples with E. amylovora (bars) by day after inoculation for the cultivars A. Cameo B. Gingergold C. McIntosh D. Delicious and E. Royal Cortland.](image-url)
were plotted by date, it was noted that the EIP curve peaked ahead of the curve of the frequency of blossoms with *E. amylovora* (Figure 1A). The fact that the EIP curve was ahead of the blossoms with *E. amylovora* curve suggested that the EIP could be improved by using the previous day’s EIP forecast to predict the current day’s frequency of blossoms with *E. amylovora*, otherwise known as a “lag period”. When a one-day lag period was added to the EIP, 78% of the predictions of the EIP were correct, resulting in a 10% improvement (Fig. 1B,C). Unfortunately we were not able to confirm these results in either 2005 or 2006, because the cool weather in both those years did not allow for spread of *E. amylovora* in the orchard.

Another feature of the EIP calculation is a cool weather adjustment. The MARYBLYT program reduces the EIP by a third, then a half and finally to zero with each passing day that the maximum daily temperature is below 17.8°C (64°F), except if the EIP is above 200 and then there is no adjustment. This particular feature of the EIP seemed to be arbitrary. There was little evidence about this subject in the literature to help decide if the cool weather adjustment was appropriate. In fact, the growth of *E. amylovora* on blossom stigma surfaces at cool temperatures had never been fully determined. We studied the effects of cool temperatures on *E. amylovora* multiplication on the stigma surface of several cultivars over three days. As expected

Figure 3. The proportion of trees with *Erwinia amylovora* by day after inoculation for lateral and king blossoms of each age (1-day, 3-days and 5-days old) for A. Cameo, B. Gingergold, C. McIntosh, D. Delicious and E. Royal Cortland.
we found that temperature was very important for the multiplication of *E. amylovora*. At the warmer temperatures of 25 and 18°C (77 and 64.4°F), multiplication of *E. amylovora* was rapid, reaching high levels the first day.

The population of *E. amylovora* was lower the first day at 18°C (64.4°F) than at 25°C (77°F) but reached comparable levels by the second and third days. The number of blossoms with stigmas with *E. amylovora* present was comparable for 25 and 18°C (77 and 64.4°F). At the low temperature of 11°C (51.8°F), it was less certain what we would find, as the assumption had been that *E. amylovora* would either slowly die or become inactive. In fact this was not always the case. Instead, we found that at 11°C (51.8°F), the population of *E. amylovora* dropped close to or below the level of detection on the day after inoculation, but by the second and third day the populations slowly rose (Figure 2). However, at the cool temperature there were fewer stigmas with detectable numbers of *E. amylovora* cells than at the warm temperature on each day that was sampled after inoculation. To sum it all up, at cool temperatures (approx. 10°C; 50°F), *E. amylovora* multiplied at a slower rate and on fewer blossoms than at warmer temperatures (Figure 2).

There was no information about whether the apple cultivar had a role in how well *E. amylovora* survived on the stigma of blossoms. We wanted to determine if the susceptibility of the cultivar to fire blight affected survival of *E. amylovora* on the blossom surface. Five cultivars of varying susceptibility were chosen. In order of susceptibility from high to low, they were Gingergold, Royal Cortland, McIntosh and (Red) Delicious. We also studied Cameo, which had never been experimentally tested for fire blight susceptibility, so was an unknown. Subsequently anecdotal reports have described Cameo as moderately susceptible. We showed that cultivar had a minimal effect on the population of *E. amylovora* but the number of blossoms with *E. amylovora* was affected (Figure 2). Gingergold had the most blossoms colonized, followed by Royal Cortland and Cameo. McIntosh and Delicious were the least likely to have *E. amylovora* on the stigma.

From the data presented here and the conclusions from other factors in the study of the effect of cool temperatures on *E. amylovora*, the three day reduction of EIP at temperatures below 17.8°C (64°F) does not seem warranted. A less drastic reduction of the EIP over a longer period of time is likely to better reflect the epidemiology of *E. amylovora*. Colonization appears to be the rate limiting step in the spread of *E. amylovora* through an orchard, so greater attention to this aspect of fire blight epidemiology is necessary.

