Editorial

An idea for a partnership of agricultural producers and government to fund research

Farmers in New York State have been successfully producing a very diverse number of agricultural products for many years. Success has come partly because of our climate and soils but also because producers have been on the cutting edge of new technologies and growing practices that have allowed us to compete with other production areas. We all agree that production research and producer educational programs are vital for us to stay competitive and successful in the future. Today we must ask: how can we maintain the level of research and extension needed to keep us in business? Where will the money come from to conduct the research and educational programs and how do we make sure it is spent wisely? Can a mechanism be created for grower and industry funds that can be matched at some level with government funds to get the job done? How do we make sure there is coordination and collaboration between researchers and educators? Existing, but diminishing, public funds are not and will not be adequate to support the research and education programs growers and the wider public need. A better coordinated, more efficient system would complete the critical function of allocating these funds to their best purpose more effectively than the existing system can. More private sector dollars and a demonstrably efficient, accountable, well-coordinated system is necessary to move government to recognize that matching public investments, along with grower investments in agricultural research, extension and education will provide high returns and spur practitioners to make those investments.

This discussion has been on-going the last few years and an idea has emerged. What if an organization existed with one of its jobs being to get producers to prioritize the production issues they see as critical to being successful? It could take those issues to the research and education professionals and solicit proposals from them that address the high priority producer issues. Then, the producers who are contributing financial support decide which proposals will best solve these identified production issues. Finally, this organization would work with the researchers and educators to make sure the required work gets done in a cost efficient way. After the research is done, it could make sure the information gets to the producers so they can put it to work to make their businesses profitable into the future. The organization would ensure that grower funds are used for projects producers request and available government funds are added to the efforts.

Ten years ago, the New York Farm Viability Institute (NYFVI) was formed to fund research and education projects that would improve the profitability of agriculture producers in NYS. It started with some federal funds and has been funded by annual state appropriations since. What if the NYFVI was changed so it facilitated a government match to funds producers are already investing in research and education projects and was operated as described in the paragraph above? NYFVI might also receive federal and corporate funds that could also be used to match grower funds. Besides facilitating the process, NYFVI could also coordinate projects that have impact in more than one commodity area. NYFVI could do all this if the producers of NYS believe it would be beneficial and would leverage their personal contributions. This model could be applied to all of NY agriculture, keeping us on the cutting edge and profitable into the future. Many grower-funded and managed programs, including the Apple Research and Development Program, provide critical support every year for research that improves the profitability of fruit, vegetable, dairy, and corn and soybean production. We can substantially improve the existing system through better coordination and efficiency, more opportunity for the public to recognize the benefits of applied research; and most important, by using grower dollars as a lever to add government matching funds to the effort. Some commodity groups do not put anything into research or education. If a government match was available, it would be an incentive for (Continued on p.2)
those growers to contribute to research and education projects that will help their industry.

This idea has been discussed for a few years now and it is time to put it into motion. Some details need to be worked out, but we do need to start with a few grower groups and get moving along this path. What are your thoughts? We need to get producer feedback on this plan so it can be implemented in the near future. Please, contact me with your thoughts. I would be glad to hear from you.

Jim Bittner
Fruit grower and Chair of the NYFVI. Jim@singerfarms.com 716-778-7330

APPLE RESEARCH & DEVELOPMENT PROGRAM ADVISORY BOARD

Chairman Walt Blakely, Apple Acres 4633 Cherry Valley Tp, Lafayette, NY 13084 Ph: 315-677-5144 (H) wblakely@gmail.com

Alan Burr 7575 Slaton Settlement Road, Gaspart, NY 14067 Ph: 518-772-2497; greeperhp46@juno.com

Steve Clarke 40 Clarks Lane, Milton, NY 12547 Ph: 842-792-2363; agestowe@twcnet.com

Rod Farrow 12786 Kendrick Road, Waterport, NY 14571 Ph: 585-589-7022

Jason Forrence 2740 Route 22, Peru, NY 12972 Ph: 518-643-9227; ferncomcs@verizon.net

Ted Furber, Cherry Lawn Farms 8099 Gausset Rd., Sodus, NY 14571 Ph: 315-483-8529

Dan McCarthy NY State Dept. of Agriculture & Markets 108 Airline Drive, Albany, NY 12235 Ph: 518-457-8857; dan.mccarthy@gmtk.state.ny.us

Peter Ten Eyck, Indian Ladder Farms 342 Altamont Road Altamont, NY 12009 Ph: 518-746-2556; pgteII@aol.com

Robert Deemer, Dr. Popular/Apple Group 6581 Rte 104 Williamson, NY 14589 Ph: 315-589-9695 ext. 713

NEW YORK STATE HORTICULTURAL SOCIETY

President William R. Garrison
Garrison Lakeshore Orchards
3716 W 96.Rd., Crown Point, NY 12928
PH: 518-597-3390; 518-597-381790
CELL: 518-572-4642

garrisonorchards@yahoo.com

Vice President Chuck Head, Head Orchard LLC
15 Scorn Rd., Trula, NY 12383
Ph: 845-756-5641 (W); 845-389-0731
chuck@headorchards.com

Treasurer/Secretary Doug Fox, D&L Ventures LLC
4595 Fish Farm Rd., Sodus, NY 14551
PH: 315-483-4556
df123@outlook.com

Executive Director Paul Baker
3568 Saunders Settlement Rd., Sodus, NY 14132
Ph: 716-807-6827; 716-319-4089
phbaker@meadorchards.com

Assistant Karen Wilson
60 W. North St., Geneva, NY 14456
PH: 315-787-7004; CELL: 315-571-0952
FAX: 315-787-7226; wilsonk36@hotmail.com

NYC Director Dr. Terence Robinson, NYCSES
1170 W 96.Rd., Crown Point, NY 12928
PH: 716-807-6827; FAX: 716-319-4089
phbaker@meadorchards.com

Director Tom DeRame, DeRame Fruit Farm
2654 Townline Rd.
Williamson, NY 14589
PH: 315-589-9098; CELL: 315-576-3244
demarre1@aol.com

Director Peter Fleckenstein, Marshall S. Kiff orchard
4472 Cherry Valley Tp. LaFayette, NY 13084
PH: (315) 436-0041; CELL: (315) 664-0391
peterfbk6@verizon.net

Director Dan Sievert
Laikewen Orchards, Inc.
4941 Lake Road, Burt, NY 14028
PH: 716-375-7941 (W); CELL: 716-870-8968
nortonghan@hotmail.com

Director Roderick Dressel, Jr., Dressel Farms
271 Rte 208, New Paltz, NY 12561
PH: 845-255-0093 (W); 845-255-7717 (H)
rodrickonly@aol.com

Director Robert DelBello, Lake Bierce Fruit Farm
6272 Lake Road, Sodus, NY 14551
PH: 315-483-0100 (W); 315-483-9904 (H)
bubdelba@gmail.com; (Summer – use H only)

Director Peter Barton
55 Apple Tree Lane, Fairport, NY 14509
PH: 585-227-2096; 585-227-7149 (H)
CELL: 585-656-5217
plarton@bestweb.net

Director John Irwin, Helena Chemical Co.
165 S. Platt St, Suite 100
Albany, NY 12211, PH: 518-589-4195 (W)
CELL: 518-589-2262
uinty@helenaehemical.com

Chair Dale Riggs, Growers Hill Farm
15730 NY R F 22, Stephensville, NY 12168
PH: 518-733-6712; growershill@nycsu.net

Treasurer Tony Emmi, Emmi Farms
14264 Roosevelt-Hwy, Waterport, NY 14571
PH: 585-682-5569

Bruce Carson, Corners Bloomer Berries
3228 Rived Rd.
Bergen, NY 14466
PH: 585-494-1187; bcarsen@fruitsnet.com

David Coulter, Coulter Farms
3871 N. Ridge Road, Lockport, NY 14094
PH: 716-453-5355; coultarfarms@aol.com

John Cashin
Cashin Farm
225 Argosier Road, Fultonville, New York 12072
PH: 518-289-6009; cashinfarms.com

Terry Mesher, Mesher Farms
RD 1 Box 69, Boudouer, NY 13110
PH: 315-693-7137, tmesher@dircom.com

Chuck Head, Head Orchard LLC
15 Scorn Rd., Trula, NY 12383
PH: 845-756-5641 (W); CELL: 845-389-0731
chuck@headorchards.com

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 NYSGA.

NEW YORK STATE HORTICULTURAL SOCIETY
Crop load management is the single most important yet difficult management strategy that determines the annual profitability of apple orchards. The number of fruit that remain on a tree directly affects yield, fruit size and the quality of fruit that are harvested, which largely determine crop value. If thinning is inadequate and too many fruits remain on the tree, fruit size will be small, fruit quality will be poor and flower bud initiation for the following year’s crop may be either reduced or eliminated. Consequently, poor or inadequate thinning will reduce profitability in the current year and result in inadequate return bloom in the following year. Over thinning also carries economic perils since yield and crop value the year of application will be reduced and fruit size will be excessively large with reduced fruit quality due to reduced flesh firmness, reduced color and a much-reduced postharvest life. Thus, management of crop load is a balancing act between reducing crop load (yield) sufficiently to achieve optimum fruit size and adequate return bloom without reducing yield excessively (Figure 1).

**Economic Impacts of Crop Load**

Calculations of crop value at various crop load levels using fruit size and yield as the main variables has shown in a number of experiments to that the relationship of crop value to crop load is curvilinear (Figure 1). At very high crop loads (unthinned Gala trees) fruit size is often very small but yield is very high. Crop value in this situation is almost zero since the value of the fruit is often exceeded by the packing and storage costs. When crop load is reduced to more moderate levels through thinning, then crop value rises dramatically even though yield is lower due to larger fruit size, which has greater value. At some point crop value peaks and then with further reductions in crop load crop value declines due to lower and lower yield. Although fruit size continues to increase it does not compensate for the loss in yield. It is striking how narrow the crop value peak is in many situations. Identifying and then achieving this optimum crop value is often very difficult for apple growers. It is difficult for fruit growers to know the economic impact of not achieving the optimum crop load without having various levels of thinning each year to construct the curves shown in Figure 1. The difference between the optimum crop load and under thinning or over thinning can sometimes be a difference of thousands of dollars per acre. Thus growers often fail to capture the full crop value possible without knowing how much “money they left on the table”. More precisely managing crop load will help growers achieve the optimum crop load and maximize crop value.

**Management Approaches to Precisely Managing Crop Load**

There are 3 management practices that have a large effect on crop load: 1) pruning, 2) chemical thinning and 3) hand thinning. In recent years growers have relied primarily on chemical thinning to adjust crop load with a lesser reliance on hand thinning to reduce labor requirements. In other countries hand thinning is still the primary means of adjusting crop load. This research was partially supported by the New York Apple Research and Development Program.
A few progressive growers have also begun to view pruning as a means to adjust crop load.

Precision crop load management utilizes all three management approaches to adjust crop load. It begins with precision pruning to leave on the tree a preset bud load, followed by precision chemical thinning to reduce initial flower number per tree to as close as possible to a preset fruit number per tree and ends with precision hand thinning to leave a precise number of fruits per tree.

**Chemical Thinning**

For the past 50 years chemical thinning has been the primary method growers have used to achieve the proper crop load and consistent annual cropping but despite over 50 years of experience with chemical thinning, it remains an unpredictable part of apple production with large variations from year to year and within years due to weather.

The interactions of environment with thinning have been observed for many years. Beginning in 2000, we began to study this variability by conducting annual spray timing trials in NY State, which showed extreme variation in timing of response and thinning efficacy between years over the 3 week period after bloom when chemical thinners are applied (Robinson and Lakso, 2004; Lakso et al. 2006).

There are two major sources of this variability: spray chemical uptake and environmental effects on tree physiology. Variability in spray uptake includes the chemical thinner concentration, the environment at the time of application (temperature and humidity), application method and coverage, drying conditions, and leaf epicuticular wax. However, generally temperature and humidity largely compensate for one another in affecting drying time and uptake.

