New York State Horticultural Society

www.NYSHS.org

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

It accomplishes this by:

- Supporting educational opportunities for members
- Promoting the industry
- Representing the industry in matters of public policy

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Geneva, NY 14456
www.NYSHS.org
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wilsonk36@hotmail.com

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#### APPLE VARIETIES

<table>
<thead>
<tr>
<th>Variety</th>
<th>Origin</th>
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<td>Granny Smith</td>
<td>New York</td>
<td>Green, firm, excellent flavor</td>
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<table>
<thead>
<tr>
<th>Membership Type</th>
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**Sponsors:**

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- Areas you’d like NYSHS to spend more effort on:
  - AgJobs $75 $______
  - H2A Reform $50 $______
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Please return application form to:
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If you are already a member, thank you for your support!
You may use this form if you wish to consider an additional membership for another person in your organization.

**Thank You for Your Support!!!**
Managed New York Apple Varieties: Are You Ready to Control Your Destiny?

Hopefully by now you are aware of Cornell University’s intent to introduce two new apple varieties under a managed license contract with an exclusive partner. Prior to this announcement by Cornell, a group of apple growers representing all major production regions in New York State met last Winter and Spring and subsequently formed New York Apple Growers LLC (NYAG) whose primary focus was to gain exclusive rights to new and exciting Cornell releases. All apple growers in New York State, who pay AMO dues, were mailed a notice in August regarding the formation of NYAG, which is a new grower-owned corporation whose primary mission and objectives are as follows:

**NYAG Mission:** To manage the release of new advanced apple varieties and market these varieties at an accelerated pace that delivers profit and long term sustainability to our members and licensing partners and to overwhelm our fresh apple consumers with a positive fresh apple eating experience.

**Objectives**
- To introduce outstanding new apple cultivars to the marketplace
- To allow any NYS Apple Grower the opportunity to become a member during the founding year
- To enhance New York State apple grower sustainability, growth, and long term competitiveness
- To secure exclusive variety contracts that allow its members and licensing partners to profit from the growing and selling of these varieties
- To invest funding directly into the Cornell apple breeding program

Currently NYAG and Cornell are undergoing negotiations for exclusive rights contracts and it is our desire to have these contracts completed by the end of January. After this we will begin the process of raising capital, creating a defined corporate structure, creating variety evaluation and quality programs, creating a nursery production plan, developing a detailed marketing plan and working on all other necessary details involved with the creation of a new entity. Additionally, NYAG wishes to increase our grower board by at least five new growers. If you are interested, please contact one of the current board members in your district listed below.

**What Action Should New York Apple Growers Take Now?**

The initial grower response to the formation of NYAG has been very positive and it is the current board’s goal to get as many quality growers aboard to make NYAG a success. New York growers must now begin to contemplate what their involvement will be with NYAG. All growers from grower operations of all sizes will be invited to become members of the grower-owned corporation during the founding year. Capital investments will be acreage based and the minimum and maximum amounts of acreage each grower can obtain are currently being evaluated.

The question for growers to ponder is if and by how much should they invest in NYAG? There has been a lot of interest in managed varieties over the past few months and this topic has been reviewed by many trade journals. Despite all of the opinions of how managed varieties will perform in the marketplace, the one fact that cannot be disputed is that the overall quality of the managed variety is the number one deciding factor. Although there is a tremendous amount of work to be completed in quality evaluation for the first two Cornell releases, we are very pleased and excited by the potential of these

(Continued on p.2)
(Editorial, cont.)

selections. In order to command shelf space in an ever increasing competitive market, we feel continued variety improvement will be necessary. NYAG is offering an opportunity for growers to get on board in the managed variety system; our business plan ensures continued investment into the long-term future to create superior varieties. As a result, when conducting your financial planning activities for 2010 and beyond, we pose the question: How can you not afford to get involved with NYAG?

More details will continue to evolve with NYAG through the winter so stay tuned for the communication of more information. If you have any questions or ideas for consideration, please feel free to contact a board member in your district.

Sincerely,

New York Apple Growers, LLC Executive Board:

Chairman: Roger Lamont, lamont@rochester.rr.com
Vice Chairman: Jeff Crist, jeff@cristapples.com
Treasurer: Walt Blackler, wblackler@gmail.com
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Nutrient Requirements of ‘Gala’/M.26 Apple Trees for High Yield and Quality

Lailiang Cheng and Richard Raba
Departments of Horticulture, Cornell University, Ithaca, NY

This paper was presented at the 2009 Cornell In-depth Fruit School on Mineral Nutrition.

Nutrient management plays a more important role in ensuring good tree growth, cropping and fruit quality for apple trees on dwarfing rootstocks in high-density plantings than for those on vigorous rootstocks as dwarf apple trees crop earlier and have higher yield and smaller root systems. With the development of leaf nutrient analysis and its wide adoption for diagnosis of tree nutrient status (Bould, 1966; Stiles and Reid, 1991; Neilsen and Neilsen, 2003), fertilization practices in orchards are now routinely adjusted by comparing leaf analysis results against the optimal range of leaf nutrient concentrations. However, effective nutrient management to these dwarf trees still requires a good understanding of their nutrient demand in terms of amount and timing because optimal leaf nutrient concentrations do not reflect the actual amount and timing of tree nutrient requirements.

Due to the difficulty of destructive sampling of entire trees multiple times during the annual cycle of tree growth and development, the actual demand of dwarf apple trees for all the macro- and micro-nutrients in terms of timing and amount has not been examined in detail. In this study, we took an approach of growing apple trees in sand culture to achieve optimal tree nutrient status, high yield and good quality, and using sequential excavation of entire trees to determine the magnitude and seasonal patterns of the accumulation of macro- and micro-nutrients in apple trees on dwarfing rootstocks. The sand culture system eliminates competition for nutrients among any adjacent trees grown in the field in high-density plantings, and allows good control of nutrient supply and better recovery of the entire root system at excavation.

Experimental Procedures
Six-year-old Gala/M.26 trees were grown in 55-L plastic containers in acid-washed sand (pH 6.2) at a spacing 3.5 by 11.0 feet (1129 trees/acre) at Cornell Orchards. These trees were trained as tall spindles. They had produced regular crops over the previous three years. Nutrient supply to these trees was based on a previous study (Xia et al., 2009). Briefly, all trees were fertigated with four liters of 15N-ammonium nitrate (210 ppm N) balanced with all other nutrients in Hoagland’s #2 solution twice a week from May 2 to one month before fruit harvest except during active shoot growth when the trees were fertigated three times per week. Fertigation continued from one month before harvest to fruit harvest but nitrogen was provided at half the concentration for the first two weeks and then was completed omitted from the fertigation solution in the two weeks immediately preceding fruit harvest. After fruit harvest, each tree was fertigated with four liters of the Hoagland’s solution at an N concentration of 210 ppm twice (September 22 and October 2). Each tree received a total of 30 grams of actual nitrogen during the entire growing season (equivalent to 75 lbs actual N per acre). The cropload of these trees was adjusted to 8.2 fruit per cm² trunk cross-sectional area via hand-thinning at 10mm king fruit (104 fruit per tree), and this cropload was maintained to fruit harvest. Irrigation was provided with two spray sticks per tree and the trees were well watered throughout the growing season. No foliar application of nutrients was applied to these trees. All the trees received standard disease and insect control throughout the growing season. A copper spray was put on at budbreak to control fire blight, but the spray made it difficult to accurately determine the accumulation patterns of total Cu in the new growth and the whole tree during the early part of the season.

At each of the 7 key developmental stages throughout the annual growth cycle (budbreak, bloom, end of spur leaf growth, end of shoot growth, rapid fruit expansion period, fruit harvest, and after leaf fall), a set of four trees was excavated. Each tree was partitioned to spurs, shoots, spur leaves, shoot leaves, fruit, one-year-old stem, branches, trunk, upper shank, lower shank and roots. All the samples were dried in a forced-air oven, and the dry weight of each tissue was recorded. Each sample was ground twice to pass a 40 mesh screen and measured for N, P, K, Ca, Mg, S, B, Zn, Cu, Fe, and Mn using combustion analysis and inductively coupled plasma emission spectrometry. Total N, P, K, Ca, Mg, S, B, Zn, Cu, Fe, and Mn in each organ type and the whole tree were calculated based on its concentration and dry weight data.

Results
Fruit yield, size and quality at harvest. Fruit yield was 18.8 kg per tree (equivalent to 1113 bushels/acre) with an average fruit size of 181 g. Fruit soluble solids concentration was 14.5% and fruit firmness was 16.8 lbs.
Leaf and fruit nutrient status. The concentration of N, P, K, S, Zn and Fe in both leaves and fruit decreased from bloom to fruit harvest, with concentrations being higher in leaves than in fruit from the end of shoot growth to fruit harvest (Figure 1A, B, C, F, H and I). The concentration of Ca, Mg, and Mn in leaves decreased from bloom to the end of spur leaf growth, and then increased thereafter, whereas fruit Ca, Mg, and Mn concentrations decreased from bloom to fruit harvest (Figure 1D, E, and J). The B concentration was higher in fruit than in leaves at bloom, but both had similar B concentrations from the end of spur leaf growth to fruit harvest (Figure 1G).

Leaf samples taken at the regular time recommended for nutrient analysis (90 days after bloom), and fruit samples taken at harvest, showed that both leaf and fruit nutrient status were in the satisfactory range for this cultivar (Table 1).

Dry matter accumulation and partitioning. Total dry matter of the tree showed an expolinear increase from budbreak to fruit harvest, with a net dry matter gain of 4.3 kg (Figure 2). Total dry matter of shoots and leaves increased rapidly from bloom to the end of shoot growth in early July, and then remained unchanged till fruit harvest. The total dry matter in shoots and leaves at fruit harvest only accounted for about 17.3% of the net dry matter gain of the whole tree from budbreak to fruit harvest. Total dry matter of fruit increased slowly from bloom to the end of shoot growth, then rapidly in a linear fashion till fruit harvest. The total dry matter of fruit accounted for about 72.2% of the net dry matter gain of the whole tree. At fruit harvest, approximately 10.5% of the net dry matter gain was found in the woody perennial parts (branches, central leader, shank and roots) of the tree. No significant increase was observed in the dry matter of roots between budbreak and fruit harvest.