A final area of interest was whether blossoms of different ages were equally able to support the growth of *E. amylovora*. This question is important because blossoms age in groups. If the majority of blossoms in an orchard are older and less susceptible by the time conditions for rapid spread of *E. amylovora* and blossom blight infection occur, then the risk of a major epidemic would be reduced. There was already good evidence that as blossoms aged they were less able to support high populations of *E. amylovora*, but no evidence about whether it was more difficult for the bacterium to become established and if there was a difference between king and lateral blossoms as well as cultivars. Our results agreed with previous studies; the populations of *E. amylovora* were much higher on young, newly opened blossoms than blossoms that were three or five days old when inoculated. We also showed for the first time that the newly opened blossoms were also better able to support the establishment of *E. amylovora* on the stigmas (Figure 3). When a blossom was king or lateral, there was no difference in the number of bacteria on a stigma or whether *E. amylovora* became established on a stigma. The same cultivars were used as in the experiment above and we had very similar results. Cultivar did not affect the population levels but it did affect the number of blossoms with *E. amylovora* on the stigma surface. In this experiment, Gingergold had far more blossoms with *E. amylovora* than any other cultivar and the other cultivars had comparable numbers. In conclusion, blossom age had an effect on the population and the number of blossoms with *E. amylovora*, but blossom position did not. Cultivar was important for the establishment of *E. amylovora* on the stigma surface, but not for the ultimate population size.

**Conclusions**

Blossom blight epidemiology is important for a better understanding of the processes that influence infection periods. We have shown that the two most commonly used blossom blight forecasters, MARYBLYT and Cougarblight, could be substantially improved. To improve blossom blight forecasts, whether from MARYBLYT, Cougarblight or another system, a better understanding of the epidemiology of blossom blight is needed. From our work and the work of others, it is clear that the spread and multiplication of *E. amylovora* is strongly affected by temperature and blossom age. The effect of cultivar is not as influential as temperature and blossom age but is not negligible. The studies in this work are the first to look at establishment of *E. amylovora* on the apple stigma. It is hoped that future work on blossom blight epidemiology will explore how other factors such as humidity, precipitation or inoculum dose influence establishment as well as population. Further research into how to best change blossom blight forecasters to reflect the new findings in blossom blight epidemiology is still needed so that apple growers will have better tools to predict when an infection period is likely.

*Megan Dewdney is a former graduate student at Cornell University with Herb Aldwinckle. She is currently an assistant professor at the University of Florida. Herb Aldwinckle is a professor of plant pathology who leads Cornell's program on apple genetic engineering and the control of fire blight.*
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The Hudson Valley Region of New York is noted for both its abundance and diversity of plants and wildlife. In many respects this wealth of flora and fauna creates ecological niches for beneficial predatory and parasitic organisms that provides a foundation for agricultural bio-control. Yet this plant diversity flourishing along the hedgerows and fields of our orchards often harbors insects that can damage pome and stone fruit.

Stink bugs (Heteroptera: Pentatomidae) are native to the region. They are notable examples of migratory insects that live on a broad complex of plant hosts, erratically feeding on tree fruits. Principle hosts of the stink bug include mullein, mustard, dock, plantain, milkweed, mallow, morning glory, thistles, vetch, and velvet grass. These adult ‘seed-feeders’ enter our orchards during the dry periods of the season as host-plant seed pods dry out. Tree fruit becomes very attractive to the stink bug complex during drought conditions, leading to late season feeding damage in pear, apple and peach orchards. Their mouthparts are designed to pierce the fruit skin and draw out the cell contents of the fruit flesh, leaving behind dry cell walls that appear as corking when peeled.

As one might suspect stink bugs derive their name from the production of pungent and offensive chemicals released when they are disturbed. The green and brown stink bugs (Acrosternum hilare and Euschistus servus respectively) are found throughout New York State (Figures 1 & 2). They are cold hardy insects, perennial neighbors along the perimeter of the orchard environment. While relatively mild winters foster their overwintering success, sporadic weather patterns do not always provide favorable conditions for fruit feeding. Predictive models used successfully for other insects have not been successfully developed for use in predicting stink bug fruit feeding patterns. And pheromones, although available for stink bugs, are not effective at capturing significant numbers for predicting the occurrence of feeding and subsequent fruit injury. The insect tends to be very elusive. They have good vision and shy away from movement, making it difficult to scout for adults and effectively employ IPM treatment thresholds.

In general we consider late season drought conditions the motivating influence prompting adult stinkbug movement into orchards to feed.

The brown marmorated stink bug, Halyomorpha halys, is a newly emerging pest on fruit in the northern mid-Atlantic region. Although it has yet to be observed in the lower Hudson Valley, it is a likely candidate for migration into the southern part of the state. E. Richard Hoebeke, a Cornell University senior extension associate in entomology, first identified the brown-marmorated stink bug in the United States from samples obtained in 2001 from Allentown, PA. He surmised that the insect had hitchhiked in cargo containers from Asia. Since then the brown-marmorated stink bug has been identified in parts of New Jersey, Maryland and Delaware.