A second and more important source of variation is the sensitivity of the tree itself, which is related to the level of bloom, how many fruits are present at the time of application, leaf area, temperatures, sunlight, and tree vigor. Many of these factors are directly related to the balance of carbohydrate supply from tree photosynthesis in relation to the demand for carbohydrates from all of the competing organs of the tree (crop, shoots, roots, and woody structure).

**Carbohydrates and Fruit Growth**

Considerable research has examined the role of carbohydrates as pivotal to the fate of young developing apple fruit. Carbohydrates are stored as reserves in the dormant tree but these reserves are depleted by bloom as tree use these to produce energy for pre-bloom growth and respiration.

After flower fertilization young fruits require currently produced carbohydrates for continuous development and the extent of this demand appears to be associated with the stage of fruit development and level of light. Immediately after petal fall, demand for carbohydrates by developing fruit is only moderate during the initial lag phase of an expolinear growth pattern. However, when fruit reach 8-10 mm in diameter (about 1-2 weeks after petal fall), rapid fruit growth results in an ever-increasingly large carbohydrate demand which may not be met by current photosynthesis.

At that time in spring, considerable variation in temperature and light gives large variations in carbohydrate balance. Temperature, number of shoots, and number of fruit are important factors that control the demand for carbohydrates. With cool sunny days with a light initial crop, the balance of supply and demand carbohydrates is positive due to the high photosynthesis while the cool temperatures limit demand for carbohydrates by shoots and fruits. On the other hand, hot cloudy days with a heavy initial crop load have a negative balance of carbohydrates due to a reduced supply but the high temperatures drive up demand by stimulating growth rates of shoots and fruits.

Chemical thinners are reputed to work by providing a transient stress on the tree during the rapid growth stage of shoots and fruits and when fruits are most susceptible to a carbohydrate deficit. Chemical thinners appear to have the capability to create a carbohydrate stress by reducing photosynthesis, increasing respiration or impeding carbohydrate movement to the fruit. Many have observed that the greatest fruit abscission caused by thinners is associated with periods of 3-5 days of reduced carbohydrate availability immediately following thinner application. These weather conditions are generally a combination of warm temperatures and low light. Unfortunately, these are empirical observations that have not been quantified to aid in prediction of thinner response or used to make thinner recommendations.

**Apple Tree Carbohydrate Balance Model**

Alan Lakso at Cornell University has developed a simplified mathematical model that mechanistically estimates apple tree photosynthesis, respiration and growth of fruits, leaves, roots and woody structure (Lakso et al., 2006, 2007). The model uses daily maximum and minimum temperatures and sunlight to calculate the production of carbohydrates each day and allocates the available carbohydrates to the organs of the tree. From these data the model calculates the daily balance of carbohydrates for a virtual tree based on an Empire/M.9 tree grown in Geneva, NY.

Although 50 years of experience with chemical thinning has taught us that what to expect with extreme weather conditions, the model is especially valuable in estimating carbohydrate balance in less obvious conditions such as cool and cloudy compared to hot and sunny and gives a quantitative value under all conditions.

The value of the model in predicting chemical thinner efficacy has been studied since 2000 in both field and greenhouse thinning studies at Cornell University. In each year we identified periods during the 2-3 week thinning window where the model estimated either a carbohydrate surplus or a deficit and compared them to our observed thinning responses from the spray timing studies mentioned earlier (Lakso et al., 2007; Robinson and Lakso, 2011). For example, in 2004 a very warm, cloudy period occurred shortly after bloom resulted in a net carbohydrate deficit during the first 10-14 days after petal fall followed by a sunny cool period of particularly good carbohydrate balance. The poor carbohydrate balance period correlated well with the strongest thinning response while the least thinning response later during the good carbohydrate balance. In 2006, however, the carbohydrate balance was good initially after bloom corresponding to light-moderate thinning. The hot period beginning at about 21 days after bloom led to a poor carbohydrate balance that correlated with the strongest thinning effect. Other years showed similar correlations that explained many of the year-to-year variations shown earlier (Figure 2). We have used the estimated supply-demand balance of the tree to predict or explain thinning response as follows:
You can rely on Farm Credit East for record-keeping and reporting.

Sound financial management begins with reliable, real-time records and financial reports that enable you to identify key issues. Whether you’re a small family business or a large operation with diverse markets, Farm Credit East can help.

For more information, watch our video on record-keeping services at youtube.com/FarmCreditEast.

Farm Credit East

800.562.2235
FarmCreditEast.com
carbohydrate surplus will support fruit growth giving less thinning while carbohydrate deficits will limit fruit growth giving more thinning.

In 2008 we conducted a greenhouse study using potted apple trees where we imposed one of 3 temperature regimes (15/7.5°C; 22/15°C; 29/22.5°C with 30–35% of outside light) for a 5-day period immediately after thinner application of Naphthaleneacetic acid (NAA)+Carbaryl or Benzyladenine (BA)+Carbaryl) (Yoon et al., 2010). The combined effects of the reduced light and temperature of the glasshouse were calculated as carbohydrate balance using the model. The 5-day average carbohydrate balance affected by temperatures and light was well correlated with fruit set in a strongly positive manner. At all levels of deficit there was a strong added thinner effect with little difference between NAA+Carbaryl and BA+Carbaryl. Only when the carbohydrate balance showed no deficit did the chemicals thin moderately.

We have used these results to develop simple decision rules based on carbohydrate balance for the day of thinning and the next 3 days (Table 1).

The carbohydrate model has potential to predict thinner responses prior to the application of thinners thus allowing growers to adjust thinner treatment and timing to achieve an optimal amount of thinning. However, it imprecisely assesses the real effect of the chemical thinner after application. A more precise assessment tool after application would be of value to growers in deciding whether to apply a second application of chemical thinner.

**Apple Fruit Growth Rate Model**

A precise method of early assessment of thinning efficacy after chemical application based on fruit growth rate has been developed by Duane Greene, and others (Greene et al., 2013). The model is based on the observation that fruitlets which have slowed growth rates (less than 50% of the fastest growth rates) are usually destined to abscise. The model requires the measurement of the diameter of fruitlets on 75 spurs (375 fruitlets) at 3 and 8 days after application of the chemical thinner to clearly differentiate abscising versus retained fruit. The growth rate of the fastest-growing fruitlets is used as reference to determine the percentage growth of fruitlets and what percent will abscise.

Early estimates of thinning efficacy after application allow timely decisions about the need for a second chemical application if needed.

In 2008 the fruit growth model was evaluated at NC and NY with several varieties. Thinning response to the thinner and final fruit set in NC was accurately predicted. In NY, initial fruit abscission response to the thinner was accurately predicted although a later cloudy period caused additional drop. As with the carbohydrate model this model needs additional validation in other climates, especially in arid climates.

**Precision Chemical Thinning**

In the last 3 years we have developed an improved method of conducting chemical thinning that utilizes both the carbohydrate model and the fruit growth model. We have named the method “Precision Chemical Thinning”. This method uses the carbon balance model as a predictive tool for predicting response prior to application and the fruit growth rate model for early assessment of thinning response immediately following application.

The method begins with first calculating the final fruit number (target fruit number) needed per tree (based on desired yield) and secondly assessing the number of flower clusters on the trees (after pruning) by counting 5 representative trees. Once the number of flower clusters/tree is known (each cluster with 5 flowers) and the final fruit number needed for the desired yield the percent of the initial flowers needed after thinning can be calculated. The optimum final fruit number per tree is different for each variety and depends on genetic fruit size of the variety (Gala is small genetically and Jonagold is large genetically) and the price in the market (large Gala’s have a much higher price than small Gala’s while Jonagold’s that are too big have a lower market price) and the inherent bienniality of the variety (Honeycrisp are very biennial and must be managed at a lower crop load than Gala which is not biennial). An example of calculating the optimum fruit number per tree is given for Gala.

**Calculation of Desired Fruit Number (Gala Tall Spindle Example)**

1. Determine desired yield/acre (in this example I chose 1500 bu/acre) and desired fruit size (in this example I chose 100 count fruit size ~175-180g)
2. Calculate the desired number of fruits per acre (1500bu/acre X 100 fruits/bu=150,000 fruits/acre

<table>
<thead>
<tr>
<th>Table 1. Decision rules for using the output of the carbohydrate model to adjust chemical thinning rates.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>4-day Av. Carb. Balance</strong></td>
</tr>
<tr>
<td>+20g/day to +80g/day</td>
</tr>
<tr>
<td>+20g/day to 0g/day</td>
</tr>
<tr>
<td>0g/day to -20g/day</td>
</tr>
<tr>
<td>-20g/day to -40g/day</td>
</tr>
<tr>
<td>-40g/day to -60 g/day</td>
</tr>
<tr>
<td>-60g/day to -80 g/day</td>
</tr>
<tr>
<td>&lt; than -80g/day</td>
</tr>
</tbody>
</table>

**Figure 2. Flow chart of precision thinning program to achieve a target crop load**

NEW YORK STATE HORTICULTURAL SOCIETY
Triumph over worms in grapes, tree nuts, stone fruit and pome fruit with powerful, flexible Belt® insecticide. Belt is your first line of defense against worms. It’s long-lasting, soft on beneficials, and is a key part of a winning Integrated Pest Management program, which means fewer sprays. When it comes to worms, Belt goes above and beyond. Kind of like you.

BeltInsecticide.us

Bayer CropScience LP, 2 T.W. Alexander Drive, Research Triangle Park, NC 27709. Always read and follow label instructions. Bayer, the Bayer Cross and Belt are registered trademarks of Bayer. Belt is not registered in all states and is a Restricted Use Pesticide in New York state. For additional product information call toll-free 1-866-99-BAYER (1-866-996-2373) or visit our website at www.BayerCropScience.us

CR0213BELTTTA051V02R0

Worm control for overachievers.
3. Calculate the desired number of fruits per tree ((150,000 fruits per acre / 1210 trees/acre = 124 fruits/tree)
4. Count flowering spurs on 5 representative trees at pink. (In this example I counted flower clusters on 5 trees, which had an average of 200 flowering cluster/tree
5. Calculate the number of potential fruits per tree (200 flowering spurs X 5 flowers per spur = 1,000 potential fruits/tree)
6. Calculate percent of fruits needed after thinning which equals the thinning task (124 desired fruits per tree/1000 potential fruits per tree = 12.4%)

With the variety specific target of final fruit number per tree and the thinning task in mind a precision thinning program is conducted by applying sequential thinning sprays followed by rapid assessment of the results in time to apply a subsequent thinning spray and then an early re-assessment, followed by another spray if needed until the final target fruit number for each variety is achieved.

**In practice precision thinning begins with:**

1. A bloom thinning spray at 60-80% full bloom.
2. The first spray is followed by a petal fall spray applied 2-4 days after petal fall (about 1 week after the bloom spray) when fruits are 5-6mm in diameter. Before the petal fall spray the results of the carbohydrate model are used to guide the rate of chemical and the exact timing of the petal fall spray.
3. The first two sprays are followed by an assessment of the efficacy of those 2 sprays using the fruit growth rate model which indicates the percentage of thinning achieved with the first 2 sprays.
4. Then, if needed, a third spray is applied at 10-13mm fruit diameter (about 1 week after the petal fall spray). Before the petal fall spray the results of the carbohydrate model are used to guide the rate of chemical and the exact timing of the third spray.
5. The third spray is followed by an assessment of the effectiveness of all previous sprays using the fruit growth rate model, which indicates the percentage of thinning achieved with all 3 previous sprays.
6. Lastly, if still more thinning is needed, a fourth spray is applied at 16-20mm (about 1 week after the third spray) to achieve the target fruit number.

Figure 5? shows a decision making tree we envision being used by growers to achieve the optimum crop load.

