N E W Y O R K
FRUIT QUARTERLY

Editorial

'Honeycrisp' Apple: Team Work and Lessons Learned

Any new apple cultivar presents challenges to growers and researchers, and 'Honeycrisp' is no exception. However, the situation with 'Honeycrisp' is unique in that consumer reaction, market acceptance, and grower enthusiasm drove the popularity of this cultivar much more rapidly than usually occurs. Therefore, our learning curve coincides with commercial production. Researchers at Cornell have joined efforts to investigate the many challenges to growing 'Honeycrisp'. These teams have made excellent progress, as evident by the research reviewed in this issue of *The Fruit Quarterly*. Additional research is underway in testing selections propagated from 'Honeycrisp' trees that had better color, more uniform color and/or a less blotchy finish. The leaf yellowing and necrosis of 'Honeycrisp' is also being investigated.

Early testing of 'Honeycrisp' revealed that disease susceptibility, management of cropping and determination of proper maturity and its effect on storage disorders (especially soft scald and bitter pit) would be priorities. Its performance in the NE-183 regional project "Multidisciplinary Evaluation of New Apple Cultivars" reconfirmed Honeycrisp's susceptibility to soft scald, bitter pit, powdery mildew, and fire blight, and its tendency toward biennial bearing.

In this issue, thinning of 'Honeycrisp' is reviewed by Jim Schupp et al., while crop load effects on maturity, storage and return bloom are covered by Terence Robinson and Chris Watkins. Maturity guidelines were developed by Jim Wargo and Chris Watkins based on their research and sensory evaluations of fruit from commercial trials harvested at different dates. Postharvest disease management has been investigated by David Rosenberger et al. Finally, the storage of 'Honeycrisp', including storage disorders, is examined by Chris Watkins et al.

This compilation of research on 'Honeycrisp' is an example of the synergy between researchers that results in valuable information being made available to growers on how to handle this potentially profitable, yet difficult, cultivar. The complexity and interactions between problems means that growers may need to evaluate the benefits of different treatments: for example, the reduction of soft scald by the use of warmer storage temperatures versus the likelihood of increasing bitter pit with this treatment. Many new varieties do not live up to our expectations, but 'Honeycrisp' is an example where a team approach to research has succeeded in lessening the risks involved in growing a new cultivar.

Growing 'Honeycrisp' is still a challenge, but growers now have more information with which to meet the challenge.

Susan Brown
Professor of Horticultural Sciences
NYS Agricultural Experiment Station
Geneva, NY

CONTENTS

FRONT COVER: Honeycrisp apples can be extremely attractive and very high quality, however, bitterpit and soft scald can often be serious problems for growers. In this issue, research on solving these problems is presented. Photos by Susan Brown and Chris Watkins.

BACK COVER: Research on optimum harvest dates for Honeycrisp is reported in articles by Watkins and Wargo. Photos by Jim Wargo.

N E W Y O R K
FRUIT QUARTERLY
VOLUME 11 • NUMBER 3 • AUTUMN 2003

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

Editors:
Terence Robinson and Steve Hoying
Dept. of Horticultural Sciences
New York State Agricultural Experiment Station
Geneva, New York 14456-0462
Telephone: 315-787-2227
Fax: 315-787-2216
Subscriptions: $20/year. Contact Karen Wilson, NYSHS, PO Box 462, Geneva, NY 14456
or call: 315-787-2404
Advertising: Warren Smith: 845-255-1442
Production: Communications Services, NYSAES, Geneva

Effects of Chemical Thinners on Fruit Set, Yield, Fruit Size, and Fruit Quality of Honeycrisp Apple

J. R. Schupp

Dept. of Horticultural Sciences, Hudson Valley Lab, Cornell University, Highland, NY

Since Honeycrisp is a new variety, optimal thinning chemistries and rates are unknown. Based on this research, Honeycrisp is relatively easy to thin chemically at the traditional 10-12 mm growth stage. Best results were with NAA at 5 ppm, or the combination of 2.5 NAA plus 1 pint Sevin XLR/ 100 gal. Honeycrisp appears to be very sensitive to benzyladenine (Accel), and is easily over-thinned with this chemical.

Honeycrisp is being extensively planted as growers seek profitable new cultivars to diversify their variety mix. Because it is new, Honeycrisp has not been well studied and there is little information available to make recommendations about specific horticultural practices. Chemical thinning is important for managing crop load, fruit size and quality, and for increasing return bloom of apple. The optimal thinning chemistries and rates are variety specific. This study was initiated to evaluate the effect of chemical thinners on fruit set, yield, fruit size, and fruit quality of Honeycrisp.

Materials and Methods

These studies were conducted in a commercial orchard in Milton, NY, in 1999, 2000, and 2001 on fifth, sixth, and seventh leaf Honeycrisp/M.26 trees, respectively. To avoid complications due to differences in bloom density, different trees were used in each year. The trees were planted at 8 X 16 ft. spacing with trickle irrigation, and trained to the vertical axe system.

Chemical thinners were applied to drip with an air-blast sprayer when the largest fruit were 10-12 mm in diameter. The flower clusters on one or two scaffold limbs per tree were counted at bloom and the number of fruits remaining after June drop were counted on the same limbs. Fruit set was calculated as the ratio of fruits per 100 flower clusters. The fruit were harvested in three or four pickings each season and weighed. The total yield per tree was the sum of all harvests. A sample of 20 fruits per tree was evaluated for mean fruit weight, diameter, percent blush, incidence of bitter pit, and firmness.

Experiments 1 and 2: Experiments to evaluate a range of napthaleneacetic acid (NAA) concentrations, with and without carbaryl, as well as carbaryl alone, and Accel plus carbaryl were conducted in 1999 and 2000. The treatments were: 1) untreated control; 2) carbaryl, 600 ppm (Sevin XLR Plus, 1 pint/100 gallons); 3) NAA, 2.5 ppm (Fruitone N, 1 oz./100 gal.); 4) NAA, 5 ppm (Fruitone N, 2 oz./ 100 gal.); 5) NAA, 7.5 ppm (Fruitone N, 3 oz./100 gal.); 6) NAA, 2.5 ppm plus Sevin; 7) NAA, 5 ppm plus Sevin; and 8) benzyladenine, 75 ppm, plus carbaryl (Accel, 53 fl. oz/100 gal plus Sevin).

Experiment 3: This experiment was conducted in 2001 to evaluate two rates of Accel, with and without carbaryl, compared to NAA plus carbaryl and an untreated control. The treatments were: 1) untreated control; 2) NAA, 2.5 ppm plus Sevin; 3) benzyladenine, 50 ppm, (Accel, 35.3 fl. oz/100 gal); 4) benzyladenine, 75 ppm, (Accel, 53 fl. oz/ 100 gal); 5) benzyladenine, 50 ppm, plus carbaryl (Accel, 35.3 fl. oz/100 gal plus Sevin); and 6) benzyladenine, 75 ppm, plus carbaryl (Accel, 53 fl. oz/100 gal plus Sevin).

Results and Discussion

Experiments 1 and 2: NAA at 5 ppm or greater concentrations, as well as 2.5 ppm NAA plus carbaryl provided thinning activity on Honeycrisp (Table 1). NAA alone at 2.5 ppm and carbaryl alone appeared to provide some mild thinning, but the effect on fruit set was not significant. NAA at 7.5 ppm did not remove more fruit than NAA at 5 ppm. The tank mix sprays of 5 ppm NAA plus Sevin, and Accel plus Sevin both over-thinned Honeycrisp severely. The fruit set results followed similar trends in 2000, although there was greater variability within the experiment, and few statistical differences as a result. Accel plus Sevin over-thinned Honeycrisp again.

Yield per tree followed the same trends as fruit set (Table 2). Five ppm NAA tank mixed with Sevin greatly reduced yield in 1999. Accel plus Sevin greatly reduced yield in both years.

In 1999, Accel plus Sevin and 5 ppm NAA plus Sevin increased mean fruit weight relative to unthinned trees, with the other thinning treatments resulting in intermediate values (Table 3). Mean fruit weights were more variable in 2000, and only the severely thinned Accel plus Sevin trees produced larger fruit than the controls. Mean fruit diameter exceeded 3 inches for all thinning treatments in both years (data not presented). Fruit from excessively thinned trees was especially large and had more bitter pit at harvest than fruit from moderately thinned trees (data not presented). Honeycrisp is susceptible to bitter pit in part due to the large size of its fruit (Schupp et al., 2001a). Thus thinning lightly to produce optimal crop load is important not only for obtaining good productivity, but to prevent excessive loss of marketable fruit due to bitter pit.

Chemical thinners had no effect on red fruit color, and all thinning treatments increased soluble solids slightly, compared to the unthinned control (data not presented). Fruit from Accel-treated trees were firmer than other treatments, despite the very large size (data not presented).

Honeycrisp leaves often develop a zonal chlorosis that resembles potato leafhopper damage (Rosenberger et al., 2001). Studies at Cornell's Hudson Valley Lab have shown that the damage is caused independently of the presence of potato leafhopper (Schupp, et al., 2001b). Differences in the severity of zonal chlorosis between trees in the 1999 experiment were observed and visually rated on a 1-5 scale, where 1= no chlorosis and 5=100 percent chlorotic. The chemical thinners tested provided a range of crop loads on the trees, and the severity of the chlorosis was inversely related to crop load. Leaf rating ranged from 1.8 on the untreated controls with the heaviest yield, to 4.5 on the Accel + carbaryl treated trees, which had the lightest crop (Table 4).

Based upon preliminary research, the zonal chlorosis of Honeycrisp leaves appears to have a physiological cause, and may be triggered by the buildup of starch grains in the chloroplasts. Schupp, et al (1992) reported that deblossoming Golden Delicious apple trees led to development of numerous large starch granules in the chloroplasts, which disrupted the membranes, leading to chlorosis. Similarly, Schaffer et al. (1986) reported chlorosis and chloroplast disruption due to starch buildup in leaves of de-fruited, girdled citrus trees. It may be that anatomical differences in Honeycrisp leaves may impair phloem loading, causing the leaves to be more susceptible to this injury. We have cooperative research underway with Drs. Lailiang Cheng, Dept. of Horticulture, Cornell, and Teresa Snyder-Lieby, Dept. of Biology, SUNY New Paltz, to determine if this hypothesis is valid.

Experiment 3: Fruit set was low in this experiment, even in the untreated trees (Table 5). Accel severely over-thinned Honeycrisp, even when applied alone at two-thirds the standard rate. Benzyladenine (Accel) at 50 ppm reduced yield by 74 percent. Increasing the benzyladenine concentration to 75 ppm or adding carbaryl reduced yield by 86 to 93 percent. Fruit size was excessively large for all Accel-treated trees. The combination of 2.5 ppm NAA plus carbaryl had no effect on fruit set, yield, or mean fruit weight, which was a desirable outcome in this season's lightly cropped trees.

Return bloom in all three experiments was low for all but the over-thinned trees (data not presented). Honeycrisp is a large fruited variety, and thinning it severely enough to assure return bloom not only reduced yield, but also caused the remaining fruit to be excessively large and more susceptible to bitter pit. It is unlikely that alternate bearing in Honeycrisp will be managed by thinning at the 10-12 mm fruit growth stage alone.

Alternative strategies to promote return bloom in alternate bearing varieties include reducing the crop load earlier, (i.e. at bloom or at petal fall), and spraying with ethephon or NAA five to six weeks after petal fall (Agnello et al., 2003). Investigations to determine the critical time period for crop load adjustment and to evaluate the efficacy of plant growth regulators to stimulate flower formation are underway, but the results are not definitive at the time of writing.

Summary

Based on this research, Honeycrisp is a large-fruited cultivar that is relatively easy to thin chemically at the traditional 10-12 mm growth stage. For a starting point, I suggest NAA at 5 ppm, or the combination of 2.5 ppm NAA plus 1 pint Sevin XLR / 100 gal. If initial set is very heavy and a stronger thinning response is needed, try the combination of 5 ppm NAA plus 1 pint Sevin XLR / 100 gal. Honeycrisp is very sensitive to benzyladenine, and is easily over-thinned with this chemistry. I recommend that growers not use this material to thin Honeycrisp, unless they are trying to de-fruit young trees to encourage more vegetative growth.

TABLE 1

Effect of thinning treatments on Honeycrisp fruit set (%).

Treatment	1999	2000
Control	66 a	81 a
Sevin XLR	55 ab	71 a
NAA 2.5 ppm	51 ab	71 a
NAA 5 ppm	38 b	64 ab
NAA 7.5 ppm	43 b	62 ab
NAA 2.5ppm + Sevin	39 b	61 ab
NAA 5 ppm + Sevin	19 c	56 ab
Accel + Sevin	2 d	41 b

TABLE 2

Effect of thinning treatments on Honeycrisp yield (kg).

Treatment	1999	2000
Control	49 a	116 a
Sevin XLR	37 ab	102 ab
NAA 2.5 ppm	41 ab	110 a
NAA 5 ppm	41 ab	102 ab
NAA 7.5 ppm	33 ab	99 ab
NAA 2.5ppm + Sevin	36 ab	98 ab
NAA 5 ppm + Sevin	24 b	82 ab
Accel + Sevin	5 c	59 b

TABLE 3

Effect of thinning treatments on Honeycrisp fruit weight (g).

Treatment	1999	2000
Control	153 b	175 b
Sevin XLR	196 ab	203 ab
NAA 2.5 ppm	184 ab	194 b
NAA 5 ppm	208 ab	197 ab
NAA 7.5 ppm	190 ab	193 b
NAA 2.5ppm + Sevin	203 ab	198 ab
NAA 5 ppm + Sevin	249 a	207 ab
Accel + Sevin	225 a	238 a

TABLE 4

Effect of thinning treatments on Honeycrisp leaf chlorosis, 1999 (Scale of 1=none to 5=100% chlorotic).

Treatment	Yield (lb)	Chlorosis Rating
Control	107	1.8
Sevin XLR	81	2.5
NAA 2.5 ppm	90	2.3
NAA 5 ppm	90	2.8
NAA 7.5 ppm	73	3.0
NAA 2.5ppm + Sevin	80	2.3
NAA 5 ppm + Sevin	54	3.3
Accel + Sevin	12	4.5

TABLE 5

Effect of Accel, with or without Sevin on Honeycrisp set, yield, and fruit weight, 2001.