Accumulation of nutrients in the whole tree. Total tree N increased very rapidly from bloom to the end of shoot growth, and then continued to increase, but at a slower rate to fruit harvest (Figure 3A). Total P, K, Ca, Mg, S and B in the tree increased slightly from budbreak to bloom and then in a near linear manner from bloom to fruit harvest, although accumulation of Ca, Mg, and B slowed starting from one month before harvest (Figure 3B-G). Both total Zn and total Mn in the tree showed a gradual increase from budbreak to the end of spur leaf growth, and then a rapid increase till one month before fruit harvest, followed by a slow increase to fruit harvest (Figure 3H, J). Total Fe in the tree increased rapidly from bloom to the end of shoot growth, followed by a slower increase till fruit harvest (Figure 3I).

The net gains of total N, P, K, Ca, Mg, and S from budbreak to fruit harvest were 19.8, 3.3, 36.0, 14.2, 4.4 and 1.6 g/tree, and those for B, Zn, Cu, Mn, and Fe were 93.6, 60.9, 46.5, 184.8 and 148.7 mg/tree, which were equivalent to 49.3, 8.2, 89.4, 35.4, 10.9 and 4.0 lbs/acre for N, P, K, Ca, Mg, and S, and 105.7, 68.8, 52.5, 208.6 and 167.9 grams/acre for B, Zn, Cu, Mn, and Fe at a
Total N in new growth showed almost the same pattern as total N harvest, total N in fruit accounted for 37.6% of N in new growth. The increase in total N in the new growth, because the total N made up 65.4% of fruit N accumulation, and accounted for all of total N in fruit from the end of shoot growth to fruit harvest. The increase then remained unchanged till fruit harvest. In contrast, total dry matter (Figures 2, 4A). It increased slowly from budbreak to bloom, end of spur leaf growth, end of shoot growth, rapid fruit expansion period, and fruit harvest, respectively. Each point is mean ± SE of four replicates.

Accumulation of nutrients in the new growth (fruit, shoots and leaves) Because fruit and shoots and leaves are the most dynamic parts of the tree, determining their nutrient accumulation patterns may help us understand their differential requirements for nutrients.

Total N in shoots and leaves followed the same pattern as dry matter (Figures 2, 4A). It increased slowly from budbreak to bloom, very rapidly from bloom to the end of shoot growth, and then remained unchanged till fruit harvest. In contrast, total N in fruit increased gradually from bloom to the end of shoot growth, and then rapidly in a linear fashion till fruit harvest. The increase of P, K, B and Fe in fruit increased gradually from budbreak to the end of shoot growth, and then rapidly in a linear fashion till fruit harvest. The increase of P, K and Mn in fruit at harvest accounted for 60.7%, 71.3%, 77.7% and 60.4% of their total amount in new growth, respectively. Total P, K, B, and Mn in new growth showed a slight increase from budbreak to bloom, then a very rapid increase from bloom to one month before harvest, followed by a slow increase to fruit harvest (Figure 4D, J). Total Ca and Mn in shoots and leaves increased very rapidly from budbreak to the end of shoot growth, then remained unchanged till fruit harvest (Figure 4B, C, G, I). In contrast, total P, K, B and Fe in shoots and leaves increased very rapidly from budbreak to the end of shoot growth, then remained unchanged till fruit harvest (Figure 4B, C, G, I). In contrast, total P, K, B and Fe in shoots and leaves increased very rapidly from budbreak to the end of shoot growth, then rapidly in a linear fashion till fruit harvest. The increase of P, K and Mn in fruit at harvest accounted for 97.6%, 96.7%, 93.3%, and 87.2% of their net accumulation in the whole tree from budbreak to fruit harvest.

Total Ca and Mn in new growth showed a slight increase from budbreak to bloom, then a very rapid increase from bloom to one month before harvest, followed by a slow increase to fruit harvest (Figure 4D, J). Total Ca and Mn in shoots and leaves increased very rapidly from budbreak to the end of shoot growth, then remained unchanged till fruit harvest (Figure 4B, C, G, I). In contrast, total P, K, B and Fe in shoots and leaves increased very rapidly from budbreak to the end of shoot growth, then rapidly in a linear fashion till fruit harvest. The increase of P, K and Mn in fruit at harvest accounted for 97.6%, 96.7%, 93.3%, and 87.2% of their net accumulation in the whole tree from budbreak to fruit harvest, respectively.

Both total Mg and total Zn in shoots and leaves increased rapidly from budbreak to the end of shoot growth, and then increased slowly till fruit harvest (Figure 4E, H). In contrast, total Mg and total Zn in fruit increased slowly from budbreak to the end of shoot growth and then rapidly from the end of shoot growth to fruit harvest, with 67.8% and 58.1% of the total accumulation taking place during the latter period. Total Mg and total Zn in fruit at harvest accounted for 31.3% and 30.8% of the total Mg and total Zn in new growth, respectively. Total Mg and total Zn in new growth at fruit harvest accounted for 90.4% and 58.1% of

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<th>K</th>
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<td>Net gain</td>
<td>105.7</td>
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Figure 3. Total accumulation of nitrogen (A), phosphorus (B), potassium (C), calcium (D), magnesium (E), sulfur (F), boron (G), zinc (H), iron (I) and manganese (J) in 6-year-old ‘Gala/M.26’ apple trees from budbreak to fruit harvest. The six points in each line correspond with budbreak, bloom, end of spur leaf growth, end of shoot growth, rapid fruit expansion period, and fruit harvest, respectively. Each point is mean ± SE of four replicates.
time, has generated a comprehensive nutrient accumulation data set for ‘Gala’/‘M.26’ trees trained in tall spindle. It is interesting to note that the accumulation of nutrients in new growth (fruit plus shoots and leaves) accounted for over 90% of the net gain for total N, P, K, Mg, S, and B in the entire tree and a large proportion of the net gain for Ca, Zn, Mn, and Fe (ranging from 58.1% in Zn to 87.2% in Fe) from budbreak to fruit harvest in this study (Table 2). Therefore, future studies of this type might gain most of the information on tree nutrient needs by just focusing on new growth (fruit, shoots and leaves).

Although the trees we used in this study were grown in sand culture, our data on total nutrient accumulation in fruit (or fruit nutrient removal at harvest) are very similar to those reported by Palmer and Dryden (2006) on ‘Royal Gala’, ‘Fuji’ and ‘Braeburn’, and Drahorad (1999) on several apple cultivars for commercial apple production, one can readily calculate the total requirement for each nutrient at any expected fruit yield by using the data generated in this study (See Table 4 for an example). It’s clear that the requirement for each nutrient increases as fruit yield increases.

Of the macronutrients required by ‘Gala’ apple trees, K is the one whose amount in the fruit at harvest accounted for the largest proportion of its net gain in the entire tree from budbreak to fruit harvest, i.e. more than two thirds of the total tree K requirement was found in fruit although fruit K concentration was only about half of that in leaves on a dry weight basis (Table 1, Figure 4C). Because of this large demand for K by fruit, apple trees on dwarfing rootstocks need adequate K supply to achieve high yield and good quality. However, it is possible that too much K can negatively affect fruit quality as K may compete with the uptake of Ca and Mg. It should be noted that the widely cited work of Haynes and Goh (1980) on nutrient budget of apple orchards significantly over-estimated the amount of K in fruit. Based on the amount of K in fruit and fruit dry matter reported in Haynes and Goh (1980), the calculated fruit K concentration would be over 2% on a dry weight basis. Either the trees used in their experiment were in luxury consumption of K, or an error was made by the authors (Haynes and Goh, 1980) in measuring or calculating the total amount of K in fruit. However, the former does not seem to be the case as leaf K concentration was only 1.2% at the end of the season.

Table 3. Comparison of total amounts of nutrients in ‘Gala’ fruit at harvest obtained in this study with those obtained in the Nelson region of New Zealand by Palmer and Dryden (2006) at a fruit yield of 1113 bushels/acre (52.45 metric tons per hectare).

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<th>Cu</th>
<th>Mn</th>
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Figure 4. Total accumulation of nitrogen (A), phosphorus (B), potassium (C), calcium (D), magnesium (E), sulfur (F), boron (G), zinc (H), iron (I) and manganese (J) in shoots and leaves, fruit, and new growth (fruit plus shoots and leaves) of 6-year-old ‘Gala’/‘M.26’ apple trees from budbreak to fruit harvest. The six points in each line correspond with budbreak, bloom, end of spur leaf growth, end of shoot growth, rapid fruit expansion period, and fruit harvest, respectively. Each point is mean ± SE of four replicates.

Discussion

Since the trees used in this study had optimal nutrient levels in both leaves and fruit (Table 1, Figure 1) and they produced a high fruit yield (equivalent to 52.45 metric tons per hectare) with good fruit size and quality, the observed accumulation of nutrients represents the nutrient requirements of these trees. The net accumulation of N, P, K, Ca, Mg, and S in the whole tree from budbreak to fruit harvest was 19.8, 3.3, 36.0, 14.2, 4.4 and 1.6 g/tree and that for B, Zn, Cu, Mn, and Fe was 93.6, 60.9, 46.5, 184.8 and 148.7 mg/tree, which was equivalent to 49.3, 8.2, 89.4, 35.4, 10.9 and 4.0 lbs per acre for N, P, K, Ca, Mg, and S and 105.7, 68.8, 52.5, 208.6 and 167.9 grams per acre for B, Zn, Cu, Mn, and Fe at a tree density of 1129 trees per acre. This study, for the first time, has generated a comprehensive nutrient accumulation data
Fruits, shoots and leaves have differential nutrient accumulation patterns (Figure 4). Our data indicate that the most rapid accumulation of all nutrients in shoots and leaves took place during active shoot growth, from bloom to the end of shoot growth, and the accumulation pattern of most nutrients corresponded well with the accumulation of dry matter, with continued accumulation observed only in total Ca and Mn in shoots and leaves after the end of shoot growth. Nutrient accumulation in fruit largely followed its dry matter accumulation, and a large proportion of the nutrient accumulation (ranging from 58.1% of Zn to 77.4% of K) occurred from the end of shoot growth to fruit harvest. The differential patterns of nutrient accumulation between fruit and shoots and leaves, and the similarity between dry matter accumulation and accumulation patterns of most nutrients within each organ (Figures 2B, 4), indicate that nutrient accumulation is demand-driven. The linear increase in both P and K in the whole tree, and in new growth from bloom to harvest (Figures 3B, C, 4B, C) indicates a constant demand for both nutrients during this period. The demand by shoots and leaves before the end of shoot growth accounted for a larger proportion of the total demand for both P and K, whereas the demand by fruit from the end of shoot growth to fruit harvest made up nearly the entire demand for new growth and for the whole tree. At fruit harvest, shoots and leaves had more N, Ca, Mg, S, Zn, and Mn, whereas fruit had more P, K, B, and Fe. It should be noted that B had the highest proportion (77.7%) partitioned to fruit among all nutrients (Figure 4G) and was the only nutrient that had a much higher concentration in fruit (flowers) than in leaves at bloom (Figure 1G), which clearly indicates the importance of B to fruit growth and development.