**Precision Thinning in NY, MA, VT and NJ States in 2013**

The precision thinning program was implemented in 2013 with growers, consultants and extension field staff in NY, MA, VT, and NJ. In 2013 we placed the apple carbohydrate thinning model on a web server at Cornell University, which is available over the Internet at the NEWA site (http://www.newa.cornell.edu). It is linked to on-farm weather stations in NY, MA, VT, NJ and eastern PA from which the model uses temperature and sunlight data beginning each year with the date of bud-break in the spring to daily calculate tree carbohydrate balance. The web version of the carbohydrate model also uses weather forecasts for prediction of carbohydrate balance 7 days into the future. The web site allows apple growers or consultants to run the model and receive predictions in real time of carbohydrate balance and suggested chemical thinner doses.

The fruit growth rate model is used to rapidly assess the effect of each chemical thinning spray. It requires growers to tag 15 representative spurs of 5 representative trees and then measure their diameter 3 and 8 days after each chemical thinning sprays. From these measurements fruit growth rate of each measured fruits is determined and those that are growing slow are predicted to fall off. From these data a percentage of the total fruitlets on the tree expected to fall off from the thinning spray is calculated. The fruit growth measurements require laborious and time consuming fruit tagging and fruit diameter measurements. This aspect will discourage some growers from using this valuable tool. However, the economic impact of optimum crop load adjustment can be worth $5,000-10,000 per acre. Thus a labor intense assessment of fruit thinning is justified and is much less expensive than hand thinning or the losses incurred by over thinning.

For many fruit growers, it may be impractical to use the fruit growth rate model on all varieties since more than 20 varieties are grown in NY State. We suggest growers make the fruit diameter measurements on 3 varieties (2 hard to thin varieties and an easy to thin variety) to guide the decisions for other varieties. We suggest growers measure fruit diameters with Gala, McIntosh and Honeycrisp in the Northeast.

In 2013 more than 20 cooperating growers, consultants and extension staff implemented the precision thinning program on Gala and Honeycrisp in NY, MA, VT and NJ. The results of fruit diameter measurements made after petal fall thinning sprays around May 19th or 20th show that the sprays provided significant thinning on Gala and Honeycrisp but that additional thinning was

---

**Table 2. Chemical thinning recommendations for 8 field studies using the fruit growth rate model to assess chemical thinner efficacy after the petal fall spray during May 2013 in NY State.**

<table>
<thead>
<tr>
<th>Cultivar/Farm</th>
<th>Initial number of clusters/fruitlets per tree (averaged from 5 trees)</th>
<th>Current number of clusters/fruitlets after bloom and/or petal fall spray(s) as May 28, 2013</th>
<th>Current set (% fruitlets/tree) after thinning</th>
<th>Target fruit number per tree(s)</th>
<th>Chemical thinning recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gala Farm 1</td>
<td>146 initial clusters (or 729 initial fruitlets)</td>
<td>224 fruitlets</td>
<td>30.7%</td>
<td>111 fruits</td>
<td>Spray again</td>
</tr>
<tr>
<td>Honeycrisp Farm 1</td>
<td>210 clusters (or 1050 fruitlets)</td>
<td>414 fruitlets</td>
<td>39.4%</td>
<td>61 fruits</td>
<td>Spray again</td>
</tr>
<tr>
<td>Gala Farm 2</td>
<td>235 clusters (or 1175 fruitlets)</td>
<td>328 fruitlets</td>
<td>32.5%</td>
<td>135 fruits</td>
<td>Spray again</td>
</tr>
<tr>
<td>Gala Farm 3</td>
<td>488 clusters (or 2440 fruitlets)</td>
<td>748 fruitlets</td>
<td>30.6%</td>
<td>231 fruits</td>
<td>Spray again</td>
</tr>
<tr>
<td>Honeycrisp Farm 4</td>
<td>225 clusters (or 1125 fruitlets)</td>
<td>321 fruitlets</td>
<td>28.6%</td>
<td>65 fruits</td>
<td>Spray again</td>
</tr>
<tr>
<td>Gala Farm 4</td>
<td>470 clusters (or 2350 fruitlets)</td>
<td>578 fruitlets</td>
<td>24.6%</td>
<td>135 fruits</td>
<td>Spray again</td>
</tr>
<tr>
<td>Gala Farm 5</td>
<td>200 clusters (or 1000 fruitlets)</td>
<td>375 fruitlets</td>
<td>37.5%</td>
<td>80 fruits</td>
<td>Spray again</td>
</tr>
<tr>
<td>Honeycrisp Farm 5</td>
<td>200 clusters (or 1000 fruitlets)</td>
<td>213 fruitlets</td>
<td>21.3%</td>
<td>60 fruits</td>
<td>Spray again</td>
</tr>
</tbody>
</table>
still needed. In general fruit set was reduced by about 70% from the bloom and petal fall sprays (Table 2), however the target was to reduce fruit set by 90%. Thus substantial thinning on Gala and Honeycrisp remained to be done. This suggested another spray in these block at the 10-12mm fruit size stage. From this assessment we gave specific recommendations to each grower for another spray. A similar process was repeated after the 10-12mm spray to determine if another final spray was needed at 18-20mm fruit size stage.

Conclusions

The new precision thinning program for managing apple crop load allows growers to first determine a target fruit number and the initial fruit number per tree and then apply sequential thinning sprays beginning at bloom to reduce fruit number per tree in a step wise manner down to the target fruit number. The program utilizes the Cornell Apple Carbohydrate Thinning model and the Fruit Growth Rate model to provide real time information to growers of the progress in this step wise thinning process. The program gives growers confidence to thin when appropriate and sound information about when not to thin. The economic implications of optimum crop load and optimum fruit size are large and justify this more intensive management approach required by the Precision Thinning program.

Lastly, precision thinning will be more easily applied to the simple trees in high-density orchards such as the Tall Spindle or Super Spindle where counting of whole trees is easier than large trees.

Acknowledgements

This research was partially supported by the New York Apple Research and Development Program, NY Farm Viability Center and the NY State Specialty Crops Block Grant Program. We thank Jim Myers, Keith Eggleston and Art DeGaetano for support in developing the web version of the carbohydrate thinning model. We also thank the growers, consultants and extension educators who worked with us over several years to develop the precision thinning program.

Literature Cited


Terence Robinson is a research and extension professor at Cornell’s Geneva Experiment Station who leads Cornell’s program in high-density orchard systems and plant growth regulators. Alan Lakso is a research and teaching professor at Cornell’s Geneva Experiment Station who leads Cornell’s program in applied physiology of apples and grapes. Duane Greene is a professor at the Univ. of Mass. who specializes in plant growth regulators and fruit thinning. Steve Hoying is a senior extension associate who is located at Cornell’s Hudson Valley Lab who specializes in orchard management.

Believe in the Future of New York Agriculture

Invest in Your Industry - Join Today!

Members Enjoy Tremendous Discounts and Savings Provided by our Business Partners!

Worker's Compensation Safety Group 486 and Many More!

Call New York Farm Bureau Member Services today to learn about all of our exciting member benefits!

NYFB.org
1-800-342-4143

Columbia Tractor, Inc.
Serving the Hudson Valley & Western New England
with these quality lines of tractors & equipment:

— Case IH — Kubota — Bush Hog — Woods — Kinze —
— Unverferth — Brillion — Monosem — Unverferth —
— Ag-Tec Sprayers — Aerway Aerators — Husqvarna —
— Kawasaki Mule — Befco — Echo — Great Plains Drills —

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

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

Chris B Watkins, Jackie F. Nock, Xingang Lu
Department of Horticulture
Cornell University
Ithaca, NY

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

SmartFresh™ technology, based on the inhibitor of ethylene action 1-methylcyclopropene (1-MCP), is used extensively on many major varieties by the New York apple industry. The maintenance of quality factors such as freshness and texture during and after storage as a result of 1-MCP treatment can help deliver a more desirable fruit to the market place. 1-MCP treatment can also inhibit development of physiological storage disorders such as superficial scald (storage scald), although it can sometimes increase susceptibility of fruit to other disorders, such as carbon dioxide injury and firm flesh browning. Varieties differ in their responses to 1-MCP treatment, effects being shorter-lived in some, e.g. 'McIntosh' and 'Cortland,' than in others, e.g. 'Delicious,' 'Empire' and 'Honeycrisp.' These differences are likely due to different metabolic rates; sometimes genetic, but also because varieties such as 'McIntosh' are often harvested close to, or at the increase of ethylene production that occurs when apples ripen. High ethylene production by the fruit can be important because ethylene can decrease the effectiveness of 1-MCP. Also, for rapid ripening varieties, any delays between harvest and treatment, even a day or two, during which ethylene production can increase, can result in softer fruit after storage. In 2009, the SmartFresh label was modified to allow multiple 1-MCP treatments in the US. Therefore, 1-MCP can be applied to fruit during room loading and/or during storage, minimizing delays between harvest and treatment. 'Rapid controlled atmosphere (CA)' storage, in which oxygen concentrations are decreased to 2.5-5% or less within 9 days of harvest, improves maintenance of fruit quality. Subsequently, 'Rapid CA' has become standard practice for many apple regions where volume of fruit and scale of operation permit, and delays between harvest and CA application of as little as 4 days has become increasingly common. Rapid room filling is less common for smaller operations, however, because of limited numbers of CA storage rooms and the need to store varieties with different harvest windows in the same room. Repeated 1-MCP treatments offer flexibility to smaller operations where fruit are loaded into CA storage rooms over extended periods, as well as to large-scale operations where the goal is long term CA storage and therefore short intervals between harvest and CA application are more important. In a previous New York Fruit Quarterly article, we have shown that rapid treatment with 1-MCP can allow delayed application of CA without loss of quality (Watkins et al., 2008). Those studies indicate that application of 1-MCP with minimal delays after harvest can maximize the results obtained from investment in SmartFresh technology. Now that 1-MCP can be applied to fruit more than once, a number of interesting questions are raised. These include:

1) Can multiple applications be used effectively to improve quality maintenance of our more difficult New York varieties, especially important because the benefits of 1-MCP include control of superficial scald? We know for example, that the control of scald can be lost when fruit recover from 1-MCP-induced inhibition of ripening.

2) Do multiple 1-MCP treatments increase the risk of disorders such as carbon dioxide injury and firm flesh browning?

3) Can 1-MCP be applied during storage to maintain quality and inhibition of scald?

4) Could multiple 1-MCP treatments be used as a way of improving storage of fruit in air, and perhaps as an alternative to CA storage, at least in the short to medium term?

We have started to address these and other questions, and here we present key findings from recently published work (Nock and Watkins, 2013; Lu et al., 2013).

The Effects of Repeated Treatments of 1-MCP on 'McIntosh' and 'Empire' Apples Prior to CA Storage

'McIntosh' and 'Empire' apples were harvested from trees grown at the Cornell Orchards, Ithaca, three times over the course of one week in the middle of the harvest window, a plausible scenario for filling a typical grower storage room. Fruit from the first harvest were treated with 1-MCP either once, twice or three times over the course of filling a room, while fruit from a second harvest were treated once or twice, and fruit from a third harvest treated once.

'McIntosh' apples were harvested on Sept 7, Sept 10 and Sept 14, 2010, while 'Empire' apples were harvested on Oct 7, Oct 10 and Oct 14, 2011. After harvest, fruit were separated into replicates, cooled overnight to 36°F, and then either not treated or treated with 1ppm 1-MCP at different times after harvest.
Fruits from harvest 1 were treated either on day 1, 4 or 8, 1 and 4 (‘McIntosh’ and ‘Empire’), and 4 and 8 (‘Empire’ only), or 1, 4 and 8; fruits from harvest 2 were treated on day 1 or 4, or 1 and 4 after harvest; and fruits from harvest 3 was treated only on day 1 after harvest.