Treatment	Fruit Set (%)	Yield (kg)	Fruit Wt. (g)
Control	28 a	58 a	220 b
NAA, 2.5 ppm + Sevin	24 a	56 a	223 b
Accel 50 ppm	4 b	15 b	293 a
Accel 75 ppm	3 b	6 b	313 a
Accel 50 + Sevin	2 b	8 b	306 a
Accel 75 + Sevin	1 b	4 b	295 a

Rather than fruit size or quality, the challenge in thinning Honeycrisp is achieving adequate return bloom. It seems unlikely that chemical thinning at the traditional timing of 10-12 mm fruit diameter growth stage will result in adequate return bloom. Although our knowledge is not complete on how well these techniques will work on Honeycrisp, growers may want to conduct small-scale on-farm trials with blossom thinning or thinning at petal fall to see if earlier thinning results in increased return bloom.

Acknowledgements

The author thanks the owners and management of Crist Brothers Orchards for the use of the Honeycrisp trees and the donation of the sampled fruit used in these experiments. I thank Valent Biosciences for partial support of this research. Thanks also to Jay Osborne and Richard Christiana for technical assistance.

References

Agnello, A. M., A.J. Landers, W. W. Turechek, D. A. Rosenberger, T. L. Robinson, J. R. Schupp, J.E. Carroll, L. Cheng, P. D. Curtis, D. I. Breth, and S. A. Hoying. 2003. Pest management guidelines for commercial tree-fruit production 2003. A Cornell Coop. Ext. Publ.

Rosenberger, D., J. Schupp, C. Watkins, K. Iungerman, S. Hoying, D. Straub, and L. Cheng. 2001. Honeycrisp: A darling new apple variety or just another problem child? N. Y. Fruit Quarterly 9(3): 9-13.

Schaffer, A. A., K. Liu, E. E. Goldschmidt, C. D. Boyer, and R. Goren. 1986. Citrus leaf chlorosis induced by sink removal: starch, nitrogen and chloroplast ultrastructure. J. Plant Phys. 124:111-121.

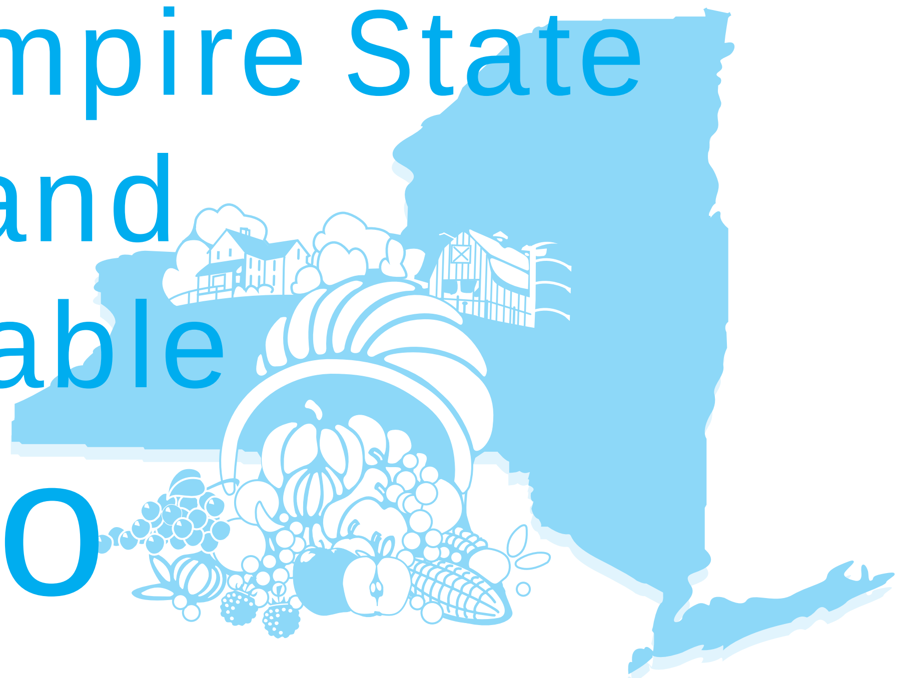
Schupp, J. R., D. C. Ferree and I. J. Warrington. 1992. Interactions of root pruning, and deblossoming on growth, development and yield of 'Golden Delicious' apple. J. Hort. Sci. 67:465-480.

Schupp, J.R., D.A. Rosenberger, C.B. Watkins, L. Cheng, and S. Hoying. 2001a. Understanding the bitter pit problem in Honeycrisp. Apple Handling and Storage, NRAES 153:1-8.

Schupp, J., R. Straub, D. Rosenberger and C. Watkins. 2001b. Managing Honeycrisp for production and quality. Compact Fruit Tree 34: 107-109.

Jim Schupp is a research and extension professor at Cornell's Hudson Valley Lab. He specializes in the use of plant growth regulators in fruit crops.

The Empire State Fruit and Vegetable Expo



"Growing for the Health of New York"

February 9, 10, 11 and 12, 2004

Clarion Riverside Hotel and the
Rochester Riverside Convention Center, Rochester, NY

Sponsored by the NYS Vegetable Growers Association, the Empire State Potato Growers, the NYS Horticultural Society and the NYS Berry Growers and Cornell Cooperative Extension.

The Expo will include sessions focused on apples, stone fruit, potatoes, beans, sweet corn, onions, pumpkins, berries and many more. In addition, the International Cabbage Conference, a joint venture between New York and Ontario, Canada, will be meeting at the Expo.

All of this with a Trade Show with more than 100 exhibitors.

For more information, contact Jeff and Lindy Kubecka at 315-687-5734 or the web site: http://www.nysaes.cornell.edu/hort/04expo/

Cropload of Honeycrisp Affects Not Only Fruit Size But Many Quality Attributes

Terence L. Robinson[1] and Christopher B. Watkins[2]

[1] Dept. of Horticultural Sciences, NYSAES, Cornell University, Geneva, NY
[2] Dept. of Horticulture, Cornell University, Ithaca, NY

This work was funded in part by the NY Apple Research and Development Program and the New York Apple Research Association, and Federal Formula Funds Project NE103.

Honeycrisp can develop extremely high quality fruit if grown optimally, but quality can be greatly reduced if croploads are too high. In addition to the reduction in fruit size and return bloom from excessive croploads, our research has shown that fruit firmness, total acidity, soluble solids, color and starch are all reduced when croploads are above optimum.

The popularity of Honeycrisp in the market and the high fruit prices it commands are largely due to consumer demand based on the unique experience of eating a good apple. Most consumers of Honeycrisp view fruit appearance as secondary to the flavor, crispness and juiciness it delivers when it is grown well. However, optimum fruit quality (taste and eating experience) are not always easy to achieve. The biennial bearing tendency of this variety leads the tree to produce very low crops one year followed by very high crops the second year. In both situations, quality is not optimal. Our objective with this project has been to define appropriate croploads that give adequate repeat bloom and also the best fruit quality.

The 1998 Honeycrisp Trial at Geneva

We planted 150 Honeycrisp/M.9 apple trees in the spring of 1998 to study the influence of cropload on tree growth in the early years and then to study the effects of cropload on fruit quality and repeat bloom as the trees matured. The trees were trained in a vertical axis system and did not have irrigation. The soil was a fertile Honeoye silt loam. In the second year, we allowed the trees to set a modest crop and then imposed a range of croploads on the trees through thinning at 2 weeks after bloom. This procedure was continued in years 3 and 4. Each year we selected the heavy cropping trees and thinned them to various cropload levels to give a range of cropping from none to very heavy. The level of cropload was quantified by counting the number of apples on the tree and then calculating the number of apples per cm^2 of trunk cross-sectional area. The typical range of croploads for many varieties grown in New York State is 5-6 fruits/cm^2 of TCA.

Beginning in the fourth year (2001), we had a sufficiently heavy bloom to impose a wide range of croploads (0-12 fruits/cm^2 of TCA). In the fifth year (2002), we were able to impose croploads up to 15 fruits/ cm^2 of TCA. Near harvest each year we began weekly sampling of the Honeycrisp trees to determine the impact of the different croploads on fruit ripening and flavor development. At each weekly sampling we selected a sub-sample for analysis of fruit maturity and quality factors and divided the remaining fruit into two lots to evaluate the impact of cropload on fruit storage disorders. We stored half of each sample at 38°F and the other half at 33°F for five months in air. After the five month storage period, we evaluated the samples for fruit firmness and storage disorders including bitter pit, senescence breakdown, soggy breakdown, soft scald and superficial scald.

Horticultural Results

The level of cropload carried by Honeycrisp trees affected tree vegetative growth in both the fourth and fifth years. All trees generally grew well with the fertile soils at the Geneva Experiment Station, but trees with a very low or non-existent cropload had greater growth (as measured by the increase in trunk cross-sectional area) than trees with a heavy cropload (Fig. 1). The relationship between cropload and trunk growth was curvilinear indicating that, as cropload on Honeycrisp trees is increased, tree growth declined rapidly up to a cropload of about 5 fruits/cm^2 of TCA. Beyond that, up to a cropload of 12 fruits/cm^2 of TCA, there was similar but slow growth from the trees.

It should be noted that under weaker soils than those at Geneva, it is likely that the heavy croploads would have stopped tree growth almost completely. This point is critical for growers who plant Honeycrisp trees on M.9 rootstock on weak soils. During the developmental years of the orchard, it may be necessary to limit cropload to allow the trees to fill their space.

Fruit size was also reduced by increasing cropload in a curvilinear relationship (Fig. 2) that was very similar to that shown for trunk growth. Fruit size was reduced rapidly as cropload increased from 0 to about 7 fruits/cm^2 of TCA. Even at a cropload of 6-7 fruits/cm^2 of TCA, fruit size was still about 175g (100 count fruit size). Fruit size was 150g at croploads of 10 fruits/cm^2 or greater. Although a 150g Empire or Jonamac apple is still marketable, for Honeycrisp, which is sold as a premium apple, this size is not commercially acceptable. In contrast, at very low croploads, fruit size often approached 300g which is considered excessive by most marketers. In today's market, a Honeycrisp fruit size between 200 and 250g is considered optimal. To obtain that fruit size in our study would have required a cropload of less than 5 fruits/cm² of TCA. This seems suboptimal compared with Empire and Gala and is indicative of the need to sacrifice total yield to obtain the optimum fruit size for the market.

Return bloom the following season was also reduced by increasing croploads (Fig. 3). The statistical relationship was linear and steeper indicating that the higher the cropload that is allowed to persist on a Honeycrisp tree, the greater the inhibition of flowering the following year. The trees became non-flowering at croploads greater than 9 fruits/cm² of TCA. Also surprising was the significant variation about the trend line. There were some trees which had relatively low croploads and produced very few flower buds the following year (points in the lower left hand corner of Fig. 3). There were very few trees that had a heavy cropload the previous year that came back with significant flowering (points in the top right hand corner of the figure. The suppressive effect of high croploads on next year's flowering was slightly greater in 2002 than in 2001 as indicated by the dashed line in Fig. 3 that dips below the solid line at the high croploads. It is disturbing to see that many trees had no flowers following what we typically have called medium croploads (6-7 fruits/cm² of TCA).

For adequate cropping, most growers prefer to have a minimum of 40-50 percent of the spurs flowering each year. To achieve that level of flowering would have required relatively low croploads of 3-4 fruits/cm² of TCA the previous year. An undesirable situation is to have every spur on the tree flowering (snowball bloom indicated by points in the upper left-hand side of the figure) because this is almost always followed by no flowering the following year. Management strategies to stimulate a 50-60 percent of the spurs to flower are needed.

Many Honeycrisp growers have observed leaves with a blotchy or mottled appearance that is first evident in mid-July. We related this disorder to cropload (Fig. 4). Trees with light or no crop always had more serious leaf mottling than heavy cropping trees. The severity of the disorder increased rapidly as cropload dropped below 5 fruits/cm² of TCA. It is not known if this disorder causes any deleterious effects on the tree or its longevity.

Fruit Maturation

Internal fruit ethylene concentration (IEC) measurements over the harvest period showed that ethylene in the fruit gradually rose as the fruits matured but that Honeycrisp does not produce high amounts of ethylene like McIntosh. At each harvest date in 2002, there was a consistent trend of higher ethylene associated with the higher cropload trees (Fig. 5). However, this relationship was quite weak and, in 2001, there was no statistical relationship between cropload and IEC. The higher IEC in fruit from heavy cropping trees indicates that they are slightly more mature than those from light cropping trees. This view was supported by the other harvest indices: a negative relationship between fruit firmness and cropload (Fig. 6), increased starch ratings associated with higher croploads (Fig. 7), and lower total acidity in the heavy cropping trees (Fig. 8).

In contrast, soluble solids content was lower in fruit from heavy cropping trees than that from light cropping trees (Fig. 9). Typically soluble solids increase during fruit ripening. However, the effect of high croploads depressing fruit soluble solids is probably not related to delayed ripening but rather to a shortage of carbohydrate supply for the developing fruits on the heavy cropping trees. In this case, soluble solids content is not a good indicator of fruit ripening.

Similarly, measurements of fruit red color indicated that the heavy cropping trees had poorer fruit color than light cropping trees (Fig. 10). This was the most striking visual evidence of the cropload effect on fruit ripening. At harvest we observed that fruit from trees which had in excess of 10 fruits/cm² of TCA just did not develop commercially acceptable fruit color. The curvilinear relationship in Figure 10 indicates that fruit color is reduced slowly as cropload is increased up to about 6 fruits/cm² of TCA. However, the curve becomes very steep at the higher croploads. The lack of characteristic fruit color development at high croploads is probably indicative of a shortage of resources rather than delayed maturity of the fruit.

In summary, fruit from heavy cropping trees appeared to be more

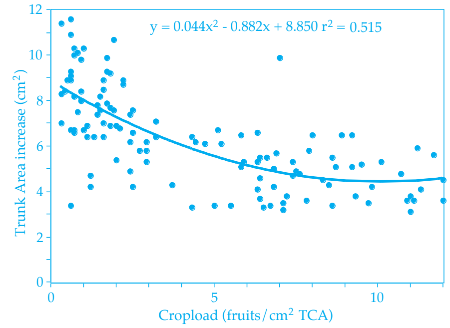


Figure 1. Effect of cropload on trunk cross sectional area increase of Honeycrisp/M.9 in the fourth year (2001).

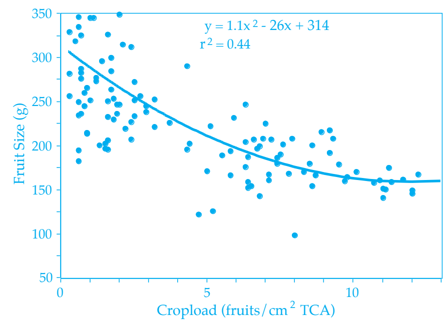


Figure 2. Effect of cropload on fruit size of Honeycrisp/M.9 in the fourth year (2001).