Although the Ca concentration in leaf samples taken in early August was at the lower end of the optimal range, fruit had a good Ca level with a Ca to Mg ratio at 16 in this study. However, it should be pointed out that the net accumulation of Ca for the whole tree from budbreak to fruit harvest obtained in this study might be an underestimate of Ca requirements for apple cultivars.
that are more susceptible to Ca-deficiency induced disorders relative to ‘Gala’.

Ca accumulation in ‘Gala’ fruit was found to continue throughout its entire growth period from bloom to harvest, with 61.7% of total accumulation occurring from the end of shoot growth to harvest in this study (Figure 4D). This contrasts with some of the earlier studies suggesting that Ca accumulation primarily takes place in the first few weeks after bloom (Faust, 1989; Wilkinson, 1968). The lack of continued increase in fruit Ca content previously observed in New York (Faust, 1989) may have been related to drought conditions during the summer, as most orchards were not irrigated then. The continued accumulation of Ca throughout fruit growth observed in central Washington under irrigated conditions (Rogers and Batjer, 1954) is also consistent with the idea that soil moisture may play an important role in determining Ca accumulation patterns in apple fruit. Wilkinson (1968) observed that more Ca was accumulated during the cell expansion stage of fruit development in wet years or under irrigation than in dry years without irrigation. The fact that Ca accumulation occurs during the entire fruit growth period suggests a wide window for enhancing fruit Ca levels via irrigation and foliar applications of Ca.

Conclusions
Nutrient requirements of ‘Gala’/M.26 trees from budbreak to fruit harvest are estimated to be 49.3, 8.2, 89.4, 35.4, 10.9 and 4.0 lbs per acre for N, P, K, Ca, Mg, and S, and 105.7, 68.8, 52.5, 208.6 and 167.9 grams per acre for B, Zn, Cu, Mn, and Fe at a density of 1129 trees/acre to achieve high yield and good fruit size and quality. Shoots and leaves and fruit have differential patterns of nutrient requirements: the high demand period for shoots and leaves is from bloom to end of shoot growth whereas that for fruit is from the end of shoot growth to fruit harvest. At harvest, fruit contains more P, K, B, and Fe whereas shoots and leaves have more N, Ca, Mg, S, Zn, and Mn. When developing fertilization programs in apple orchards, soil nutrient availability and tree nutrient status must be taken into consideration along with tree nutrient requirements.

Acknowledgments
This work was primarily supported by a generous gift from Dr. David Zimerman, Cornell Pomology Ph.D. 1954. Additional support was provided by the New York Apple Research and Development Program. The ‘Gala’ trees used in this study were generously donated by Van Well Nursery in Wenatchee, WA. We thank Andrea Mason, Louise Gray, Scott Henning, and Cornell Orchard crew for technical assistance.

References
Fertigation is the application of nutrients through irrigation lines, during watering. In general, it is more readily adapted for use in micro-irrigation systems such as micro-sprinkler, micro-jet and drip than to more extensive systems such as sprinkler or furrow. It has the advantage of allowing flexibility in the timing of nutrient additions, and under micro-irrigation, targeting the nutrients into the tree root zone with higher precision than possible with high-pressure irrigation or rain-fed watering. It is particularly well suited to high-density production systems.

Nutrient uptake by trees is determined by the availability of nutrients in the soil, interception of nutrients by the roots and by tree demand. Nutrient availability in the soil is related to native soil fertility. Soils with a coarse texture (sandy and gravelly) or with low organic matter content tend to be less fertile than soils that are fine textured (loamy, silty, clayey) or have high organic matter content. Delivery of nutrients to the tree is affected by nutrient mobility. Mobile nutrients such as nitrogen and boron are dissolved in soil solution and move easily to roots. Less mobile nutrients such as calcium, magnesium, sodium and potassium are somewhat soluble but are also easily detached from soil particles. In some soils, potassium also falls into the class of immobile nutrients, which includes, phosphorus and zinc. The immobile nutrients are fixed onto soil particles, have low soil solution concentrations and tend to move slowly to the root by diffusion. Apple trees also have sparse roots and so cannot easily intercept immobile nutrients. A final factor is retention in the root zone. For mobile nutrients, movement of nutrients out of the root zone with water prevents interception; for immobile nutrients the issue is retaining the nutrient in solution long enough for root interception and uptake to occur.

**Mobile Nutrients**

**Nitrogen** (N). Careful management of water and nitrogen is important because fruit trees are very inefficient in their use of nitrogen. A comparison of retention of applied nitrogen in the root zone is shown in Figure 1 and shows how fertigation might help N fertilizer use efficiency. Soil solution concentrations of nitrate nitrogen quickly declined when the fertilizer was broadcast and sprinkler irrigation was used (Figure 1a). In contrast, an almost constant concentration in the root zone was maintained when nitrogen was supplied daily through fertigation at different times (Figure 1b) allowing nitrogen supply to be managed with more precision than when broadcast.

In irrigated production systems the supply of nitrogen and water are closely linked. As nitrate is highly mobile, irrigation

Figure 1. Soil solution nitrate-N concentration measured throughout the growing season at 30cm depth in (A) plot receiving a single application of broadcast N fertilizer and weekly high impact sprinkler irrigation and (B) plot receiving daily N fertigation and drip irrigation at different times N1(triangle) and N3 (square).
management is key to the retention of nitrate in the root zone and hence to nitrate availability to the tree. Several strategies can be employed to reduce the over application of water which leads to losses of both water and nitrogen beneath the tree root zone. These include the use of conservative micro-irrigation systems to reduce total water inputs (Figure 1), the use of irrigation scheduling techniques to match water supply to demand and mulching to reduce water losses from the soil surface through evaporation. The effect of scheduling irrigation to meet crop water demand and thereby reducing nitrate losses beneath the root zone illustrates the relationship between water and nitrogen management (Figure 2). In this example an automated system, which is based on estimates of evaporative demand using a commercially available electronic atmometer (Etgage Co., Loveland Colorado) was used to control irrigation. Water (Figure 2a) and nitrate-nitrogen (Figure 2b) losses were greater beneath the root zone of trees receiving a fixed irrigation rate than for those receiving irrigation scheduled to meet evaporative demand as described above. There were no differences in tree growth between the sets of trees receiving the two types of irrigation.

Efficient use of nitrogen requires an estimate of the size and timing of tree N demand. We have used a variety of measurements to determine the nitrogen demand of dwarf apple tree including total tree excavation and partitioning, the use of labeled nitrogen fertilizer and assessment of annual removal in leaves and fruit. During the first few years after planting, these values ranged from 8 lb/acre to 38 lb/acre of nitrogen for trees grown on M.9 rootstock that were newly planted to six-year-olds respectively. Recommended rates of fertilizer are often higher ranging from 40 to 100 lb N/acre.

It has been well documented for apple and other fruit trees that N is withdrawn from foliage prior to leaf fall, stored in woody tissues and roots and that in spring N is remobilised from storage to support new growth. For apple trees, development of the spur leaf canopy is largely dependent on remobilised N. Both remobilisation and current season uptake supply N for shoot leaf canopy growth and high root uptake commences around bloom. Fruit N requirements are met mainly by remobilisation during cell division, but mainly by root uptake during cell expansion. Thus application of fertilizer N can be timed to match maximum demand for shoot leaf canopy development, that is, during the six weeks after bloom, without necessarily having a potential negative impact on fruit quality by elevating fruit N concentration.

**Less Mobile Nutrients**

**Potassium (K).** The mobility of K in soil is generally reduced compared to N but greater than P. The mobility of surface-applied K is highest in sandy soils, reduced for soils with high exchange capacity (higher clay and organic matter content) and very limited for soils known to fix K. Potassium deficiency can be increased in drip-irrigated orchards on sandy soils where root distribution can be restricted by poor lateral spread of applied water. Deficiency symptoms appear first in spur leaves adjacent to fruit. These leaves develop an irregular chlorotic leaf surface during midsummer which progresses into interveinal browning and marginal leaf scorch by fruit harvest.

However, soil K status at the main rooting depth can be easily altered. Daily fertigation of K from mid-June to mid-August at a rate of 15 g (0.83 oz) /tree/year increased the concentration of K in the soil solution (Figure 3). These application rates were...
sufficient to prevent the development of deficient leaf K concentrations during the first five years for four apple cultivars on M.9 rootstock.

There appears to be little effect of the form of K fertilizer on tree response as demonstrated in a three year experiment with ‘Jonagold’ on M.9 rootstock in which K in different forms was fertigated daily over a six week period from late June to mid-August (Table 1). There were no major differences in leaf K concentration among K forms which was generally above leaf deficiency levels (1.3%) regardless of treatment.