Fruit were stored under CA conditions on the day that the last 1-MCP treatment fruit were removed from the treatment tent. The storage regimens were: ‘McIntosh’, 2% oxygen and 2% carbon dioxide for one month and then 5% carbon dioxide, and for ‘Empire’, 2% oxygen and 2% carbon dioxide. Fruit were evaluated after 4 and 8 months of storage, with 10 fruit from each of the four replications assessed for all treatments after both 1 and 7 d at 68°F. Each fruit was inspected for external disorders, followed by firmness readings, and then sliced 3-6 times to check for presence of any internal disorders. Greasiness was subjectively measured by rubbing the apple. Only data from 2010 are presented here to illustrate the main findings.

‘McIntosh’ Results. The internal ethylene concentrations (IECs) of the fruit increased with later harvests, while fruit soft-

tened significantly over the one-week harvest period (Table 1). The starch pattern index increased with each successive harvest.

After storage, fruit treated with 1-MCP were always firmer than untreated fruit (Figure 1). Overall, fruit softened between 4 and 8 months of CA storage plus a 7-day shelf life, but the effects of treatment were consistent at both removals from storage.

If we look at delays between harvest and 1-MCP treatment (Figure 1), it is clear that even a 4 day delay results in softer fruit compared to harvests 1 and 2 – and a delay of 8 days resulted in even softer fruit after storage. Repeat treatments either once or twice resulted in firmness that was as high, or higher, than the single 1-day treatment. The ripening of fruit over the harvest period is reflected in softer fruit even with 1-MCP treatment on day 1.

Except for external CO₂ injury, which had similar incidences at both 4 and 8 months, few disorders were detected in fruit stored for 4 months. Therefore, only data for 8 months of CA storage are shown. External CO₂ injury was more prevalent if 1-MCP was applied soon after the first two harvests (H1 and H2) (Figure 2A). Untreated fruit from all harvests and those of H3 that were treated on day 1 had no detectable injury. In general, increasing delays before 1-MCP treatment resulted in lower injury levels and fruit from later harvests had less external CO₂ injury.

The incidence of senescent breakdown of untreated fruit increased as harvest was delayed, and when 1-MCP treatment was delayed (Figure 2B).

Flesh browning incidence was higher at H3 than at earlier harvests and also in H1 fruit when the 1-MCP treatment was delayed until day 8, and bitter pit incidence decreased progressively with increasing harvest time and disappeared by harvest 3 (results not shown). Decay, vascular browning and brown core were detected but were not affected by treatment (results not shown).

‘Empire’ Results. ‘Empire’ was harvested later than the optimum period for CA storage, as indicated by high IECs and starch index values, and soft fruit (Table 1). Nevertheless, there were few effects of harvest time on these indices.

After storage, fruit treated with 1-MCP were always firmer than untreated fruit (Figure 3), and like ‘McIntosh’, untreated and treated fruit softened with increasing storage time. However, unlike ‘McIntosh’ the effects of delayed 1-MCP application of 1 and 4 days were negligible after 4 months of storage. A small effect was evident with a 7-day delay after 4 months of storage, and for 4 and 7 days after 8 months of storage. Repeat treatments either once or twice resulted in firmness that was as high, or higher, than the single 1-day treatment.

Flesh browning was higher in ‘Empire’, with higher levels in untreated fruit, especially in H3, although levels were low (Figure 5A). Greasiness was more common in un-

Table 1. Maturity data for ‘McIntosh’ and ‘Empire’ harvested in 2010.

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Harvest date</th>
<th>IEC (ppm)</th>
<th>Flesh firmness (lb-f)</th>
<th>Starch pattern index (1-8)</th>
</tr>
</thead>
<tbody>
<tr>
<td>‘McIntosh’</td>
<td>Sept. 7</td>
<td>10.9 b</td>
<td>15.7 a</td>
<td>5.5 c</td>
</tr>
<tr>
<td></td>
<td>Sept. 10</td>
<td>60.2 a</td>
<td>15.6 a</td>
<td>5.8 b</td>
</tr>
<tr>
<td></td>
<td>Sept. 14</td>
<td>71.6 a</td>
<td>14.3 b</td>
<td>6.7 a</td>
</tr>
<tr>
<td>‘Empire’</td>
<td>Oct. 7</td>
<td>34.4 a</td>
<td>14.8 ab</td>
<td>6.6 a</td>
</tr>
<tr>
<td></td>
<td>Oct. 10</td>
<td>18.3 b</td>
<td>15.3 a</td>
<td>6.7 a</td>
</tr>
<tr>
<td></td>
<td>Oct. 14</td>
<td>12.9 b</td>
<td>14.3 b</td>
<td>6.8 a</td>
</tr>
</tbody>
</table>

*Means that do not share a letter are significantly different at P=0.05.
treated fruit, being suppressed by 1-MCP (Figure 5B). Incidence was higher at H2 and H3 than at H1, but in all cases, greasiness was rated as slight.

Overall, the effects of rapid 1-MCP treatment were much more pronounced for ‘McIntosh’ than for ‘Empire’. This occurred even though ‘Empire’ apples are harvested later than they should have been for long term CA storage. It should be noted that the late harvest of ‘Empire’ is also known to increase susceptibility of the fruit to flesh browning.

The Effects of Repeated 1-MCP Treatments on Ripening and Superficial Scald Control of ‘Cortland’ and ‘Delicious’ Apples

‘Cortland’ and ‘Delicious’ apples were harvested in 2011 from commercial orchards in Western NY on September 21 and 29, respectively, to provide 48 crates of 100 fruit. The fruit, (four crate replicates) were either not treated or treated with 1-MCP (1 ppm) after overnight cooling. Treatments were applied only once on day 1, 4 or 7 after harvest, or on multiple occasions, 1 + 4, 4 + 7, 1 + 4 + 7, 7 + 14, 7 + 28, 7 + 42, and 7 + 84 days. A further set of fruit was treated with diphenylamine (DPA), the commercially available antioxidant used to inhibit superficial scald development. Fruit were stored in air at 33°F for up 36 weeks. Firmness was measured at weeks 18 and 36, while the...
incidence of superficial scald was measured only at 36 weeks. All measurements were taken after fruit were kept at 68°F for 7 days.

‘Cortland’ Results. At harvest, the IECs of ‘Cortland’ and ‘Delicious’ apples were 0.09 ppm and 6.4 ppm indicating that ‘Cortland’ fruit were preclimacteric, while those of ‘Delicious’ had started producing climacteric ethylene. Firmness of ‘Cortland’ was 16.2 lb-f and ‘Delicious’ was 17.1 lb-f. The firmness of ‘Cortland’ and ‘Delicious’ apples after storage is shown in Tables 2 and 3, respectively.

Untreated fruit were the softest within each storage period (Table 2). While DPA-treated fruit were slightly firmer than untreated fruit, the differences were minor when compared with the higher firmness of fruit from all 1-MCP treatments. If we first consider the fruit stored for 18 weeks, all treatments where fruit were treated with 1-MCP one day after harvest, either alone or in combination (1, 1 + 4, 1 + 4 + 7 d), were 1 lb-f higher than fruit treated after four days (4, 4 + 7 d). Fruit stored for 36 weeks were softer overall, but the differences between treatments applied either alone or in combination when the first application was made day 1 or day 4 after harvest were similar, averaging 13 lb-f and 12.4 lb-f, respectively.

When 1-MCP application is delayed for 7 days after harvest, the loss of firmness after 18 weeks was 1.9 lb-f, and after 36 weeks was 2.5 lb-f, compared with fruit treated one day after harvest. Additional 1-MCP treatments after 7 days during the storage period did not result in any effect on firmness.

Overall the results indicate that rapid treatment of fruit within a day of harvest results in superior firmness of the rapid ripening apple ‘Cortland,’ and even a 4-day delay results in loss of firmness. A delay until 7 days results in even further loss of firmness. Multiple treatments within a week of harvest do not provide additional benefits.

It is important to remember that 1-MCP based technology has changed the whole standard for fruit quality; even the softest fruit measured after 18 weeks of cold storage (a not uncommon but increasingly unacceptable storage time for air stored fruit) after 1-MCP treatment was 12.4 lb-f, still markedly firmer than untreated (9.8 lb-f) or DPA-treated (10.4 lb-f) fruit. Also, titratable acidity data are not provided here, but acidity was also always higher in 1-MCP-treated fruit than either untreated or DPA-treated fruit.

### Table 2. Post-storage flesh firmness (lb-f) of ‘Cortland’ apples either untreated or treated with 1000ppm diphenylamine (DPA) or 1ppm 1-methylcyclopropene (1-MCP) and stored for 18 or 36 weeks at 33°F plus 7 days at 68°F. Fruit were treated either once or on multiple occasions as indicated after overnight cooling to 33°F.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Days after harvest</th>
<th>18 weeks</th>
<th>36 weeks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Untreated</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DPA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-MCP</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 + 4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 + 7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 + 4 + 7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7 + 14</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7 + 28</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7 + 42</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7 + 84</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1-MCP: 1-methylcyclopropene

*Means with different letters are significantly different at P = 0.05

### Table 3. Post-storage flesh firmness (lb-f) of ‘Delicious’ apples either untreated or treated with 1000ppm diphenylamine (DPA) or 1ppm 1-methylcyclopropene (1-MCP) and stored for 18 or 36 weeks at 33°F plus 7 days at 68°F. Fruit were treated either once or on multiple occasions as indicated after overnight cooling to 33°F.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Days after harvest</th>
<th>18 weeks</th>
<th>36 weeks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Untreated</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DPA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-MCP</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 + 4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 + 7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 + 4 + 7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7 + 14</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7 + 28</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7 + 42</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7 + 84</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1-MCP: 1-methylcyclopropene

*Means with different letters are significantly different at P = 0.05

NEW YORK STATE HORTICULTURAL SOCIETY
The fruit used in these experiments were highly susceptible to superficial scald with 100% incidence in untreated fruit (Table 4). The incidence was reduced to 46% in DPA-treated fruit, poor control from a commercial perspective perhaps because we used 1000 ppm rather than 2000 ppm. Treatment of fruit with 1-MCP after overnight cooling eliminated scald and control was excellent with the 4 day, 1 + 4 day, 1 + 4 + 7 day, and 4 + 7 day treatments. Control of scald was poor if 1-MCP was not applied until day 7. A small reduction was detected when the 7-day fruit were given a repeat treatment on day 14, but no later second applications affected disorder incidence.

‘Delicious’ Results. The softest fruit were untreated or DPA-treated, those treated with 1-MCP always being firmer after 18 or 36 weeks (Table 3). Fruit of this variety do not soften as markedly as those of ‘Cortland’ and the firmness data differences with 1-MCP treatment were less marked than for that variety. The effects of treatment time were less consistent; delays between harvest and application of 1-MCP after 1, 4 or 7 days, either alone or in combination, have little effect on firmness. Titratable acidity was always higher in 1-MCP-treated fruit than either untreated or DPA-treated fruit (data not presented).

Untreated fruit developed 51% superficial scald after 36 weeks of air storage. No scald was detected in the DPA or any 1-MCP treatment.

Summary

Overall, this study again highlights the powerful effect of 1-MCP-based technology on controlling ripening of apple fruit, and why SmartFresh has been adopted by the New York industry as it seeks to provide the highest quality apples to the consumer. The opportunity to apply 1-MCP more than once affords the industry the opportunity to apply it to fruit while storage rooms are being loaded.

