NEW YORK FRUIT QUARTERLY

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Editorial

Am I Growing Apples I Can Sell?

As everyone in the apple industry should be aware the market has and is changing rapidly. What was desired just a few years or in some cases months ago is no longer wanted. There are many reasons why these changes are taking place, some make sense, and some do not. However if anyone expects to make money in today's fruit industry they need to be aware of what is happening and try to adjust to the changes.

One of the first facts we have to adjust to is that not everything we are expected to do is fair. But as my mother use to tell me as I was growing up and complying that it wasn't fair, "who ever said life was fair", learn to deal with it. Whether we like it or not we have to learn to deal with it. Gone are the days that a grower can grow what he wants to, harvest the crop, expect somebody to market that crop and make money doing so, Also gone are the days when a apple handler can take what ever fruit is available, store and pack it how they feel it should be done and sell the product at a price both they and the grower can make money.

Today's customers expect any increasing amount of service from their suppliers; have ever increasing demands regarding the varieties they will handle and fruit size and quality they will buy. Are much more demanding as to the type of packaging and increasing less reasonable on lead time in placing orders.

What do we have to do to make money in today's market?

- Try to stay on top of what is happening.
- Be critical of what you are growing and selling.
- Look at how you can improve.
- Have a marketing plan that doesn't start the day it is time to pick or sell the apples.
- Know what you have to sell and where it is going.
- A grower has to maximize both yield and return to bushel just doing one or the other is not enough.
- Make changes, just because something work 5 years ago does not mean it will today, in fact it probably will not.

It never ceases to amaze me as to how many growers and sellers do not have any idea of what they have to pick, what the fruit looks like, and what they are going to do with it. With out this basic knowledge it is impossible to develop any type of marketing plan. With out a marketing plan it is impossible to sell fruit. The plan doesn't always work and normally needs adjusting but you have to have one to start with. Fruit that does not meet the needs and desires of the market place is better dealt at harvest time than after it has incurred additional cost. Growers are upset when fruit is rejected at harvest time but at least they have other alternatives then. When the problem is dealt with in after storage all anyone has done is spend more money on an unusable product.

Bill Gerling
General Manager
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FRONT COVER: Twelve different varieties of summer raspberries show the range of colors available, everything from the black of 'Rubus Occidentalis' [black raspberry] to the yellow, amber and red of 'Rubus Idaeus' [red raspberry]. All are commercially available. CREDIT: J. Ogrodnick/NYSAES/Cornell

BACK COVER: Top: Fresh and processed products from elderberry and aronia include the elderberry flowers themselves, berries, syrup, tea, jam and juice. Plants are easy to grow, have few pests, and can be mechanically cultivated and harvested. Article on page 5. CREDIT: S. McKay/CCE/Cornell
Bottom: These four raspberries are in the study on antioxidant capacity and anticancer properties. Article on page 25. CREDIT: J. Ogrodnick/NYSAES/Cornell

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Demand Increasing for Aronia and Elderberry in North America

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Elderberry and Aronia are gaining popularity in the US for their health benefits and quality processed products. Both plants are easy to grow, have few pests, and can be mechanically cultivated and harvested. Global prices are high and demand is expected to grow.

Elderberry and Aronia (chokeberry) are common in different parts of Europe, but seldom seen in the US. This situation is changing as products from these berries begin to appear in shops and superstores. In spite of the high price of the fruit and its primary processed products, very little crop is actually produced in the US. There is only one US Aronia producer, located in Oregon. Several small-scale scattered elderberry growers produce mainly for local consumption. The recent rise in popularity for Aronia is due to a line of juice blends introduced by Wildland brand a few years ago. The juice is doing very well in Costco Wholesale Corporation, Seattle, WA. Elderberry is appearing more and more as it replaces Echinaceae as a popular cold and flu nutraceutical. Syrup and pulp are imported from abroad. Both are used as food coloring because of their deep purple pigment.

Botanical Classification

Aronia - The genus name Aronia has been replacing the rather unpleasant sounding common name, black chokeberry. Aronia is a member of the Rosaceae family, and the cultivars used for fruit production are from the species *Aronia melanocarpa*. The plant originated in North America, and cultivar selection was done in Europe. Cultivars are self-fertile.

Elderberry - Elderberry is a member of the family Caprifoliaceae with 13 species native to North America. Commercially, we are interested in *Sambucus nigra L. ssp.canadensis* (North American, formerly classified as a separate species), and *Sambucus nigra L.* which is native to Europe. The fruit clusters (cymes) of the *S. nigra* cultivars are larger than those of *S. n. canadensis*. In addition, some of the *S. nigra* cultivars have superior growth habits. Elderberries are only partially self-fruitful, but planting two or more varieties within 60 feet of one another is beneficial. It is assumed that any pair of cultivars will function as mutual pollenizers.

Cultivars

Aronia – 'Viking' and 'Nero' are cultivars that are commonly available in North American plant catalogs. DNA fingerprinting research done in Sweden by Niklas Jeppsson has shown very little difference between available cultivars. In fact, the cultivars perform about the same commercially, and Niklas stated in an interview that it doesn't really matter which cultivar one uses. Seeds of the cultivars can even be planted, and the plants will be like their parents, quite suitable for commercial production.

Elderberry - In the *S. nigra* species, 'Samdal' and 'Samyl' are the most highly recommended for yield and desirable growth habit (produce new suckers annually). Two North American nurseries have germplasm and are propagating these in tissue culture. In the *S. n. canadensis* species, 'York', 'Nova', 'Johns', and the 'Adams' series are available. York and Nova are touted as the heavier yielders. These cultivars are products of breeding work that ended in 1960.

Propagation

Aronia is very easy to propagate. Softwood or semi-softwood cuttings can be propagated with mist in July. Divisions from established plants can be made at a rate of as many as 25 per two-year-old plant. Stool beds are often used, and, of course, seeds that have been stratified.

Elderberry can be propagated from softwood cuttings in June and from tissue culture. Hardwood cuttings taken in early spring have about a 50% rooting rate, and are susceptible to damage in overly wet media. Divisions, and even seed propagation, can also be used for propagation.

Cultural Practices

Aronia is adaptable to a wide variety of neutral to slightly acid soils. Less fertile soils are desirable to keep plants smaller in size. It is suggested that plants be placed 0.8-1.0 meters apart and mulched with plastic to prevent weed growth. Plastic can be removed after two to three years as plants sucker and fill in the hedgerow. Plant growth is usually so dense after three to four years that further weed control within the row is unnecessary. At five to seven years, selective pruning is done to remove the oldest, thickest branches, and keep the center open (Figure 1). Frost protection is not necessary since plants bloom so late, mid-May in New York. Aphids on shoot tips,

Figure 1. Selective pruning of Aronia removes the oldest branches allowing improved light distribution throughout the plant.

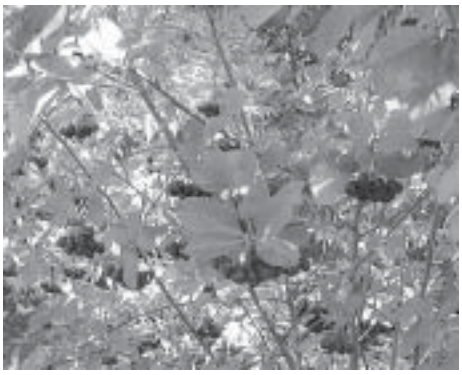


Figure 2. Ripe Aronia berries ready for harvest.

Figure 3. Elderberry flowers can be harvested in June and sold fresh or processed.

Figure 4. Elderberry fruit approaching harvest.

and leaf-eating beetles are possible pests, but plants are so vigorous that pest damage that slows them down will not have much negative effect. Since Aronia is in the Rosaceae family, fire blight is a potential problem, but has not been reported.

Elderberry prefers a sandy to heavy loam soil with a pH of 5.5-6.5. It is recommended that plants be set out at a 0.75-1.0 meter spacing, and that every other plant be removed after three to four years. This will improve chances of getting an economic return faster. The 'Samdal' and 'Samyl' cultivars have a nice growth habit where they throw canes from the base every year in good numbers. Six to eight canes per plant are kept to fruit the following year. Flowering takes place in mid-June in New York. Following fruiting in the fall, spent and excess canes are removed. This way, canes are never more than a year old, and plants remain five- to seven-foot bushes. Aphids, leaf wrinkling mites, birds, cane borers, mildew, and botrytis blossom blight can be pest problems. Tomato ringspot virus has been a problem in the past with *S. n. canadensis* cultivars, but is less of a problem with *S. nigra*.

Harvest

Aronia is mechanically harvested between August and September. Five to ten tons per hectare can be expected in about five years, once plants have matured. Some yield can be expected in the first years, but plants often have weak branches that fall over onto the ground. (Figure 2).

Elderberry is picked by hand in the US, although mechanical harvesting is a possibility. Twenty tons per acre are produced in Denmark, while four to twelve tons per acre are recorded in New York. The *S. nigra* cultivars are higher yielding, especially when grown as hedge-rowed bushes. Fruits are picked as whole cymes and frozen until ready to use. A premium is paid for stemless frozen berries. Harvest takes place from August through September. Flowers can also be harvested around June 15 and sold fresh or processed (Figure 3).