### Immobile Nutrients

#### Phosphorus (P)

Poor downward movement of surface applied P-fertilizer into the root zone of many orchard soils has long been recognized. The mobility of P through soil can be further reduced in finer-textured and other soils with a high P-sorption capacity. This is illustrated from field studies in Washington State and British Columbia which measured changes in soil P values with depth after surface fertilizer application (Figure 4). To move P-fertilizers distances as short as six inches requires the application of large quantities of water, particularly for calcareous fine textured soils such as the Warden silt loam (Figure 4). Around 30 times the amount of water was required to move P using daily fertigation or a broadcast application compared with a single fertigated dose. The single fertigated application temporarily saturates the P fixing sites in the soil allowing more downward movement of P. Similar responses occur with high rates of monosaturates the P fixing sites in the soil allowing more downward movement of P. Similar responses occur with high rates of monosaturates the P fixing sites in the soil allowing more downward movement of P.

Few responses to broadcast fertilizer P have been reported. However, fertigation of P in first year results in the same beneficial effects associated with planting hole P applications, namely increased leaf P concentration and improved tree establishment and initial fruiting. A single annual pulse application of fertilizer P to five different apple cultivars (Gala, Fuji, Cameo, Ambrosia, Silken) planted on M.9 rootstock at high densities (3 foot by 10 foot spacing) improved cumulative yield performance of these cultivars during the first five growing seasons. The experiment tested a range of fertigation treatments including low (28 ppm N in irrigation water) and high (168 ppm) nitrogen applications, each applied for four weeks at three different times after bloom including early (first 4 weeks postbloom), mid season (four-eight weeks postbloom) and late applications (8-12 weeks postbloom). The treatment involving high early N plus a pulse of P (4.6 oz/ tree of ammonium polyphosphate (10-34-0)) in the week immediately following bloom has produced the most fruit over all cultivars (Table 2).

#### Zinc (Zn)

Zinc deficiency is a common problem in apple. Symptoms of Zn deficiency are most usually observed in the spring and include chlorosis (yellowing) of the youngest shoot leaves that are often somewhat undersized and narrower than normal (referred to as little leaf). The deficiency may also result in blind bud and rosetting (small basal leaves which form on shortened terminals and lateral shoots of current year’s growth).

Zinc occurs in the soil in relatively insoluble forms and is easily precipitated on solid surfaces of carbonates and iron and manganese oxides. As a result, it is considered relatively immobile in the soil and a large fraction of Zn applied to the soil is absorbed by soil particles unless extremely high application rates are made. There are some differences among soils with less adsorption on noncalcareous sandy soils, which have reduced capacity to fix Zn.

There have been limited studies investigating fertigation of Zn. Zn fertigation research has been undertaken in an experimental block of four different apple cultivars on M.9 rootstock at the Pacific Agri-Food Research Centre at Summerland, BC (Figure 5). If no Zn was applied (1992 and 1993) all trees, regardless of cultivar, had leaf Zn concentrations below the 14 ppm deficiency threshold. In 1994, application of dormant zinc sulphate and foliar Zn chelates, postbloom in early summer, resulted in very high leaf Zn concentrations across cultivars, probably through contamination from surface residues from the foliar Zn sprays. Commencing in 1995, efforts were made to fertigate Zn as zinc sulphate (36% Zn) dissolved in the irrigation water and applied for four weeks during the growing season. The application rate ranged from 0.34 oz liquid zinc sulphate (36% Zn) per tree (3.5 g Zn per tree) in 1995 and 1996 to double these rates in 1997 and to 1.7 oz liquid zinc sulphate per tree (17.5 g Zn per tree) in 1998. Regardless of the fertigated Zn application rate, leaf Zn concentration did not generally increase above deficiency thresholds for any

| Table 1. Effect of K-fertilizer form on K-nutrition of >Jonagold< on M.9 rootstock grown on sandy loam soil, 2000-2002. |
|-----------------|-----------------|-----------------|
| Fertigation treatment (Kg/tree) | Mid-July leaf K concentration (% DW) |
| | 2000 | 2001 | 2002 |
| Control (0g) | 1.38c | 1.58c | 1.46c |
| KCl (15 g) | 1.60b | 1.81b | 1.73b |
| KCl (30 g) | 1.67ab | 1.96b | 1.83ab |
| KMag (15 g) | 1.66ab | 1.89ab | 1.74b |
| KMag (30 g) | 1.72a | 1.98a | 1.85ab |
| K2SO4 (30 g) | 1.66ab | 2.00a | 1.91a |
| K thiosulfate (30 g) | 1.76a | 2.01a | 1.94a |

* ** *** **** significantly different at p<0.05, 0.01, 0.001, 0.0001

Within columns different values followed by different letters are significantly different.

| Table 2. Cumulative yield per tree of apples from 2nd - 5th leaf for selected treatments averaged over all cultivars (Silken, Cameo, Fuji, Gala and Ambrosia). |
|-----------------|-----------------|-----------------|
| Fertigation Treatment | Cultivar | Cumulative yield (pounds/tree) |
| High early N + P pulse | All | 86.5a |
| High N (all times) | All | 73.5b |

Within columns different values followed by different letters are significantly different.

| Table 3. Soil chemical changes at 30 cm depth directly beneath the emitter, in 20 orchards (3-5 years old) receiving drip irrigation and fertigation with NH4-based fertilizers |
|-----------------|-----------------|-----------------|
| pH² | Ca (ppm) | Mg (ppm) | K (ppm) | B (ppm) |
| Between rows | 7.0 | 1235 | 144 | 211 | 0.97 |
| Beneath emitter | 6.2 | 911 | 114 | 88 | 0.19 |
| Significance | *** | ** | ** | ** | **** |

² pH (1:2 soilwater); Ca, Mg, K extracted in 0.25M acetic acid + 0.015M NH4F; B (hot water extractable).

*** **** **** significantly different at p<0.05, 0.01, 0.001, 0.0001
cultivar. Since the site was a sandy soil, these results imply that correction of inadequate Zn nutrition via fertigation of mineral zinc sulphate will be difficult. Fertigation of more expensive chelated Zn forms may be more effective but have not undergone extensive testing.

Effects Of Fertigation On Soil Properties
Fertigating ammoniacal forms of N and P can affect the base status of soils as transformation of ammonium to nitrate is an acidifying process, which may also accelerate leaching. The widespread nature of this problem was indicated in a survey of 20 commercial orchards on coarse-textured soils which had undergone three to five yrs. of NP-fertigation in British Columbia. Soil pH, extractable soil bases and soil B measured at 0 to 15 cm depth directly beneath the drip emitter, were all reduced (Table 3). In response to this survey, a soil test was designed to determine the susceptibility of soils to acidification. An acidification resistance index (ARI) was developed from analysis of buffer curves for 50 soils of differing composition and was defined as the amount of acid required to reduce soil pH from initial status to pH 5.0. These values were then compared to common soil test analysis data and a relationship defined between the acidification resistance index, soil pH and soil extractable bases. It was recommended that soils with a low acidification resistance index be fertigated with NO₃⁻-based rather than NH₄⁺-based fertilizers.

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Antioxidant contents and activity in SmartFresh-treated ‘Empire’ apples during air and controlled atmosphere storage

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Department of Horticulture, Cornell University, Ithaca, NY

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

Many consumers think that vitamin C (ascorbic acid) is the major antioxidant in fruits and vegetables, but in fact it is increasingly recognized that phenolic compounds often represent the majority of health-related antioxidant activity in plant products. The phenolic compounds also contribute to appearance, as well as taste and flavor. Apples are one of the best sources of antioxidant and phenolic compounds of all fruit, and are especially beneficial to our diet because they are available year-round. Research from the Cornell laboratories of Drs. Cy Lee and Rui Hai Liu, as well as elsewhere, has shown that apples provide protection against cardiovascular disease and various cancers. Of the top 25 fruits consumed in the United States, apples are the number one source of phenolics in the American diet and provide Americans with 33% of the phenolics they consume (Boyer and Liu, 2004).

For apples, the major focus on health-related properties has been on phenolic compounds, including flavonoids such as the anthocyanins that are responsible for red color of the fruit. Apple varieties vary greatly in antioxidant components and individual phenolic compounds have different antioxidant potential. Interestingly, reactions among individual compounds may be synergistic, and therefore, total antioxidant activities potentially provide a better estimate of the overall contributions of antioxidant components than individual components alone. Phenolic and flavonoid contents are consistently higher in the skin than in the flesh, and peel tissues have the highest antioxidant activity and anti-proliferation activity.

In general, the total phenolic concentrations in both peel and flesh tissues of apples remain relatively stable during storage, although individual components may vary. The advent of SmartFresh storage technology based on 1-methylcyclopropene (1-MCP), an inhibitor of ethylene perception, has raised the question about its effects on the nutritional quality of apple fruit. Knowledge about responses of fruit in both air and controlled atmosphere (CA) storage is important. CA can prolong the impact of 1-MCP on both physical and sensory responses of apple and the two technologies generally are most effective when used in combination.

To date, studies on the effects of 1-MCP on antioxidant components are limited. MacLean et al. (2006) found that 1-MCP treatment inhibited an increase in chlorogenic acid in peel tissues of Red Delicious apples during storage, and resulted in higher flavonoid concentrations. MacLean et al. (2003) also found that total antioxidant activity was higher in peels of 1-MCP-treated than untreated Empire and Red Delicious apples during storage. The total antioxidant activity (DPPH) of Golden Smoothee flesh was unaffected by 1-MCP treatment, but total ascorbic acid concentrations were slightly lower after 30 and 90 days of air storage (Vilaplana et al., 2006).

The objective of the current study was to investigate the effects of 1-MCP treatment during air and CA storage on antioxidant components and antioxidant activity of peel and flesh tissues of the Empire apple. This research was carried out as part of a PhD program and has been published in full (Fawbush et al., 2009). Here, we highlight the main findings of importance to the New York apple industry.

Materials and Methods

The Empire apple fruit used in these experiments were all harvested on the same day from mature trees growing at the Cornell University orchards at Lansing. The IEC, flesh firmness, SSC and starch index of the fruit at harvest were 2.7 ppm, 16.6 lb-f, 12.5% and 5.7 units, respectively. Fruit were randomly sorted into experimental units for either air or CA storage experiments.