In the first study, we used ‘McIntosh’ and ‘Empire’ apples to investigate the effects of a scenario where fruit would be harvested over a week and loaded into a CA storage room. Fruit from the first harvest received up to three applications before fruit from the last harvest were loaded and treated with 1-MCP. The effect of variety is important. For ‘McIntosh’ apples, delays between harvest and treatment with 1-MCP of only 4 days resulted in loss of fruit firmness, even for a short CA period of 4 months. The effects of delays were much less evident for ‘Empire’ even though fruit of this cultivar were harvested after the optimum maturity for CA storage. Our results also show, however, that susceptibility of varieties for various storage disorders must also be taken into account. For ‘McIntosh’ the major disorder was external CO2 injury, and the 1-MCP applications that resulted in the best maintenance of flesh firmness resulted in highest injury incidences. As long as fruit are treated with DPA, which prevents development of external CO2 injury, there is no concern about rapid and/or multiple 1-MCP treatments to maximize quality. However, storage operators who do not use DPA, or stop using it for ‘McIntosh’ and other varieties susceptible to injury, such as ‘Cortland’ and ‘Empire’, need to be aware of the increased risk. The ‘Empire’ fruit used in this experiment came from a block where susceptibility of fruit to CO2 injury is low, but this variety can be very susceptible. ‘Empire’ is also susceptible to flesh browning. This disorder can be worse in 1-MCP treated fruit, and risk of injury is enhanced in later harvested fruit. Until satisfactory control methods for this disorder are developed, storage operators should keep this increased risk in mind as they develop their marketing strategies.

The second study, in which we compared 1-MCP applications either alone or in combination, to ‘Cortland’ and ‘Delicious’ apples, we again found that the effect of variety is important when considering the urgency of 1-MCP application. For ‘Cortland’, treatment of fruit with 1-MCP after cooling overnight resulted in optimal responses in terms of firmness and superficial scald control. Delaying treatment of fruit with 1-MCP by 4 days resulted in slightly softer fruit, and fruit were even softer after a 7-day delay. Multiple 1-MCP treatments did not enhance firmness, but as importantly, did not cause any negative effects. Control of scald by 1-MCP was also affected by delay, with ineffective

Table 4. Post-storage percentage of superficial scald in ‘Cortland’ apples either untreated or treated with 1000ppm diphenylamine (DPA) or 1ppm 1-methylcyclopropene (1-MCP) and stored for 36 weeks at 33°F plus 7 days at 68°F. Fruit were treated either once or on multiple occasions as indicated after overnight cooling to 33°F.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Days after harvest</th>
<th>Scald (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Untreated</td>
<td>-</td>
<td>100 a+b</td>
</tr>
<tr>
<td>DPA</td>
<td>1</td>
<td>46 b</td>
</tr>
<tr>
<td>1-MCP</td>
<td>1</td>
<td>0 f</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>1 f</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>32 c</td>
</tr>
<tr>
<td></td>
<td>1 + 4</td>
<td>2 f</td>
</tr>
<tr>
<td></td>
<td>4 + 7</td>
<td>6 ef</td>
</tr>
<tr>
<td></td>
<td>1 + 4 + 7</td>
<td>0.6 f</td>
</tr>
<tr>
<td></td>
<td>7 + 14</td>
<td>9 e</td>
</tr>
<tr>
<td></td>
<td>7 + 28</td>
<td>35 cd</td>
</tr>
<tr>
<td></td>
<td>7 + 42</td>
<td>36 cd</td>
</tr>
<tr>
<td></td>
<td>7 + 84</td>
<td>38 cd</td>
</tr>
</tbody>
</table>

*Means with different letters are significantly different at P = 0.05

Well built and reliable, these boxes will protect your produce. In bulk, $5.50 each

Hamlin Sawmill
1873 Redman Rd. Hamlin, NY 14464
585-964-3561
art@rochester.rr.com
www.OneBushelCrate.com
control, the same as that in DPA treated fruit, if 1-MCP treatment was delayed by 7 days. Therefore, if DPA is not used for scald control (at a higher rate than used here), minimizing delays between harvest and 1-MCP treatment is critical. In contrast, the effects of delayed 1-MCP applications to Delicious within the AgroFresh guidelines of 7 days between harvest and treatment were negligible. Nevertheless, given the uncertain effects of season, harvest date, maturity and postharvest factors such as fruit cooling, we suggest that it is a good practice to apply 1-MCP with minimum delay even to ‘Delicious’ and ‘Empire,’ and other varieties that are highly responsive to treatment.

Recognition of the importance of rapid 1-MCP treatment has led to increased use of treatment tents and pre-treatment rooms by storage operators. The label revision for SmartFresh that now permits repeated applications provides a useful tool to treat fruit with 1-MCP while rooms are being loaded with fruit and thereby obtain the highest quality fruit possible.

Acknowledgements
This research was partly supported by the New York Apple Research and Development Program, AgroFresh, Inc., and Federal Formula Funds NE1036.

Literature Cited
Watkins, C., Nock, J., James, H. 2008. Rapid application of SmartFresh™ (1-MCP) to apples after harvest is more important than rapid CA. New York Fruit Quarterly 16(3):3-9.

Chris Watkins is a professor of horticulture located at Cornell’s Ithaca campus who leads Cornell’s postharvest physiology program for fruit crops. Jackie Nock is a research support specialist who works with Chris Watkins. Xingang Lu is a post-doctoral research associate who works with Dr. Watkins.
Precision Irrigation Management

Terence Robinson, Alan Lakso and Leo Dominguez
Dept. of Horticulture
NYSAES, Cornell University
Geneva, NY 14456

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

The ability to repeatedly produce high quality apples of the optimum economic size is critical to grower’s economic success. The two most important biological and management factors affecting fruit size are crop load and water stress. To repeatedly produce consistent crops of large fruit size requires precise control over crop load and tree water status. Irrigation is essential to preventing water stress in dry summers and small fruit size. The apple market expects growers to deliver large size apples (160-200 gram fruits). Growers attempt to achieve this fruit size by properly reducing crop load with chemical thinners in the spring but if the summer turns out to be dry they will still not achieve the desired fruit size and crop value will be severely compromised. To precisely manage fruit size requires precision in chemical thinning and precision in irrigation.

A second critical value of irrigation is to improve and maximize tree growth of newly planted or young apple trees. The economic success of high-density orchards depend on obtaining significant yields in the third, fourth and fifth years to repay the establishment costs. To obtain the expected high yields requires excellent tree growth during the first 3 years after planting. However, one of the biggest problems we see with new high-density orchards is inadequate tree growth during the first 3 years. Gerling (1981) has estimated that when poor tree growth in the early years delays in adequate tree growth during the first 3 years. In an average growing season in the northeast, rainfall is usually less than required for optimal tree performance during critical periods of tree establishment and growth. In addition during 3 years in 10, severe water shortages occur during the months of June, July and/or August.

Irrigation is essential to producing large fruit size in dry summers. We have developed a new web-based irrigation model (Cornell Apple Irrigation Model) that uses weather data from the network of weather stations in NY, MA, VT, NY and Pa which allows growers to determine the quantity of irrigation water to apply to both young and mature apple orchards of various densities. This allows growers to more precisely manage soil moisture in the humid and often rainy climate of the eastern US for consistently achieving the optimum fruit size.”

A third benefit of irrigation in the eastern US is to improve uptake of calcium and other nutrients from the soil. When the soil dries and the trees undergo water stress, uptake of many nutrients is limited since they must be in solution in the soil to be taken up by the plant. Work done at Geneva by Sergio Lopez and Terence Robinson showed that 2-week periods of poor water balance during different periods of the season resulted in more bitter pit with Honeycrisp. The most critical periods were in May during and after bloom and July. Precise management of irrigation could reduce bitter pit by ensuring a steady uptake of soil calcium.

As a result of these 3 significant benefits of trickle irrigation (improved fruit size, better tree growth and yield of young trees and improved bitter pit control) many apple growers in the humid eastern growing areas who plant high-density orchards are increasingly adding trickle irrigation as an important ingredient to ensure the success of the new planting. However with both mature trees and young non-bearing trees the amount of irrigation needed by apple orchards is difficult to estimate and often is estimated imprecisely by experience or “feel” or by using imprecise “rules of thumb” or models using crop coefficients.

Cornell Apple Irrigation Model

In 2006, Alan Lakso and his graduate student Danilo Dragoni (Dragoni and Lakso, 2010) developed an improved mathematical model to calculate water use by apples trees. The model is based on the famous Pennman-Monteith model, which calculates water use by a field of grass using weather variables. The new Cornell apple evapotranspiration model more accurately estimates apple orchard water use from a discontinuous orchard canopy than using the Pennman-Monteith model with corrections for orchards (crop coefficients Kc).

In 2011 and 2012 we developed a web-based tool to use the output of the ET model to estimate for both young, medium aged and old apple orchards the amount of water needed each day or week. This web-based tool has been placed on the NEWA website and allows growers and consultants to daily or weekly access the model to estimate orchard irrigation requirements using local (on-farm NEWA) weather stations or regional weather stations (airports) to determine water needs.

The website allows users to select a weather station close to their farm and then enter information on the spacing and age of the orchard (Figure 1). The model will then calculate and display the amount of water needed for that orchard for each of the last 7 days and for the upcoming 6 days based on the weather over the last 7 days (from the weather station data) and from forecasted weather data expected over the upcoming 7 days (Figure 1). The
calculated water volume needed by the orchard is displayed in gallons/acre. If the number is negative the grower should add that amount of water to his orchard. If the number is positive it means that rainfall exceeded transpiration and more water is available than needed and no more water should be added. The website also allows a user to enter his own recorded rainfall since rainfall varies considerably within short distances and the weather station data may not represent the actual rainfall at the farm.

The Cornell ET model has the feature that rainfall is considered and subtracted from the water requirement of the trees. It also considers the effective rooting area of different age orchards to include only the portion of the rainfall that is available to the trees in the calculations of tree water requirement.

**Precision Irrigation Management**

This new model and website will allow more precise management of tree water status in both wet and dry year than previously possible. Precisely managing soil water supply will require:

1. The grower or his consultant to weekly log onto the NEWA website (http://www.newa.cornell.edu) and determine the daily water requirement for his specific orchard (spacing and age) for the previous week and the upcoming week.

2. Irrigate the orchard to fully replace the estimated water requirement of the particular orchard via trickle irrigation.

3. To avoid oversaturating the soil when irrigation water is applied just before a large rainfall event or just after a large rainfall event we suggest not applying the suggested irrigation amount for 1 day before a predicted large rainfall event (0.5 inches or more) or for 3 days after a large rainfall event (Figure 2).

4. The frequency of adding the required water depends on soil type. With sandy soils water should be added either daily or every 2 days. With silt or clay soils the daily amount of water needed can be summed up for several days and then added in one irrigation cycle.

5. In the early part of the season (early May to mid-June), we suggest that water be supplied once per week for both sandy and clay soils.

6. From mid-June until the end of August we suggest that water be supplied twice per week in clay soils and every other day with sandy soils.

**Results from 2012**

In 2012 we used the model to calculate transpiration and water balance for a mature and a newly planted tall spindle orchard in Western NY. The daily water requirement showed that in the early season transpiration was about 1,000 gallons per acre and progressed to about 4,000-5,000 gallons/acre in mid-summer (Figure 3). A newly planted tall spindle orchard required much less water (never exceeding 500 gallons/day) due to smaller trees with a fraction of the leaf area of mature trees. Daily effective rainfall was quite variable but in general 2012 was a dry year with infrequent rains that exceeded ½ inch (7,000 gallons/day) (Figure 4). The effective rainfall for a newly planted trees was usually less than 1,000 gallons/day.

The difference between tree water requirement and rainfall is the water balance with a negative number indicating the need for irrigation and a positive number indicating too much water. In 2012 there were only about 20 days when water supply exceeded water requirement and more than 100 days where water supply was less than the need (Figure 5).

Accumulating the water balance values from bud break gives cumulative water supply and water demand. In 2012 the cumulative graph showed that water supply from rainfall was sufficient to meet water requirement by the tree until June 10 after which
Figure 6. Cumulative transpiration and rainfall in 2012 of a mature or a newly planted Tall Spindle Orchard in Williamson NY.

Figure 3. Daily transpiration of a mature or a newly planted Tall Spindle Orchard in Williamson, NY in 2012.

Figure 4. Daily rainfall received by a mature or a newly planted Tall Spindle Orchard in Williamson, NY in 2012.

Figure 5. Daily water balance of a mature or a newly planted Tall Spindle Orchard in Williamson NY in 2012.