Products and Uses

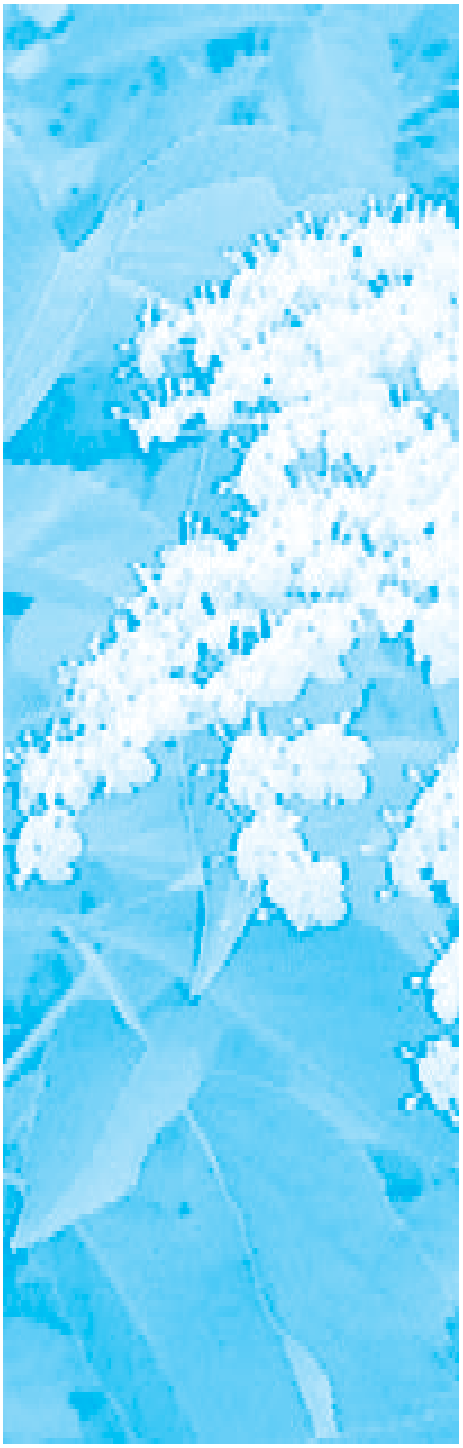
Aronia is used to produce syrup, juice, soft spreads, and tea. The tea is usually a blend with other more flavorful ingredients including black currant. The berries are also used to make food coloring.

Elderberry - Both flowers and fruits are used to produce cordials, beverages, soft spreads, wine, tea, and nutraceutical products. It can also be used as a natural food coloring. Flowers and fruits are both marketed fresh in New York and elsewhere. Fresh flowers are used to make fritters, in fruit salad (delightful star-shaped petals), and baked goods. Many folks say that elderberry will replace Echinaceae as a top cold and flu remedy.

Summary

Both elderberry and Aronia are gaining popularity in the US for their health benefits and quality processed products. Both plants are easy to grow, have few pests, and can be mechanically cultivated and harvested. There are a number of processors looking for growers interested in contract production. Global prices are high, and demand is expected to continue to grow.

Steve McKay is an Extension Educator with Cornell Cooperative Extension and is based in Hudson, NY. He specializes in the production of Ribes and is nationally and internationally recognized.



Honeycrisp: Promising Profit Maker or Just Another Problem Child?

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'Honeycrisp' is a new apple variety that commands high prices in the marketplace, but it is not an easy variety to grow. Honeycrisp's mild flavor, juicy crispness and excellent keeping qualities are offset by problems with bitter pit, soft scald, and color variability. Cornell researchers are working to resolve many of these problems.

'Honeycrisp' is a new apple variety with unique qualities that could eventually propel it into mainstream apple markets. Honeycrisp resulted from a cross of 'Macoun' and 'Honeygold' and was named by the University of Minnesota in 1992. Several years ago, Brown et al. (1999) provided the following description of Honeycrisp:

"The performance and attributes of Honeycrisp are varied and can be grouped under the heading, 'The good, the bad, and the ugly.' The 'good' refers to a great name for marketing and excellent texture, crispness, and juiciness. The 'bad' refers to coloring problems, appearance defects, and susceptibility to an undiagnosed leaf disorder. The 'ugly' refers to bitter pit, scald, soft scald, and a tendency to ferment due to skin permeability problems."

Despite its faults, Honeycrisp is being planted throughout northern fruit producing regions in the United States. Sizable plantings have been made in New England, New York, Michigan, Wisconsin, Minnesota, and Washington State. Growers have been receiving $35 to $50 per packed box for Honeycrisp when prices for other varieties generally ranged from $8 to $15 per box. Prices for Honeycrisp may decline as the volume of Honeycrisp increases. Nevertheless, the unique eating quality, storageability, and shelf life of Honeycrisp should create sustained demand for this variety if producers can produce Honeycrisp of consistently high quality.

The Sales Pitch on Honeycrisp

Honeycrisp has a crisp juicy texture that exists in no other commercially available apple variety. The flavor of Honeycrisp is mild, becoming slightly aromatic in fully matured fruit. However, it is the unique texture of this apple that will generate consumer demand. According to information released by the University of Minnesota, the sensation of juicy crispness in Honeycrisp derives from the fact that, when bitten, this apple shears apart by breaking through cells in the flesh rather than by separating between cells. The breaking of the flesh cells not only releases more juice, it also contributes to a nearly audible sense of crunchiness that contributes to eating pleasure.

Honeycrisp also has excellent keeping quality. Apples held in regular air storage for nine months are indistinguishable from freshly harvested fruit and still have more crispness than most apples available in retail stores during May and June. In casual observations over the past several years, the eating quality of Honeycrisp actually seemed to improve when fruit were held for 7-10 days at room temperature after removal from cold storage. Post-storage ripening allowed development of more varietal flavor without the loss of crispness that would occur with most other varieties. As a result, consumers may well find that the last apple they eat after purchasing Honeycrisp is the best apple in the bag, and that perception should benefit repeat sales.

Problems with Honeycrisp

Honeycrisp is not an easy variety to grow. Some of the major horticultural and storage problems reported for Honeycrisp are listed below in approximate order of severity, with the more severe problems listed first:

1. More than 50% of fruit in some years and locations are unmarketable because of bitter pit.
2. Under certain conditions, virtually 100% of fruit develop soft scald during cold storage.
3. Variability in fruit coloration suggests that multiple strains of Honeycrisp may already exist in commercial plantings. Within the same planting, some trees produce fruit with an attractive pink blush whereas other trees produce fruit that are coarsely-striped, poorly-colored and/or have blotchy coloration.
4. In some plantings and some years, preharvest drop may be similar to what commonly occurs with McIntosh.
5. Production of Honeycrisp with acceptable color may be limited to regions where McIntosh is being grown successfully.
6. Fruit mature unevenly, so multiple harvests may be necessary.
7. Fruit harvested too early never develop varietal flavor and remain almost tasteless. Fruit on over-cropped trees may never mature and therefore are of poor eating quality.
8. Leaves on Honeycrisp trees often develop a disconcerting zonal chlorosis

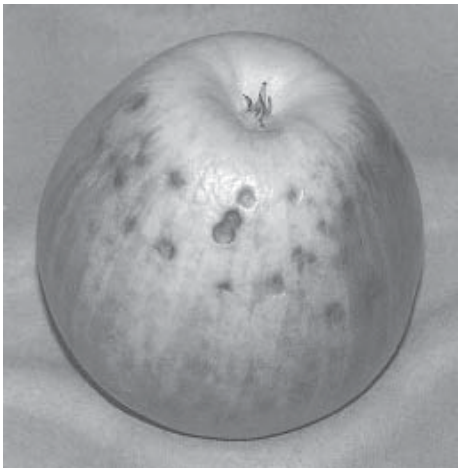

Figure 1. Honeycrisp fruit showing sunken lesions typical of bitter pit.

that resembles the damage caused by potato leafhopper.

Production and storage problems with Honeycrisp are currently being addressed by a group of researchers and cooperative extension specialists at Cornell in cooperation with commercial growers who are pioneering this variety in New York. What follows is a progress report on Honeycrisp research conducted both collaboratively and independently by the contributing authors. Results reported here must be interpreted with caution because many of the results are based on a single year of field trials.

Bitter Pit

Bitter pit is a physiological disorder caused by calcium deficiency in the fruit flesh. Bitter pit is characterized by dark sunken lesions at or beneath the fruit surface (Figure 1). Pits may be present at harvest or, more frequently, become evident after the fruits have been placed in storage. Often the lesions appear first at the surface near the blossom end of the fruit, but symptoms can occur throughout the flesh of the fruit in severe cases.

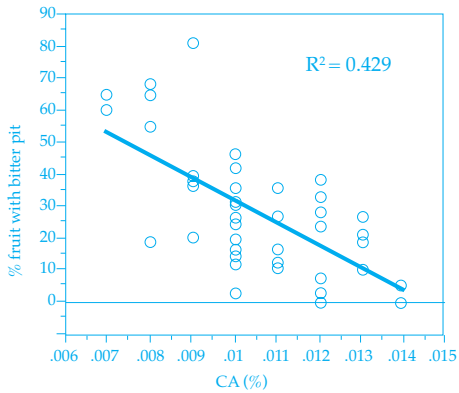

Figure 2. Effect of calcium level on incidence of bitter pit noted on Honeycrisp after storage for 85 days at 35°F.