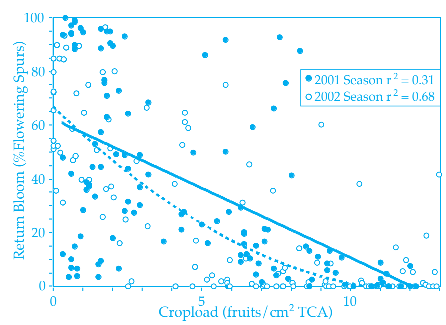


Figure 3. Effect of cropload on return bloom of Honeycrisp/M.9 in the fourth and fifth years (2001 and 2002).

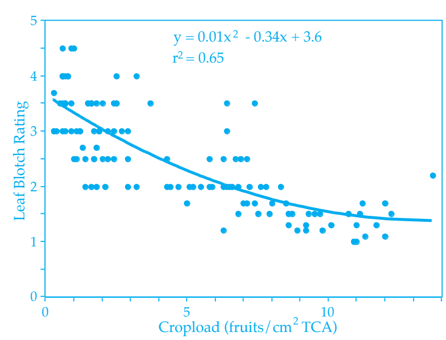


Figure 4. Effect of cropload on leaf blotch symptoms of Honeycrisp/M.9 in the fourth year (2001). Rating scale: 1=no symptoms, 2=25% of shoots show symptoms, 3=50% of shoots show symptoms, 4=75% of shoots show symptoms, 5=100% of shoots show symptoms.

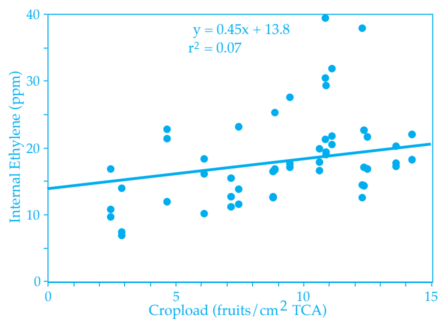


Figure 5. Effect of cropload on internal fruit ethylene concentration of Honeycrisp/M.9 in the fifth year (2002).

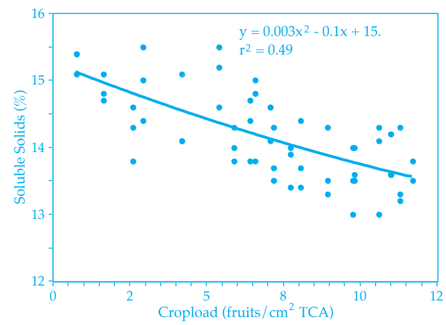


Figure 9. Effect of cropload on soluble solids content of Honeycrisp/M.9 in the fourth year (2001).

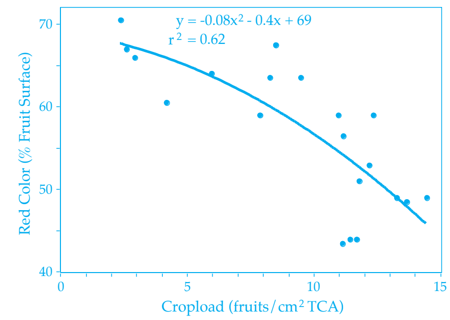


Figure 10. Effect of cropload on fruit red color of Honeycrisp/M.9 in the fifth year (2002).

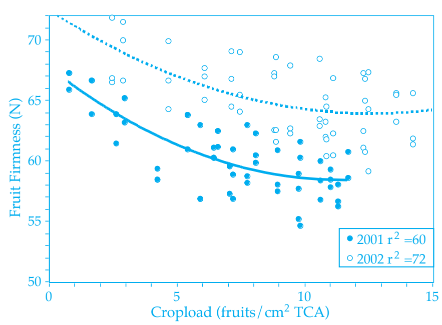


Figure 6. Effect of cropload on fruit firmness of Honeycrisp/M.9 in the fourth and fifth years (2001 and 2002).

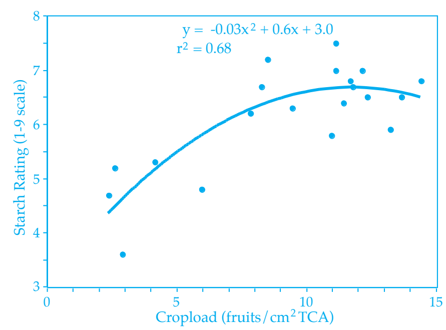


Figure 7. Effect of cropload on starch rating of Honeycrisp/M.9 in the fifth year (2002).

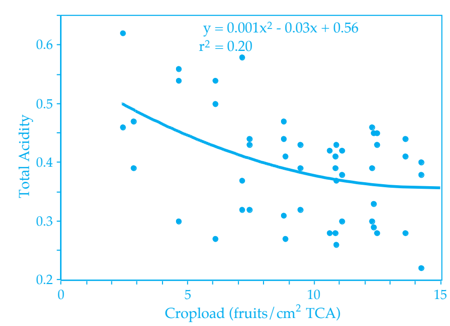


Figure 8. Effect of cropload on total acidity of Honeycrisp/M.9 in the fifth year (2002).

mature because they produced more ethylene, were softer, had lower acidity, and higher starch ratings. Additionally, the poorer fruit color and reduced sweetness of the fruit probably indicates lack of adequate resources to develop optimum quality. We did not objectively measure taste and juiciness, but subjective judgements indicate that the fruit from trees with croploads greater than 9-10 fruits/cm² of TCA were of very poor quality and would be less acceptable in the marketplace. From a fruit quality perspective, it would appear that croploads around 5 fruits/cm² of TCA are optimum, resulting in good fruit color and soluble solids and medium acidity.

Fruit Storage Disorders

Cropload also greatly affected storage quality of Honeycrisp apples. After storage for five months, fruit from trees with higher croploads were softer, but had lower incidences of bitterpit, senescent breakdown, rot and superficial scald (Table 1). Fruit from trees with higher croploads had greater soggy breakdown, but not soft scald. The poorer fruit firmness and quality from the high cropload tress at harvest resulted in poorer firmness after storage but lower susceptibility to fruit storage disorders.

Harvest date influenced fruit firmness and many of the storage disorders (Table 1). Firmness was greatest with the earliest harvest date, however, bitter pit

TABLE 1

Effect of cropload, storage temperature and harvest date on fruit quality after 5 months of air storage at 33°F or 38°F of Honeycrisp apples from four-year-old Honeycrisp/M.9 (2001).

		Firmness (lb)	Bitter pit	Senescent Breakdown	Rot	Soggy breakdown	Soft Scald	Superficial Scald
Regressions with Cropload		Negative**	Negative**	Negative*	Negative *	Positive *	NS	Negative *
Harvest Date								
	Sept. 11	13.7	5	1	1	4	6	7
	Sept. 18	13.3	3	4	2	9	16	2
	Sept. 25	12.9	1	2	12	7	14	2
Statistical significance of harvest date		**	**	NS	**	**	**	**
Storage Temperature (°F)	33	13.2	1	1	4	12	17.0	8
	38	13.3	5	4	6	0.4	7.2	0
Statistical Significance of storage temperature		NS	**	**	**	**	**	**

NS=Means were not significantly different, *=Means were significantly different, **= Means were highly significantly different.

was also greater at the earlier harvest date. Fruit rot, soggy breakdown, and soft scald were increased by the later harvest.

Storage temperature did not have a significant influence on fruit firmness but did influence storage disorders (Table 1). The warmer storage atmosphere resulted in more bitterpit, more senescent breakdown, and more rot but lower incidences of soggy breakdown, soft scald and superficial scald.

Conclusions

The major effects of excessive cropload with Honeycrisp are reduced flowering the following year and reduced fruit size. In addition, tree growth is sensitive to excessive croploads. Of particular importance for this variety may also be the negative impact of excessive croploads on fruit quality maturation and storage. Croploads above 10 fruits/cm^2 of TCA resulted in poor size, poor color and poor flavor which did not improve in storage, although they tended to have the least storage disorders. Even moderate croploads of 7-8 fruits/cm^2 of TCA resulted in disappointing return bloom and mediocre fruit quality. It appears that for optimum quality and annual cropping, relatively low croploads of 4-5 fruits/cm^2 of TCA will be necessary. This will require precise chemical thinning followed by accurate hand thinning.

Precise management of Honeycrips is a necessity from the production standpoint to avoid biennial bearing, and from the marketing perspective to continue to provide the consumer with an extremely high quality apple that will result in an outstanding eating experience.

Acknowledgements

We thank Jackie Nock, John Reynolds, Karen Scott, Elizabeth Brinck and Jason Osborne for excellent technical assistance in these trials.

Terence Robinson is a research and extension professor in the Dept. of Horticultural Sciences who specializes in canopy and cropload management strategies. Christopher Watkins is a research and extension professor who leads Cornell's postharvest research and extension program in fruit crops.

Managing Diseases and Arthropod Pests on Honeycrisp

Dave Rosenberger

Dept. of Plant Pathology, Hudson Valley Laboratory, Highland, NY

Early-season pest control on Honeycrisp is relatively straightforward, but controlling pests during summer and diseases after harvest can be more challenging. Honeycrisp will almost certainly require more care during late summer and harvest than most traditional commercial varieties.

Managing seasonal diseases and arthropod pests on Honeycrisp is somewhat analogous to raising a placid child who becomes rebellious as (s)he matures. Early-season pest control on Honeycrisp is relatively straightforward, but controlling pests during summer and diseases after harvest can be more challenging.

Honeycrisp was included in the 1995 uniform plantings established by participants in the NE-183 project (Rosenberger, 2003). Detailed data on disease susceptibility of cultivars in these plantings were collected in Michigan, Virginia, West Virginia, Connecticut, and New York. When the 23 cultivars in the planting were ranked from most susceptible to least susceptible, Honeycrisp usually appeared near the middle of the rankings (Table 1). Thus, a modest early-season fungicide program should provide adequate control of the common early-season diseases. McIntosh growers who switch to Honeycrisp may be pleasantly surprised by how easily scab can be controlled on this new cultivar. Controlling mildew should be

TABLE 1

Relative susceptibility of 'Honeycrisp' foliage and fruit to various plant pathogens and arthropod pests as determined from comparisons of cultivars in the NE-183 uniform plantings that were established in 1995.

Disease or arthropod pest	Year	Ranking: 1= most susceptible	Incidence on Honeycrisp (HC) compared to a susceptible commonly-grown cultivar	States that supplied data used in rankings	Literature citation
Apple scab (leaf infection)	1997	17th of 23	HC: 10%, Pioneer Mac: 44%	CT, MI, NY, VA, WV	Jones et al., 1998
Venturia inaequalis	1996	10th of 23	HC: 11%, Pioneer Mac 21%	CT, NY, VA, WV	Yoder et al., 1997
Powdery mildew	1997	14th of 23	HC: 27%, Ginger Gold 67%	NY, VA	Kiyomoto et al., 1998
Podosphaera leucotricha	1996	11th of 23	HC: 6%, Ginger Gold 18%	NY, VA, WV	Yoder et al., 1997
Cedar apple rust (leaf infection)	1997	15th of 23	HC: 7%, Golden Delic. 17%	CT, NY, VA, WV	Kiyomoto et al., 1998
*G. juniperi-virginianea**	1996	14th of 23	HC: 8%, Golden Delic. 17%	CT, NY, VA, WV	Yoder et al., 1997
White rot					
Botryosphaeria dothidea	2000-01	20th of 23	similar to Pioneer Mac	WV	Biggs & Miller, 2003
Bitter rot					
Colletotrichum acutatum	1998-99	12th of 14	similar to Ginger Gold	WV	Biggs & Miller, 2001
Codling moth					
Cydia pomonella	2001	20th of 24	similar to Pioneer Mac	NY	Straub, 2003
Plum curculio					
Conotyrachelus nenuphar	2001	18th of 24	similar to Braeburn	NY	Straub, 2003
Phytophagous mites**	1999	14th of 24	similar to Braeburn	NY	Straub, 2003
Obliquebanded leafroller					
Choristoneura resaceana	2001	5th of 24	similar to Ginger Gold	NY	Straub, 2003
Apple maggot					
Rhagoletis pomonella	2001	3rd of 24	similar to Braeburn	NY	Straub, 2003

* *Gymnosporangium juniperi-virginianae*

** European red mite (*Panonychus ulmi*) and two-spotted spider mite (*Tetranychus urtica*) no more difficult than controlling mildew on Cortland.

Fire blight can be a problem on Honeycrisp. Detailed ratings have not yet been compiled for fire blight infections in the NE-183 plantings, but initial reports suggest that Honeycrisp is quite susceptible to fire blight during the orchard establishment years. However, susceptibility to fire blight may decline rapidly as trees come into full production because Honeycrisp trees with a full crop have only low to moderate vegetative vigor. Fire blight rarely causes extensive damage to mature trees that are not vegetatively vigorous.

Casual observations from Honeycrisp trees at the Hudson Valley Lab suggest that Honeycrisp will prove exceptionally susceptible to black rot and white rot. When susceptibility to white rot was evaluated by inoculating wounded fruit in West Virginia, Honeycrisp was among the more resistant cultivars in the NE-183 trial (Table 1). However, those evaluations were made using wounded and uniformly-inoculated fruit, a method that does not take into account the high levels of inoculum that may be present in Honeycrisp trees. Honeycrisp trees retain thinned fruitlets just as Cortland trees do. On Cortland, these retained fruitlets often become infected with *Botryosphaeria* species, the fungi that cause black rot and white rot. The fruitlet mummies provide inoculum for infecting fruit as they mature in autumn (Fig. 2). Because Honeycrisp retains thinned fruitlets, Honeycrisp fruit will be exposed to higher doses of inoculum than fruit from cultivars that do not retain thinned fruitlets.

Black rot and white rot occur more frequently in warmer climates such as the Hudson Valley than in colder climates such as the Champlain Valley and New England. Black rot and white rot rarely cause decays in green fruit. Where cool conditions prevail at the time of fruit ripening, large decays are unlikely to develop prior to harvest. However, pinpoint decay lesions and quiescent infections that go unnoticed at harvest may develop into larger decays after harvest. Development of black rot and white rot after harvest may be more problematic if cooling after harvest is delayed so as to reduce susceptibility to chilling injury and soft scald. Long-term storage at 38°F may also allow more development of black rot and white rot than would occur if fruit were held at a colder storage temperature.