Water needs of the tree far exceeded rainfall (Figure 6). With newly planted trees the cumulative water requirement exceeded supply from rain earlier (27 May) indicating the need to irrigate young trees earlier. From these data we see the significant need for irrigation in 2012. It also illustrates the need to regularly add water and precisely manage soil moisture. If growers delay adding trickle irrigation it becomes very difficult to “catch up” when the cumulative water deficit become large.

Summary
Irrigation is essential to maximize fruit size at any given crop load. Water stress at any time of the season reduces fruit growth rate with a permanent loss in fruit size, which is difficult to recover later. Water stress also limits uptake of calcium into the fruit and can result in more bitter pit. With more precise water management growers will be able to limit plant water stress and more consistently achieve the optimum economic fruit size and calcium content for each variety. The new Cornell Apple Irrigation Model will allow growers to more precisely manage soil moisture in the humid and often rainy climate of the eastern US. In the future with automated electronic irrigation controls growers could precisely add the needed water each day based on the forecast for that day.

Acknowledgements
This research was partially supported by the New York Apple Research and Development Program, and the NY Farm Viability Center. We thank Keith Eggleston and Art DeGaetano for support in developing the we version of the apple irrigation model.

Terence Robinson is a research and extension professor at Cornell’s Geneva Experiment Station who leads Cornell’s program in high-density orchard systems, irrigation and plant growth regulators. Alan Lakso is a research and teaching professor at Cornell’s Geneva Experiment Station who leads Cornell’s program in applied physiology of apples and grapes. Leonel Dominguez is a graduate student and research support specialist who works with Dr. Robinson.
PLUK-O-TRAK MACHINE

**NEW**

Increase picker’s efficiency by 80-100%
Increase fruit quality by 15-20%
Eliminate ladders and picking buckets

**Use for:**
- Harvesting
- Dormant & Summer Pruning
- Hand Thinning
- Tying Tree Leaders
- Trelis Work
- Net Installation

**Features include:**
- Automatic hydraulic steering
- Leveling system: 2 or 4-way
- Two or four wheel drive
- Compressor for air pruning tools
- Pre-sort bin

Hydraulic platforms are adjustable in height and move in and out to allow pickers convenient access to all fruit.

**2 Models Available**
- Pluk-O-Trak Senior (for row spacing up to 15 feet)
- Pluk-O-Trak Junior (for row spacing of 12 feet & under)

8 Ashfield Road on Route 116
Conway, MA 01341
800-634-5557 • 413-369-4335 • info@oescoinc.com

Visit our NEW website - www.oescoinc.com

---

**Cornell Fruit Field Day to be held August 1st.**

Come and see the latest research and extension advances.

See details and contact info on back cover.

**Wafler Nursery**

Producing Quality Apple, Cherry & Pear Trees for Over 51 years

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

Call today for your future tree needs
Now carry Gisela 5, 6, & 12 cherry rootstock

Wafler Nursery 10748 Slaght Rd. Wolcott, NY 14590
Phone: 315-594-2399 Toll Free: 877-397-0874 Fax: 315-594-8829
www.waflernursery.com Email: info@waflernursery.com
The “Split” Application Strategy for Pre-Harvest Fruit Drop Control in a Super Spindle Apple Orchard in Western NY

Mario Miranda Sazo1 and T. L. Robinson2
1Cornell Cooperative Extension, Lake Ontario Fruit Program, Newark, NY
2Dept. of Horticulture, NY State Agric. Exp. Station, Cornell University, Geneva, NY

Our 2011 and 2012 field studies support the inclusion of NAA with Retain sprays and give good evidence that lower rates of Retain will provide good drop control when combined with NAA when using the “split” application strategy. This strategy consists of applying 1/2 the normal rate of Retain + NAA 4 weeks before normal harvest and 1/2 the normal rate of Retain + NAA 2 weeks before normal harvest. This study showed there was no deleterious effect of combining NAA with Retain on fruit firmness after CA storage for these cultivars.

R etain is an excellent plant growth regulator for reducing preharvest drop, fruit cracking and fruit greasiness. It usually provides excellent drop control except in hot years. Our trials over the last five years in Western NY, the Hudson Valley and the Champlain Valley have shown that when NAA is tank-mixed with Retain at 2-3 weeks before normal harvest, or NAA is applied one week after Retain, then drop control is improved without any negative effects on fruit quality or fruit storage life after 45 and 90 days under regular cold storage conditions (33°F).

It appears that both products work better together than either product alone. The Retain prevents ethylene production induced by the NAA, and the two chemicals together jointly prevent abscission zone formation and provide improved preharvest drop control compared to either product alone (for more details about a proposed model of abscission based on gene regulation data from Rongcai Yuan, 2008, please review Robinson et al., 2010).

In 2011 we recommended for the first time the strategy of combining Retain and NAA for improved drop control. In 2011 and 2012 we conducted 2 commercial demonstration trials of combining Retain and NAA in a single application or in a split double application in a mature McIntosh and Honeycrisp orchard in Western NY. The objective of these studies was to demonstrate the benefits of combining Retain and NAA on preharvest drop of three apple cultivars, evaluate fruit maturity at a delayed harvest date, and evaluate fruit quality after a long CA storage period.

Materials and Methods

2011 McIntosh Experiment: A non-replicated demonstration trial to control pre-harvest fruit drop of McIntosh was conducted at Fowler Farms, Wolcott, NY. A block of mature ‘McIntosh” trees trained as Super Spindle (2,100 trees/acre) was used. Trees were on M.9 rootstock and were summer pruned one week before treatments were applied. Four treatments were compared. An early treatment was sprayed with a full rate of Retain (333 g/acre) on August 16, 2011. A late treatment was sprayed with a full rate of Retain plus NAA 20ppm (Fruitone L) on August 30, 2011. A split application treatment was sprayed with a half rate of Retain (167 g/acre) on August 16, 2011 and was re-sprayed with a half rate of Retain plus NAA 20ppm (Fruitone L) on August 30, 2011. All treatments applied in 2011 included Silwett L-77 0.1% v/v. Treatments were sprayed with a 4 row sprayer with 80 gallons of water per acre. For each treatment, four rows of 1100 trees were sprayed and 32 trees on the end of each row were left untreated. The grower harvested most of the block on September 24 but left 50 trees of each treatment for a late evaluation of drop control.

On October 6, 2011 (11 days after normal harvest) the fruit remaining on the trees were counted, placed on bins, labeled, and treated or not treated with 1-MCP before CA storage. The number of fruit dropped was counted for each treatment. In February 2012, fruit size, weight, color distribution, and fruit defects were graded by a Greefa computerized apple sorter at the grower’s packing facilities.

2012 Linda Mac and Honeycrisp Experiments: In 2012 we conducted two replicated field trials in a Super Spindle orchard (2,100 trees/acre) of Linda Mac and Honeycrisp on M.9 rootstock at Fowler Farms. The orchard selected for these studies had acceptable crop loads despite the severe frost damage, which occurred in Western NY in 2012. Both varieties were summer pruned one week before treatments were applied. Five treatments were: (1) an early treatment was sprayed with a full rate of Retain (333 g/acre) for Linda Mac and of 111g/acre for Honeycrisp on August 9, 2012; (2) a late treatment with a ½ rate was sprayed with a full rate of Retain (333g/acre) plus NAA (10ppm Fruitone L) for Linda Mac and (111g/acre) plus NAA (10ppm) for Honeycrisp on August 23, 2012 with a ⅓ rate of Retain; (3) a split application treatment for Linda Mac was sprayed with a half rate of Retain (167 g/acre) plus NAA (10ppm) on August 9, 2012 and was re-sprayed with a half rate of Retain (167 g/acre) plus NAA (10ppm Fruitone L) on August 23, 2012. The split application treatment for Honeycrisp was sprayed with a quarter rate of Retain (75.5g/acre) plus NAA 10ppm on August 9, 2012 and was re-sprayed with a quarter rate
of Retain (75.5 g/acre) plus NAA (10ppm Fruitone L) on August 23, 2012. As in 2011, all treatments applied in 2012 included Silwett L-77 (0.1% v/v) and were sprayed with same 4-row sprayer with 80 gallons of water per acre.

Each experimental plot consisted of a 4-row section of 50 trees. Five adjacent trees in the middle section of row 2 served to collect drop data and 10 adjacent trees in the middle section of row three served to collect fruit samples for fruit quality analysis. At weekly intervals beginning on Sept. 6, 2012, the number of dropped fruits was counted and fruit samples were collected and evaluated for fruit maturity. Pre-harvest fruit drop from each 5-tree replicate was measured by counting and removing dropped fruit each week (Sept. 6, 14, 20, 26, and Oct 3, 2012).

At the delayed harvest date on October 3, 2012, the fruit remaining on the trees were counted, placed on bins, labeled, and treated or not treated with 1-MCP before CA storage. The number of fruit dropped was counted for each treatment and cumulative drop was calculated for each evaluation date.

In February 2013, fruit size, weight, color distribution, and fruit defects were graded by a Greefa computerized apple sorter (Sept. 6, 14, 20, 26, and Oct 3, 2012).

Results

2011 McIntosh Results: All treatments with Retain reduced fruit drop compared to the untreated control (79%) at commercial harvest on September 24 and at the delayed harvest on October 6. Among Retain treatments, the full rate of Retain (333g/acre) applied early on August 16 (trt 4) had the best drop control (29%), while the split application of half rate of Retain on August 16 and August 30 with the second spray containing 20ppm NAA (trt 4) had the best drop control (29%) (Table 1).

After fruit were removed from CA storage after four months, fruit from the split application (trt 4) had 62% XFancy color and this was the treatment that most impressed the grower cooperator for this commercial demonstration trial. After storage the best fruit firmness was with the split application of Retain and there was no negative effect of including NAA in the spray on fruit firmness (Table 2).

2012 Linda Mac Results: Pre-harvest fruit drop from

---

Table 1. Effect of AVG (Retain) sprayed alone or in combination with NAA (Fruitone L) at two timings for fruit drop control of mature McIntosh/M.9 Super Spindle trees in 2011 and mature Linda Mac/M.9 and Honeyscris/M.9 Super Spindle trees in Wolcott, NY.