Conditions that favor excessive fruit size make bitter pit worse. Trees with excessive vegetative growth often produce fruits with low calcium because active vegetative growing points compete strongly with developing fruits for calcium. Bitter pit is worsened by drought, boron deficiency, and excess amounts of soil potassium, magnesium, or nitrogen. Low seed numbers also worsen bitter pit because seeds produce the plant growth substances that direct the movement of calcium into the fruit.

During summer of 2000, Rosenberger, Schupp, Hoying, Cheng, and Watkins cooperated on trials in three 'Honeycrisp' orchards where calcium sprays and Flint fungicide were applied to control bitter pit. Previous reports suggested that Flint fungicide could reduce the incidence of bitter pit in some varieties, although no mechanism for such activity has been elucidated. Trees in test plots were treated during summer with varying rates and/or combinations of calcium and Flint. Fruit were harvested at maturity and evaluated to determine how field treatments affect fruit mineral content and the incidence of bitter pit both at harvest and after cold storage.

Statistically significant reductions in bitter pit could not be detected in two of the three trials because bitter pit incidence varied greatly from tree to tree within treatments. In the third trial, two Flint applications in August reduced the incidence of bitter pit at harvest by 40% compared to control trees. However, the incidence of bitter pit in fruit from Flint treatments increased during cold storage, and there were no significant differences among treatments after 85 days of cold storage at 35°F. Additional work with Flint is underway to determine its usefulness for reducing bitter pit.

There was a highly significant relationship between incidence of bitter pit and calcium content of Honeycrisp fruit from the 45 individual trees in the Hudson Valley trial even though the low rates foliar calcium applied during summer did not reduce bitter pit significantly in statistical comparisons of the treatments themselves. Differences in calcium content accounted for 42.9% of the variability in incidence of bitter pit evident after cold storage (Fig. 2). The positive correlation between calcium content of fruit and reduction in bitter pit suggests that bitter pit problems in Honeycrisp can be resolved with calcium sprays. Additional research is needed to find the best way to get enough calcium into the fruit.

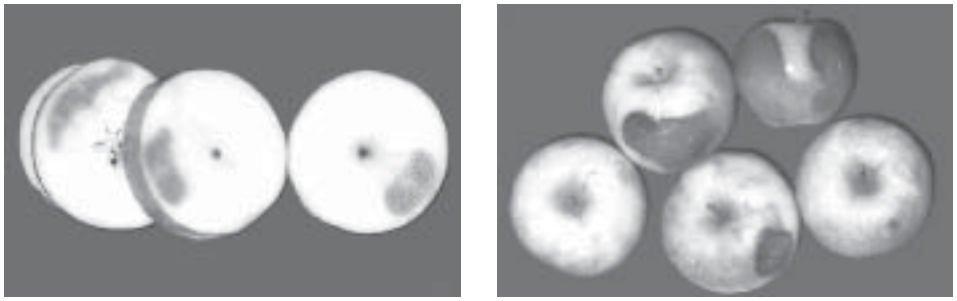

Figure 3. Honeycrisp showing typical symptoms of soft scald.

Soft Scald

Soft scald, also called ribbon scald or deep scald, is a low temperature disorder of apples that can be induced in some varieties by storing them at temperatures of 36-37°F or lower. Soft scald has caused extensive losses in some lots of Honeycrisp that have been held in cold storage (Fig. 3).

During the 2000 harvest season, Watkins and Iungerman cooperated on a study of preharvest factors that might affect susceptibility of Honeycrisp to soft scald. Fruit samples were collected from four orchards in the Champlain Valley planted in 1995, 1996 and 1997 on M.26 and B.9. Fruit were harvested from a minimum of 10 trees in each block on September 14, 21 and 28, 2000. The most mature fruit were selected on each occasion, except for orchard #2, where high-blush fruit from some trees was kept separate from lowblush fruit from other trees. Two bushels of fruit were harvested from each block for storage for 12 weeks at either 33 or 37°F.

TABLE 1

Incidence of soft scald and bitter pit in Honeycrisp harvested in the Champlain Valley on 14, 21 and 28 Sept. 2000 and stored at 33 or 37 °F for 12 weeks followed by 7 days at 68°F.

Orchard block	% fruit with soft scald						% fruit with bitter pit[1]			
	14 Sept.		21 Sept.		28 Sept.		14 Sept.		21 Sept.	
	33°F	37°F	33°F	37°F	33°F	37°F	33°F	37°F	33°F	37°F
1	21	3	52	0	97	42	15	42	33	54
2 (high blush)	17	0	52	0	-	-	28	40	4	11
2 (low blush)	2	0	16	2	-[2]	-	9	16	5	5
3	3	0	33	0	78	48	0	14	9	13
4	0	0	64	3	70	28	6	51	8	8
Mean for all samples	**9**	**1**	**43**	**1**	**82**	**39**	**12**	**33**	**12**	**18**

[1]Data on bitter pit was not collected for fruit harvested 28 Sept. because the severe soft scald obscured bitter pit.
[2]No samples were available from Orchard 2 on 28 Sept.

Fruit quality was assessed according to standard procedures.

A sub-population of 20 fruit was examined after six weeks of storage. Soft scald had already developed by this time, but the incidence was affected by harvest date, orchard and storage temperature (Figure 4). Informal tasting of fruit also indicated that presence of alcoholic off-flavors was affected by these same factors. In general, adverse affects on fruit metabolism as evidenced by off-flavors and soft scald were greatest in fruit stored at 33 compared with 37°F, and in fruit from later harvests. Soft scald incidence was extremely high in fruit harvested on September 28 and stored at 33°F. However, soft scald occurred in this fruit even at 37°F, and off-flavor development was apparent in all fruit harvested on that date.

The remaining fruit (n = 30-60) were tested 12 weeks after harvest (Table 1). By this time, soft scald was present even in the earliest harvested fruit stored at 33°F. Incidence of the disorder at this temperature increased rapidly with advancing harvest date. By the September 28 harvest date, incidence of soft scald was high irrespective of harvest date. Bitter pit was present in fruit from most orchard blocks, but incidence of the disorder tended to be higher at 37°F than at 33°F.

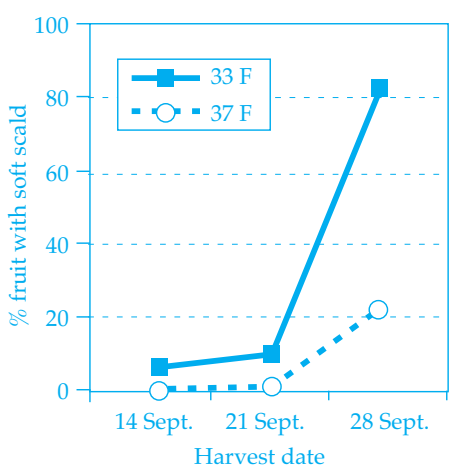

Figure 4. Effects of harvest date and storage temperature on incidence of soft scald in Honeycrisp apples after 6 weeks of storage. Apples were harvested from four orchards in the Champlain Valley during September of 2000.

Watkins also evaluated three postharvest factors for their effect on soft scald development. These factors were: (i) storage temperature, because soft scald in other varieties can be controlled by raising the storage temperature; (ii) postharvest application of diphenylamine (DPA), because this antioxidant compound has controlled soft scald in other varieties; and (iii) a postharvest cooling delay.

In 1999, 'Honeycrisp' apples were harvested from a Western New York orchard on September 17, and randomized into 24 lots of 40 fruit. In addition three 10-fruit samples were taken for analysis of maturity. Fruit were then transported to the Cornell University Orchard laboratory in Ithaca. Internal ethylene concentration (IEC) was measured on each fruit of the maturity samples. The fruit lots were divided to provide three replicates for treatments involving factorial comparisons of 33°F versus 36°F, DPA treatment versus no DPA, and a one-week holding period at 50°F prior to cold storage versus cold storage immediately after harvest. For DPA treatment, fruit were dipped in 1000ppm for 1 minute, allowed to drain for 2 hours, and placed into cold storage at the same time as non-treated fruit. After storage for 12 weeks, fruit were transferred to an evaluation room maintained at 68°F. After 1 d, IEC and firmness were measured on 50 fruit samples per replicate. On day 7, the firmness of 50-fruit replicates was again measured, and all fruit assessed for presence of disorders. A similar experiment was completed using fruit harvested in 2000.

Fruit were climacteric at harvest in both years with average internal ethylene concentrations of 50 ppm and 30 ppm in 1999 and 2000, respectively. For fruit moved to cold storage immediately after harvest, the lowest soft scald incidence occurred in fruit treated with DPA and held at 36°F. Holding fruit for one week at 50°F resulted in a significant reduction in soft scald. Fruit with delayed cooling averaging less than 1% soft scald, irrespective of prior DPA treatment or subsequent storage temperature. No interactions between the main factors were detected.

Bitter pit incidence was not affected by DPA treatment, but bitter pit incidence averaged 25% in fruit with delayed cooling compared with only 14%

TABLE 2

Incidence of soft scald and bitter pit in 'Honeycrisp' apples grown in 1999 as affected by storage temperature, DPA treatment, and cooling to the indicated temperatures immediately after harvest or only after holding fruit for one week at 50 °F.