For air storage, four replicates of 100 fruit were pre-cooled overnight at 33°F and then they were either untreated or treated with 1 ppm 1-MCP (SmartFresh powder) for 24 hours. Fruit were stored for up to five months. For CA storage, replicates of 55-60 fruits were cooled overnight at 36°F, and either untreated or treated with 1 ppm 1-MCP. Four replicates of fruit for each treatment and temperature were stored in steel chambers, with 2 or 3% O2 (with 2% CO2). Final atmosphere regimes were established within 48 hours and were maintained within 0.2% of target atmospheres. CA storage was carried out for 9 months.
Ten fruit per treatment replicates were taken at harvest for assessment of internal ethylene concentration (IEC), flesh firmness, soluble solids concentration (SSC) and starch pattern indices. IEC and firmness were measured on 10 fruit replicates after 1, 2, 3, 4 and 5 months for the air-stored fruit, and after 4.5 and 9 months for the CA stored fruit, plus 1 day at 68°F. At the last removal from storage, all remaining fruit were kept at 68°F for 7 days and then assessed for disorders.

For extraction of phenolic and other compounds, 10 fruit per treatment replicate were taken on the day of removal of fruit from air and CA storage. Total phenolics, flavonoids, anthocyanins, total antioxidant activity and total ascorbic acid were measured on apple peel and flesh using standard procedures as described by Fawbush et al. (2009).

Results

Air storage. 1-MCP prevented any increase in the internal ethylene concentrations (IEC) during storage, while the IEC in untreated fruit reached 43.9 ppm after 5 months of storage (Figure 1). Untreated fruit softened during this time to 11.4 lb-f, compared with 14.0 lb-f in 1-MCP treated fruit (Figure 1). No storage disorders were observed in air stored fruit.

At harvest, the phenolic concentrations in peel and flesh tissues were 2.82 and 1.24 g kg⁻¹, respectively (Figure 2). Overall, the phenolic concentration was significantly higher (2.56 g kg⁻¹) in peel tissues of 1-MCP treated fruit than in those of untreated fruit (2.16 g kg⁻¹). In the flesh, total phenolic concentrations of untreated fruit were significantly higher at 0.90 g kg⁻¹ than the 0.84 g kg⁻¹ of 1-MCP treated fruit. No effect of storage time was detected for either tissue type.

Total flavonoid and anthocyanin concentrations in the peel were affected only by storage time, but the patterns of change were inconsistent (results not shown). In flesh tissues, total flavonoids were not affected by either 1-MCP treatment or storage time.

At harvest, the total ascorbic acid concentrations in the peel and flesh were 0.55 and 0.11 g kg⁻¹, respectively, and these concentrations declined in both untreated and 1-MCP-treated fruit during storage (Figure 3). There was no significant effect of 1-MCP treatment on peel concentrations, although in the flesh tissues, the total ascorbic acid concentrations were slightly lower in 1-MCP-treated tissues than untreated tissues, averaging 0.07 and 0.06 g kg⁻¹, respectively. However, effects were evident at only some time points.

The total antioxidant activity in the peel was 2.82 mmol kg⁻¹ at harvest, and overall, the activity in peel tissue from 1-MCP treated fruit was 2.64 mmol kg⁻¹, compared with 2.12 mmol kg⁻¹ in untreated fruit. However, differences between treatments were evident only at months 1 to 3 (Figure 3). Total antioxidant activity in flesh tissues was also significantly higher in 1-MCP treated fruit than untreated fruit, averaging 1.14 and 0.95 mmol kg⁻¹, respectively. Total antioxidant activity was not affected by storage time.

CA storage. The IEC was much lower, and firmness higher, in 1-MCP treated fruit than in untreated fruit (Table 1). No external or internal disorders were detected after 4.5 months of CA storage, but a high incidence of flesh browning was observed in fruit after 9 months of storage.

The total phenolics, total flavonoid and ascorbic acid concentrations in peel and flesh tissues were not consistently affected by 1-MCP treatment (Tables 2, 3 and 4). Total anthocyanin concentrations in peel tissues were also unaffected by 1-MCP treatment (data not shown).

The total antioxidant activity in peel tissues was not affected by 1-MCP (Table 5), but the total antioxidant activity was higher in flesh tissues of 1-MCP treated than untreated fruit, being 1.40 and 1.25 mmol kg⁻¹, respectively. Interactions among all storage factors were detected, however, and overall trends were inconsistent.
Discussion
The effects of storage conditions on antioxidants in the absence of 1-MCP treatment have been well studied, and in general, total phenolics, total antioxidant activity and radical scavenging capacity are stable or increase during storage. The results of our study also largely indicate that concentrations of total phenolics, flavonoids, anthocyanins and total antioxidant activity are stable or increase during storage. The results of our study also largely indicate that concentrations of total phenolics, flavonoids, anthocyanins and total antioxidant activity are stable or increase during storage.

Table 1. Internal ethylene concentrations (IEC), flesh firmness and flesh browning of Empire apples, either untreated or treated with 1 ppm 1-MCP, and stored in controlled atmospheres of 2% or 3% oxygen with 2% carbon dioxide at 36°F for 4.5 and 9 months. Different letters associated with means indicate that there are differences between treatments.

<table>
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<tr>
<th>Storage time (months)</th>
<th>1-MCP</th>
<th>IEC (ppm)</th>
<th>Firmness (lb-f)</th>
<th>Flesh browning (%)</th>
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<td>14.3b 14.4b</td>
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Table 2. Total phenolic concentrations (g kg⁻¹) in peel and flesh tissues of Empire apples, either untreated or treated with 1 ppm 1-MCP, and stored in controlled atmospheres of 2% or 3% oxygen with 2% carbon dioxide at 36°F for 4.5 and 9 months. Different letters associated with means indicate that there are differences between treatments for a tissue type.

<table>
<thead>
<tr>
<th>Storage time (months)</th>
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<th>Peel</th>
<th>Flesh</th>
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<td>0.98bc 1.01abc</td>
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</table>

Table 3. Total flavonoid concentrations (g kg⁻¹) in peel and flesh tissues of Empire apples, either untreated or treated with 1 ppm 1-MCP, and stored in controlled atmospheres of 2% or 3% oxygen with 2% carbon dioxide at 36°F for 4.5 and 9 months. Different letters associated with means indicate that there are differences between treatments for a tissue type.

<table>
<thead>
<tr>
<th>Storage time (months)</th>
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<th>Peel</th>
<th>Flesh</th>
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</table>

Table 4. Total ascorbic acid concentrations (g kg⁻¹) in peel and flesh tissues of Empire apples, either untreated or treated with 1 ppm 1-MCP, and stored in controlled atmospheres of 2% or 3% oxygen with 2% carbon dioxide at 36°F for 4.5 and 9 months. Different letters associated with means indicate that there are differences between treatments for a tissue type.

<table>
<thead>
<tr>
<th>Storage time (months)</th>
<th>1-MCP</th>
<th>Peel</th>
<th>Flesh</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.5</td>
<td>-</td>
<td>0.37a 0.35a</td>
<td>0.11a 0.09bc</td>
</tr>
<tr>
<td></td>
<td>+</td>
<td>0.35a 0.31a</td>
<td>0.10ab 0.09bc</td>
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<td>9</td>
<td>-</td>
<td>0.38a 0.33a</td>
<td>0.10ab 0.09bc</td>
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<tr>
<td></td>
<td>+</td>
<td>0.36a 0.33a</td>
<td>0.09bc 0.08c</td>
</tr>
</tbody>
</table>

Table 5. Total antioxidant activity (vitamin C equivalents, mmol kg⁻¹) in peel and flesh tissues of Empire apples, either untreated or treated with 1 ppm 1-MCP, and stored in controlled atmospheres of 2% or 3% oxygen with 2% carbon dioxide at 36°F for 4.5 and 9 months. Different letters associated with means indicate that there are differences between treatments for a tissue type.

<table>
<thead>
<tr>
<th>Storage time (months)</th>
<th>1-MCP</th>
<th>Peel</th>
<th>Flesh</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.5</td>
<td>-</td>
<td>2.66f 3.76f</td>
<td>1.95bc 1.52f</td>
</tr>
<tr>
<td></td>
<td>+</td>
<td>3.5ab 4.7b</td>
<td>1.86a 1.03d</td>
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<tr>
<td>9</td>
<td>-</td>
<td>2.07cd 2.84ab</td>
<td>1.28bcd 1.32bc</td>
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<tr>
<td></td>
<td>+</td>
<td>1.91d 2.37bcd</td>
<td>1.19cd 1.16cd</td>
</tr>
</tbody>
</table>
relatively stable during air and CA storage. However, the effects of 1-MCP on individual phytochemical groups were variable. In air-stored fruit, total phenolic concentrations were higher in peel tissues, but lower in flesh tissues, of 1-MCP treated fruit compared with untreated fruit. No effects of 1-MCP were found for total flavonoid or anthocyanin concentrations, except that flavonoid concentrations were higher in 1-MCP treated fruit than untreated fruit during CA storage.

Total antioxidant activity, assayed using a recently developed method (Adom and Liu, 2005), was higher in both peel and flesh tissues of 1-MCP-treated fruit compared with untreated fruit, although higher only in flesh tissues of CA-stored fruit. Higher total antioxidant activity in 1-MCP treated peel tissues of air-stored Empire and Delicious apples was also found by MacLean et al. (2003). The reasons for higher antioxidant activity in air-stored 1-MCP-treated fruit are uncertain. Both total phenolic concentrations and total antioxidant activity were higher in peel tissues, and these two factors have been strongly correlated with each other in other studies.

Ascorbic acid concentrations declined in both peel and flesh tissues during air storage, while in CA storage, patterns of change over time were inconsistent, depending on the O₂ concentration. Surprisingly little information is available concerning changes in ascorbic acid concentrations in apple fruits during storage, especially in CA, and even less is known about the effects of 1-MCP. The significance of decreased ascorbic acid concentrations during storage with and without 1-MCP-treated fruit in this study and others is uncertain. Although ascorbic acid is generally considered to be important in nutrition, it represents a minor component of the total antioxidant activity of apples. Ascorbic acid, however, is a critical component of antioxidative processes in plant cells, interacting enzymatically and non-enzymatically with damaging oxygen radical and reactive oxygen species.

Conclusion
1-MCP delays fruit ripening of Empire apples, but the effects of treatment on phytochemical groups are relatively small. The results show that eating apples, regardless of storage technology, is the right thing to do to keep the doctor away!