<table>
<thead>
<tr>
<th>Treatment Name</th>
<th>Date of Application</th>
<th>Rate of Retain</th>
<th>Rate of NAA</th>
<th>% Fruit Drop*</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011 McIntosh M.9 Study</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Untreated Control</td>
<td></td>
<td>-</td>
<td>-</td>
<td>79</td>
</tr>
<tr>
<td>Full Rate of Retain Applied Early (28 Days Before Harvest)</td>
<td>Aug. 16, 2011</td>
<td>333g/acre</td>
<td>-</td>
<td>47</td>
</tr>
<tr>
<td>Full Rate of Retain + NAA Applied Late (14 Days Before Harvest)</td>
<td>Aug. 30, 2011</td>
<td>333g/acre</td>
<td>800z/acre</td>
<td>35</td>
</tr>
<tr>
<td>Split Rate (1/2 Rate of Retain + NAA Applied Early (28 Days Before Harvest) and 1/2 Rate of Retain + NAA Applied Late (14 Days Before Harvest)</td>
<td>Aug. 16, 2011</td>
<td>167g/acre</td>
<td>800z/acre</td>
<td>29</td>
</tr>
<tr>
<td>Aug. 30, 2011</td>
<td>167g/acre</td>
<td>800z/acre</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2012 Linda McIntosh/M.9 Study</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Full Rate of Retain Applied Early (28 Days Before Harvest)</td>
<td>Aug. 9, 2012</td>
<td>333g/acre</td>
<td>-</td>
<td>57</td>
</tr>
<tr>
<td>Full Rate of Retain + NAA Applied Late (14 Days Before Harvest)</td>
<td>Aug. 23, 2012</td>
<td>333g/acre</td>
<td>400z/acre</td>
<td>38</td>
</tr>
<tr>
<td>Split Rate (1/2 Rate of Retain + NAA Applied Early (28 Days Before Harvest) and 1/2 Rate of Retain + NAA Applied Late (14 Days Before Harvest)</td>
<td>Aug. 9, 2012</td>
<td>167g/acre</td>
<td>400z/acre</td>
<td>26</td>
</tr>
<tr>
<td>Aug. 23, 2012</td>
<td>167g/acre</td>
<td>400z/acre</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Half Rate of Retain + NAA Applied Late (14 Days Before Harvest)</td>
<td>Aug. 23, 2012</td>
<td>167g/acre</td>
<td>400z/acre</td>
<td>48</td>
</tr>
<tr>
<td>2012 Honeyscris/M.9 Study</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Untreated Control</td>
<td></td>
<td>-</td>
<td>-</td>
<td>24</td>
</tr>
<tr>
<td>1/3 Rate of Retain Applied Early (28 Days Before Harvest)</td>
<td>Aug. 9, 2012</td>
<td>111g/acre</td>
<td>-</td>
<td>16</td>
</tr>
<tr>
<td>1/3 Rate of Retain + NAA Applied Late (14 Days Before Harvest)</td>
<td>Aug. 23, 2012</td>
<td>111g/acre</td>
<td>400z/acre</td>
<td>16</td>
</tr>
<tr>
<td>Split Rate (1/4 Rate of Retain + NAA Applied Early (28 Days Before Harvest) and 1/4 Rate of Retain + NAA Applied Late (14 Days Before Harvest)</td>
<td>Aug. 9, 2012</td>
<td>76g/acre</td>
<td>400z/acre</td>
<td>15</td>
</tr>
<tr>
<td>Aug. 23, 2012</td>
<td>76g/acre</td>
<td>400z/acre</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1/4 Rate of Retain + NAA Applied Late (14 Days Before Harvest)</td>
<td>Aug. 23, 2012</td>
<td>76g/acre</td>
<td>400z/acre</td>
<td>18</td>
</tr>
</tbody>
</table>

* Fruit drop evaluated on Oct. 6 in 2011 and Oct. 3 in 2012

Table 2. Effect of AVG (Retain) sprayed alone or in combination with NAA (Fruitone L) at two timings on color, flesh firmness, soluble solids, and internal disorders of mature McIntosh/M.9 Super Spindle trees in 2011.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Retain Rate (g/acre)</th>
<th>NAA Rate (ppm)</th>
<th>Application Date</th>
<th>XFancy (%)</th>
<th>Fancy (%)</th>
<th>Culls (%)</th>
<th>1-MCP Internal</th>
<th>Fruit quality after 4 months in CA storage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Untreated Control</td>
<td>0</td>
<td>0</td>
<td></td>
<td>64</td>
<td>1.1</td>
<td>35</td>
<td>Yes</td>
<td>11.4</td>
</tr>
<tr>
<td>Full rate early</td>
<td>333</td>
<td>0</td>
<td>Aug. 16</td>
<td>67</td>
<td>1.5</td>
<td>31</td>
<td>Yes</td>
<td>11.7</td>
</tr>
<tr>
<td>Full rate late</td>
<td>333</td>
<td>20</td>
<td>Aug. 30</td>
<td>57</td>
<td>4.1</td>
<td>39</td>
<td>Yes</td>
<td>11.6</td>
</tr>
<tr>
<td>Split Rate (½ rate early, ½ rate late)</td>
<td>167</td>
<td>20</td>
<td>Aug. 16</td>
<td>62</td>
<td>1.7</td>
<td>36</td>
<td>Yes</td>
<td>12.1</td>
</tr>
<tr>
<td>1/2 Rate of Retain + NAA Applied Late (14 Days Before Harvest)</td>
<td>167</td>
<td>20</td>
<td>Aug. 30</td>
<td>62</td>
<td>1.7</td>
<td>36</td>
<td>Yes</td>
<td>11.3</td>
</tr>
</tbody>
</table>
untreated Linda Mac trees was 8% by early September, 40% by the end of September, and had exceeded 60% fruit drop by the delayed harvest date of October 3 (Figure 1). The full rate of Retain (333g/acre) applied early (August 9 without NAA) reduced fruit drop compared to the untreated control at each sampling date. The half rate of Retain + 10 ppm NAA applied late (August 23) was no better than the untreated control. The addition of 10 ppm NAA to the full rate of Retain applied late improved the preharvest drop control. The split application sprays of Retain (167g/acre) + NAA (10 ppm) applied in 2 applications (½ early and ½ late) on August 9 and August 23 had the lowest fruit drop of any treatment (Table 1).

Applications or Retain had little effect on fruit firmness compared to the untreated control treatment. There was no negative effect of NAA in the Retain spray on fruit color and fruit firmness. The split application treatment had similar fruit color and firmness as the rest of the treatments (Table 3). When 1-MCP was used after harvest, fruit firmness and color after CA storage was consistently improved for all treatments.

2012 Honeycrisp Results: Pre-harvest fruit drop from untreated Honeycrisp trees was 5% by early September, 14% by the end of September, and 18% by the delayed harvest date on October 3 (Figure 2). A similar but slightly higher fruit drop of 23.6% was measured when all the fruit were counted on all the trees in the entire 4-row sections of Honeycrisp (Table 1).

The 1/3 rate of Retain (111 g/acre) applied early (August 9) with or without NAA did not reduce fruit drop until late in the harvest season (after September 20) (Figure 2). Likewise the 1/4 rate + NAA applied late (Aug. 23) did not reduce fruit drop. The only treatment which reduced fruit drop of Honeycrisp was the split rate of Retain + NAA applied on Aug. 9 and Aug. 23 with a 1/4 rate of Retain (75.5 g/acre) applied each time. The split application treatment was also the best drop control treatment when all the fruit on the trees of the entire 4-row section were counted.

Retain treatments reduced fruit color resulting in more undercolor fruit (Table 4). XFancy color was reduced the most with the split treatment and was similarly affected by the 1/3 rate of Retain (111 g/acre) applied early. There was no negative effect of adding NAA to the spray mixture on fruit firmness after CA storage. The use of 1-MCP after harvest consistently improved Honeycrisp color for all treatments after CA storage.

Table 3. Effect of AVG (Retain) sprayed alone or in combination with NAA (Fruitone L) at two timings on color, flesh firmness, soluble solids, and external and internal disorders of mature Linda Mac/M.9 Super Spindle trees in 2012.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Retain Rate (g/acre)</th>
<th>NAA Rate (ppm)</th>
<th>Application Date</th>
<th>1-MCP</th>
<th>Fruit quality after 4 months in CA storage</th>
<th>Sol. Solids (%)</th>
<th>Soft Scald</th>
<th>Bitter Pit</th>
<th>Lentilce Breakdown</th>
<th>Senesc. Breakdown</th>
</tr>
</thead>
<tbody>
<tr>
<td>Untreated Control</td>
<td>0</td>
<td>0</td>
<td>-</td>
<td>No</td>
<td>Yes</td>
<td>94</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Full Rate Early</td>
<td>333</td>
<td>Aug. 9</td>
<td>Yes</td>
<td>94</td>
<td>0.3</td>
<td>6.1</td>
<td>0</td>
<td>0</td>
<td>14.1</td>
<td>1.9</td>
</tr>
<tr>
<td>Full Rate Late</td>
<td>333</td>
<td>Aug. 23</td>
<td>Yes</td>
<td>94</td>
<td>0.5</td>
<td>6.7</td>
<td>0</td>
<td>0</td>
<td>14.5</td>
<td>4.7</td>
</tr>
<tr>
<td>Split Rate (1/2 early 1/2 late)</td>
<td>167</td>
<td>Aug. 9</td>
<td>Yes</td>
<td>96</td>
<td>0.3</td>
<td>3.7</td>
<td>0</td>
<td>0</td>
<td>14.4</td>
<td>0.0</td>
</tr>
<tr>
<td>Half Rate Late</td>
<td>167</td>
<td>Aug. 23</td>
<td>No</td>
<td>91</td>
<td>0.5</td>
<td>8.6</td>
<td>0.4</td>
<td>0</td>
<td>14.6</td>
<td>1.5</td>
</tr>
</tbody>
</table>

Discussion

Preharvest fruit drop of McIntosh in both 2011 and 2012 and Honeycrisp in 2012 was reduced the most by the split application strategy where a normal dose of Retain was split into 2 applications.
One of the concerns about including NAA in the Retain spray was the possibility that NAA could cause a loss of fruit firmness after regular or CA storage. Our earlier studies showed that there was no negative effect of inclusion of NAA in the Retain spray after regular storage (Robinson et al., 2010). The current study extends this result to show that there is no negative effect of inclusion of NAA in the Retain spray on fruit firmness after CA storage. There was also no negative effect of NAA on fruit storage disorders or fruit color. We did find a reduction of fruit color from Retain.

**Summary**

The application of a 1/2 normal rate of Retain mixed with 10ppm NAA applied twice (4 and 2 weeks before normal harvest) gave the longest and best drop control of McIntosh and Honeycrisp in 2011 and 2012. A single application of a reduced rate of Retain (1/2 normal rate) combined with 10ppm NAA gave poorer drop control than the split application strategy. The combination of Retain and NAA gave excellent drop control and did not reduce fruit firmness after CA storage. However we did find that this treatment as well as the rest of Retain treatments produced more undercolor fruit.

**Acknowledgements**

This project was partially funded by the New York State Apple Research and Development Program, Valent BioSciences, and Fowler Farms.

**Literature Cited**


**Table 4.** Effect of AVG (Retain) sprayed alone or in combination with NAA (Fruitone L) at two timings on color, flesh firmness, soluble solids, and external and internal disorders of mature Honeycrisp/M.9 Super Spindle trees in 2012.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Retain Rate (g/acre)</th>
<th>NAA Rate (ppm)</th>
<th>Application Date</th>
<th>Under color (%)</th>
<th>Firm. (lb)</th>
<th>Sol. Solids (%)</th>
<th>Soft Scald</th>
<th>Bitter Pit</th>
<th>Lenticel break down</th>
<th>Senesc. Break down</th>
<th>XFancy (%)</th>
<th>Fancy (%)</th>
<th>Culls (%)</th>
<th>1-MCP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Untreated Control</td>
<td>0</td>
<td>0</td>
<td>-</td>
<td>Yes</td>
<td>12.4</td>
<td>13.4</td>
<td>0.0</td>
<td>0.0</td>
<td>16.4</td>
<td>1.8</td>
<td>6.7</td>
<td>36.1</td>
<td>3.1</td>
<td>11.4</td>
</tr>
<tr>
<td>1/3 Rate Early</td>
<td>111</td>
<td>Aug. 9</td>
<td>Yes</td>
<td>12.3</td>
<td>13.3</td>
<td>1.8</td>
<td>5.3</td>
<td>12.3</td>
<td>0.0</td>
<td>14.0</td>
<td>10.5</td>
<td>4.2</td>
<td>27.9</td>
<td>16.3</td>
</tr>
<tr>
<td>1/3 Rate Late</td>
<td>111</td>
<td>Aug. 23</td>
<td>Yes</td>
<td>12.2</td>
<td>13.9</td>
<td>0.0</td>
<td>0.0</td>
<td>14.0</td>
<td>7.3</td>
<td>9.1</td>
<td>11.3</td>
<td>4.3</td>
<td>26.8</td>
<td>15.4</td>
</tr>
<tr>
<td>Split Rate (1/4 early 1/4 late)</td>
<td>76</td>
<td>Aug. 9</td>
<td>Yes</td>
<td>12.4</td>
<td>13.4</td>
<td>0.0</td>
<td>1.7</td>
<td>15.3</td>
<td>1.7</td>
<td>13.0</td>
<td>10.6</td>
<td>5.5</td>
<td>7.0</td>
<td>15.6</td>
</tr>
<tr>
<td>1/3 Rate Late</td>
<td>76</td>
<td>Aug. 23</td>
<td>Yes</td>
<td>12.4</td>
<td>12.9</td>
<td>0.0</td>
<td>1.5</td>
<td>13.2</td>
<td>0.0</td>
<td>17.9</td>
<td>9.8</td>
<td>6.1</td>
<td>3.6</td>
<td>10.9</td>
</tr>
</tbody>
</table>

One of the concerns about including NAA in the Retain spray was the possibility that NAA could cause a loss of fruit firmness after regular or CA storage. Our earlier studies showed that there was no negative effect of inclusion of NAA in the Retain spray after regular storage (Robinson et al., 2010). The current study extends this result to show that there is no negative effect of inclusion of NAA in the Retain spray on fruit firmness after CA storage. There was also no negative effect of NAA on fruit storage disorders or fruit color. We did find a reduction of fruit color from Retain.