Treatment	% fruit affected by	
	Soft scald	Bitter pit (%)
33°F	28	14
36°F	19	11
33°F + DPA	19	11
36°F + DPA	8	18
33°F + delay	2	20
36°F + delay	0	34
33°F + DPA + delay	0	17
36°F + DPA + delay	0	27
$LSD_{.0.05}$	**5.3**	**7.6**

in fruit cooled immediately after harvest (Table 2). No other significant fruit quality effects were detected. Results were similar in the trial conducted with fruit grown in 2000.

This research clearly shows that severity of soft scald is affected by storage temperature and harvest dates. Soft scald was consistently severe on fruit moved directly to storage at 33 F. Severity of soft scald at 36-37°F increased as harvest was delayed into late September. A one-week holding period at 50°F also markedly reduced soft scald development. Informal tasting of fruit indicated that Honeycrisp quality was not deleteriously affected by this treatment, and at least two growers have applied this method with good results.

The major recommendations from this work are that fruit should be harvested as soon as appropriate color and flavor have been obtained. Of the maturity indicators available, starch may be useful as a guide to over-maturity, and we tentatively suggest a starch-iodine index of 6 as a cut-off for harvest. A storage temperature of 38°F is tentatively recommended. Storage operators need to find a way to ensure a dedicated room is available to hold fruit at the appropriate temperature, especially as crop volume increases.

Delayed cooling and/or warmer storage temperatures significantly reduced losses to soft scald, but both of those strategies resulted in increased losses to bitter pit. Thus, storage temperature adjustments will need to be combined with a rigorous calcium nutrition program to produce fruit that can withstand the warmer storage temperatures without undue losses to bitter pit. Postharvest drenches with calcium chloride may be essential for minimizing bitter pit at warmer storage temperatures.

Strain Variations

Many Honeycrisp growers are finding that consistent production of fruit with attractive red color is more difficult than with most other apple varieties. The amount of fruit color and fruit appearance of Honeycrisp is highly variable from tree-to-tree (see Fig.5). Highly colored strains of some other apple cultivars vary in their genetic stability and their frequency of reversions to less-desirable fruit color. Genetic instability in Honeycrisp could explain the large tree-to-tree variation in the intensity and pattern of red color that is found in many orchards. Careful selection of propagation wood from trees with the preferred red-blush color development will be of limited value if blush-type Honeycrisp do not stay true-to-type.

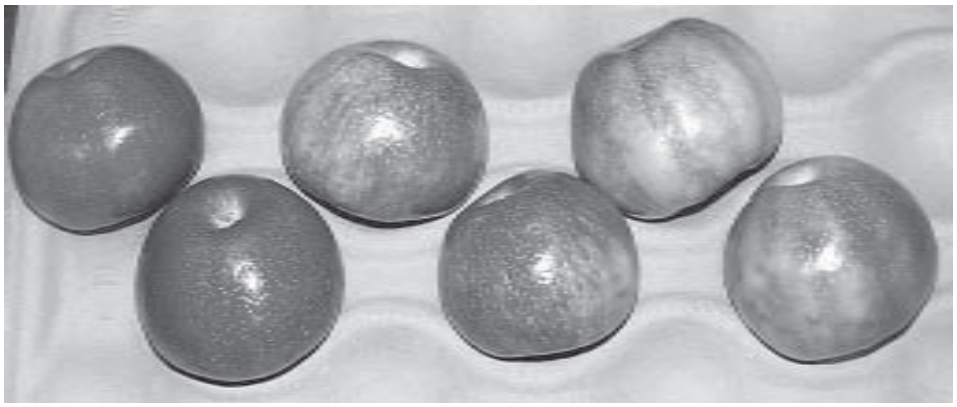

Figure 5. Variations in fruit color of Honeycrisp from various New York orchard blocks.

Fifty Honeycrisp selections with the potential for improved red color have been identified by researchers at the University of Minnesota and were propagated on Bud.9 rootstocks. Two plantings were made in 2001, one in Minnesota and another at Cornell's Hudson Valley Lab where Jim Schupp will be evaluating the selections for horticultural characteristics and fruit quality. It is hoped that one or more of these selections may have improved color while maintaining the texture and flavor that has made Honeycrisp so desirable. Observations in these plantings, combined with those from commercial orchards, should provide good information on genetic stability and strain variations.

Enhancing Color

Red color formation in Honeycrisp fruit may be temperature sensitive in the same way as observed for McIntosh and other cool climate cultivars. Whether Honeycrisp of marketable color can be consistently produced in regions such as the Hudson Valley is yet to be determined.

Particle film sprays such as Surround have been recommended for improving red fruit color in situations where temperatures are supra optimal. Jim Schupp conducted a study in Milton, NY, during the 2000 growing season to determine the effect of Surround on fruit color and fruit maturity of Honeycrisp apples. Surround applied in the weeks following petal fall had no effect on fruit color of Honeycrisp apples, and Surround applied later in the season actually reduced red fruit color. Furthermore, Surround applications resulted in undesirable residues in the calyx basins and stem cavities on fruit. The residues were not removed by brushes on a commercial packing line and were so disgusting as to preclude repetition of the experiment. Thus, Surround is not the answer for improving fruit color of Honeycrisp.

Schupp and Watkins also evaluated the effects of Retain used alone or in combination with Ethrel to determine effects of these plant growth regulators on fruit color and quality. ReTain was applied to Honeycrisp/M.26 trees four weeks prior to anticipated harvest. Ethrel was applied at one pint/100 gallons seven days prior to the first harvest. Fruit samples were harvested on 5 Sept. and on 11 Sept. for evaluation of fruit maturity and quality at harvest and after storage.

Ethrel treatment did not increase Honeycrisp fruit color when applied either with or without ReTain, but ReTain blocked the expected effects of Ethrel on maturity indices. Harvest evaluations showed that ReTain reduced internal ethylene concentration, starch index rating and red fruit coloration while increasing fruit firmness. Ethrel had little or no effect on any measurable fruit maturity or fruit quality parameter, but it did cause increased fruit drop. Application of ReTain prior to Ethrel resulted in preharvest fruit drop similar to that of the untreated controls. Schupp and Watkins are continuing studies to determine how ReTain and Ethrel affect fruit maturity, fruit color, fruit quality, and storage potential of Honeycrisp fruit.

Zonal Chlorosis on Leaves

Honeycrisp leaves often develop a zonal chlorosis that resembles the damage caused by potato leafhopper (Fig. 6). To determine if potato leafhoppers (PLH) caused the symptoms on Honeycrisp,

Rosenberger and Straub used whole-tree cages to exclude leafhoppers from four Honeycrisp/M.9 trees during summer of 1999. The caged trees were paired with similar non-caged trees. The trees were monitored throughout the summer for the presence of PLH on the leaves and for chlorotic symptoms.

For both caged and uncaged trees, three out of four trees developed leaf chlorosis symptoms by 17 June. One uncaged tree remained free of symptoms throughout the entire monitoring period whereas all of the caged trees eventually developed symptoms in the absence of PLH. Only low levels of PLH infestation occurred in the uncaged trees. This experiment verified that the chlorotic leaf symptoms on Honeycrisp are not due to PLH. Schupp hypothesized that the zonal chlorosis of Honeycrisp leaves may have a physiological cause and might be related to the buildup of starch grains in the chloroplasts. Impaired phloem loading or phloem transport in Honeycrisp could cause toxic accumulations of carbohydrate in leaves under certain conditions. This hypothesis is supported by the fact that zonal chlorosis occurs earlier in the season on non-bearing or lightly-cropping trees than on heavily cropping trees where the fruit provide a large carbohydrate sink. Schupp and Cheng are cooperating on research to test the hypothesis that zonal chlorosis results from carbohydrate build-up in leaves.

Figure 6. Zonal chlorosis of Honeycrisp leaves.

Conclusions

The consensus of those contributing to this paper is that most of the horticultural problems that have surfaced with Honeycrisp can be and are being resolved. We believe that bitter pit in Honeycrisp can be managed by maintaining reasonable crop loads, applying foliar calcium sprays during summer, and using a postharvest calcium chloride drench. Soft scald and the fermented flavors that are a precursor to soft scald can be avoided by adjusting storage temperature and harvest dates. The multi-strain plantings in the Hudson Valley and in Minnesota should improve our understanding of strain differences and/or variability and stability of the germplasm. We may not be able to eliminate zonal necrosis on Honeycrisp leaves, but there is no evidence that this phenomenon affects productivity or fruit quality.

Unless stable, high-coloring strains of Honeycrisp can be selected, acceptable fruit color development could remain as a significant problem for southern production areas in New York and other states. Poorly colored fruit from southern production regions will not compete well against the best fruit from western NY and the Champlain Valley. However, marketing Honeycrisp based on color may prove a faulty strategy for all concerned because no production area is immune to production of poorly-colored fruit given the variability that currently exists in established plantings and variability that has been observed from one season to the next.

More important to the success of Honeycrisp than fruit color will be the quality of the product that is sent to consumers during the early years of Honeycrisp marketing. High prices for Honeycrisp increase the temptation to sell fruit of sub-optimal quality (i.e., immature fruit that lack flavor, or fruit with bitter pit, soft scald, or fermented off-flavors). Marketing poor quality fruit will quickly cement Honeycrisp's reputation as a problem child among apple varieties. If Honeycrisp growers and packers commit themselves to producing and marketing only high-quality fruit, then Honeycrisp might contribute significantly to improved profitability of the apple industry over the next decade.