Acknowledgments
This research was supported by the New York Apple Research and Development Program, AgroFresh, Inc., and the Cornell University Agricultural Experiment Station, federal formula funds, Project NE-1018, received from the Cooperative State Research, Education and Extension Service, U.S. Department of Agriculture. We thank Dr. Adom and Dr. Liu for advice on the total antioxidant assay.

References


Fanjaniaina Fawbush was a graduate student working with Chris Watkins. Jackie Nock is a research support specialist who works with Chris Watkins. Chris Watkins is a research and extension professor in the Department of Horticulture at Cornell’s Ithaca Campus who leads Cornell’s program in postharvest biology of fruit crops.

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Results of a New York Blueberry Survey

Juliet E. Carroll1,2, Marc Fuchs2 and Kerik Cox2
1 New York State IPM Program
2 Dept. of Plant Pathology and Plant Microbe-Biology
New York State Ag. Exp. Station, Cornell University
Geneva, NY

“Early managed blueberry plantings can remain productive for 25 years or more. Canker and dieback diseases rob plants of fruiting wood and reduce planting longevity. The two most common canker diseases identified by J. Carroll in specimens submitted to the plant pathology diagnostic lab in the 1980’s were Phomopsis canker and Fusicoccum (Godronia) canker, prompting her to undertake a survey for these diseases.

While cultural practices to manage these two canker diseases are similar, intensive management to bring the cankers under control in severely affected plantings may need to rely on pathogen-specific fungicide programs over a two to three year period, rather than a one-size-fits-all approach.

Infection by canker fungi causes leaves to turn reddish-brown, wilt and remain attached to shoots. Typically, symptoms first occur when fruit is present and temperatures are warm. Cankers are often found near the base of the affected canes, but can occur higher in the canopy on branches. When pruning out affected canes, look for tan, pink, or brown discoloration in the wood in cross-section. Fungal spores, produced on infected wood, spread the diseases within and among the plants so it is very important to rid the planting of this inoculum.

Fusicoccum spore release occurs during rain events essentially all season long, from bud break to leaf drop, with peak spore production and release during bloom (Caruso & Ramsdell 1995). Phomopsis spore release occurs during rain events from blossom bud swell (pink bud) through late August. As little as 0.15 inch of rain can trigger spore release. Infections occur within 48 hours in the presence of free water, warm temperatures (50F-80F), and susceptible tissues.

Fusicoccum cankers on one-to-two-yr-old canes typically develop from infections that occurred the previous year, while those from Phomopsis canker can develop in the same year of infection. Wounds are not required for infection by Fusicoccum. Although this is also true for Phomopsis, mechanically wounded or freeze-damaged stems are more prone to Phomopsis infection.

Phomopsis cankers are brownish with a lighter brown center, while Fusicoccum cankers are redder and may have a target pattern of alternating bands of light and dark reddish-brown. As infected stems age, Phomopsis cankers turn gray and the canes become flattened because the infected side of the stem fails to put down new wood.

Management relies principally on proper site selection and maintaining vigorous plants: proper soil pH, plant nutrition, irrigation, avoiding frost pockets and winter injury. IPM principals of sanitation and canopy management are paramount. Prune out diseased and dead canes. Remove prunings from the planting and destroy them by chopping or burning. Be mindful of restrictions against burning, but do not neglect the importance of removing prunings from the planting. Manage the planting to allow for rapid drying of the plant canopy after rain: manage weeds, prune out old canes, orient rows with prevailing winds, and select sites with good air drainage.

Survey Methods

Extension educators in each of the growing regions assisted with the surveys and received reports on the results found. Their cooperation is gratefully acknowledged; they included:

- Deborah Breth, Cornell Cooperative Extension Lake Ontario Fruit Program
- Cathy Heidenreich, Department of Horticulture, Cornell University
- Kevin Lungerman, Cornell Cooperative Extension Northeastern New York Fruit Program
- Laura McDermott, Department of Horticulture, Cornell University
- Steven McKay, Cornell Cooperative Extension Hudson Valley Fruit Program
- Molly Shaw, Southern Tier Ag Team, Tioga County Cornell Cooperative Extension

During June and July, 33 farms were visited, seven in 2007 (Tioga, Orleans, and Niagara counties) (Carroll 2007b), 12 in 2008 (Essex, Washington, Saratoga, Albany, Columbia, and Dutchess counties), and 14 in 2009 (Oswego, Onondaga, and Yates coun-
ties). Plantings were traversed randomly, unless specific areas were identified by the grower as having problems, and plants examined.

Suspicious canes were removed and brought back to the laboratory for analysis. Subsamples of the canes and branches were incubated in a moist chamber to encourage sporulation of fungi which were identified microscopically. Identity of fungi was based on characteristic size, shape and color of the fungal fruiting bodies and spores (stroma, pycnidia, acervuli, conidiophores, cirrhi, and conidia) (Caruso & Ramsdell 1995, Farr et al. 1989). Samples with suspected virus infection were tested with virus-specific antisera and via indicator plants.

Results

The farms surveyed ranged in size from under one to over 20 acres, with plantings from one to over 25 yrs old. One farm had long-established plantings still producing well that were pushing 100 years old. The majority of the plantings had irrigation. Those with good weed management used sawdust or wood chip mulch within the plant row. Plantings with vigorous, high-yielding plants were pruned primarily to remove old canes, allowing canes to achieve their natural height of five to eight ft (Pritts & Hancock 1992), had drip irrigation, were mulched, and had excellent weed control.

Phomopsis was the most prevalent canker disease in the New York blueberry plantings surveyed, especially in Eastern NY where Fusicoccum was not found. By contrast, in Western NY farms Fusicoccum canker was more frequently found (Table 1). Phomopsis canker was associated with the most severely affected plantings with 10-50% infected plants. Typically, incidence of cankers within a planting was low, ranging from 2-5% infected plants. When canker incidence was ~10% infected plants, growers became concerned. Most often only one infected cane was found per plant, and therefore, the disease would go unnoticed. But, when incidence in the planting exceeded 10%, several canes per plant were infected (Figure 1). Severe Phomopsis canker incidence approaching 50% infected plants was found in three plantings in NY. On four of the 33 farms surveyed, no canker diseases were found.

Canker incidence varied among cultivars. It is known that certain cultivars are very susceptible to Phomopsis canker (Weymouth, Earliblue, and Berkeley) and to Fusicoccum canker (Jersey, Earliblue, and Bluecrop) (Pritts et al. 2009). While only some growers had good records of which cultivars were found in their plantings, this information can be fundamental to IPM and to advancing blueberry production in NY.

Botryosphaeria stem blight (Figure 2) was tentatively identified from four farms in NY (Table 1). This disease on blueberry had not been previously described from NY. This fungus has a broad host range, attacking deciduous trees and shrubs including maple, birch, sumac, elm, viburnum, apple, buckthorn, etc.) Management practices for this disease would be similar to those for the other canker diseases. Twig blights were found associated with infection by Colletotrichum spp. and Botrytis cinerea, anthracnose ripe rot and Botrytis blight, respectively, were also found. A Pestalotiopsis-like fungus was found on a small number of samples collected in 2007 and 2008 and may be the same as one reported from blueberry plantings in Chile Pestalotiopsis clavispora (Espinoza et al 2008).

Mummy berry primary infections can also cause small Table 1. Prevalence of canker and dieback diseases found in 33 blueberry farms surveyed during the summers of 2007, 2008, and 2009.

<table>
<thead>
<tr>
<th>Canker / Dieback</th>
<th>W NY Farms</th>
<th>E NY Farms</th>
<th>C NY Farms</th>
<th>Total of Disease</th>
</tr>
</thead>
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<tr>
<td>Phomopsis a</td>
<td>3</td>
<td>12</td>
<td>8</td>
<td>23</td>
</tr>
<tr>
<td>Fusicoccum b</td>
<td>5</td>
<td>0</td>
<td>4</td>
<td>9</td>
</tr>
<tr>
<td>Anthracnose c</td>
<td>2</td>
<td>0</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Botryosphaeria d</td>
<td>1</td>
<td>3</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>Botrytis e</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td><strong>Number of Farms</strong></td>
<td><strong>7</strong></td>
<td><strong>12</strong></td>
<td><strong>14</strong></td>
<td></td>
</tr>
</tbody>
</table>

a Phomopsis canker, Phomopsis vaccinii Shear.
b Fusicoccum canker or Godronia canker, anamorph (conidial stage) Fusicoccum putrefaciens Shear and teleomorph (ascospore stage) Godronia cassandrae Peck. Ascospor infections are relatively unimportant in the disease cycle.
c Twig blight caused by the anthracnose fruit rot or ripe rot pathogens, Colletotrichum gloeosporioides (Penz.) Penz. & Sacc. or C. acutatum J.H. Simmonds.
d Botryosphaeria stem blight, putative identification of Fusicoccum aesulci Corda (conidial stage) of Botryosphaeria dothidea (Maug.,Fr.) Ces. & De Not.
e Botrytis blight, Botrytis cinerea Pers.-Fr.

Figure 2. Microscopic view of squashed fruiting body and spores of asexual state of Botryosphaeria dothidea (400X magnification).

Figure 3. Cross-section of mummy-berry-infected immature blueberry fruit.
twig blight symptoms in the absence of fruit infections. Lack of fruit infection may result from dry, hot conditions following a wet spring, from flowering time not coinciding well with production of spores on blighted leaves and twigs, perhaps from early abscission of infected fruit, or from well-timed fungicide sprays protecting blossoms. In 2009, likely favored by the wet growing season, mummy berry on fruit (Figure 3) was found in half of the plantings visited and affected up to 70% of the fruit in two of the 14 surveyed plantings. In prior years it was found only in one planting in 2007.

Weed management problems were most frequently encountered in plantings that had recently changed hands, where time allotted to farm management was insufficient, and where herbicide applications were poorly timed or inadequate. Instances where perennial weeds had encroached on plantings, serious economic impact on yield resulted. One interesting weed was found in two Eastern NY plantings. It was groundnut, *Apios americana*, a perennial vine which grows from edible tubers (Jungerman 2008) (Figure 4 A B C D).