Given their presence in the Mid-Atlantic region, the brown-marmorated stink bug may appear in the Hudson Valley...
Valley before too long. They stand out as having alternating light dark bands on the antennae and darker bands on the overlapping membranous portion at the rear of the front pair of wings. They have copper, bluish-metallic tinted depressions on the head and pronotum not exhibited in other species of regional stink bugs (Figure 3). In its native range of China, Japan, Korea, and Taiwan, the brown-marmorated stink bug feeds on a wide variety of host plants including apple, peach, figs, mulberries, citrus fruits and persimmons, along with ornamental plants, weeds, and soybeans. Its been observed feeding on tree fruits in the U.S., resulting in the characteristic “cat facing,” on peaches that renders fruit unmarketable. It also can be a nuisance urban pest as it seeks protected overwintering sites in and around homes.

What does this all mean for tree fruit managers in the Hudson Valley? The first stage of management for this pest is determining the level of damage your farm has experienced over the past five years. Simply stated, if injury has been observed in years past, late season management of the stink bug complex should be conducted upon observation of adult presence in the tree canopy.

To determine injury from stink bug, it’s important to note that stink bug feeding differs dramatically between stone fruit, apple and pear. ‘Catfacing’ injury to peaches by stink bug is very similar to that of the plant bug complex. Stone cells naturally occurring in pears are more pronounced in fruit with stink bug feeding injury as cell contents are removed and thickened cell walls of stone cells remain. Yet on apple, fruit damage appears as shallow, circular, light brown to white spongy pockets in the fruit flesh, usually from 5-10 mm in circumference, and 5-8 mm in depth. Stink bug feeding and cork spot (bitter-pit) can easily be mistaken for one another.

Working at the USDA-Agricultural Research Station in Kearneysville, West Virginia, Dr. Mark Brown has conducted studies to discern the differences of fruit injury on apples in late summer and fall between the damage caused by stink bug feeding and the physiological disorder called cork spot. The damage caused by stink bug complex has been characterized and several apple cultivars have been evaluated for different levels of susceptibility to injury. Typical feeding injury tends to be on the stem end or sides of the fruit, as those parts of the fruit surface are easier for the insect to stand on, and most likely to be covered by foliage, providing protection to the feeding bug.

On apple, Brown demonstrated key differences between stink bug feeding and cork spot characterized by the depressions on the apple surface. The edge of the depression on the fruit surface from stink bug feeding is gradual rather than abrupt as observed in cork spot. The corky flesh is always immediately beneath the skin in stink bug injury and often separates from the skin, yet cork spot typically penetrates deeper toward the core (Figure 4). Stink bug injury always has a small puncture near the center of the depression, requiring magnification to observe the feeding site (Figure 5). Occasionally, stink bug feeding may leave a ‘feeding sheath’ within the flesh protruding above the fruit surface (Figure 6).

To further emphasize the difference between stink bug damage and cork spot, studies were also conducted by Brown to determine the significance of calcium and boron levels related to stink bug injury. Applications of foliar calcium chloride was not found to affect the occurrence of corking damage related to stink bug feeding. Fruit flesh immediately below the skin in stink bug damaged fruit has been observed...
to have the same concentration of calcium and boron as fruit flesh from undamaged fruit.

To determine varietal susceptibility to stink bug injury, Brown evaluated 31 apple cultivars with fruit damage ranging from 0 to 28% injury from blocks of selected varieties at the Appalachian Fruit Research Station. Most stink bug damage occurred from 26 to 60 days before harvest. ‘Braeburn’, ‘Jonica’, ‘Jonagold’, ‘Granny Smith’ and ‘Stayman’ had consistently high stink bug injury levels at harvest, whereas, ‘Imperial Gala’, ‘Lawspur Rome’, and ‘Red Fuji’ had consistently low levels of stink bug injury.

Stink bugs are very difficult to manage for a number of reasons. They have a broad host range, including many crops and broadleaf weeds. They are highly mobile, frequently moving between weed hosts and fruit trees. They tend to be more active in the evening and during the night. Insecticide applications made during the day may not come in direct contact with the insect, subsequently reducing the effectiveness of the materials. Therefore, stink bugs are not continually exposed to insecticide residues for long periods of time, as are most other managed orchard insect pests. Consequently, the management of stink bug points toward effective control requiring repeated applications of insecticides, especially along the borders of orchards during the period of ‘adult flight’ occurring late in the growing season.