Acknowledgments

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Dave Rosenberger, professor of plant pathology, has worked at Cornell's Hudson Valley Laboratory in Highland since 1977. Jim Schupp, assistant professor in the department of horticultural sciences, and Dick Straub, professor of entomology, also work at the Hudson Valley Lab. Chris Watkins, associate professor of horticulture, is a postharvest physiologist based in Ithaca. Lailiang Cheng, assistant professor of horticulture, conducts research on fruit nutrition. Kevin Iungerman and Steve Hoying are Cornell Cooperative Extension Educators with responsibilities for the Northern NY Extension Fruit Program and the Lake Ontario Fruit Program, respectively. All of the authors have a common interest in the development of Honeycrisp.

Mineral Nutrition as a Factor In Cold Tolerance Of Apple Trees

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Tree nutritional levels must be kept at optimum for reducing the risk of cold injury to fruit trees. Carbohydrates, nitrogen, potassium, boron, copper, zinc, and manganese are all involved.

Cold injury to plant tissue occurs when the water inside cells freezes. When this happens, the cell membranes fail, and the cell contents leak out, resulting in death. The development of cold hardiness can only begin when the plant has stopped growing. It is a series of processes by which the cells in the plant become increasingly resistant to intra-cellular freezing. How many cells die, and how well the plant is able to heal the damage by creating new cells to replace those that have been lost, are the key factors that determine the extent of injury and the chances of recovery.

Cold injury to apple trees can occur at various times of the year and be evident in different forms according to when the injury occurs. Although absolute mid-winter low temperatures can be of concern in some years, many of the cold damage problems encountered in the Northeastern US occur in late fall and early winter when hardening of the trees is delayed, or with spring frost damage. In this article, we review the roles of various nutrients in determining cold tolerance of trees and report on three research projects pertaining to apple tree cold hardiness that are ongoing or recently concluded. The first of these studies was to determine if foliar sprays of copper chelate can induce earlier cold tolerance, the second was on the impact of fall foliar urea on cold hardiness, and the third was on remedial treatments for cold damaged trees. Finally, we offer some suggestions for minimizing the potential for cold damage to apple trees.

Nutritional Factors and Interactions

Carbohydrates - These are the most important "nutrients" involved in cold hardiness. Hardening off is a biological process that requires carbohydrate reserves both for energy to drive the various biochemical processes along, and for providing carbon, the building blocks of the many organic molecules that are needed in the process. There is also evidence that plants synthesize sugar alcohols that act as anti-freeze inside the cells.

Trees that are over-cropped or lose adequate effective leaf surface prematurely due to insects, mites or disease have low carbohydrate reserves and lack cold hardiness. Likewise, any mineral nutrient deficiency that limits the photosynthetic potential of the leaves or interferes with energy storage or utilization will also reduce cold hardiness of fruit trees.

The effects of individual mineral nutrients on cold hardiness are usually indirect and result from disturbances of normal growth patterns or disruption of normal physiological processes within the tree. The following are some of the more commonly observed relationships of various nutrient elements to cold tolerance, or susceptibility to cold damage.

Nitrogen - Low tolerance of nitrogen deficient trees to cold damage is associated with poor tree growth. While nitrogen deficient trees usually cease growth and harden off earlier than trees with adequate N, such trees do not reach the same level of mid-winter cold tolerance. At the opposite extreme, excessive nitrogen often extends the growth of plant tissues late in the fall, delaying hardening of the trees, thus predisposing the trees to cold damage. This condition is often associated with young trees that are being pushed to grow with high fertilizer rates in an effort to fill their allotted space in the new planting.

It is desirable to have a relatively high nitrogen level early in the spring to encourage adequate growth of young trees and to favor fruit set on bearing trees. Trees that produce good extension shoot growth early in the growing season, and then set terminal buds relatively early are usually more cold tolerant than those that continue growing late into the fall. In this regard, young non-bearing trees and varieties such as McIntosh can be troublesome since they often continue growing until frost occurs. This problem is accentuated in seasons when an extended dry period is followed by late summer rains.

Potassium - Inadequate potassium leads to greater susceptibility of vegetative tissues, trunks, and flowers to cold damage. The greater susceptibility of trees to cold damage after bearing a heavy crop load is related in part to the effects of the crop on the potassium status of the trees. Potassium requirements are determined to a large extent by crop load and potassium moves from leaves and other tissues into the fruit as the fruit matures. Further, when the available supply of potassium is inadequate, fruit maturation is delayed and the period of time between harvest and the occurrence of killing frosts is shortened. This further leads to greater susceptibility of the trees to cold damage because of the reduced photosynthate that the trees are able to produce during this

critical period. As mid-summer leaf potassium levels decrease below about 1.5%, cold tolerance of apple trees has been shown to decrease.

Nitrogen-Potassium Relationship - In addition to the individual influences of nitrogen and potassium on cold tolerance, the relationship between levels of these two elements is also of concern. Potassium requirements become greater as the nitrogen level is increased. Thus, a higher level of potassium in leaf tissue samples is required at higher levels of nitrogen in the tissues. It should be emphasized, however, that the effects of high nitrogen cannot be totally overcome by increasing potassium supplies.

Magnesium - Trees that are deficient in magnesium produce weak growth, small spurs and flowers as a result of reduced carbohydrate supply. Such trees are less cold tolerant. Magnesium requirements become greater as the potassium levels increase, and leaf sample ratios of potassium to magnesium that approach or exceed 4:1 indicate magnesium deficiency even when the magnesium levels are in the sufficient range.

***ZINC* -** Zinc deficient plants show increased susceptibility to cold injury, including both winter injury and frost damage to flowers. The reduced photosynthesis resulting from poor shoot growth and leaf development has been implicated, but this does not appear to explain the total role of zinc in this arena. Zinc is essential in the development of hormones that have a myriad of effects on plant growth regulation in trees. It would appear that the zinc level required to assure best cold tolerance may be somewhat higher than is usually considered to be adequate for normal crop development.

Copper - Copper deficient trees also exhibit poor quality of growth, similar to that shown by zinc deficient trees. Further, normal development of woody tissues in shoots and roots is impaired. Low cold tolerance of such trees has been attributed to reduced carbohydrate supply resulting from stunted shoot growth and small leaves.

Manganese - Leaves on trees that are deficient in manganese are relatively thin and show loss of chlorophyll which also results in reduced photosynthesis and carbohydrate supply.

Boron - Boron plays several roles that have direct or indirect bearing on the development of cold tolerance or recovery of cold-injured trees. It is essential for root development that is necessary for uptake of other nutrient elements. Boron is involved in sugar transport within the tree and appears to have a role in stimulating development of cambial activity that is necessary in the recovery of the trees from cold injury.

Recent Research to Enhance Cold Tolerance

Cold damage to apple trees occurs quite frequently in the Champlain and Hudson Valley regions of New York State. Often this damage can be associated with high N levels or with weather conditions that encourage prolonged late-season growth and delayed hardening of the trees. Studies were initiated to develop methods that might promote earlier dormancy and hardening off of the trees. The approach used was to apply a series of post-harvest foliar sprays of copper chelate (Cu-EDTA) plus oil for enhancing dormancy. Fruit tree nurseries use Cu-EDTA sprays to defoliate nursery stock prior to digging in the fall, but since nursery trees are stored indoors after digging, the effect of chemical defoliation on cold hardiness is not known.

In 1994, Drs. Stover and Stiles initiated studies to encourage earlier dormancy and increase cold hardiness in young apple trees. Dilute foliar sprays of copper chelate (Cu-EDTA), plus ultrafine spray oil, applied in mid-October, accelerated leaf drop of apple trees by three to four weeks compared to untreated trees. Copper-EDTA sprays increased early winter cold hardiness in laboratory cold chamber studies with detached twigs. Mid-winter hardiness was not adversely affected, and there was less visible bud injury on Cu-EDTA treated trees. These initial studies suggested that mid-October applications of Cu-EDTA plus oil might have potential for increasing early winter hardiness of apple by hastening dormancy.

This line of research was resumed in 1999. Additional research was needed to confirm these results and to make the transition from small plots applied by handgun to full-scale orchard treatments applied by air-blast sprayer.

In 1999, we tested four concentrations of Cu-EDTA applied by handgun, and evaluated air-blast sprays of 150 and 75 gallons per acre on young McIntosh/M.26 apple trees growing in a commercial orchard. Shoots were collected in early December, and again in late January, and subjected to a range of cold temperatures in a programmable cold chamber at the Hudson Valley Lab. Cold injury resulting from these temperatures was evaluated by determining electrolyte leakage, using a conductivity meter. Results of this research showed that while both handgun and air-blast sprays of Cu-EDTA were highly effective defoliants at concentrations of 0.1% copper and up (Figures 1, 2a and b), they did not enhance early winter cold hardiness (data not presented).

In September 2000, a block of late growing young trees was identified in a commercial orchard. The trees were three-year-old McIntosh on M.9/111 with active terminal shoots. The treatments were: a) Untreated control; b) Apogee; c) Cu-EDTA; and d) Apogee, followed by Cu-EDTA. Apogee plant growth regulator was applied at 250 ppm (12 ounces per 100 gallons) on 5 October, with 0.05% Silwet surfactant. Copper-EDTA (1.2%) was applied on 19 October, with 0.1% ultra-fine oil.