Symptoms of viral disease were found on 12 farms surveyed and samples brought back for analysis (Carroll 2007a). Of these, samples from four farms tested positive for the presence of tomato ringspot virus (ToRSV) (Figure 5) and additional samples from one of these four farms tested positive for tobacco ringspot virus (TRSV) which causes the disease known as necrotic ringspot of blueberry (Converse 1987) (Figure 6). The prevalence of virus symptoms in plantings and the concern expressed by the growers and extension specialists has prompted the authors to embark next spring on a statewide survey of viral diseases in blueberries.

**Discussion**

New York ranked 10th in the nation in blueberry production, with 700 acres producing 2.3 million pounds valued at $3.37 million in 2007 (Anonymous 2006). The demand for blueberry and blueberry products has increased given the interest in foods high in antioxidants. This survey was undertaken primarily to determine the prevalence of canker pathogens in blueberry plantings, but also to survey for other problems impacting blueberry production in NY. It will benefit our blueberry industry to gain knowledge about factors that limit production.

This survey uncovered *Phomopsis* canker as a principal canker disease in NY, being found more often than other canker diseases and, on three farms, causing severe disease. Canker management relies almost exclusively on proper pruning and plant health maintenance. Although *Phomopsis* canker can be associated with winter injury, occurring on weakened branches, it can be a serious primary causes of plant damage, as was found on three farms. Intensive management to bring cankers under control in severely affected plantings may need to be supplemented...
by aggressive fungicide programs over a two to three year period, spanning the disease cycle. Research on specific treatments for managing this disease under NY conditions is needed.

*Botryosphaeria* stem blight, previously unreported from NY, was uncovered by this survey. The importance of mummy berry as a limiting factor in blueberry production was also underlined by the survey. Interestingly, while the ringspot viruses are soil born an IPM practice for mummy berry, which is to bury the mummies, could contribute to spreading the nematode vector of ToRSV and TRSV within and among plantings. Here is an example of why it is crucial to know the pest complex in your blueberry plantings in order to best apply IPM practices. Virus diseases can be propagated with infected, symptomless blueberry cuttings and lead to serious decline of plantings. Research on the extent and impact of viral diseases in blueberry will be addressed in an upcoming survey in the spring of 2010.

**Literature Cited**
The codling moth (CM) *Cydia pomonella* (Linnaeus), a European native, is a principal insect pest of pome fruit throughout much of the world. A member of the lepidopteran family Tortricidae, it is a bivoltine moth, having two generations in most of the U.S. including New York State. A partial third generation exists in the Pacific Northwest. Introduced to the New World during the earliest years of pome fruit production, the codling moth has historically been a very difficult insect to control. It was not until the development of the synthetic insecticides, broad-spectrum materials with extended residual, contact and feeding efficacy, that economic damage imposed by this insect was, for a period, curtailed.

The larvae overwinter in cocoons on the trunk and limbs, emerging as adults during the tight cluster through bloom period of apple. Shortly after mating, the female deposits her eggs onto foliage and fruit, giving rise to larva that cause significant feeding damage to the surface, flesh, core and seed of the fruit if unmanaged. A mechanism of survival contributing to the codling moth persistent success are the well-developed feeding habits of the larva. Larva emerging from eggs laid onto the fruit often begins burrowing through the egg covering, directly into the fruit, with little to no surface activity. To evade toxins present on the surface or skin of the fruit, the newly emerged larva will chew and excrete the skin prior to entry, only then proceeding into the fruit to feed. This tactic of fruit skin disposal reduces the amount of toxin the larva consumes while feeding.

Emergence of the CM first generation larva coincides with the immigration of adult plum curculio (PC) *Conotrachelus nenuphar* (Herbst) into commercial orchards. For more than 50 years, the CM has been effectively managed through the use of the organophosphate class of insecticides against the PC. Later in the season the second generation of CM larval emergence overlaps, at least in part, with other principle fruit pests, including the obliquebanded leafroller (*Choristoneura rosaceana* (Harris)), apple maggot *Rhagoletis pomonella* (Walsh), oriental fruit moth, *Grapholita molesta*, and the lesser apple worm *Grapholitha Prunivora* Walsh. Management of these insects provides fair to excellent levels of CM control depending on a number of management and biotic factors. Recent restrictions placed on the organophosphate class of insecticides, such as worker re-entry intervals, lengthened days to harvest and limits on total applications per season, have substantially reduced late season OP use. This shift in insecticide use may require the control of these insects through the use of multiple and more species-specific classes of insecticides, and incorporation of mating disruption to achieve comparable control yet increasing the cost of pome fruit production.

Insects with multiple generations, which maintain a constant presence in commercial orchards, are exposed to the selection pressure insect pest management tool impose. This constant exposure provides the mechanism for insecticide resistance development. Over the last two decades codling moth populations throughout North America have become increasingly tolerant of pest management practices, with increasing levels of insecticide resistance to the organophosphate class of chemistries used in pome fruit pest management. Insecticide resistance to azinphos-methyl (*Guthion*) has been well documented in codling moth populations throughout the western United States fruit growing regions for the past 20 years (Varela, et al., 1993; Reidhl et al., 1986, Steenwyck and Welter, 1998). Ohio, Michigan and Pennsylvania have seen increasingly high internal lepidopteran damage levels in harvested fruit. Over the past nine years western New York processing blocks of apple have seen increasing numbers of damaged fruit due to internal worm infestations. Infested fruit sampled from these orchards contained larvae of either insect from a complex of internal worm, consisting of the codling moth, the oriental fruit moth and the lesser apple worm. In 2002 infestations were found to contain predominately oriental fruit moth larvae, yet in 2005, a year in which 100 loads from 60 farms were ticketed...
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from processing centers by USDA inspectors, the predominate species was and continues to be the codling moth.

Given the dramatic increase in the presence of the internal worm complex in processing fruit, we were hard-pressed to ask to the question; ‘Has there been an increase in tolerance or resistance of the internal worm population in western NY’ or is this simply related to a shift in specific practices used in managing processing apple blocks? Historically, insecticide resistance development in CM populations has been a reoccurring and economically devastating event, and as such, it seemed prudent to investigate state wide CM populations for levels of susceptibility to commonly used insecticides. In collaboration with the Lake Ontario Fruit Team (LOFT) and the Hudson Valley Laboratory, a study was initiated to establish the insecticidal tolerance of azinphos-methyl in regional adult codling moth populations given its seasonal use patterns. A concurrent evaluation was also made of currently used insecticides to determine the efficacy of these materials against susceptible CM adult and 1st instar larva.

To determine insect population levels of resistance to a specific chemical or insecticide class, comparison bioassay studies to both field collected and susceptible populations to the specific insecticide in question are conducted. In a classic case study, shortly after azinphos-methyl was released for use in commercial orchards, Barnes and Moffitt (1963) at the University of California-Riverside conducted a resistance study on codling moth populations obtained in commercial and abandoned orchards. They determined that field populations of codling moth had a lethal dose or LD90 level of 0.158 μg/μl of azinphos-methyl, considered to be the standard susceptible level of mortality to this insecticide. Helmut Riedl conducted a follow-up study in 1985 to confirm that New York orchards still had susceptible populations of codling moth with adults taken from a site in Geneva, NY exhibiting LD90 levels of 0.350 μg/μl of azinphos-methyl. Although this concentration was two fold higher than the Barnes and Moffitt study population, it was not considered to be resistant.

**Results: Adult Bioassay**

In our first series of tests conducted in 2008-09 on adult codling moths, we collected adults from four western NY processing orchards in Williamson and Wolcott and five Hudson Valley fresh market orchards in Marlboro, Milton, Highland, Altamont, Burnt Hills to compare levels of susceptibility to azinphos-methyl. Approximately 20-100 CM traps were set at each site to collect adults from the 1st generation flight. Moths flying between dawn and dusk were captured on pheromone trap cards and returned to the laboratory within 24 hours. Adults were then treated using 1 μl (micro liter) droplets of laboratory grade acetone, applied to our control population, and serial dilutions of 98.9% concentration of azinphos-methyl (Pestanal; Sigma-Aldrich, Atlanta, GA), dissolved in acetone to achieve rates of 0.1, 0.2, 0.4, 0.8, 1.6 part per million concentrations, equivalent to μg/μl (microgram per micro liter) doses. Applications of these concentrations were made to the dorsal thoracic plate of the moth with mortality assessed using two evaluations at 24 and 48 hours after treatment. Moths were scored as live or dead based on antenna-stimulated and or probed movement response of the adult. In order to establish differences in levels of insecticide tolerance, mortality

| Azinphos-methyl LD90 Levels of Adult Codling Moth Populations in NY Orchards, 2009 |
|---------------------|---------------------|---------------------|
| NY Orchard          | More Susceptible    | Less Susceptible    |
| Assail 30SG Belt SC |                     |                     |
| NY Indian Ladder    |                     |                     |
| NY Calypso 4F       |                     |                     |
| ENY Knights          |                     |                     |
| WNY Wolcott 1       |                     |                     |
| WNY Williamson       |                     |                     |
| WNY Atlantic 2       |                     |                     |
| WNY Atlantic 3       |                     |                     |
| WNY Voorlage         |                     |                     |

**Figure 2.** The concentration of Guthion 50W (azinphos-methyl) required to produce morality in 90% of the adult codling population trapped from Eastern (ENY) and Western (WNY) orchards.

**Codling Moth Larvae Bioassay (susceptible ‘Benzon’ Colony), NYSAES, Highland NY 2009**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Percent Mortality After 2hrs.</th>
<th>Percent Mortality After 24hrs.</th>
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<tbody>
<tr>
<td>Lorsban 75WG</td>
<td>a</td>
<td>a</td>
</tr>
<tr>
<td>Delegate WG Guthion 50WP</td>
<td>b</td>
<td>b</td>
</tr>
<tr>
<td>Proclaim</td>
<td>c</td>
<td>c</td>
</tr>
<tr>
<td>ENY Indian Ladder</td>
<td>d</td>
<td>d</td>
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<tr>
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<td>e</td>
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<tr>
<td>ENY Knights</td>
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</tr>
<tr>
<td>WNY Voorlage</td>
<td>q</td>
<td>q</td>
</tr>
</tbody>
</table>

**Figure 3.** Percent mortality of 1st instar laboratory reared susceptible codling moth larva topically exposed to highest labeled field rate insecticides.