Effective fungicides applied after petal fall can reduce *Botryosphaeria* infections in retained fruitlets, and late summer sprays can protect maturing fruit. The benzimidazoles, captan, and the strobilurin fungicides are all reasonably effective for controlling black rot and white rot so long as fungicide coverage is renewed after rains and maintained until harvest.

Figure 1: Honeycrisp fruit at harvest show a fruitlet mummy (arrow) that provided inoculum both for the large decay seen on the left and for the smaller lesion in the center of the apple on the right.

Growers producing and storing Honeycrisp have reported that this variety is especially susceptible to postharvest blue mold decay caused by *Penicillium expansum*. The tender skin and stiff stems of Honeycrisp fruit contributed to a high incidence of stem punctures. When fruit with stem punctures are exposed to water-borne or air-borne spores of *P. expansum*, those fruit are likely to develop blue mold decay. The problem can be especially severe because no effective postharvest fungicides are currently available for controlling blue mold. Good sanitation is the only approach for minimizing losses to blue mold. Several new fungicides that control postharvest decays may become available within the next several years, but, until then, special care should be taken to keep Honeycrisp fruit away from bins and storage areas that are contaminated with *P. expansum*. Honeycrisp fruit should not be run through a postharvest drench treatment because recycling drench water redistributes spores of *P. expansum* to wounds. Postharvest drenching to control *P. expansum* may become feasible again if new postharvest fungicides are registered in the future.

To summarize, late summer sprays will probably prove more critical for managing Honeycrisp than they are for most other cultivars. Effective fungicide protection will be needed throughout July and August to protect fruit from infection by pathogens that cause summer fruit decays. Calcium sprays will be needed to control bitter pit. Protection against apple maggot will also be critical during late summer. Although Honeycrisp is generally susceptible to a complex of arthropod pests (Table 1), the fruit appear to be highly attractive to oviposition by apple maggot. Protecting Honeycrisp from this particular pest may be more difficult when the trees are planted along border areas that are sources of pressure from apple maggot.

Careful harvesting and postharvest handling will be required to minimize losses to *P. expansum*. Registration of new postharvest fungicides within the next several years might make it easier to protect stem punctures from *P. expansum*, but Honeycrisp will almost certainly require more care during late summer and harvest than most traditional commercial varieties.

Literature Cited

Biggs, A. R. and S. S. Miller. 2001. Relative susceptibility of selected apple cultivars to *Colletotrichum acutatum*. Plant Disease 85:657-660.

Biggs, A. R. and S. S. Miller. 2003. Relative susceptibility of selected apple cultivars to *Botryosphaeria dothidea*. HortScience 38:400-403.

Jones, A. L., Biggs, A. R., Kiyomoto, R. K., McNew, R. W., Rosenberger, D. A, and Yoder, K. S. 1998. Susceptibility foliage and fruit of 23 apple cultivars in the NE-183 trial to apple scab. Biologic. Cult. Tests 13:35.

Kiyomoto, R. K., Biggs, A. R., Copes, W. E., McNew, R. W., Rosenberger, D. A, and Yoder, K. S. 1998. Susceptibility of foliage of 23 apple cultivars in the NE-183 trial to cedar-apple rust, powdery mildew, and leaf spots. Biologic. Cult. Tests 13:36-37.

Rosenberger, D. 2003. Susceptibility of new apple cultivars to common apple diseases. N.Y. Fruit Quarterly 11(2):17-22.

Rosenberger, D., J. Schupp, C. Watkins, K Iungerman, S. Hoying, D. Straub, and L. Cheng. 2001. Honeycrisp: promising profit maker or just another problem child? NY Fruit Quarterly 9(3):9-13.

Straub, R. 2003. Susceptibility of new apple cultivars to various arthropod pests. N.Y. Fruit Quarterly 11(2):25-28.

Yoder, K. S, Biggs, A. R., Kiyomoto, R. K., McNew, R. W., and Rosenberger, D.A. 1997. Foliage susceptibility of 23 apple cultivars in the NE-183 trial to scab, powdery mildew, cedar-apple rust, and leaf spots, 1996. Biologic. Cult. Tests 12:42-43.

Acknowledgements

Thanks to Richard Straub for assistance in preparing information related to arthropod pests on Honeycrisp apples. This work was supported in part by Federal Formula Funds from the United States Department of Agriculture.

Dave Rosenberger is a professor of plant pathology at the Hudson Valley Lab where he specializes in diseases of fruits.

Managing Bitter Pit in Honeycrisp

Dave Rosenberger[1], Jim Schupp[2], Steve Hoying[2], Lailiang Cheng[3], and Chris Watkins[3]

[1]Hudson Valley Laboratory, Highland, NY,
[2]Lake Ontario Fruit Team, Lockport, NY,
[3]Dept. of Horticulture, Cornell University, Ithaca, NY.

This work was funded in part by grants from the New York Apple Research and Development Program and by Smith Lever funds from the Cooperative State Research, Education, and Extension Service, U.S. Department of Agriculture.

The susceptibility of Honeycrisp to bitter pit can limit pack-out and profitability for growers. Susceptibility of fruit to bitter pit is associated with low calcium content of the fruit. In this study, different foliar calcium sprays were tested for effectiveness in controlling bitter pit in Honeycrisp, and to determine if the effectiveness could be enhanced by applying Solubor, Flint, or Messenger with the calcium.

The positive attributes of Honeycrisp and various problems associated with this cultivar were reviewed in a previous article in *The New York Fruit Quarterly* (Rosenberger et al, 2001). As noted in that article, the susceptibility of Honeycrisp to bitter pit can limit pack-out and profitability.

Bitter pit is a physiological disorder that has been a persistent problem with cultivars such as Northern Spy, SpyGold, and York Imperial. It is a problem on cultivars such as Delicious and Cortland only when fruit of these cultivars are allowed to grow too large. Bitter pit is characterized by dark sunken lesions at or beneath the fruit surface. Pits may be present at harvest. More frequently, they become evident after the fruits have been placed in storage.

Susceptibility of fruit to bitter pit is associated with low calcium content of the fruit. 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 also aggravated by low soil pH and by drought.

In cultivars that are prone to this disorder, bitter pit has been managed by applying foliar sprays of calcium salts four to eight times during summer. Such spray regimes are bothersome: calcium solutions are corrosive to equipment; effectiveness for controlling bitter pit has been highly variable; and the sprays can be phytotoxic to apple foliage, especially when calcium is applied at high concentrations, high temperatures, or in combination with other pesticides. Several new chemistries that reportedly affect plant physiology and stress responses have recently been registered for application to apples. Strobilurin fungicides affect many different aspects of plant metabolism, and Flint fungicide has been reported to reduce bitter pit incidence in some apple trials. Harpin protein, a product derived from a bacterium that has been tested as a biocontrol for fire blight, induces systemic acquired resistance in plants and triggers changes in plant biochemistry that are similar to those used by plants challenged by environmental stresses. Harpin has also been reported to increase nutrient uptake in plants. Harpin protein is being marketed as 'Messenger' by Eden Biosciences.

The objectives of the experiments reported here were to determine if foliar calcium sprays would prove effective for controlling bitter pit on Honeycrisp, and to determine if the effectiveness of calcium sprays could be enhanced by applying Solubor, Flint, or Messenger with the calcium.

Materials and Methods

Field trials were conducted for two consecutive years in commercial plantings of Honeycrisp located in the Hudson Valley and Lake Ontario fruit growing regions of New York State. Methods for the first year of trials in the Hudson Valley were included in an earlier report (Rosenberger et al., 2001) and will not be repeated here. The Hudson Valley experiment in 2001 was conducted using seventh-leaf trees on M.26 rootstock near Milton, NY. In the Lake Ontario fruit region, treatments in 2000 were applied to fifth-leaf trees on M.9 rootstock growing near Lyons, NY. Treatments in 2001 were applied to third-leaf trees on M.9 rootstock near Lyndonville, NY. In all of the trials, the growers applied routine fungicide, insecticide, and nutritional programs, but did not include any strobilurin fungicide sprays or foliar calcium sprays in their programs.

A randomized-block design was used for all field trials. In the Hudson Valley, trees were placed into replicates based on bloom density as assessed when trees were slightly past king bloom. Trees with similar blossom densities were used for comparisons within replicates because fruit load is known to influence susceptibility to bitter pit. Single-tree plots were used in the Hudson Valley trials. Two tree plots were used at Lyons in 2000 and five-tree plots were used at

Lyndonville in 2001. Treatments were replicated five times in all locations.

Treatments at Lyons and Lyndonville were applied with a Solo 425 backpack sprayer whereas a high-pressure pump and handgun were used to spray trees at Milton. In all locations, spray volume was determined by spraying trees until the spray solution began to drip from the leaves. Fruit were harvested and evaluated to determine how field treatments affected fruit maturity, fruit mineral content, and the incidence of bitter pit at harvest and after cold storage.

Milton Trial 2001: Trees in test plots were treated during summer with CorClear Calcium Chloride (97% $CaCl_2$) either alone or in combinations with other products that might affect development of bitter pit (Table 1). In addition to foliar calcium sprays, other products tested as foliar sprays during summer included Flint fungicide, Solubor (20.5% boron), and Messenger (3% harpin protein). A factorial design was used to compare five treatments (control, Flint, Solubor, Messenger, and a Flint plus Solubor plus Messenger combination) applied either alone or in conjunction with calcium chloride sprays (Table 1). CorClear was applied six times at roughly bi-weekly intervals. Messenger was applied five times on alternate weeks to avoid any possibility that the harpin protein would be broken down by other products in a tank mix. Solubor was applied three times to the replicated plots. Flint was applied twice in August, approximately 28 and 14 days before harvest. The trees reached petal fall on 12 May. Treatments were superimposed over the grower's normal spray program which included Solubor applied at 2.4 lb/A on 2, 22, and 29 May and Epsom salts at 21 lb/A on 29 May, 29 lb/A on 6 & 26 June, and 14 lb/A on 15 June and 9 July.

A random sample of 90 fruit was harvested from each tree on 29 August, and fruit remaining on the tree after sampling were counted. Mature fruit that had dropped to the ground prior to 29 August were also counted. Trunk diameters were measured at 30 cm above the soil line on 30 October to allow calculation of fruit numbers per square cm of trunk cross-sectional area.

Ten fruit were used to assess fruit firmness and starch content immediately after harvest. Starch content was assessed using the index developed by Blanpied and Silsby (1992). Eighty fruit were evaluated for bitter pit. The 80 fruit were then divided into two boxes of 40 fruit each. One box was dipped for 30 seconds in a solution containing CorClear Calcium Chloride at 2.5 lb/100 gal. All fruit in this experiment were held at 69°F until 31 Aug, and all fruit were then moved to cold storage at 37°F after the $CaCl_2$ postharvest treatments had been completed. Fruit were assessed for

TABLE 1

Products applied and treatment dates at Milton 2001.

Materials and rate of	May			June		July			Aug		
formulated product per 100 gal	**16**	**24**	**30**	**13**	**20**	**11**	**17**	**24**	**1**	**8**	**14**
1. Grower standard (no additional sprays)											
2. Flint 50WDG 1 oz									X		X
3. Solubor 1 lb			X		X		X				
4. Messenger 4.5 oz*		X		X		X		X		X	
5. Messenger 4.5 oz*		X		X		X		X		X	
+ Solubor 1 lb			X		X		X				
+ Flint 50 WDG 1 oz									X		X
Trts 6-10: same as above but add:											
CorClear $CaCl_2$ (94-97%) 1 lb	X		X		X						
CorClear $CaCl_2$ 2 lb							X		X		X

*Messenger was always applied alone, never in tank mixes.
**$CaCl_2$ sprays were tank mixed with other products applied on the same dates.

TABLE 2

Foliar treatments applied to 'Honeycrisp' trees at Lyons and Lyndonville, NY, and effects of treatments on incidence of bitter pit after 90 days of cold storage.

Product	% elemental calcium in the formulation	Application rate/ 100 gal	seasonal total (lb) of elemental calcium applied per 100 gal TRV	% fruit with bitter pit after storage
Lyons, 2000				
Control	....	...	....	42.6
Calcium Chloride 405 Concentrate (33% $CaCl_2$)	12	1 gal/2 gal	8.78	19.0
Stop It Liquid Calcium Chloride (33% $CaCl_2$)	12	1 gal/2 gal	8.78	24.9
Foli Cal (Manitol Chelated Calcium)	10	1 gal/2 gal	7.32	37.8
Quelant—Ca (Calcium and Amino Acids)	8	1 qt/2 qt	1.32	16.1
Metalosate Calcium (Liquid Amino Acid Chelate)	6	1 qt/2 qt	0.90	33.4
Flint fungicide	....	1.0 oz	.....	33.8
Lyndonville, 2001				
Control	....	...	....	27.3 c
Calcium Chloride Flake (77-80% $CaCl_2$)	28	3 lb/6 lb	6.76	2.7 a
Calcium Chloride 405 Concentrate (33% $CaCl_2$)	12	1 qt/2 qt	2.93	2.4 a
Stop It Liquid Calcium Chloride (33% $CaCl_2$)	12	1 qt/2 qt	2.93	4.4 a
Nortrace 10% Calcium (10% Ca, 8% N)	10	2 qt	3.54	5.6 a
Citraplex (20% Ca)	20	2 qt	2.64	10.0 ab
Nortrace Norplex 6 (6% Ca)	6	2 qt	1.82	17.6 ab
Nortrace Norplex 6 plus Boron (6% Ca, 0.5% B)	6	2 qt	1.82	16.4 ab
Flint fungicide		....1.0 oz		...19.4 bc

TABLE 3

Effects of 2001 treatments at Milton on the incidence of bitter pit and on harvest maturity indices for 'Honeycrisp' fruit.