Defoliation was estimated thereafter on a weekly basis, until defoliation was complete for all treatments. Shoots were collected on 4 December, and again on 22 January 2001, and subjected to a range of cold temperatures in a programmable cold chamber at the Hudson Valley Lab. Cold injury resulting from these temperatures was evaluated by determining electrolyte leakage, using a conductivity meter.

Both Apogee and Copper-EDTA accelerated defoliation (Figure 3). Copper-treated trees were defoliated by 7 November, while untreated trees weren't defoliated until 20 November. The pattern of defoliation was uncharacteristic compared to that of previous seasons in that more of the leaves from untreated trees dropped earlier. However, after 31 October all remaining leaves were young green leaves on current season growth, indicating that these shoots were still actively growing late in the season.

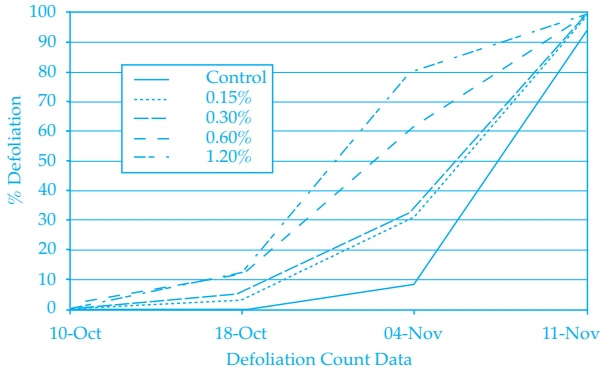

Figure 1. Effect of Cu-EDTA on defoliation, 1999.

Figure 2. Natural defoliation of unsprayed McIntosh (a) compared to similar Copper EDTA sprayed trees (b).

Shoots from all treatments demonstrated cold hardiness to about 0F by early December (Figure 4). Apogee treated trees had 17% and 25% less electrolyte leakage at –11F and –22F, respectively than untreated controls. Trees treated with Cu-EDTA had the same amount of electrolyte leakage as the untreated controls throughout the range of test temperatures, while trees that received both Apogee and Cu-EDTA had about 20% greater electrolyte leakage when exposed to temperatures of –11F and lower. All treatments had severe electrolyte leakage when exposed to -33F in early December.

In January 2001, electrolyte leakage from shoot samples exposed to –11F and –22F was lower than in December and the relative differences between treatments were lessened (data not presented). Apogee alone and Cu-EDTA alone had 18% less electrolyte leakage than controls at –22F, while the combination of Apogee and Cu-EDTA increased electrolyte leakage by 12%. All treatments had sharply increased electrolyte leakage at -33F and –44F.

Treatment with Cu-EDTA had no effect on cold hardiness, which agrees with our results from the studies conducted in Peru, NY, in 1999. Although we have been able to reproduce the accelerated leaf drop by Cu-EDTA sprays, as shown by Stover and Stiles, we have not been able to demonstrate improvement in cold hardiness for the past two seasons

These results provide strong initial evidence that treating actively growing trees in the autumn with Apogee increased early winter cold hardiness. Further study is needed to confirm these results and to determine the optimal timing and concentration of Apogee that is needed. Further study is also needed to evaluate the effect of late season Apogee on growth in the following season. Apogee is a growth retardant, and late season sprays might result in carry over effects on growth the following year which, while of potential benefit to established trees, could cause a delay in the time it takes a young trees to fill its allotted space in the orchard.

Although treatment differences were less apparent in January than in December, trees that received both Apogee and Cu-EDTA appeared to have more winter injury. This apparent increase in sensitivity to cold injury from combining the two treatments is difficult to explain, even more so because Apogee alone reduced winter injury. One possible explanation is the combination of treatments so accelerated leaf drop that remobilization of carbohydrates and mineral nutrients or some dormancy promoter back into the stems was limited.

Effects of Postharvest Foliar Urea Application on Tree Cold Hardiness

Although postharvest foliar urea spray has been widely used in other apple growing regions, it is not a common practice in our area. One of the concerns associated with foliar urea application late in the season is that tree cold hardiness may be reduced. To evaluate the effect of fall foliar urea sprays on tree cold hardiness, two experiments were initiated in the fall of 1999, one on Marshall Mac/M.9 at Lansing Experimental Orchard and the other on Empire/M.7 in the Hudson Valley. Experimental trees received one of the following four N treatments at the same rate of 46 lb

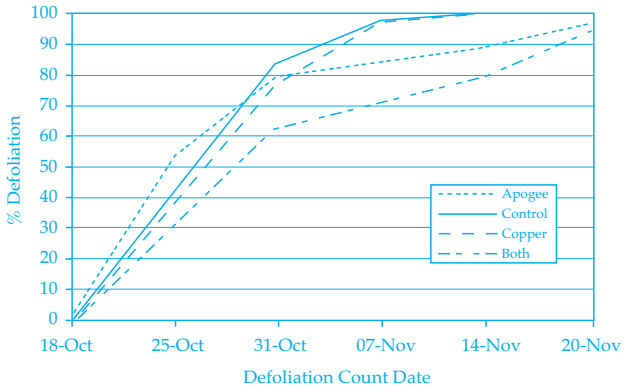

Figure 3. Effect of Cu-EDTA and Apogee on defoliation, 2000.

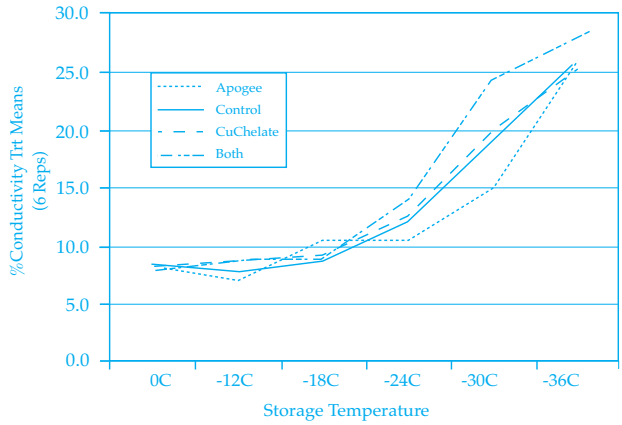

Figure 4. Cu-EDTA/Apogee study on cold hardiness, December, 2000.

N/acre:

1) Soil-applied N in spring - 100 lb urea/acre was applied to soil in early to mid-May;
2) Fall foliar N - 3% foliar urea (25 lb urea/100 gal) was sprayed at 200 gallons/acre twice at weekly intervals after harvest in late September and early October;
3) 50/50 split between fall foliar and spring soil application - Half of the N was applied as a 3% urea foliar spray after harvest in late September, while the other half applied to soil in mid May the next spring;
4) 36/64 split between spring foliar and soil-application - foliar urea (6 lb urea/100 gal at 200 gallons/acre) was applied at pink, petal fall and first cover, with the rest N applied to soil in mid May.

Tree cold hardiness was evaluated in December 1999 and January 2000 after foliar urea application in the fall of 1999, and evaluated again in December 2000 after foliar urea application in the fall of 2000. Fall foliar urea had no effect on cold hardiness in December 1999, or January 2000 on both Marshall Mac and Empire (Data similar to Fig. 4 but not shown here). There was no difference in cold hardiness in December 2000 among the four N treatments (Figure 5). This is consistent with the result we obtained with Fuji nursery trees. The data suggest that as long as tissues are well matured, foliar application of urea after fruit harvesting will not compromise the cold hardiness of the tree.

Research on Nutritional Treatments to Aid in Recovery from Cold Damage

Cold damage to spur tissues and flower buds that occurs during the winter often results in loss of cropping potential. Prebloom application of foliar sprays of boron, zinc and urea to trees that show discoloration of spur wood or flower buds has been recommended by Stiles on the basis of experience gained while working in Maine. However, it was deemed necessary to evaluate the efficacy of this recommendation under various conditions in the Champlain Valley and Hudson Valley regions.

A range of treatments was applied to McIntosh and Empire apple trees at two sites in 1994 and 1995. Treatments and application timings were as follows (all treatments applied dilute to drip):

1. Non-treated control
2. Solubor (1 lb / 100 gallons) at half-inch green stage
3. EDTA-zinc chelate (1 lb / 100 gallons) at half-inch green stage
4. Solubor plus EDTA-zinc chelate at half-inch green stage
5. olubor plus EDTA-zinc chelate plus urea (3 lbs / 100 gallons) at half-inch green
6. Solubor plus EDTA-zinc chelate at half-inch green followed by Solubor plus EDTA-zinc chelate plus urea at pink

In 1994, following a very severe winter (mid-winter low temperatures of -35F and -44F, respectively, at Hudson Valley and Champlain Valley sites) that caused visible damage to vascular tissue, Empire at both sites and McIntosh at the Hudson Valley site showed a tendancy for increased numbers of fruit/cm^2 of trunk cross-sectional area as more nutrients were applied. The combined half-inch green plus pink treatment increased cropping by about 24 % in comparison to the non-treated controls in the Hudson Valley. In the Champlain Valley, all treatments that contained a combination of boron and zinc significantly increased cropping. The combination of the half-inch green plus pink treatment produced a 43 % increase.

In 1995, following a relatively mild winter, Empire at both sites showed significant gains in cropping from the prebloom treatments. Treatments did not result in increased fruit set of McIntosh at either site. Mid-winter low temperatures of -11F and -18F were recorded at the Hudson Valley and Champlain Valley sites, respectively.