Given the extent of stink bug injury we’ve observed to Hudson Valley fruit over the past few years, we became interested in how the use of late season insecticides for obliquebanded leafroller and apple maggot management might impact the stink bug complex. We were especially interested in the efficacy of the neonicotinyl insecticide group, as Assail 30SG, Calypso 4SC, and Actara 25WDG have been used extensively for late season management of the insect complex.

Our study was conducted on apple in 2006 at Cornell University’s Hudson Valley Laboratory Research Orchard. We used a mixed block of 18-year-old ‘Ginger Gold’, ‘JerseyMac’ and ‘Liberty’ apple, top-worked onto M-26 rootstock. The block was split into two management regimes to compare a commercially managed tree fruit block (West) and a sustainably managed block (East), the latter conceivably fostering higher stink bug populations from favorable ground-cover conditions. The ‘West block’ was mowed frequently with clean herbicide strips beneath the trees to the drip line. The ‘East block’ was un-mowed without late season herbicide applications and boarded by a row of peaches. Both blocks had identical commercial insecticide and fungicide programs until 1 July. From that point on they received eight different treatments on approximately 14-day intervals, applied to three-tree plots bordered on each side by cedar trees to reduce cross plot contamination. Plots were randomized in a complete block design including an untreated control.

Treatments began at 4th cover on July 1, 5th cover on July 17, 6th cover on July 27, 7th cover on August 14 and 8th cover on August 28. Applications were made using a three-point hitch tractor mounted sprayer and pecan handgun using 300 psi spray dilute to drip. Treatments included Actara 25WDG (thiamethoxam) at 5.5 oz./A; Calypso 4SC (thiacloprid) 5.5 fluid oz./A; Assail 30SG (acetamiprid) at 5.5 oz./A; Thionex 50WP (Endosulfan) at 4.0 lbs./A; Warrior® with Zeon™ technology (Lamda-cyhalothrin) at 5.12 fluid oz./A; Danitol 2.4EC (fenpropatrin) at 6.0 fluid oz./A; Carzol 92SP (formetanate hydrochloride) at 20.0 oz./A. Carzol 92SP is presently not registered in N.Y. for late season use on apple and was used for comparison purposes only. Fruit from Ginger Gold was

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**Figure 6. Feeding sheath on pear deposited after stink bug feeding is complete.**

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harvested on the 9 and 18 of August. No visible signs of stink bug feeding were observed in the ‘JerseyMac’ or ‘Liberty’ varieties.

With regards to stink bug damage to fruit, there was no significant block effect observed between the East and West blocks. Significant differences between treatments and the untreated fruit were observed at the first harvest of Ginger Gold using ANOVA Fisher’s protected LSD shown in Table 1. There were however no apparent statistical differences between treatments. All treatments demonstrated reductions in feeding damage caused by stink bug with the possible exception of Assail treatments. Thionex 50WP, Danitol 2.4EC and Warrior® with Zeon™ Technology treated fruit exhibited lowest numeric damage levels from stink bug for both harvest dates.

### Table 1. Evaluation of Insecticides for Controlling the Stink Bug Complex, Cornell University’s Hudson Valley Lab, N.Y.-2006

<table>
<thead>
<tr>
<th>Formulation</th>
<th>Treatment amt./Acre</th>
<th>Timing</th>
<th>% SB damaged fruit eval.</th>
<th>1st Harvest eval.</th>
<th>2nd Harvest eval.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carzol 92SP</td>
<td>20.0 oz.</td>
<td>4-8C</td>
<td>0.0 a</td>
<td>0.0 a</td>
<td>0.8 a</td>
</tr>
<tr>
<td>Thiodan 50WP</td>
<td>4.0 lb.</td>
<td>4-8C</td>
<td>0.0 a</td>
<td>0.0 a</td>
<td>0.0 a</td>
</tr>
<tr>
<td>Danitol 2.4EC</td>
<td>16.0 fl.oz.</td>
<td>4-8C</td>
<td>0.2 a</td>
<td>0.0 a</td>
<td>0.0 a</td>
</tr>
<tr>
<td>Warrior w/Zeon</td>
<td>5.12 fl.oz.</td>
<td>4-8C</td>
<td>0.0 a</td>
<td>0.0 a</td>
<td>0.0 a</td>
</tr>
<tr>
<td>Assail 30SG</td>
<td>5.5 oz.</td>
<td>4-8C</td>
<td>1.0 ab</td>
<td>2.4 a</td>
<td></td>
</tr>
<tr>
<td>Calypso 45C</td>
<td>6.0 fl.oz.</td>
<td>4-8C</td>
<td>0.4 ab</td>
<td>0.0 a</td>
<td>0.0 a</td>
</tr>
<tr>
<td>Actara 25WDG</td>
<td>5.5 oz.</td>
<td>4-8C</td>
<td>0.4 ab</td>
<td>0.0 a</td>
<td>0.0 a</td>
</tr>
<tr>
<td>Untreated</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