	% fruit with bitter pit at harvest		Maturity ratings at harvest	
Spray programs	**29 Aug**	**2 Nov**	**Starch**	**P-test (lb)**
No $CaCl_2$ sprays				
No subsidiary sprays	8.6 bc*	80.3 c	3.3 abc*	17.1 bc
Flint 50W	12.6 c	84.2 c	2.9 ab	18.2 d
Solubor	6.6 bc	60.5 b	3.7 bc	17.2 bcd
Messenger	6.7 bc	86.2 c	2.7 a	17.2 bcd
Flint + Solubor + Messenger	11.7 c	85.8 c	3.9 c	17.6 cd
With $CaCl_2$ sprays				
No subsidiary sprays	0.2 a	37.2 a	3.1 ab	16.5 abc
Flint 50W	1.0 a	41.0 a	3.3 abc	15.6 a
Solubor	3.0 ab	44.0 a	4.1 c	16.3 ab
Messenger	2.8 ab	42.8 a	2.8 a	16.3 abc
Flint + Solubor + Messenger	3.9 ab	44.0 a	3.7 bc	16.9 bc
P values for interaction between $CaCl_2$ and subsidiary treatments	0.337	0.006	0.733	0.034
Over-all effects for $CaCl_2$ treatment				
No $CaCl_2$ treatments	9.2 b	79.4 b	3.3	17.4 b
With $CaCl_2$ treatments	2.2 a	41.8 a	3.4	16.3 a
P values	0.001	<0.001	0.720	<0.001
Over-all effects for subsidiary treatments				
No subsidiary sprays	4.3	58.8 ab	3.2 a	16.8
Flint 50W	6.8	62.6 b	3.1 a	16.9
Solubor	4.8	52.3 a	3.9 b	16.8
Messenger	4.7	64.5 b	2.8 a	16.8
Flint + Solubor + Messenger	7.8	64.9 b	3.8 b	17.1
P values	0.354	0.024	0.001	0.817

*Letter separations were determined using Fisher's protected LSD (P=0.05) applied to the results of two-way analyses wherein trees with or without calcium foliar sprays were subjected to five subsidiary treatments. Each treatment combination was replicated five times.

incidence of bitter pit after 63 days of cold storage. A 15-fruit sub-sample was collected from each of the 100 experimental lots (20 field treatments X five replications X two $CaCl_2$ postharvest treatments), and the sub-samples were analyzed for fruit mineral content at the Cornell Nutrient Analysis Laboratory.

Lyons 2000: Five different calcium formulations were compared using the rates recommended by the product manufacturers (Table 2). Flint fungicide was included in a single treatment. Treatment concentrations were calculated by assuming that the recommended rate of product per acre could be mixed in 100 gal of water and applied to drip on small trees. The calculated tree-row volume for this block was 102 gallons/A. Calcium treatments were applied on 21 June, 12 July, 3 and 21 August 2000, but Flint was applied only on the two application dates in August. Fruit were harvested on 18 September. Fruit firmness and mineral composition of fruit were measured as described for the Hudson Valley trial except that only 10 fruit per plot were included in the sub-samples. Fruit were held in cold storage for approximately three months and were then re-evaluated for incidence of bitter pit.

Lyndonville 2001: Seven different calcium formulations and Flint fungicide were compared using the rates suggested by the product manufacturers (Table 2). Treatments were applied on 28 June, 14 and 20 July, and 3, 17, 23 August. All calcium treatments were applied with the adjuvant LI700 used at one pint per 100 gal of dilute spray. Controls were unsprayed. Mature fruit were harvested on 15 September and held in cold storage for 90 days before final evaluation.

Results

Year 2000 Trials: Calcium treatments did not provide statistically significant reductions in bitter pit in the trial at Lyons where trees had a very light crop. Of the 35 individual plots at Lyons, 15 plots did not have enough fruit to allow both mineral analysis and bitter pit analysis after storage, necessitating "missing data" entries for those plots in the mineral analysis. None of the treatments at Lyons resulted in significantly increased concentrations of calcium in fruit (P=0.21).

Milton, 2001: $CaCl_2$ applied six times during summer reduced the incidence of bitter pit by 76% and 47%, for ratings made at harvest and after 63 days of storage, respectively (Table 3, grand means for $CaCl_2$ treatment). Treatments involving Flint, Solubor, and Messenger had no effect on the incidence of bitter pit. The incidence of bitter pit increased dramatically during storage, but postharvest treatment with $CaCl_2$ had no affect on the development of bitter pit during storage. Therefore, the two samples per tree (with and without postharvest calcium treatment) were used as two independent observations for each tree in subsequent analyses of fruit from storage. Fruit from trees sprayed with $CaCl_2$ had significantly less bitter pit on all evaluation dates. However, after 63 days of storage, there was a significant interaction between the $CaCl_2$ and the supplemental treatments because Solubor suppressed bitter pit slightly in trees that received no $CaCl_2$ sprays but had less effect on trees that were sprayed with $CaCl_2$ (Table 3). Thus, the effects of $CaCl_2$ and Solubor were not additive.

TABLE 4

Effects of summer spray programs on productivity, fruit size and shoot growth.

Spray programs	Number of fruit per cm² of trunk cross-sectional area	Mean fruit weight (g)	Mean shoot growth (cm)
No $CaCl_2$ sprays			
No subsidiary sprays	3.61 abc	299 cd	32.1
Flint 50W	2.08 a	300 cd	26.5
Solubor	4.25 bcd	294 cd	21.8
Messenger	3.19 ab	313 d	30.4
Flint, Solubor, Messenger	2.38 a	322 d	29.8
With $CaCl_2$ sprays			
No subsidiary sprays	6.10 e	240 a	27.0
Flint 50W	5.78 de	256 ab	26.6
Solubor	3.89 abcd	275 bc	26.9
Messenger	5.38 cde	256 ab	29.0
Flint, Solubor, Messenger	3.69 abc	269 abc	29.1
P values for interaction between $CaCl_2$ and subsidiary treatments	0.039	0.408	0.505
Grand means for $CaCl_2$ treatment			
No $CaCl_2$ treatments	3.10 a	305 b	28.1
With $CaCl_2$ treatments	4.97 b	259 a	27.7
P values		<0.001	0.825
Grand means for subsidiary treatments			
No subsidiary treatment	4.85	269	29.6
Flint 50W	3.93	278	26.4
Solubor	4.07	284	24.7
Messenger	4.29	284	29.7
Flint, Solubor, Messenger	3.04	296	29.5
P values	0.092	0.214	0.238
Effects among replicates (blocks)			
Block I (full bloom, large trees)	2.34 a	331 d	31.1 cd
Block IV (light bloom large trees)	3.13 ab	274 b	35.0 d
Block V (light bloom small trees)	4.24 b	247 a	25.3 ab
Block II (full bloom, medium trees)	4.40 b	301 c	28.1 bc
Block III (full bloom, small trees)	6.07 c	258 ab	20.2 a
P-values for block effects	<0.001	<0.001	<0.001

*Letter separations were determined using Fisher's protected LSD (P=0.05) applied to the results of two-way analyses wherein trees with or without calcium foliar sprays were subjected to five subsidiary treatments. Each treatment combination was replicated five times.

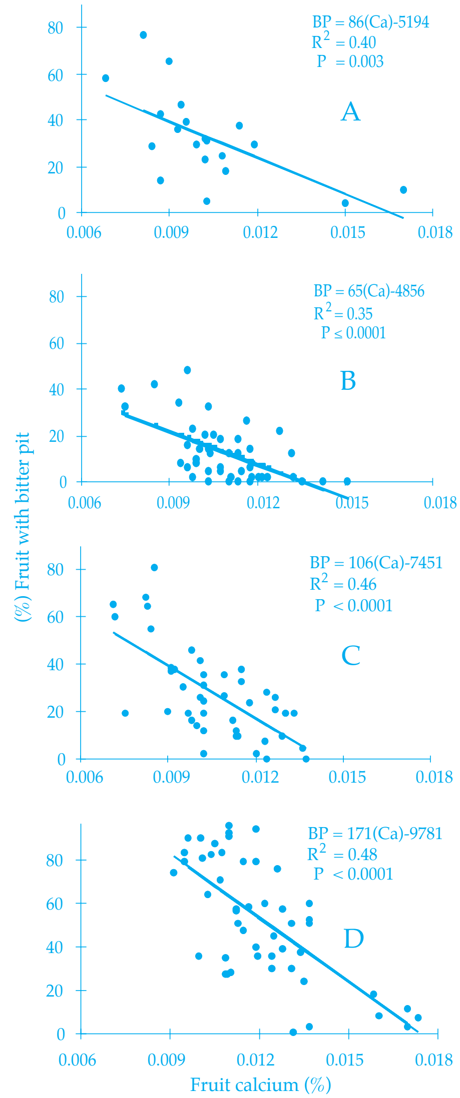


Fig. 1. Linear regressions showing effects of fruit calcium concentrations on incidence of bitter pit after cold storage for the experiments conducted at Lyons in 2000 (A), Lyndonville in 2001(B) and Milton in 2000 (C) and 2001 (D).

Fruit from trees sprayed with $CaCl_2$ were less firm at harvest than fruit from trees that received no $CaCl_2$ (Table 3). $CaCl_2$ did not affect the starch index, so the difference in firmness is not attributable to advanced maturity of fruit from trees sprayed with $CaCl_2$. Reduced fruit firmness in $CaCl_2$-treated trees is especially surprising because $CaCl_2$ treatment also resulted in increased fruit set and reduced fruit size (Table 4). Because Flint applied alone produced the firmest fruit whereas Flint applied with $CaCl_2$ produced the softest fruit, there was a statistically significant interaction effect between $CaCl_2$ treatment and the subsidiary treatments.

The mean fruit calcium content across all trees that received $CaCl_2$ sprays during summer was 200 ppm greater than for fruit from trees that did not receive calcium sprays during summer. Solubor treatments resulted in significant increases in fruit boron concentrations. Trees treated with $CaCl_2$ carried 5.0 fruit per square cm of trunk cross-sectional area compared to only 3.1 for trees that did not receive $CaCl_2$ (Table 4). There was a significant interaction between $CaCl_2$ sprays and Solubor sprays in their effects on crop load. Solubor treatment produced the highest crop load among trees not sprayed with $CaCl_2$ and the second lowest crop load among trees that were sprayed with $CaCl_2$.

Lyndonville, 2001: Control of bitter pit was directly related to the amount of calcium that was applied during the season regardless of the formulation of calcium that was used. In four treatments where trees received more than 2.9 lb of elemental calcium per acre, bitter pit was reduced by 79-91% compared to control trees whereas bitter pit was reduced by only 36-40% in two treatments where trees received only 1.8 lb / A of elemental calcium (Table 2). Flint did not provide any significant control of bitter pit in the Lyndonville trial.

In all four trials, there was a significant linear relationship between mean calcium content in fruit from individual trees and the incidence of bitter pit in fruit from those same trees (Fig. 1). Calcium concentrations in fruit accounted for 36 to 48% of the variability in incidence of bitter pit after cold storage. Calcium concentrations measured in fruit fell within the same range for Lyons, Lyndonville, and Milton 2000, but were somewhat higher for fruit from Milton in 2001. In the latter trial, tissue samples for mineral analyses were collected after fruit were removed from cold storage whereas tissue sample were collected at harvest for the other tree trials.

Discussion

The experimental design used for experiments reported here provided a severe test for controlling bitter pit. Treatments were applied to young, lightly cropping trees. Fruit were harvested at the very earliest stages of acceptable fruit maturity because the random samples had to be harvested before the first color-picking was done by the cooperating growers. The fruit used for bitter pit evaluations were randomly selected from throughout the tree canopy and were therefore even more immature than commercially-harvested fruit where only highly-colored fruit are removed on the first harvest. Cooling of harvested fruit from the 2001 Milton trial was delayed two days while fruit were being evaluated, and fruit were then stored at 37°F to avoid chilling injury (soft scald) that would have interfered with evaluations for bitter pit. Early harvest, delayed cooling and warmer storage temperatures can all favor development of bitter pit

$CaCl_2$ provided better control of bitter pit than any of the other materials evaluated in this study. In the Milton orchard, control was better in 2001 than in 2000 when lower concentrations of $CaCl_2$ were used and sprays were applied less often. The total amount of elemental calcium that was applied at Milton in 2000 was too low to control bitter pit on young trees of a bitter-pit susceptible cultivar such as Honeycrisp. However, the higher rates of calcium applied at Lyons in 2000 also failed to significantly reduce bitter pit. The latter result indicates that $CaCl_2$ sprays alone will not control bitter pit on lightly-cropping, immature Honeycrisp trees.

Activity of $CaCl_2$ was not enhanced by combining $CaCl_2$ with Flint, Solubor, or Messenger. Multiple applications of Solubor in Milton in 2000 resulted in earlier ripening but did not enhance the control of bitter pit. Results clearly show that $CaCl_2$ will provide better control of bitter pit than any of the other materials and that activity of $CaCl_2$ cannot be enhanced by adding the other products tested.

More research is needed to determine if $CaCl_2$ applied shortly after bloom will consistently enhance fruit set. The first $CaCl_2$ spray applied on 16 May preceded the thinning spray by four days, and there was only 0.01 inch of rain during that four-day interval. The $CaCl_2$ residues might have reduced activity or uptake of the carbaryl and NAA applied on 20 May to adjust crop load, or the $CaCl_2$ might have directly affected the physiology of the trees during the period of fruit set. The $CaCl_2$ effect on crop load in this experiment made it impossible to determine how much of the $CaCl_2$-induced reduction in bitter pit in the Milton 2001 trial is attributable to physiological effects of the calcium within the fruit and how much is due to the reduction in fruit size that that resulted from increased fruit set where calcium was applied.

Acknowledgments

The authors thank Fritz Meyer, Cathy Ahlers, Keri VanCamp, Jackie Nock, Jay Osborne, Richard Christiana, and Albert Woelfersheim for technical assistance and the cooperating growers for contributing fruit for postharvest experiments and allowing experiments to be conducted in their plantings.

Literature Cited

Blanpied, G.D., and K.J. Silsby. 1992. Predicting harvest date windows for apples. Cornell Cooperative Ext. Information Bull 221. 12 pages.

Rosenberger, D., J. Schupp, C. Watkins, K Iungerman, S. Hoying, D. Straub, and L. Cheng. 2001. Honeycrisp: promising profit maker or just another problem child? NY Fruit Quarterly 9(3):9-13.

Dave Rosenberger is a professor of plant pathology at the Hudson Valley Lab who specializes in diseases of fruits. Jim Schupp is a research and extension professor at Hudson Valley Lab who specializes in the use of plant growth regulators in fruit crops. Steve Hoying is an area extension educator with the Lake Ontario Fruit Team. Lailiang Cheng is an assistant professor in the department of horticulture in Ithaca who specializes in tree fruit nutrition. Chris Watkins leads Cornell's postharvest research and extension in fruit crops.

Harvest Date Effects on Maturity, Quality and Storage Disorders of Honeycrisp Apples from the Champlain Valley

Chris B. Watkins[1], Jackie F. Nock[1] and Kevin A. Iungerman[2]

[1]Department of Horticulture, Cornell University, Ithaca, NY
[2]Cornell Cooperative Extension, Ballston Spa, NY

Initial enthusiasm for Honeycrisp has been tempered by concern about high incidences of bitter pit, soft scald, soggy breakdown and off-flavors associated with fermentation. This project determined that late harvest and low storage temperatures (33°F) increased the incidence of storage disorders. We recommend that fruit should be harvested as soon as appropriate color and flavor have been obtained. Ideal harvest would be about the second or third week of September in the Champlain region.