**Summary**

The application of a 1/2 normal rate of Retain mixed with 10ppm NAA applied twice (4 and 2 weeks before normal harvest) gave the longest and best drop control of McIntosh and Honeycrisp in 2011 and 2012. A single application of a reduced rate of Retain (1/2 normal rate) combined with 10ppm NAA gave poorer drop control than the split application strategy. The combination of Retain and NAA gave excellent drop control and did not reduce fruit firmness after CA storage. However we did find that this treatment as well as the rest of Retain treatments produced more undercolor fruit.
Production of Sweet Cherries under High Tunnels in Either the Modified Spanish Bush and the Tall Spindle Systems

Terence L. Robinson and Leonel I. Dominguez
Department of Horticulture
New York State Agricultural Experiment Station, Cornell University
Geneva, NY 14456, USA

Production of sweet cherries in humid climates like NY State is constrained by rain induced fruit cracking. The introduction of dwarfing cherry rootstocks has allowed new possibilities for developing high-density cherry orchards with smaller trees that are more precocious and productive and that can be either covered with rain exclusion shelters or high tunnels to prevent rain cracking (Lang, 2005; Robinson et al., 2004). Several high-density training systems have been developed for sweet cherries giving fruit growers many options for choosing a planting density, rootstock and training protocol. The objective of this project was to compare 2 high-density production systems on dwarfing rootstocks for both self-fertile and self-infertile sweet cherries grown in a high tunnel.

Materials and Methods
In May, 2008, we planted a replicated field trial at Geneva, New York with 'Rainer' on Gisela 5 (Gi.5), and Gi.6 rootstocks and, 'Lapins', 'Regina' and 'Sweetheart' on Gisela 6 (Gi.6) Each variety/rootstock combination was planted in two training systems: Tall Spindle (TS) and Modified Spanish Bush (our version of the Kym Green Bush, KGB). Within each training system, trees were planted at two in-row spacings: 1m and 2m. The between row spacing was 3.6m giving planting densities of 1,366 and 2,732 trees/ha. Two of the three replicates were covered with a Haygrove high tunnel while the third replicate was grown with no cover.

The Tall Spindle system was developed by heading the leader at 120cm at planting and stubbing back any lateral branches to a 3cm stub. In addition, 2 out of 3 buds along the trunk were removed at bud swell. The bud removal process was repeated in years 2 and 3 on the 1 year-old portion of the trunk. This resulted in 15-18 lateral shoots along the trunk. Beginning in year 4 the trees were pruned each spring at bud swell by removing 1-3 of the largest limbs (>5cm) along the trunk by cutting them back to a 15 cm long stub or to a sub-lateral branch.

The Modified Spanish Bush trees were developed by repeated heading of the tree. First at 45cm above the soil at planting and allowing 3-4 vertical shoots to grow and heading each of those again in late June to produce 10 upright shoots for the 1m spacing. In the spring of the second year all of the vertical shoots of the 2m spaced Spanish Bush trees were re-headed to 15cm long stubs and then again on July 1 to produce 20 upright shoots. Beginning in year 3 the trees were topped at 2.5m after harvest and the lateral shoots on each of the 10 or 20 vertical fruiting branches was removed leaving long columns of spurred shoots.

Yield, fruit size, soluble solids, and proportion of cracked fruit were recorded each year and trunk circumference at the end of the experiment. A fruit packout was calculated and economic crop value was calculated by first subtracting yield of cracked fruit from total yield and then calculating crop value of each fruit size class. The effect of the tunnel on cracking was evaluated by comparing the effect of rep 1 and 2 compared to rep 3.

Results
Systems The trees in both the Tall Spindle system and the Modified Spanish Bush system grew well in the first and second year. The trees flowered in the third year and produced a good yield. The trees planted at the 1m spacing had significantly higher 3rd year yield than those planted at the lower density of 2m
between trees (Figure 1). At the 1m spacing there was no difference in yield between the Tall Spindle system and the Modified Spanish Bush system while at the 2m spacing the Tall Spindle system had significantly higher yield than the Spanish Bush. Among varieties, yields in the 3rd year were highest for Lapins followed by Rainer and lowest with Sweetheart.

In the fourth year, the yield of the Tall Spindle system declined slightly while the yield of the Modified Spanish Bush system increased resulting in significantly greater yield with the Spanish Bush. Within the Tall Spindle system, the 1m spacing continued to have higher yield than the 2m spacing but with the Spanish Bush system there was no difference in yield between the two tree spacings. Among varieties, Rainer had the highest 4th year yield followed by Lapins and Sweetheart which had the lowest yield.

In the fifth year the yield of the Tall Spindle was greater than the Modified Spanish Bush. With the Tall Spindle, the 1m spacing continued to have higher yield than the 2m spacing but with the Spanish Bush system the 2m spacing had higher yield than the 1m spacing.

There was an interaction of spacing and system on cumulative yield (Figure 2). With

![Figure 2](image2.png)

**Figure 2.** Interaction of plant spacing and training system on annual yield/ha (left figure) or cumulative yield/ha (right figure) of 3 sweet cherry cultivars (Lapins, Rainer, Sweetheart) on G1.6 rootstock over the first 5 years at Geneva, NY.

![Figure 3](image3.png)

**Figure 3.** Interaction of plant spacing and training system on trunk cross-sectional area (left figure) or canopy volume (right figure) of 3 sweet cherry cultivars (Lapins, Rainer, Sweetheart) on G1.6 rootstock over the first 5 years at Geneva, NY.
the Tall Spindle, the 1m spacing had higher cumulative yield/ha than the 2m spacing but with the Modified Spanish Bush, the 1m and the 2m spacing had similar cumulative yields. The Tall Spindle system at 1m spacing had higher cumulative yield/ha than the Modified Spanish Bush or the low density Tall Spindle.

Tree size as measured by trunk cross-sectional area (TCA) after 5 years was smaller with the 1m spacing than at the 2m spacing for both systems (Figure 3). Canopy volume was greater for the 2m spacing than the 1m spacing. Training system did not affect TCA but did affect canopy volume. The Tall Spindle system had a greater canopy volume than the Modified Spanish Bush.

Yield efficiency when based on TCA was higher for the Tall Spindle at the 1m or 2m spacing than the Modified Spanish Bush at 1m (Figure 4). However when yield efficiency was based on canopy volume then efficiency was higher for the Modified Spanish Bush at 2m spacing than the Tall Spindle or the Modified Spanish Bush at 1m spacing.

Fruit size of the Modified Spanish Bush was larger than the Tall Spindle (Figure 5). There was no effect of spacing on fruit size. Fruit soluble solids were not different among systems or spacings (Figure 5).

Light exposure in the lower canopy of the Modified Spanish Bush was very low even with the use of reflective film “Extenday.” There was no effect of this reduced light level on average fruit size or fruit soluble solids. The use of Extenday in the plastic tunnels improved light levels in the lower canopy but not in the middle or upper canopy.

Cumulative crop value was highest for the Tall Spindle system at the 1m spacing while the other 3 systems had lower and similar cumulative crop value (Figure 6). With the Modified Spanish Bush, there was no difference in cumulative crop value between the 1m and 2m spacings.

**Rootstock** With Rainer we compared the performance of Gi.5 and Gi.6 rootstocks. Gi.5 induced greater yields of Rainer cherry but with similar fruit size and soluble solids concentration (Figure 7). Rainer on Gi.5 rootstock had greater cumulative crop value than trees on G.6.

**Tunnel** The use of a high plastic tunnel to grow high-density sweet cherries resulted in increased yield, reduced fruit cracking and improved cumulative crop value regardless of system, rootstock or cultivar (Figure 8). The increase in crop value has been about $38,000/ha over the first 5 years.

**Discussion**

Our results after 5 years show the strong positive relationship of tree planting density and cumulative yields with the Tall Spindle system but not with the Modified Spanish Bush. The level of cumulative yield with the high-density Tall Spindle plantings was 1.5 times the level of low-density plantings. This is similar to the results of planting density studies with cherry and apple (Robinson, 2003). The Spanish Bush system at the 2m spacing gave lower initial yield in the third year compared to the 1m spacing but in the 4th and 5th years the 2m spacing did as well or better than the 1m spacing resulting in no effect of planting density on cumulative yield with the Modified Spanish Bush. This was likely due to the design of the trees at each spacing, which resulted in 10 upright fruiting shoots per tree at the 1m spacing but 20 upright shoots/tree at the 2m spacing. This resulted in a similar number of upright fruiting shoots/acre between the two spacings, thus similar cumulative yield. The lower yield of the Modified Spanish Bush compared to the Tall Spindle was due to the greater pruning with Spanish Bush system which received 2 heading cuts (spring and mid summer) of all shoots in both years 1 and year 2 while the Tall Spindle system was not headed. It is clear from this work that to maximize early yield, pruning during the first 2 years must be minimized. To reduce or eliminate this negative aspect of the Modified Spanish Bush system, pre-formed nursery trees should be planted which have multiple leaders when planted. This would eliminate all but the heading cuts in year 1.
The comparison of Gi.5 and Gi.6 showed that Gi.5 is a superior rootstock to Gi.6 when planted at high tree densities and grown under tunnels since it results in greater yield with similar fruit size and quality resulting in greater crop value over the first 5 years.

Another important result is that covering cherry trees with a high tunnel can significantly reduce fruit cracking in humid climates like New York State. With cracking sensitive cultivars like Rainer, this can be worth ~$38,000 per ha over the first 5 years (first 3 cropping years). Although cracking was reduced under the tunnel it was not completely eliminated. The economic value of the tunnel is not clear due to the high cost of purchasing the tunnel. Although the tunnels have reduced cracking and increased cumulative crop value by $38,000/ha, the cost of the tunnel is about $70,000/ha so the tunnel has not paid for itself in the first 3 cropping years. A complete economic analysis will be done after a few more years but it is likely that the tunnel cost will not be recovered until after year 7 or 8.

Considering both yield, fruit size, and cumulative crop value, the Tall Spindle system is the best system. However the Modified Spanish Bush performed very well in the tunnel. Its major drawback is the repeated heading of the shoots in the first 2 years. However, starting the orchard with pre-formed trees should improve its performance compared to the Tall Spindle. Its main advantage is that it is a pedestrian system, which is easier to harvest than the Tall Spindle.

Conclusions

Our experiment has shown very high early yields of Rainer, Lapins and Sweetheart sweet cherries are possible in the first 5 years with high planting densities. The high-density Tall Spindle system outperformed the high density Modified Spanish Bush system. The Modified Spanish Bush would have performed better if we had planted pre-formed bush trees. There was little benefit to high planting densities (1m vs. 2m) with the Modified Spanish Bush. Gi.5 rootstock produced higher yields and higher cumulative crop value than G.6. High tunnels increased yield, gave good fruit crack control and increased crop value substantially, but not yet enough to pay for the tunnel after 3 cropping seasons.

Acknowledgements

This research was partially supported by International Fruit Tree Association.

Literature Cited


Terence Robinson is a research and extension professor at Cornell’s Geneva Experiment Station who leads Cornell’s program in high-density orchard systems, irrigation and plant growth regulators. Leonel Dominguez is a graduate student and research support specialist who works with Dr. Robinson.