1st Harvest on 9 August, 2nd Harvest on 18 August.
4C on 1 July, 5C on 17 July 6C on 27 July, 7C on 14 Aug., 8C on 28 Aug.

### Table 2. Evaluation of Insecticides for Controlling the Stink Bug Complex, Cornell University’s Hudson Valley Lab, N.Y.-2006

<table>
<thead>
<tr>
<th>Formulation</th>
<th>Treatment amt./Acre</th>
<th>Timing</th>
<th>% External Lep. Damage</th>
<th>1st Harvest eval.</th>
<th>2nd Harvest eval.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carzol 92SP</td>
<td>20.0 oz.</td>
<td>4-8C</td>
<td>0.2 a</td>
<td>0.0 b</td>
<td>1.6 a</td>
</tr>
<tr>
<td>Thiodan 50WP</td>
<td>4.0 lb.</td>
<td>4-8C</td>
<td>0.2 a</td>
<td>0.0 a</td>
<td>0.0 a</td>
</tr>
<tr>
<td>Danitol 2.4EC</td>
<td>16.0 fl.oz.</td>
<td>4-8C</td>
<td>0.2 a</td>
<td>0.0 a</td>
<td>0.0 a</td>
</tr>
<tr>
<td>Warrior w/Zeon</td>
<td>5.12 fl.oz.</td>
<td>4-8C</td>
<td>0.0 a</td>
<td>0.0 a</td>
<td>0.8 a</td>
</tr>
<tr>
<td>Assail 30SG</td>
<td>5.5 oz.</td>
<td>4-8C</td>
<td>0.8 a</td>
<td>3.2 a</td>
<td></td>
</tr>
<tr>
<td>Calypso 45C</td>
<td>6.0 fl.oz.</td>
<td>4-8C</td>
<td>0.4 a</td>
<td>1.6 a</td>
<td></td>
</tr>
<tr>
<td>Actara 25WDG</td>
<td>5.5 oz.</td>
<td>4-8C</td>
<td>0.4 a</td>
<td>0.0 a</td>
<td>0.8 a</td>
</tr>
<tr>
<td>Untreated</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

### Table 3. Evaluation of Insecticides for Controlling the Stink Bug Complex, Cornell University’s Hudson Valley Lab, N.Y.-2006

<table>
<thead>
<tr>
<th>Formulation</th>
<th>Treatment amt./A</th>
<th>Timing</th>
<th># mite or mite egg/25 lvs of ‘Liberty’</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carzol 92SP</td>
<td>20.0 oz.</td>
<td>4-8C</td>
<td>3.4 a</td>
</tr>
<tr>
<td>Thiodan 50WP</td>
<td>4.0 lb.</td>
<td>4-8C</td>
<td>5.6 ab</td>
</tr>
<tr>
<td>Danitol 2.4EC</td>
<td>16.0 fl.oz.</td>
<td>4-8C</td>
<td>4.2 ab</td>
</tr>
<tr>
<td>Warrior w/Zeon</td>
<td>5.12 fl.oz.</td>
<td>4-8C</td>
<td>18.2 c</td>
</tr>
<tr>
<td>Assail 30SG</td>
<td>5.5 oz.</td>
<td>4-8C</td>
<td>10.4 bc</td>
</tr>
<tr>
<td>Calypso 45C</td>
<td>6.0 fl.oz.</td>
<td>4-8C</td>
<td>20.8 c</td>
</tr>
<tr>
<td>Actara 25WDG</td>
<td>5.5 oz.</td>
<td>4-8C</td>
<td>12.6 abc</td>
</tr>
<tr>
<td>Untreated</td>
<td>-</td>
<td>-</td>
<td>7.6 b</td>
</tr>
</tbody>
</table>

Conclusion

In conclusion, the stink bug complex is an infrequent pest to the orchard. Its sporadic nature makes it difficult to predict and subsequently difficult to manage. The physiological disorder ‘cork spot’ is very similar in appearance to the stink bug feeding site and may have been confused as such in years past. Determining the difference between the two is essential for initiating proper management programs for either fruit deficit. Technologies to assist growers in predicting stink bug damage levels are as of yet unavailable. Using historical levels of orchard injury in combination with traditional scouting methods of observing adult presence and observations of fresh fruit damage are still our most reliable indicators to begin control measures for this insect. Many of the materials available for late season management of apple maggot and obliquebanded leafroller can be used against the stink bug complex to achieve a degree of control. However, in years of prolonged drought prior to harvesting fruit in highly susceptible blocks, directed applications of various classes of materials such as Danitol 2.4EC or Thionex 50WP would be required to obtain commercially acceptable quality.