The Honeycrisp apple has been planted extensively in New York State, especially in Western New York and the Champlain Valley. The cultivar has outstanding flavor characteristics, and has been reported to remain crisp during air storage for nine months. The unusual crispness can be attributed to maintenance of high turgor potential and cell wall integrity. The industry's initial enthusiasm for Honeycrisp, however, has been tempered by concern about high incidences of bitter pit, soft scald and soggy breakdown in the fruit. Bitter pit is a calcium-related disorder that can occur on the tree or develop during storage, but can be managed by management practices such as calcium spray application. In contrast, the occurrence of soft scald and soggy breakdown (and off-flavors associated with fermentation) in the fruit has been erratic in the marketplace, resulting in loss of confidence in the cultivar.

The symptoms of soft scald (synonym=deep scald) are the development of sharply defined brown lesions on the skin of the apple (Fig. 1), and can extend into the flesh. Susceptible cultivars include Fuji, Jonathan, McIntosh, Delicious and Golden Delicious. Soggy breakdown is an internal disorder, which in the worst cases results in a complete ring of soft, brown, spongy tissue that is often associated with soft scald symptoms (Fig. 2). Soggy breakdown may be present without soft scald, however, resulting in a nasty surprise for the unsuspecting consumer who bites into an affected Honeycrisp (fig. 3).

Major disposing factors that have been implicated in the occurrence of soft scald in several apple cultivars are over-maturity of fruit at harvest, and pre-harvest factors such as climate (dull, cool, wet summers), light crops, large fruit, and vigorous soils. A recent study of fruit from five growing locations in the United States indicated that susceptibility of Honeycrisp fruit to soft scald was affected by growing location, was usually greater in the second of two harvest dates, but was not associated with internal ethylene concentrations (IEC) in the fruit. However, no detailed information exists on harvest indices and the relationship of these to storage performance for Honeycrisp.

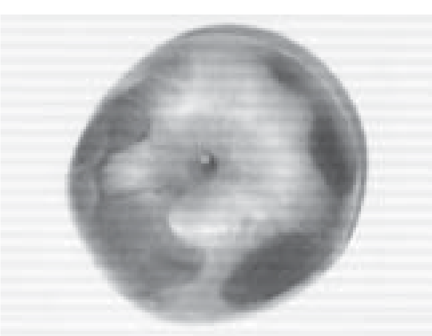


Figure 1. Soft scald on Honeycrisp.

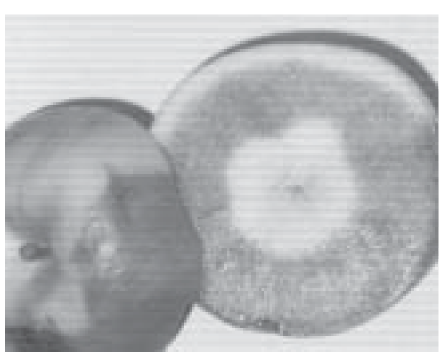


Figure 2. Soft scald and soggy breakdown of Honeycrisp.

Figure 3. Soggy breakdown of Honeycrisp—internal symptoms only with no external symptoms.

The objective of the present study was to investigate harvest date effects on quality, and storage temperature relationships with fruit susceptibility to soft scald and soggy breakdown.

Materials and Methods

In the 2000 harvest season, three orchard blocks were chosen in the Champlain region. These trees ranged from 3- to 5-years-old and were grafted on M.26 (blocks 1 and 2) or Bud.9 (block 3). Fruit were harvested from a minimum of 10 trees in each block on September 14, 21, and 28. The most commercially mature fruit were harvested on each occasion as judged by blush area, which usually was greater than 80 percent. In the 2001 harvest season, two orchard blocks were used for the experiments. Harvest dates were September 10, 17, 24, and October 1.

At each harvest, two replicate samples of 10 fruit were used for assessment of fruit maturity and quality. IEC, starch index, firmness, percent blush and soluble solids concentration (SSC) were measured in 2000 and 2001. Titratable acidity was measured only in 2000.

A further sample of 50-80 fruit was harvested, placed into perforated plastic bags, and stored on the day of harvest at 33°F or 37°F (2000), and 33°F, 38°F and 42°F (2001), for 12 weeks (2000) and 16 weeks (2001). Fruit quality after storage was assessed on a 10-fruit sub-sample after further 1 or 7 day storage at 68°F.

Results

Fruit were harvested on three occasions from three orchard blocks in the Champlain region in 2000, and stored at 33°F or 37°F. On the first harvest date (Sept. 14), IEC were high in two of the three orchards, being highest in orchard block 1 (Table 1). However, by Sept. 21, IEC did not increase significantly in orchard block 1, and increased only slightly in the other orchard blocks. On the last sampling date, the IEC of fruit from all blocks decreased rather than showing an autocatalytic rise that is typical of most other varieties. The starch index increased over time, but significant differences among orchard blocks were not detected for the second and third harvest dates. Firmness decreased over time, although there were differences in firmness among fruit from the three orchard blocks. SSC was not affected by harvest date, but varied by orchard block. Titratable acidity decreased over time, but the higher acidity of fruit from orchard block 1 compared with the other fruit was not consistently significant.

TABLE 1

Internal ethylene concentrations (IEC), starch index, firmness, soluble solids content (SSC) and titratable acidity in Honeycrisp apples harvested in the Champlain Valley, New York, on September 14, 21 and 28, 2000.

Harvest date (2000)	Orchard block	IEC (ppm)	Starch Index (1-8)	Firmness (lb)	SSC (%)	Titratable acidity (% malic acid)
Sept. 14	1	24.4	5.7	14.9	13.1	0.57
	2	0.4	4.6	13.7	11.0	0.41
	3	3.0	4.8	15.5	11.7	0.44
	Average	9.3	5.0	14.7	11.9	0.47
Sept. 21	1	29.2	6.0	14.6	12.6	0.42
	2	13.8	5.5	13.3	11.5	0.33
	3	12.4	5.9	14.5	11.8	0.40
	Average	18.5	5.8	14.1	11.9	0.38
Sept. 28	1	1.9	6.8	13.6	12.9	0.38
	2	7.1	7.2	12.3	11.3	0.27
	3	3.6	6.7	13.7	12.6	0.33
	Average	4.2	6.9	13.2	12.3	0.33
Significance						
Harvest date (H)		***	***	***	NS	***
Orchard block (O)		***	*	***	***	***
H x O		***	**	NS	NS	*

TABLE 2

Incidences of soft scald, soggy breakdown, bitter pit, decay and greasiness of Honeycrisp apples harvested in the Champlain Valley, New York, on September 14, 21 and 28, 2000 and stored in air at 33°F or 37°F for 12 weeks. Fruit (n = 50-80) were evaluated after a further 7 d at 68°F.

Harvest date (2000)	Orchard block	Soft scald (%)		Soggy breakdown (%)		Bitter pit (%)		Decay (%)		Greasiness (%)	
		33°F	37°F	33°F	37°F	33°F	37°F	33°F	37°F	33°F	37°F
Sept. 14	1	12	3	18	3	15	13	0	10	0	55
	2	3	0	3	0	0	0	0	0	5	44
	3	0	0	0	0	6	0	0	0	10	57
	Average	5	1	7	1	7	4	0	3	5	52
Sept. 21	1	52	0	52	0	33	54	7	5	56	82
	2	26	0	33	0	9	13	0	0	20	56
	3	58	3	64	3	8	8	0	0	25	53
	Average	45	1	49	1	17	25	2	3	34	64
Sept. 28	1	97	42	97	42	nd[z]	nd	nd	nd	nd	nd
	2	78	48	78	48	nd	nd	nd	nd	nd	nd
	3	70	28	70	28	nd	nd	nd	nd	nd	nd
	Average	82	39	82	39						
Significance											
Harvest date (H)		***		***		NS		NS		*	
Temperature (T)		***		***		NS		NS		***	
H x T		**		**		NS		NS		NS	

[z]nd Non detectable because of high soft scald incidence. ANOVA for harvest date and temperature performed only on Sept. 14 and Sept. 21 harvest dates.

The incidences of soft scald and soggy breakdown were affected by harvest date and storage temperature (Table 2). Because within orchard block replication was not used, it is not possible to determine the significance of among-block differences. Nevertheless, the incidence of both disorders increased markedly with advancing harvest date; overall incidence at 33°F was 5 to 7 percent on Sept. 14 compared with 82 percent on Sept. 28. However, incidence of the disorders in fruit harvested on Sept. 21 increased only at 33°F. Even at the Sept. 28 harvest, the increased incidence, while averaging 39 percent, was lower at 37°F than at 33°F. Bitter pit and decay incidences were not affected by harvest date or temperature (although fruit could not be assessed on Sept. 28 because of the high soft scald and soggy breakdown incidences). The percentage of greasy fruit was higher at the Sept. 21 harvest

TABLE 3

Firmness, soluble solids content (SSC), and titratable acidity of Honeycrisp apples harvested in the Champlain Valley, New York, on September 14, 21 and 28, 2000, and stored at 33ºF or 37ºF for 12 weeks plus 7 d at 68ºF.

Main effects		Firmness (lb)	Soluble solids (%)	Titratable acidity (% malic acid)
Harvest date	Sept. 14	14.3	12.3	0.30
	Sept. 21	13.6	12.4	0.28
	Sept. 28	12.9	12.1	0.24
Significance		***	*NS*	**
Temperature	33ºF	13.7	12.4	0.28
	37ºF	13.6	12.1	0.26
Significance		NS	NS	NS
Shelf life	1 d	13.5	12.4	0.29
	7 d	13.7	12.8	0.25
Significance		NS	NS	**

TABLE 4

Incidences of soft scald, soggy breakdown, bitter pit, and decay of Honeycrisp apples harvested in the Champlain Valley, New York, on September 10, 17, 24 and October 1, 2001 and stored in air at 33ºF, 38ºF or 42ºF for 16 weeks. Fruit (n = 50-80) were evaluated after a further 7 days at 68ºF.

Harvest date (2001)	Temperature (ºF)	Soft scald (%)	Soggy breakdown (%)	Bitter pit (%)	Decay (%)
Sept. 10	33	18	20	0	0
	38	0	0	8	0
	42	0	0	5	5
Sept. 17	33	47	57	0	3
	38	19	19	0	14
	42	1	1	1	39
Sept. 24	33	56	75	0	1
	38	11	12	0	1
	42	1	0	5	5
Oct. 1	33	71	86	0	0
	38	41	54	0	2
	42	0	0	0	34
Significance					
Harvest date (H)		**	***	**	NS
Temperature (T)		***	***	*	*
H x T		NS	NS	*	NS

TABLE 5

Effects of harvest date and storage temperature on quality attributes of Honeycrisp apples harvested in the Champlain Valley, NY, on September 10, 17, 24 and October 1, 2001 and stored in air at 33ºF, 38ºF or 42ºF for 16 weeks. Factors were rated on a scale of 0=low, to 100=high.

Harvest date (2002)	Appearance	Texture	Flavor	Overall acceptability
Sept 10	50	61	52	44
Sept 17	56	56	45	42
Sept 24	69	62	52	46
Oct 1	70	52	42	42
Significance	***	NS	NS	NS
Storage temperature (ºF)	**Appearance**	**Texture**	**Flavor**	**Overall acceptability**
33	59	59	33	25
38	63	62	53	55
42	62	53	38	41
Significance	NS	NS	***	***

than the Sept. 14 harvest, and at 37°F compared with 33°F.

Firmness and SSC were not affected by temperature or any other factor, and titratable acidity decreased with advancing harvest date and shelf life period (Table 3).

In 2001, fruit were harvested from two Champlain, NY, orchards and stored at 33°F, 38°F and 42°F for 16 weeks. At harvest, the overall IEC was barely different between orchards, averaging 9.6 and 7.5 ppm for orchard 1 and 2 respectively. The IEC differed among harvest dates averaging 7.3, 5.4, 12.4, and 9.1 ppm for harvests on Sept. 10, 17, 24, and Oct. 1, respectively. However, no interaction between orchard block and harvest date was detectable. The starch index was not affected by orchard block, but increased over harvest date averaging 5.8, 6.8, 7.5, and 7.7 units for harvests on Sept. 10, 17, 24, and Oct. 1, respectively. Differences in starch index between fruit from different orchards occurred only at harvest 1. Fruit softened with advancing harvest date, being 14.6, 13.6, 13.4, and 12.1 lb for harvests on Sept. 10, 17, 24, and Oct. 1, respectively. SSC was affected by orchard block but not by any other factor (data not shown).

After storage, soft scald and soggy breakdown occurred in fruit from the Sept. 10 harvest only at 33°F, but were present in fruit at both 33°F and 38°F from the other harvests (Table 4). While incidence of both disorders was lower at 38°F than at 33°F, disorder incidences were high even at 38°F. Fruit kept at 42°F had essentially no incidence of either disorder but did have higher, though variable, rot incidence. Bitter pit incidence was affected by harvest date and storage temperature, but not in a consistent fashion.

Only fruit firmness was assessed in 2001. No effect of storage temperature was detected (data not shown), although firmness declined with advancing harvest date. Fruit evaluations using an untrained panel found that the only factor that was affected significantly by harvest date was appearance (Table 5). Averaged over all harvest dates, flavor and overall acceptability were highest for fruit stored at 38°F. Comments indicated that this was due mainly to alcoholic off-flavors in fruit at 33°F and lack of flavor at 42°F.

Conclusions

Soft scald and soggy breakdown development is increased by exposure of fruit to storage temperatures of 33°F, especially those from later harvest dates. In late September/early October, even a higher storage temperature of 37°F or 38°F did not control the disorder. Storage at 42°F controlled these disorders but resulted in higher decay and less acceptable flavor. Although advanced fruit maturity, e.g. block 1 in mid September, 2000, was sometimes associated with soft scald development, no consistent association was found that would link IEC to harvest date and storage incidence. This study did not identify any single factor that is related to fruit susceptibility to soft scald.

The major recommendations from this work are that fruit should be harvested as soon as appropriate color and flavor have been obtained. Based on the results from 2000 and 2001 season, ideal harvest would be about the second or third week of September in the Champlain region. Of the maturity indicators available, starch may be useful as a guide to over-maturity, and we tentatively suggest an index of 6 as a cut-off for harvest of fruit for long term storage in the Champlain region. A storage temperature of 38°F is recommended. Storage operators need to find a way to ensure a dedicated room is available, especially as crop volume increases.