**Figure 4.** Percent mortality of 1st instar laboratory reared susceptible codling moth larva exposed to apple residue using the highest labeled field rate insecticide, and the percent of apples to which CM larva had burrowed after 2 and 24 hours.
curves were used to determine degrees of CM susceptibility to azinphos-methyl (Figure 1).

From the data generated in this portion of the study we observed lower levels of susceptibility in all study groups compared to the previous studies mentioned. Levels of reduced susceptibility were evident in western NY orchards, primarily in Verbridge and Williamson (Figure 2). Laboratory reared populations (‘Benzon susceptible strain’), and populations collected from most eastern NY orchards exhibited an LD90 of ≤ 0.85 µg/µl for azinphos-methyl with the exception of the ‘Morello’ orchard. The western NY strains in Verbridge displayed an LD90 of 1.86 µg/µl for azinphos-methyl, approximately 2.2 fold less susceptible than the Benzoin strain. Given the findings that all NY strains demonstrated a higher tolerance to azinphos-methyl compared to that of the Riedl and Barnes/Moffit studies implies reduced susceptibility levels across the state, with lower levels of susceptibility in WNY processing orchards. The overall low levels of azinphos-methyl susceptibility of NYS codling moth populations coupled with reduced levels of susceptibility in these processing blocks, may have contributed, at least in part, to insecticide failure resulting in infested loads observed during the past seven years. Further evaluations in 2010 will help determine the degree to which these populations are comprised of tolerant or resistant population levels of susceptibility.

Results: CM Larval Studies of Insecticide Contact Activity

Additional studies were conducted using topical bioassays on susceptible strains of larva using conventional and new insecticide chemistries. ‘Benzon’ 1st instar larva were evaluated for susceptibility to 10 commercial insecticides, in which larva were placed onto moistened filter paper affixed to the lid of 25 ml plastic cups. Applications to the larvae were then made using the highest labeled field rate for each product using a micro-applicator and 1 ml syringe employing 1 µl applications. Larvae were rated for mortality and evaluated at 2 and 24-hour intervals. Larva exposed to Guthion 50WP (azinphos-methyl) exhibited 100% mortality at 24 hours evaluation, statistically equivalent to Warrior (lambda-cyhalothrin), Sevin XLR (carbaryl) and Calypso (thiacloprid), which provided 92.5% & 100%, 85.0% & 97.5 % and 60.0% & 100.0% mortality levels respectively (Figure 3).

Results: CM Larval Studies of Insecticide Residual and Feeding Activity

Residue and feeding studies to ‘Benzon’ 1st instar larva were conducted to evaluate 10 commercial insecticides on susceptible strains of larva. Treated ‘Delicious’ apple were submerged in a dilute insecticide solution using the highest labeled field rate of each insecticide for three seconds and held indoors at 70°F, offering no exposure to rain or sunlight for 1, 3, 7, 14 and 21-day periods. Ten (10) 2.5 cm apple discs were removed from two treated fruit and secured onto the lid of plastic cups, onto which were placed CM larvae. The larvae were evaluated for mortality and feeding damage 2 and 24 hour intervals (Figures 4-8). Results demonstrated that larva exposed to azinphos-methyl treated apple exhibited lower levels of mortality at both the 2 hr and 24 hour evaluation intervals compared to most other insecticides. Assail 30SG (Acetamiprid), a recently developed neonicotinoid insecticide, had significantly higher levels of fruit residual activity against 1st instar larva than other insecticides after 2 hours but not statistically different from Calypso 4F, Delegate WG, Imidan 70WP or Sevin XLR after 24 hours. The least amount of feeding after 24 hours was observed in the Assail 30SG, Calypso 4F, Delegate WG, Imidan 70WP, Sevin XLR and Warrior treatments. However, after 3 days, the organophosphates Guthion 50WP, Imidan 70WP, Lorsban 75WG and the pyrethroid Warrior demonstrated increased residual activity with the least amount of feeding observed in the Assail 30SG, Calypso 4F, Delegate WG, Guthion 50WP, and Warrior treatments. After seven days, Delegate WG, Guthion 50WP, Imidan 70WP, and Warrior demonstrated increased residual activity with the least amount

Figure 5. Percent mortality of 1st instar laboratory reared susceptible codling moth larva exposed to apple residue using the highest labeled field rate insecticide, and the percent of apples to which CM larva had burrowed after 2 and 24 hours.

Figure 6. Results of a 2 and 24 hour evaluation of 1st instar, laboratory reared susceptible codling moth larva showing percent mortality of larvae exposed to apple residue using the highest labeled field rate insecticide after 7 days, and the percent of apples to which CM larva had burrowed.
of feeding observed in the Assail 30SG, Calypso 4F, Delegate WG, Guthion 50WP, and Warrior treatments. After 21 days, the highest level of residual efficacy was observed with Assail 30SG, Lorsban 75WG and Proclaim with the least amount of feeding observed in the Delegate WG treatment, followed by Assail 30SG, Proclaim, Sevin XLR Plus, Warrior and Calypso 4F treatments.

Discussion
In this study we’ve observed a 2.2 fold greater tolerance to azinphos-methyl in adult codling moth populations trapped in commercial processing blocks when compared to the majority of Eastern NY commercial fresh market orchards and a susceptible control group of adult codling moths. Yet, a number of factors may contribute to the failure of azinphos-methyl to manage this insect. One in particular, Lorsban 75WG, a very effective material when used at petal fall, is no longer available for use as a foliar insecticide beyond the pre-bloom stage of apple, thus removing it from use against the 1st generation flight of codling moth. Lorsban has been found by researchers to have excellent efficacy against the adult CM, and demonstrates a negative cross-resistance to azinphos-methyl, allowing it to maintain effectiveness even when resistance to Guthion fails to control CM (Steenwyck and Welter, 1998). The movement of azinphos-methyl resistant CM individuals from western states such as Washington State and California, to the east by way of storage bin transport, has also been implicated as the cause of resistant population build-up, especially in and around processing centers. Another facet of discussion regarding the loss of CM control includes a possible shift in the emergence pattern of codling moth later into the season for both generations (Boivin, 1999). Pheromone trapping peaks, often called the ‘B Peaks,’ imply adult emergence delays, and have been observed in trap graphs of Western and Eastern orchards. A delay in adult and subsequent larval emergence would prolong the presence of newly hatching larva beyond prediction models and insecticide residual activity, allowing for increasing levels of damage.

Another important factor in New York appears to be the differences in fresh market and processing production methods between regions with regards to application techniques. In general, apples grown in Western NY sites for processing are produced in larger acreages often bordering contiguous orchards of neighboring processing blocks. Large blocks have a tendency to ‘promote’ endemic populations. These orchards have for many years exclusively used azinphos-methyl in season long management programs. In processing blocks of apple, fruit can be acceptably sold at reduced visual standards when compared to retail fresh fruit market standards with regards to color, size and overall appearance. In some orchards this may have led to reductions in insecticide rates, alternate row application methods, stretched intervals, reductions in horticultural practices such as summer pruning, all of which hinder effective insecticide coverage and subsequent insect control. These practices promote greater insect survival, higher levels of selection pressure with regards to insecticide resistance development and ultimately less susceptible strains of insects as we have observed in this study.

Comparatively, apples grown in the Eastern part of the state are primarily produced for fresh market or pick-your-own sales, produced in smaller acreages often isolated from other orchards, surrounded by woodlands and or abandoned orchards. In most Hudson Valley orchards, the presence of these woodlots or abandoned orchards lead to higher insect pressure, increasing insecticide rate requirements. However, the pest complex migrating in from ‘the edge’ typically has greater levels of genetic diversity leading to greater insecticide susceptibility. Fruit quality, size and color requirements for fresh market demands methodical management including intensive crop load reductions, as sales depend on visually appealing large fruit. Intensive crop load management in fresh market fruit fosters king fruit to set

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Percent Mortality</th>
<th>After 2hrs.</th>
<th>After 24hrs.1</th>
<th>After 2hrs.</th>
<th>After 24hrs.2</th>
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<tr>
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<tr>
<td>Guthion 50WP</td>
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<td>30</td>
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<td>40</td>
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<tr>
<td>Warrior</td>
<td>50</td>
<td>0</td>
<td>20</td>
<td>0</td>
<td>30</td>
</tr>
</tbody>
</table>

**Figure 7.** Results of a 2 and 24 hour evaluation of 1st instar, laboratory reared susceptible codling moth larva showing percent mortality of larvae exposed to apple residue using the highest labeled field rate insecticide after 14 days, and the percent of apples to which CM larva had burrowed.

<table>
<thead>
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<th>Treatment</th>
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<th>After 24hrs.1</th>
<th>After 2hrs.</th>
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<tr>
<td>Warrior</td>
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<td>0</td>
<td>30</td>
</tr>
</tbody>
</table>

**Figure 8.** Results of a 2 and 24 hour evaluation of 1st instar, laboratory reared susceptible codling moth larva showing percent mortality of larvae exposed to apple residue using the highest labeled field rate insecticide after 21 days, and the percent of apples to which CM larva had burrowed.
and remain, while eliciting clustered fruit to drop, significantly reduces insect harborage that would typically occur in and around the fruit cluster, offering insects less protection from insecticide applications and residue.

Conclusions
This study has demonstrated new insecticide chemistries to exhibit effective control of the early instar stages of the codling moth larva with regards to both mortality and feeding inhibition. Through the rotation of these insecticides, a different class of pest management tools can target each generation. This will effectively reduce the selection pressure exerted by any one active ingredient or insecticide class, thus reducing the resistance potential and prolonging the efficacy of these new materials for years to come.

References
Riedl, H. L. A. Hanson and A. Seaman. 1986. Toxicological response of codling moth (Lepidoptera: Tortricidae) populations from California and New York to azinphosmethyl Agriculture, Ecosystems & Environment 16 (3-4): 189-201.

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