Bibliography


Peter Jentsch is an Extension Associate in the Department of Entomology at Cornell’s Hudson Valley Laboratory specializing in arthropod management in tree fruits, grapes and vegetables.

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The introduction of new high-quality sweet cherry varieties and dwarfing cherry rootstocks, such as Gi.5 and Gi.6, has created diversification options for many fruit growers in the Northeastern U.S. In addition, dwarfing and precocious rootstocks have allowed for the possibility of developing productive high-density orchards. However, dwarfing rootstocks are often excessively productive with self-fertile varieties like Lapins or Sweetheart that result in very high crop loads and small fruit size (Figure 1).

In order to improve fruit size in New York State, some kind of crop regulation must be performed to reduce crop load and increase leaf area: fruit ratio (LA: F). Previous research has shown a linear relationship between LA: F and fruit size, and a rule of thumb has been developed that each fruit requires at least 200 cm² of leaf area to obtain large size fruit. Crop regulation can be performed through dormant pruning or flower thinning. Flower and spur thinning trials to improve fruit size have been conducted in several places in the world, and now it is well accepted that flower thinning or spur thinning generally improves fruit size. Promising results have also been obtained with chemical thinning during bloom time or even when applied 14 days after full bloom. In addition, training system can also affect fruit size especially when the training system affects leaf: fruit ratio.

Even though fruit size has been improved through crop regulation, there is an inverse relationship between fruit size and yield, with lower yield from crop regulated trees. Generally crop value has been found to be highly dependent on yield, and in many cases less crop value is obtained with crop regulated trees, which means that growers often have greater return with medium size fruit but high yields. Thus, crop regulation strategies must consider the break even point where crop value is optimized taking into account yield, fruit size and the price of the fruit in the market place. The objective of this two-year study at the New York State Agricultural Experiment Station was to evaluate the effect of crop regulation strategies and training system on ‘Sweetheart’ cherry fruit size when grown on precocious Gisela rootstocks under New York State conditions.

Material And Methods

In 2006 and 2007, two experiments were conducted using ‘Sweetheart’/Gisela5 and ‘Sweetheart’/Gisela 6 at the New York State Agricultural Experiment Station at Geneva, NY. The trees were eight years old in 2006.

2006 Experiment

A split plot, randomized complete block design was used, where each of five blocks of the same pruning system and rootstock (Gi.5) was assigned to the treatments. Two training systems were used: Vertical Axis with trees spaced 6’ by 15’ or Central Leader with trees spaced 8’ by 15’. Four crop regulation strategies were tried in each block: hard pruning (HP), where trees were lightly pruned and all branches with less than 30cm terminal shoot growth were cut back to two or three spurs; Spur extinction (SP), where trees were lightly pruned and flower bud extinction (FE), where trees were lightly pruned and flower

Figure 1. Excessive flowering of Sweetheart on Gisela 5 rootstock.
buds were removed from each spur, leaving two flower buds per spur and three to four flower buds per one year old shoot at swollen bud stage; and Control (CR) where only light pruning was performed. Light pruning was done on April 10, and consisted of cutting out damaged branches and vertical shoots and heading back old hanging branches, but no other crop regulation was performed. Three branches per tree were selected to evaluate fruit set and fruit size, which was evaluated at harvest by counting and weighing the crop. Also, on each tagged limb, leaf area was determined.

2007 Experiment

‘Sweetheart’ cherry trees on Gisela 5 and Gisela 6, trained as vertical axis were used. Each experimental block (training system) consisted of two rootstock plots, with three different crop regulation treatments each, imposed at popcorn stage (4 May, 2007) to entire trees, consisting of minimal pruning, hard pruning (Stubbing), and Spur Extinction. Three branches per tree were tagged for crop load, leaf area, and fruit quality evaluation as done in 2006.