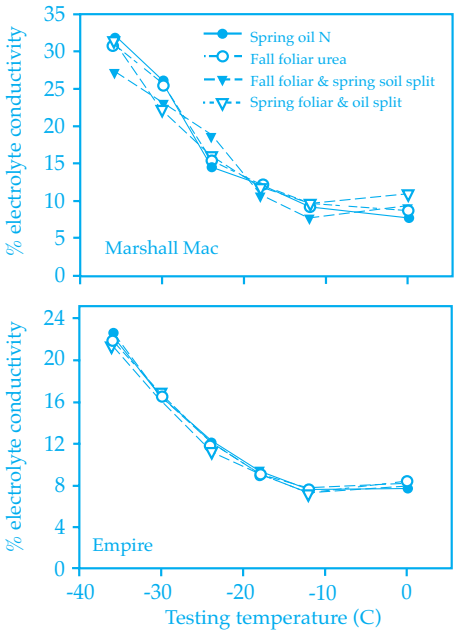

Figure 5. Effects of N treatments on tree cold hardiness as measured by electrolyte leakage method (December 2000).

In 1996, only the combination of the half-inch green plus pink treatment was tested on McIntosh and Empire in seven orchards. Across these seven orchards, cropping of McIntosh was significantly increased by an average of 9.6 %, but there was no effect on Empire. Factors influencing differences in response were not apparent from this study, but it appears that a complex of factors influencing bud development may be involved. Apparently, prebloom nutrient applications enhance cropping by increasing retention of flower buds that would otherwise abscise during early bud development.

In all cases, when increased cropping was observed there was no significant reduction in average fruit size (weight) from the increased cropload.

Suggestions for Minimizing Damage and Remedial Treatments for Cold Damaged Trees

Based on our present knowledge about the relationships between nutritional factors and cold tolerance of apple trees, the following suggestions are presented:

1. Closely monitor the nutrient status of the orchard by means of leaf analysis and soil testing.
2. Adjust the use of nitrogen fertilizers according to the individual orchard situation. This includes recognition of the impact of various components of the production system and management practices on nitrogen requirements of the trees.
3. Maintain adequate supplies of all other essential nutrient elements.
4. When trees begin to leaf out in the spring, closely examine buds and spur tissues for signs of cold damage. If this is evident, consider application of a combination of boron plus EDTA-zinc chelate at the half-inch green stage of development and follow this with a combination of boron plus EDTA-zinc chelate plus urea at pink.

Jim Schupp is an assistant professor at the Hudson Valley Lab who continues his interest in cold hardiness. Lailiang Cheng is an assistant professor whose research interests include the physiology of mineral nutrition. Warren Stiles is enjoying retirement in New Jersey but still takes time to serve the NY Fruit Industry. Ed Stover is a researcher at the University of Florida who initiated much of this work while in the Hudson Valley. Kevin Iungerman leads the NE NY Fruit Program and is keenly interested in cold hardiness.

Antioxidant Capacity and Anticancer Properties of Red Raspberry

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This study suggests that the phytochemicals in raspberries have significant antioxidant and anticancer activity. Darker raspberries show greater antioxidant activity than lighter ones but not significantly greater anticancer activity. Clearly other as yet unknown compounds are also involved.

Abundant evidence suggests that regular consumption of fruits and vegetables reduces the risks of chronic diseases such as cancer and cardiovascular disease. In the process of converting food into energy, the body naturally produces oxygen radicals, which can damage DNA and enzymes and oxidize cell membrane lipids. Accumulated damage from these radicals is thought to lead to cancer, heart disease, and other diseases. Natural antioxidants in foods help counteract these oxygen radicals and protect us from their damaging effects. Fruits and vegetables are especially rich in a variety of antioxidants called phytochemicals such as flavonoids, which give many fruits their characteristic colors. Intake of sufficient amounts of antioxidants helps the body balance the demands of producing the energy it needs and producing damaging oxygen radicals. Research on raspberries revealed high levels of phytochemicals, antioxidant activity, and anticancer activity.

Raspberries are high in phenolic phytochemicals, particularly flavonoids such as anthocyanin pigments, which give raspberries their deep red color. These potent antioxidants, along with naturally high levels of Vitamin C, minerals, and fiber, make raspberries especially good for people. In this study, the ability of raspberry fruit extracts to inhibit liver cancer cell growth in a test tube and the total antioxidant activity of four raspberry varieties was investigated. We also looked at the relationship between their total phenolics and flavonoids content and their antioxidant and anticancer activities. In addition, the relationship between fruit color and antioxidant activity was examined. Ultimately, the relationship between the food we eat and our long-term health needs to be better understood. This research gives more insight into the health benefits of fruits and vegetables.

Phytochemical Content

Fresh Heritage, Kiwigold, Goldie, and Anne raspberry fruit were obtained from plantings on the New York State Agricultural Experiment Station (Cornell University, Geneva, NY). Heritage is a dark red, fall-bearing variety that was developed at the Experiment Station in the 1960s. It remains the most widely planted raspberry in the world today. Kiwigold and Goldie are both sports of Heritage with amber colored fruit. They display a mutation in the anthocyanin biosynthesis pathway that reduces the pigment content in the fruit. Both Kiwigold and Goldie are genetically identical to Heritage except for their anthocyanin content. Anne is a yellow-fruited variety developed at the University of Maryland. Anthocyanins are a type of flavonoid pigment common in most plants. Flavonoids are, in turn, part of a broader class of

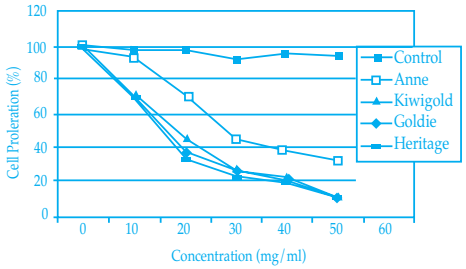

Figure 1.: Antiproliferative effects of four raspberry varieties versus apple and a control.

TABLE 1

Total phenolics, flavonoids, fruit color, optical sensor reading ratios, antioxidant activity, and cancer cell antiproliferation activity of Heritage, Kiwigold, Goldie, and Anne raspberry fruit extracts.

Raspberry Variety	Total Phenolics (mg gallic acid equivalents/100g)	Total Flavonoids (mg catechin equivalents/100g)	Fruit Color	Optical Sensor (a/b)	Antioxidant Activity (EC_{50} ug/ml)	% Inhibition (50 mg/ml equivalent)	Inhibition EC_{50} (mg/ml)
Heritage	512.70 +4.66	103.41 +2.04	Dark red	4.92	312.06 +28.27	87.96 +0.19	14.83 +0.14
Kiwigold	451.06 +4.45	87.33 +1.83	Amber	2.84	521.71 +36.91	87.55 +0.98	14.39 +0.25
Goldie	427.51 +7.51	84.16 +1.82	Amber	2.24	544.52 +12.30	89.43 +0.11	11.69 +0.61
Anne	359.19 +3.35	63.53 +0.65	Yellow	0.18	801.79 +64.93	70.33 +1.15	32.88 +0.78

phytochemicals called phenolics. In previous research on apples (Liu et al., 2001) and other crops it was found that the total content of phenolics and/or flavonoids in fruits is a good indicator of total antioxidant activity. When the content of these compounds in raspberry was measured, Heritage proved to have the highest total phenolic and flavonoid content (513 mg/100g and 103 mg/100g fruit, respectively) of the varieties tested (Table 1). The total phenolic and flavonoid content of Kiwigold (451 mg/100g and 87 mg/100g fruit, respectively) and Goldie (428mg/100g and 84mg/100g fruit, respectively) were similar to each other but lower than Heritage (Table 1). Anne had the lowest total phenolic and flavonoid content (359mg/100g and 64 mg/100g fruit, respectively) (Table 1) of the varieties tested.

Raspberry Extracts and Cancer Cell Growth

To determine the effect of raspberry extracts on the growth of HepG2 liver cancer cells in a test tube, raspberry extracts were added to HepG2 liver cancer cells in amounts equivalent to 0, 1, 5, 10, 20, 30, 40, 50 mg of raspberry and incubated for 96 hours. After 96 hours, cell growth was determined. All varieties tested showed obvious growth inhibition. Cancer cell growth was inhibited in a dose dependent manner. As more extract was added, the cells grew less (Figure 1).

At the 50mg dose, Goldie, Heritage and Kiwigold all showed nearly 90% reduction of cancer cell growth (89%, 88% and 88%, respectively) (Figure 1, Table1). Even Anne, the raspberry variety showing the lowest anticancer activity, produced a 70% reduction in cancer cell growth (Figure 1, Table 1).

The dose needed to reduce cancer cell growth by 50% (EC_{50}) was also calculated. That is, a lower EC_{50} is indicative of greater inhibitory activity. Goldie extracts had the lowest EC_{50} of antigrowth activity (11.69mg/ml) of the varieties tested, but was not significantly different from Kiwigold (14.39mg/ml) or Heritage (14.83mg/ml) (Table1). Anne, having the highest EC_{50} of antigrowth activity (32.88mg/ml), showed significantly lower inhibitory activity (Table 1).

The anticancer activity was then compared to the total phenolic and flavonoid content of the raspberries. Heritage, Kiwigold, and Goldie, which all have a common genetic background, were different in their phenolic and flavonoid content but similar in their anticancer activity. This suggests that there are phytochemicals in addition to phenolics that are active against cancer cells. Further research into the phytochemical components of raspberry is needed to determine what these additional anticancer compounds are.