Christopher Watkins is a research and extension professor who leads Cornell's postharvest research and extension in fruit crops. Jackie Nock is a research support specialist who works with Chris Watkins at Cornell University. Kevin Iungerman is a Cornell University regional extension specialist in Northern NY.

Honeycrisp Maturity Guidelines for Western NY

Jim Wargo[1] and Chris Watkins[2]

[1]Cornell Cooperative Extension, Lake Ontario Fruit Team, Lockport, NY
[2] Dept. of Horticulture, Cornell University, Ithaca, NY 14853

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

Harvest date of Honeycrisp has a large influence on fruit storage quality and the susceptibly to various postharvest disorders such as off-flavor development, the chilling disorder soft scald, superficial scald, and soggy breakdown. This project was done to establish harvest maturity guidelines to minimize the postharvest problems and maintain fruit quality.

Honeycrisp has been widely planted by growers in New York because of the potential for premium pricing. However, problems with bitter pit, both pre- and-post harvest, off-flavor development, and development of the chilling disorder soft scald, superficial scald and soggy breakdown during storage, have been of concern to growers and packers. In addition, packouts have been reduced due to susceptibility of the fruit to skin cracking, stem punctures and cuts, which occur at various stages of the handling process. However, because Honeycrisp is such a new variety, relatively little is known about proper harvest timing and maturity and quality indices that may be useful to determine the optimal harvest window, and how these relate especially to skin-related problems. In 2001, a two-year trial was initiated to provide guidelines for Honeycrisp harvest windows using Honeycrisp in Western New York. Factors that are associated with soft scald, soggy breakdown and bitter pit risk in Honeycrisp, and methods that can control these disorders, are discussed in associated articles.

Methods and Materials

Fruit samples from five Honeycrisp blocks in the Western NY area were harvested every three to four days over a three-week period in 2001 and 2002. Trees in the five blocks ranged in age from 4 to 9 years, and the same orchards were used in both years of the trial. Five trees in each orchard block were flagged off and left unharvested by the growers. Sample collection started when the fruit were at early stages of maturity and ended when fruit were over-mature. Only fruit with the most red color were selected at each sampling. On each sample date, 12 fruit were assessed for maturity by measuring internal ethylene concentration (IEC), starch index using the Cornell starch chart, firmness and soluble solids content (SSC). An additional 30-35 apples were collected and placed in regular air storage at 35°F-36°F in the first month in storage, and then 33°F-34°F for the remainder of the storage period. On Dec 5 in 2001, and January 10 in 2002, fruit were removed from storage

Honeycrisp apples on display for the taste panel evaluations in December 2001. Samples show ideal blush and background color at the time of optimal harvest. Culls appear on the table next to each sample date.

Stem punctures and cracks at harvest caused invasion by *Penicillium expansum* (Blue mold) during cold storage. Punctures and cracks can result in a high percentage of unmarketable fruit if Honeycrisp is harvested late or handled roughly.

September 2001						
						1
2	3	4	5	6	7	8
9	10	11	12 BHD	13	14	15 BHD
16	17	18 BHD	19	20	21	22
23	24	25	26	27	28	29
30	1	2	3	4	5	6

Figure 1. The acceptable harvest period for five Honeycrisp blocks in Western NY in 2001 ranged from Sept. 8 to Sept 20. The single best harvest dates (BHD) occurred on Sept. 12 (one block), Sept. 15 (two blocks), and Sept. 18 (two blocks). Individual blocks remained in acceptable condition for an average of 11 days. Acceptability was determined by a 16-member taste panel based on appearance and eating quality after fruit was stored until December 2, 2001 and held at room temperature for three days.

September 2002						
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24 BHD	25	26	27	28 BHD
29	30	1	2	3	4	5

Figure 2. The acceptable harvest period for five Honeycrisp blocks in Western NY in 2002 ranged from Sept. 14 to Oct. 1. The single best harvest dates (BHD) occurred on Sept. 24 for two blocks, and Sept. 28 for three blocks. Individual blocks remained in acceptable condition for an average of 13 days. Acceptability was determined by a 16-member taste panel based on appearance and eating quality after fruit was stored until January 6, 2003 and held at room temperature for three days.

and assessed for the occurrence of disorders and defects. A 16- to 18-member panel comprised of storage operators, packers, growers, extension faculty and agents evaluated the samples for appearance and eating quality after keeping the fruit for three days at 70°F. The panelists judged each sample as acceptable or not acceptable, and then rated the top three samples for each individual orchard block. The information from the panelists allowed us to determine the ideal harvest window in each year, and to relate post storage eating quality to maturity factors at harvest. The remaining samples were then tested for firmness and SSC on the day of the panelist evaluations.

Best Harvest Date

Best harvest date: In 2001, the best harvest dates for the five orchard blocks were between Sept. 12 and Sept. 18 (Fig. 1). The acceptable harvest period ranged from Sept. 8 to 20, but only lasted for a period of 11 days on average for individual blocks. Fruit harvested before the first acceptable harvest date lacked flavor development and were too green. Fruit harvested after the last acceptable harvest date were over mature and typically had off flavors or poor texture. Based on taste panel evaluations, Sept. 12 to 20 appeared to be the ideal harvest window for Honeycrisp in 2001.

In 2002, fruit matured 7 to 10 days later compared with 2001, and the best harvest dates ranged from Sept. 24 to Sept. 28 (Fig. 2). The acceptable harvest period fell between Sept. 14 and Oct. 1, considerably longer than the previous year, and averaged 13 days for individual blocks. Even though the single best harvest dates occurred in late September in 2002, fruit was acceptable for harvest much earlier than those dates. The ideal harvest window for the five blocks occurred between Sept. 17 and Sept. 28 based on taste panel assessments.

Honeycrisp is an apple that must be spot picked for best quality, and our results indicate that growers have about two weeks to harvest fruit of acceptable condition. In any given year, growers should expect to spot pick Honeycrisp three or more times between the second and fourth week of September, but maturity testing must be incorporated to more clearly define the harvest window. In 2001, fruit harvested in the fourth week of September were overmature and at higher risk of developing disorders.

Harvest Indices

Starch Index: In 2001, the average starch index moved from 7.0 to 7.7 during the period of best harvest dates, Sept. 12 – 18 (Figure. 3). Fruit became acceptable for harvest when the average starch index reached 6.9 for the five blocks.

In 2002, the average starch index moved from 7.5 and 7.8 during the period of best harvest dates (Sept. 24 – 28). Blocks were judged acceptable for harvest once the average starch index reached 6.7 units, a similar value that of the previous year.

Starch index changes were similar in both years, but overall index values were high, indicating that starch hydrolysis was well advanced at the time of optimal harvest. Therefore, it is difficult to determine a lower and upper starch range for identifying the harvest window of Honeycrisp, and the starch index is less useful for this variety than for others. Nevertheless, the data from this trial suggest growers in Western New York should not begin harvesting Honeycrisp until the reddest colored fruit have reached a starch index of 7. After that point, growers can choose to spot pick once a certain percentage of the crop has obtained acceptable color. Although in some cases the amount of fruit judged acceptable for

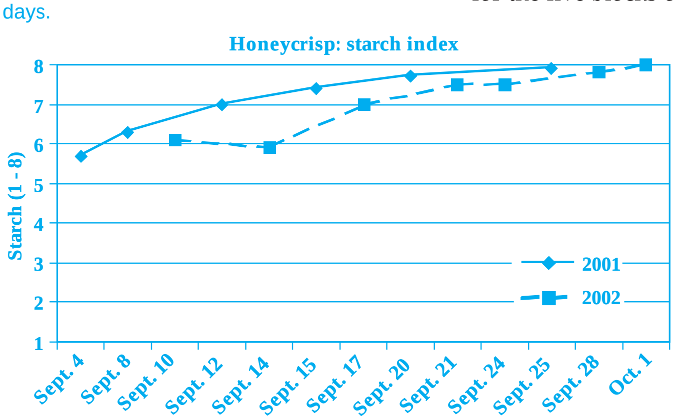


Figure 3. Average starch index of five Honeycrisp blocks in 2001 and 2002. Red colored fruit became acceptable for harvest once the starch index approached 7.0 and remained in acceptable condition even after the starch reserve was depleted. Average of five orchard blocks.

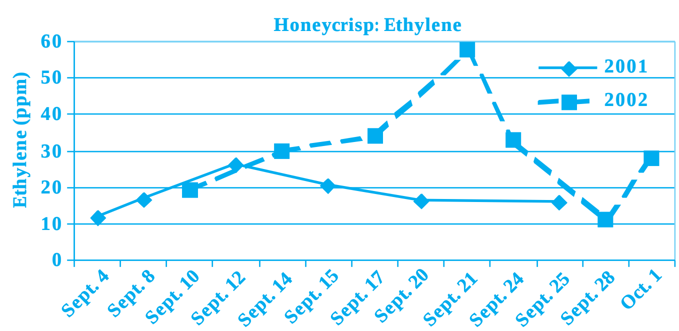


Figure 4. Internal ethylene production of four Honeycrisp blocks at harvest. Best harvest dates occurred on or after peak ethylene production in both years.

harvest may be less than 25% at the time of the first spot pick, it should be harvested.

Some orchards may have fruit in optimal condition even after the starch reserve has been totally depleted (starch index = 8), so one cannot use the upper range of the starch index to assume over maturity. It is important to remember that only the red colored fruit should be sampled for starch testing since red fruit are typically more mature than green fruit on the same tree.

Ethylene: In 2001, internal ethylene steadily increased to a high of 27 ppm on Sept. 12, and then decreased and leveled off after Sept. 20 (Fig. 4). In 2002, ethylene increased continually until reaching a peak of 59 ppm on Sept. 21, and then dropped off sharply after that date. The ethylene peak was 9 days later in 2002, again providing evidence that maturity was delayed compared with 2001.

Ethylene production in Honeycrisp is different from many other varieties because it does not increase autocatalytically. In both years, ethylene reached a peak and then decreased over time which is unusual since most apple varieties continue to produce higher amounts of ethylene as maturity advances. Interestingly enough, best harvest dates in both years occurred on, or within seven days following, the peak of ethylene production. It is generally assumed apples should be picked prior to the onset of ethylene production for best storage quality. Honeycrisp, however, does not seem to follow this trend, and storage quality appears unaffected by ethylene at harvest. Furthermore, ethylene induced fruit drop was not a problem in either year of the experiment even in orchards that produced over 60 ppm ethylene. This suggests that Honeycrisp is inherently resistant to preharvest fruit drop under Western NY conditions, even when ethylene levels are high.

Firmness: Fruit firmness decreased 2.5 lbs. over the three-week harvest period in both years (Fig. 5). This decline in firmness occurred at a much slower rate compared with other varieties that tend to soften rapidly near harvest. During the period of acceptable harvest dates, fruit firmness typically ranged from 13.5 to 15.0 lbs. at harvest.

Honeycrisp is unique in its ability to maintain firmness in regular storage conditions. Firmness loss in storage was negligible in 2001, while fruit lost only about 0.5 lbs. during storage in 2002 (Fig. 5). This may have been because of the additional month of storage in 2002.

The pressure test does not always reflect acceptability of this variety accurately, probably because of the unique texture characteristics of Honeycrisp. Nevertheless, acceptance ratings declined once firmness levels dropped below 13.0 lbs. Therefore, growers should attempt to harvest Honeycrisp above 13.5 lbs. allowing for some firmness loss in storage. Meeting this threshold should be relatively easy for most blocks, except possibly where excessive fruit size is a problem. Since harvesting fruit at high firmness is not a critical factor for Honeycrisp, growers will have greater flexibility to make harvest decisions based on other factors.

Soluble Solids: There was little gain in soluble solids content (SSC) over the three-week harvest period in either year. SSC varied in individual blocks from 12 to 14%, and this appeared to be related to

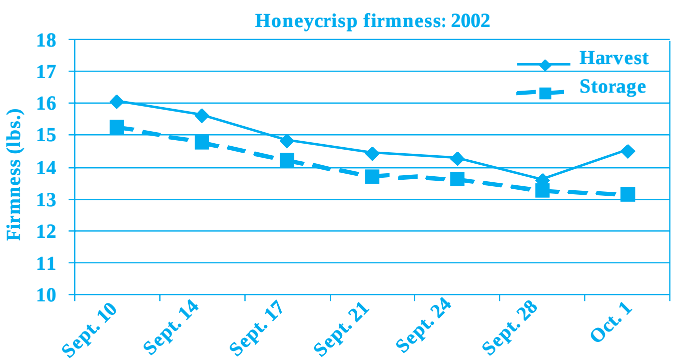


Figure 5. Honeycrisp firmness at harvest and after removal from storage in January 2003. Firmness dropped slowly over the harvest period, and declined only 0.5 lbs. in cold storage. Average of five orchard blocks.

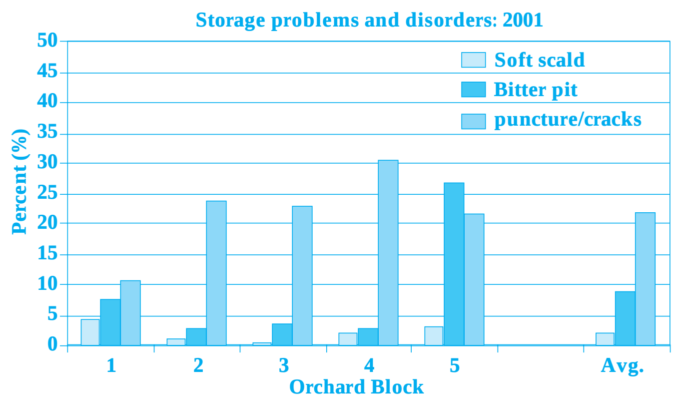


Figure 7. Percent soft scald, bitter pit, stem punctures/cracks for each of the individual orchard blocks after storage until December 2001. There was wide variation in occurrence between orchards for each disorder. Punctures/cracks were the most serious problem. A similar trend was found in 2002.

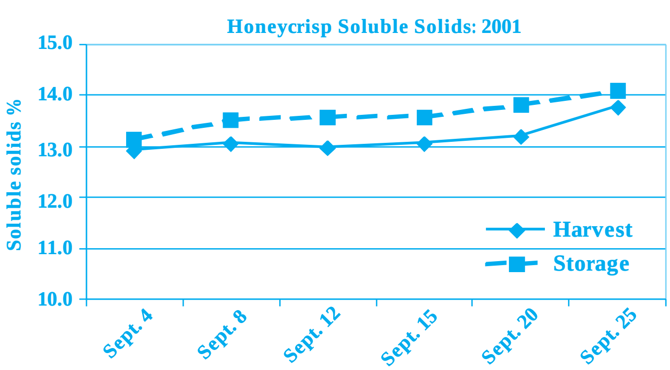


Figure 6. Soluble solids at harvest and after removal from storage in December 2001. Soluble solids did not increase much over the harvest period and increased by 0.5% in storage. No increase was found after storage in the 2002 trial. Average of five orchard blocks.