Results and Discussion

Flower and fruit density

‘Sweetheart’ cherry trees bloom profusely when they are grafted on Gi.5 or Gi.6 rootstocks, in New York State. We calculated flower density per branch based on the number of spurs per branch, average flower buds per spur, and average flowers per flower bud with units of flowers per cm² of branch cross-sectional area (BCSA); average values obtained from several shoots and spurs are given in Table 1. This table shows the great potential for fruit production that this combination of variety and rootstock has under NY conditions. Our calculations indicate that by performing minimal pruning, as it was performed in these experiments, crop load would be excessive if a high fruit set was obtained. We calculated that the minimal pruning treatment could have a potential crop load of 100 fruits/cm² of BCSA shows a fruiting potential that it well over the point where fruit size starts to be affected, as it will be seen later.

Additionally, we evaluated fruit set, as a percentage of flowers that became fruits, and we found for the spring of 2006, which had good pollination and fruit set conditions, that fruit set was very high (70%). Although fruit set was not evaluated in spring 2007, crop load levels obtained on lightly pruned trees were considerably lower than in 2006, thus a larger fruit size was achieved in 2007 than in 2006 (Table 2).

Crop regulation treatment

In 2006, flower bud thinning was by far the treatment with the lowest flower density (37.2 flowers/cm² BCA);
Table 3. Estimated yield efficiency and crop share for different cherry fruit size category, expressed as percentage of total crop. Based on results from 2007 trials.

<table>
<thead>
<tr>
<th>Fruit size category</th>
<th>Share of total crop</th>
<th>Expected YE (g/cm² TCSA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 18 mm</td>
<td>5.0, 25.7</td>
<td>57.9, 37.7, 1.9, 0.0</td>
</tr>
<tr>
<td>18 - 22 mm</td>
<td>5.5, 21.0</td>
<td>42.0, 51.3, 4.6, 0.1</td>
</tr>
<tr>
<td>22 - 25 mm</td>
<td>6.0, 19.0</td>
<td>27.3, 58.0, 11.2, 1.7</td>
</tr>
<tr>
<td>25 - 28 mm</td>
<td>6.5, 16.0</td>
<td>16.2, 58.5, 21.8, 2.0</td>
</tr>
<tr>
<td>&gt; 28 mm</td>
<td>7.0, 13.0</td>
<td>8.9, 53.8, 35.0, 1.1</td>
</tr>
<tr>
<td>8.0, 0.6</td>
<td>6.0, 25.7</td>
<td>25.2, 35.2, 59.6, 2.2</td>
</tr>
<tr>
<td>8.5, 0.4</td>
<td>1.3, 24.7</td>
<td>66.2, 73.0, 105.8</td>
</tr>
<tr>
<td>9.0, 0.2</td>
<td>0.7, 15.6</td>
<td>67.0, 16.5, 92.1</td>
</tr>
<tr>
<td>9.5, 0.1</td>
<td>0.7, 8.7</td>
<td>62.1, 28.9, 78.1</td>
</tr>
<tr>
<td>10.0, 0.0</td>
<td>0.0, 4.4</td>
<td>52.7, 42.9, 63.9</td>
</tr>
</tbody>
</table>

Yield efficiency was significantly affected by crop regulation treatments (Table 2). In 2006, flowering thinning reduced YE the most. In 2007, yield efficiency was lowest with the spur thinning (extinction) treatment and highest with the minimal pruning treatment. Yield efficiency (YE) was highly dependant on crop load. Thus, as crop load increased, greater yield efficiency was obtained, and a maximum YE was obtained when crop load was over the threshold of around 140 fruits per cm² of BCA (Figure 2). In 2007, when entire trees were evaluated and crop load was expressed as fruits/cm² TCA, the maximum of 250 g of fruit/cm² TCA appeared to be around a crop load of 40 fruits/cm² TCA (Figure 2).

Fruit size showed a great range among treatments, between 5.2 and 11.2 g per fruit, mainly due to training system and crop regulation treatment. In 2006 the largest fruit size was obtained with flowering thinning followed by spur thinning, and hard pruning while the minimal pruning treatment had the smallest fruit size (Table 2). In 2007, the spur extinction treatment had the largest fruit size followed by the stubbing back pruning and the minimally pruned treatment.