Total Antioxidant Activity

Antioxidants are thought to work in the body in a preventative manner by neutralizing destructive oxygen radicals. The potential for a food to counteract these oxygen radicals can be determined by measuring its total antioxidant activity. An assay called the Total Oxyradical Scavenging Capacity (TOSC) measures the ability of food extracts to counteract a known oxidizing chemical. This activity is expressed as the median effective dose (EC_{50}). The EC_{50} value in this test represents the dose needed to have a 50% effect in the assay much like an LD_{50} (Lethal Dose 50%) used to rate pesticide toxicity. A lower EC_{50} value indicates that a lower dose is needed to produce a 50% reduction in oxidation in the assay.

The total antioxidant activity of the phytochemical extracts from raspberry cultivars was measured by the TOSC assay. Heritage had the lowest EC_{50} of total antioxidant activity (312mg/ml) followed by Kiwigold (522mg/ml) and Goldie (545mg/ml) (Figure 2 and Table 1). Anne had the highest EC_{50} (802mg /ml) (Figure 2 and Table 1). The data shows that Heritage had the highest total antioxidant activity and Anne had the lowest antioxidant activity of the varieties tested.

Total Phenolic/Flavonoid Content Relationship to Antioxidant Activity

The total phenolic and flavonoid content correlated highly with total antioxidant activity in the raspberry varieties tested. Higher levels of phenolics and flavonoids corresponded to higher antioxidant activity (Table 1). This indicates that the phenolics and flavonoids in raspberry contribute significantly to their overall antioxidant capacity and that the levels of these compounds can be used as an indicator for the total antioxidant activity of various raspberry varieties.

Fruit Color as an Antioxidant Indicator

Various researchers have analyzed the total antioxidant activity of many fruits and vegetables. A trend seen is that more highly pigmented fruits and vegetables have higher antioxidant activity (Figure 3). Black raspberries, blackberries, red raspberries, blueberries, and strawberries are red or purple in color and all contain high levels of anthocyanin pigments. Anthocyanins, which have high antioxidant activity, are some of the many flavonoids in raspberry and other fruits. This led us to believe that anthocyanin content, i.e. fruit color, could be used as an indicator of antioxidant activity.

To determine the relationship of fruit color to total phenolic/flavonoid content and antioxidant activity, the juice of each of the four raspberry varieties was measured with a colorimeter. It measures the relative brightness and color components of the sample as numerical values of a, b, and L. Previous research showed that, of the components measured, the ratio of a/b correlates well to anthocyanin pigment content in raspberries (Moore, 1997). Darker red varieties with higher antho-

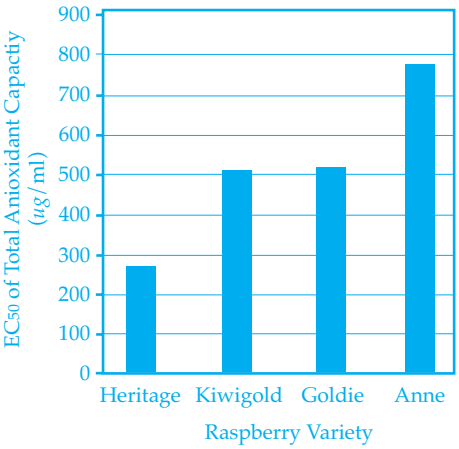

Figure 2: EC_{50} of total antioxidant capacity of four raspberry varieties. (A lower EC_{50} indicates higher antioxidant activity.) Anne has the lowest antioxidant activity, which corresponds to the highest EC_{50} value.

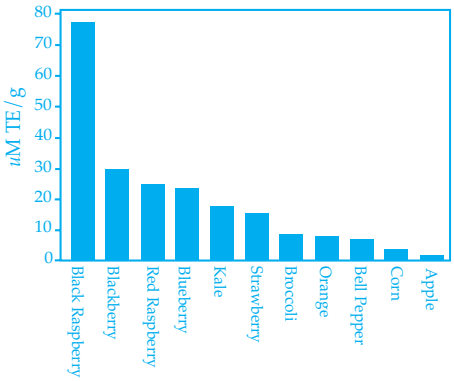

Figure 3: Antioxidant capacity of selected fruits and vegetables. (umole Trolox Equivalents (TE)/g) Trolox is a Vitamin E analog used in calculating relative antioxidant activity. (Payne, 2000)

cyanin content have a higher a/b ratio. These higher ratios also correspond to higher phenolic and flavonoid content in the varieties tested. Heritage, the darkest red berry, had the highest ratio (4.92) (Table 1). Kiwigold and Goldie were intermediate in color and in a/b ratio (2.84 and 2.24, respectively) and Anne had the lowest a/b ratio (0.18) with yellow fruit (Table 1). This was the same ranking as the total phenolic and flavonoid content of the varieties and the total antioxidant activity. This indicates that a darker red color can be used as an indicator of phytochemical content and antioxidant activity in raspberry. Using a hand-held colorimeter, instant field estimates of phytochemical content and antioxidant activity can be made. This tool will aid in the development of future varieties with enhanced health attributes.

Summary

It is well known that fruits and vegetables are good sources of antioxidants. Previously, most investigators focused mainly on the Vitamin C, Vitamin E, and b-carotene content of fruits. However the major components of fruit that act as antioxidants are phytochemicals such as phenolic compounds like flavonoids. Research shows that the Vitamin C in apples with skin accounts for only 0.4% of the total antioxidant activity indicating that almost all the antioxidant activity is from other phytochemicals in the fruit (Liu et al., 2001). Raspberries contain approximately 25 mg of Vitamin C per 100g of fruit. This accounts for a small portion of the antioxidant activity found in raspberry. Therefore, the total antioxidant activity of raspberries is mainly from the other phytochemicals in the fruit rather than from the Vitamin C. The antioxidant activity may be explained by looking at the combination of different phytochemicals functioning additively or synergistically accounting for the total antioxidant activity of raspberries.

It seems that pigment content is a factor affecting antioxidant activity, but not a factor in the inhibition of cancer cell proliferation. Except for anthocyanin content, Heritage, Kiwigold, and Goldie are genetically identical. They had different levels of phenolics and flavonoids and varying antioxidant activity. However, extracts from all three varieties reduced cancer cell grow by nearly 90%.Therefore, it is assumed that phytochemicals other than anthocyanins in the raspberries were responsible for the inhibition of tumor cells.

This study suggests that the phytochemicals in raspberries have a significant antioxidant and anticancer activity. It is clear that raspberries higher in phenolic and flavonoid compounds have higher antioxidant activity. The darker colored raspberry varieties showed greater antioxidant activity than the lighter colored variety, Anne. The antioxidant activity of the raspberry was directly related to the total amount of phenolics and flavonoids found in the raspberry, but there was no relationship between anticancer activity and the total amount of phenolics/flavonoids found in the same raspberry. The inhibition of cancer cell proliferation is further influenced by some unknown compound(s) present in raspberry fruits. The additive and synergistic roles of phytochemicals may contribute significantly to the potent antioxidant activity and the ability to inhibit tumor cell proliferation.

It is clear that choosing to eat fruits and vegetables directly affects your health. However, not all fruits and vegetables are created equal. An informed consumer realizes that eating a diverse selection of fruits and vegetables is the only way to ensure you obtain all of the nutrients your body needs. While the effectiveness of nutritional supplements still needs to be proven, it is certain that eating fruits and vegetables is good for you. For the good of us all, it is important for the grower and the consumer to be well informed about the benefits of a diet rich in fruits and vegetables.

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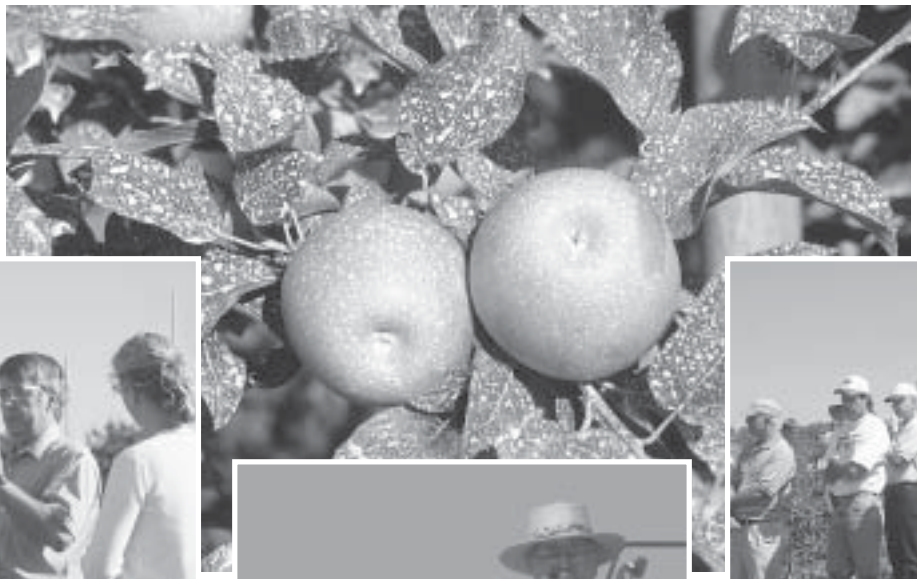
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