Fruit size and leaf area

When the data from all pruning treatments, rootstocks and training systems from the 2006 experiment were plotted together we found a strong and tight relationship between leaf area per fruit and fruit size (Figure 3). The relationship shows a maximum fruit size is achieved at around 200 cm² of leaf area per fruit. This value is similar to other published reports. Additionally, our preliminary results indicate that it does not matter how this leaf area is distributed among different plant organs. The leaves can be on the new shoots, on recently formed spurs on one year old wood, or on two year
old or older spurs, which are the carrying fruits. On average we calculated, for NY grown ‘Sweetheart’ cherry trees, that each fruit should have 4.1 leaves from new shoots, 0.9 old spurs or 1.6 newly formed spurs. Another important finding is that no matter which crop regulation treatment was applied the effect on fruit size was a function of the amount of leaf area, which resulted from the treatment.

**Fruit size and yield**

From the 2006 experiment, we found a tight curvilinear relationship between yield and crop load with a maximum yield around 700 g/cm² BCSA at a crop load of around 100 fruits/cm² BCSA. The same was observed in 2007, but with a yield maximum of around 250 g/cm² TCSA, at a crop load of around 40 fruits/cm² TCSA when entire trees were evaluated. In both years increases in yield were accompanied by reductions in fruit size. This is in contrast with some published reports, which showed no reduction in fruit size with increasing yield. This can be explained considering the data from Figure 3 described earlier which shows a curvilinear relationship between L:F and fruit size. These data predict that at high crop loads (below 200cm² leaf area per fruit), crop load reductions don’t result in yield reductions, since there is a proportional increase in fruit size. However, at low crop loads (above 200cm² leaf area per fruit) further reductions in crop load result in yield reductions since there is no further increase in fruit size due to surplus leaf area. Thus, for any given experiment, different results could be obtained depending on which part of the fruit size to leaf area response curve those particular treatments are. In our cases reducing crop load caused an increase in fruit size because we were on the high end of the crop load range (less than 200 cm² leaf area per fruit).

**Crop Value**

Since reductions in crop load result in reductions in yield, the optimum crop load is a function of economics. To determine the optimum for NY we calculated fruit size distribution for different yield efficiencies of ‘Sweetheart’ cherries on Gi.5 or Gi.6 (Table 3). The share of total crop of each commercial size category was fairly well described as a function of average fruit size. These data were used to establish a breakeven point, where yield, fruit size and price are optimized according to harvest cost and expected return for the fruit. Estimated crop value as a function of fruit size was calculated, based on the response of yield efficiency and fruit size to increasing crop load, and the estimated share and price of each fruit size category (Figure 4). There was a broad economic optimum from 7-8 g fruit size. If crop load was reduced sufficiently to produce larger fruit size than 8g, the reduction in yield was so great that the total crop value was reduced. To achieve this size in 2006 would have required a L:F ratio of about 100, while in 2007 this would have required a crop load of around 15 fruits/cm² TCSA.

**Conclusions**

Fruit size in ‘Sweetheart’ cherry is largely a function of L:F ratio. To obtain good fruit size in most years in NY State crop load of self-fertile cherries must be regulated. Pruning and other orchard management practices must be aimed at developing a well-balanced tree, which can guarantee the leaf area needed to develop the fruit. To obtain a better balance between fruit: leaf, the focus can be either to regulate crop load or to improve foliage growth. We have tried different management techniques to control crop load, to improve fruit size. From these experiments we conclude that one treatment is not better than another, but that each improves fruit size in relation to the effect on crop load and L:F ratio. Thus, growers could use a combination of the treatments we tried such as stubbing back pruning of weak shoots which naturally have a low L:F ratio, spur extinction on intermediate branches to improve L:F ratio and flower thinning by chemical treatment to increase fruit size. Using the data from Table 1 and measurements of leaf area we calculated that shoots which are shorter than 30 cm (1 ft) have a low leaf area: fruit ratio (<100) and will produce small fruit size (Figure 5). Unfortunately, Sweetheart trees in G.5 produce a large number of such short shoots. Thus shortening these shoots back to one bud is essential to improving fruit size of this combination. The need for these crop regulations and the severity of crop regulation depends on the fruit set in each year and on the economics of fruit size. From the biological perspective, NY climatic conditions almost always result in

![Figure 4. Estimated crop value, expressed as US dollars per cm² of BCSA, as a function of average fruit size for ‘Sweetheart’ cherry.](image)
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  509-829-6922

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high crop loads for self-fertile varieties on Gi.5 or Gi.6, which will almost always need some crop regulation treatment. However, from the economic perspective, the NY marketing conditions don’t offer a large premium for very large fruit size thus moderate crop regulation treatments that don’t reduce yield too much and aim to produce medium sizes of 8g per fruit will optimize crop value.

References


Acknowledgments
This work supported by the International Fruit Tree Association.

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