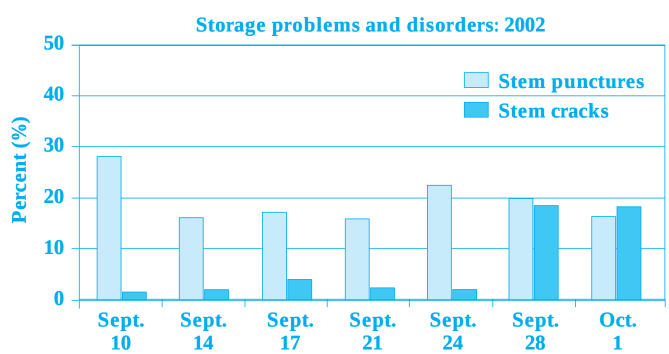


Figure 8. Honeycrisp stem punctures and stem cracks over the harvest period in 2002. Stem punctures were unaffected by harvest date, but stem cracks increased with later harvests. A similar trend was found in 2001. Average of five orchard blocks.

crop load more than any other factor. It would be reasonable to expect little increase in SSC by delaying harvest in a typical year.

SSC increased about 0.5% during storage in 2001 (Fig. 6), but not in 2002 (data not shown), and during the period of acceptable harvest dates, SSC ranged from 13.to 14% after storage in both years. The blocks that were rated highest for eating quality had SSC above 13%, while blocks that rated lowest typically had contents below 13%. Since SSC does not increase much as the fruit mature, harvest should not be delayed in anticipation of greater SSC accumulation. Achieving higher SSC can probably be best achieved by regulating crop load early in the season.

Storage and Condition Problems

The most common problems of Honeycrisp apples after storage were stem cracks and stem punctures (Fig. 7). Depending on the orchard, the combination of stem cracks and punctures ranged from 10 to 30% in each year. Stem punctures were not related to harvest timing, but stem cracks became worse with later harvest dates (Fig. 8). Stem cracks occurred while the fruit was on the tree, and were particularly noticeable on late harvested fruit after a heavy rain. Cracking may occur because the cuticle cannot keep up with the rate of expansion while fruits continue to grow.

Stem punctures appeared to occur for two primary reasons: 1) Honeycrisp stems are very rigid and thick. Some apples produce long stems that puncture other fruit when dropped in to the picking basket or bin. 2) Some fruit have very short stems that detach from the spur deep down inside the stem bowl of the apple. The sharp pointed bud located on the spur for next year's crop can puncture the skin in the stem bowl or shoulder when the apple is twisted from the spur at harvest. This type of puncture often goes undetected at harvest, or when the fruit is packed soon after harvest, but the wound ultimately becomes infected by fungi causing a visible black mark during storage. With this type of defect, the apple is usually culled out during packing.

Bitter pit was a problem in some blocks and ranged from 2 to 28% (Fig. 7). Harvest date did not affect bitter pit development. A wide variation in bitter pit occurrence among orchard blocks is quite common and typically depends on several factors such as crop load, soil water status, soil fertility and calcium availability, and the use of foliar calcium sprays. The incidence of bitter pit was greatly reduced in blocks where foliar calcium sprays were applied.

Soft scald was not severe in either year of this trial and typically averaged 2% or less (Figure. 7). This disorder is a form of chilling injury that is caused by storing fruit at too low a temperature, and can be minimized by harvesting fruit at the correct maturity and storage at elevated temperatures (36°F to 38°F). In general, we find less soft scald development in Honeycrisp from Western New York than in fruit from the Champlain at similar maturities, but the elevated storage temperature used for this trial also could explain the relative absence of this disorder. We encourage use of warmer storage temperatures for the Honeycrisp variety.

Rot was not a major problem in this trial and typically ranged from 0 to 3% for individual blocks. Rot caused by *Penicillium expansum* (Blue mold), appeared to occur in fruit that had cracks or stem punctures. Since stem cracking was more severe on later harvested fruit, rot tended to increase with later harvests as well. Storing fruit with considerable amounts of cracks and punctures is likely to result in a higher incidence of rot in storage and lower packouts.

Conclusions

1. The optimum harvest period for Western New York Honeycrisp is the second to the fourth week of September, but the optimum period within this harvest window can vary according to growing season. Honeycrisp maturity can fluctuate considerably from year to year due to seasonal variation. The precise harvest windows for each orchard block must be identified using a combination of harvest index testing and visual observations.

2. Honeycrisp must be spot-picked, at least three to four times during the harvest window. The need for multiple spot picks will require flexibility in harvest management since Honeycrisp maturity overlaps that of McIntosh. Moreover, earlier spot picks may overlap with Gala, while later ones may overlap with Cortland and Aceymac.

3. Our results suggest that Western New York-grown Honeycrisp should be harvested when the reddest colored fruit have reached a starch index of 7 (Cornell starch chart). For best post-storage eating quality, fruit should be harvested with a minimum firmness of 13.5 lbs and at least 13% soluble solids. Other factors that should be considered are the presence of varietal flavor and change in background color from green to cream yellow. Flesh texture also takes on a buttery color when the fruit are ripe.

4. Special care is needed when harvesting and handling this variety to minimize damage due to skin punctures. There is no easy solution to this problem, but growers should supervise pickers closely to avoid unacceptable amounts of punctures. If pickers are paid hourly, they should be allowed to harvest fruit at a pace that will minimize rough handling. Honeycrisp should be handled more like a McIntosh than a Rome, and while this may slow harvest, the result will be greater pack-out percentages and thus profitability.

5. Skin cracking is mostly a problem of late harvested fruit and can be reduced by harvesting at the proper maturity. If the fruit are ripe and rain is in the forecast, it will be well worth the effort to harvest before the wetting event.

6. Honeycrisp maintains acceptable texture and eating quality for a relatively long time on the tree, and preharvest fruit drop is only a minor concern in Western NY. However, harvest should not be delayed beyond optimal maturity for better color development. The greater risks associated with late harvest such as development of alcoholic flavors, increased susceptibility to stem end cracking, soft scald development in storage, degradation of the cuticle layer, and higher rot potential, resulting in reduced pack out and lower returns to the grower.

Acknowledgements

Special thanks to Dave Kast, Lamont Fruit Farms, and Peter Russell for their collaboration and donation of fruit, and to Bill Gerling for storing the samples and hosting the panel evaluations. We also thank Terence Robinson for participating in this trial and collecting samples from the Geneva station orchard.

Jim Wargo was formerly an Extension Associate with Cornell's Lake Ontario Fruit Team who specializes in harvest management and postharvest management strategies. He currently is with AgroFresh. Chris Watkins is a research and extension professor who leads Cornell's postharvest research and extension in fruit crops

Postharvest Treatments to Decrease Soggy Breakdown and Soft Scald Disorders Of Honeycrisp Apples

Chris B. Watkins and Jackie F. Nock

Department of Horticulture, Cornell University, Ithaca, NY

This work was funded in part by the NY Apple Research and Development Program and the New York Apple Research Association, and federal formula funds project NE103.

Several storage operators in New York have experienced high incidences of soft scald and soggy breakdown with Honeycrisp fruit. We know that these disorders are worse when fruit are stored at lower temperatures such as 33°F than at warmer temperatures such as 38°F, but even higher storage temperatures are not adequate for control of the disorders in very high-risk fruit. In our studies of the disorders we found that a 1-week delay in cold storage of harvested fruits eliminate soggy breakdown and soft scald development.

The post-harvest management of Honeycrisp apples is complicated by the development of high incidences of bitter pit, soft scald and soggy breakdown in the fruit. Bitter pit is a calcium-related disorder that can occur on the tree or develop during storage, but can be managed by cultural practices such as calcium spray applications in the field *(Rosenberger in this issue)*. Major disposing factors that have been implicated in the occurrence of soggy breakdown and soft scald in other varieties are over-maturity of fruit at harvest, and preharvest factors such as climate, light crops, large fruit, and vigorous soils. However, the greatest concern about soft scald and soggy breakdown is their random occurrence in the marketplace.

We have been investigating a number of postharvest treatments that might decrease the incidence of soggy breakdown and soft scald in stored Honeycrisp apples. We know that these disorders are worse when fruit are stored at lower temperatures such as 33°F than at warmer temperatures such as 38°F, but even higher storage temperatures are not adequate for control of the disorders in very high risk fruit. Preliminary studies showed that a delay in cold storage that we thought would aggravate soggy breakdown and soft scald development actually eliminated these disorders. We also investigated the effects of diphenylamine (DPA) because it has been shown to control these disorders in other varieties.

Materials and Methods

Honeycrisp apples were harvested from a Western New York orchard on September 17, 1999, 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 concentrations (IEC) were measured on the maturity samples. The fruit lots were divided to provide three replicates for each of the following treatments:

1. Stored at 33°F;
2. Stored at 36°F;
3. DPA-treated, and stored at 33°F;
4. DPA-treated, and stored at 36°F;

5-8. Same as 1-4, except that fruit were kept at 50°F for 1 week, prior to cold storage.

DPA treated fruit were dipped in 1000 ppm Shield liquid DPA 15% for 1 minute, allowed to drain for two hours, and placed into cold storage at the same time as non-treated fruit. All fruit were kept in plastic perforated bags during cold storage.

After storage for 12 weeks, fruit were transferred to an evaluation room maintained at 68°F. After one day, IEC, soluble solids content (SSC) and firmness were measured on 10 fruit samples per replicate. On day 7, the firmness and SSC of 10-fruit replicates was again measured, and all remaining fruit assessed for presence of external and internal disorders.

In 2000, fruit were treated as described in 1999, except that a different orchard block in Western New York was used to obtain fruit on September 20, the storage temperatures were 33°F and 37°F, and four replicates were used for each treatment. IEC, firmness, SSC, and titratable acidity were measured at harvest, and after storage for 12 weeks plus 1 or 7 days at 68°F.

In 2001, fruit were treated as described in 1999, except that fruit were obtained from an orchard in the Champlain Valley.

Results

In the first year, incidence of soft scald and soggy breakdown combined was decreased by 9 percent when fruit were stored at 36°F compared with 33°F, or treated with DPA before storage at 33°F (Table 1A). Without a delay treatment of one week at 50°F, the lowest disorder incidence occurred in fruit kept at 36°F after DPA treatment. However, soft scald and soggy breakdown incidences were markedly reduced by a week at 50°F, and averaged less than 1 percent, irrespective of prior DPA treatment or subsequent storage temperature.

Bitter pit incidence was not affected by storage temperature or DPA treatment, but averaged 25 percent in fruit kept for a week at 50°F compared with 14 percent in fruit without a pre-storage delay (Table 1A). Decay incidence (17 percent overall) was relatively high in fruit after storage, but was not affected by any treatment (data not shown).

Overall, in 2000, the incidence of soft scald and soggy breakdown combined was reduced by higher storage temperatures and by delays at 50°F before cold storage, and by delay at 33°F but not at 37°F (Table 1B). Soggy breakdown incidence was reduced by DPA, but only when no delay treatment was applied. Bitter pit incidence was higher at 37°F than at 33°F, and after delay treatment. The highest incidence occurred in fruit of the elay treatment stored at 37°F. However, DPA reduced bitter pit incidence at 37°F but not 33°F. Decay incidence averaged 5 percent and was not affected by any treatment (data not shown).

Quality of stored fruit was assessed in 1999 by measuring flesh firmness and soluble solids contents of the fruit (data not shown). These averaged 15.8 lb and 13.3 percent, respectively, and were not affected by treatment or shelf life of 1 or 7 day at 68°F after storage (data not shown). IEC were measured only after 1 day at 68°F after removal from storage. Fruit kept at 36°F had 68 ppm ethylene compared with 53 ppm in fruit kept at 33°F (P=0.031), and 69 ppm in DPA-treated fruit compared with 60 ppm in control fruit (P=0.009). No effect of delay treatment was detected. An interaction between temperature and delay was detected however (P=0.019); IECs in fruit kept at 50°F before storage were higher (75 ppm) and lower (45 ppm) than fruit without a delay treatment (average of 60 ppm) when stored at 36 or 33°F, respectively.

A detailed analysis of treatments on fruit quality was also performed in 2000 (Table 2). Firmness was not affected by any factor. Soluble solids contents were lower in fruit stored at 37°F than at 33°F. Informal tasting of fruit, however, could not detect any differences between treatments, and the importance of the small treatment effects on soluble solids and titratable acidity is uncertain.

TABLE 1

Incidence of soft scald, soggy breakdown and bitter pit in Honeycrisp apples either untreated or treated with 1000 ppm DPA, and stored immediately or after a week at 50°F, at 33°F or 36°F (1999), and 33°F or 37°F (2000) for 12 weeks plus 7 days at 68°F.

A. 1999

Treatment	Soft scald and soggy breakdown (%)	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

B. 2000

Treatment	Soft scald (%)	Soggy breakdown (%)	Bitter pit (%)
33°F	13	7	8
37°F	0	0	13
33°F + DPA	13	3	5
37°F + DPA	0	0	5
33°F + delay	0	0	13
37°F + delay	0	0	40
33°F + DPA + delay	3	0	22
37°F + DPA + delay	0	0	13

TABLE 2

Firmness, soluble solids content, and titratable acidity of Honeycrisp apples either non-treated or treated with 1000 ppm DPA, stored immediately, or after a week at 50°F, at 33°F or 37°F after storage for 12 weeks plus 7 days. (2001)

Effects		Firmness (lb)	Soluble solids (%)	Titratable acidity (% malic acid)
Temperature	33°F	12.2	11.9	0.233
	37°F	12.3	11.6	0.239
	Significance	NS	**	NS
DPA	-	12.2	11.8	0.237
	+	12.3	11.7	0.235
	Significance	NS	NS	NS
Delay	-	12.2	11.7	0.230
	+	12.3	11.7	0.242
	Significance	NS	NS	*
Shelf life	1 day	12.3	11.7	0.255
	7 days	12.2	11.7	0.217
	Significance	NS	NS	***

Discussion

Low storage temperature increases the incidence of soft scald and soggy breakdown in Honeycrisp apples, consistent with the view that these disorders are low temperature injuries. Injury risk for Honeycrisp, therefore, could be reduced by using warmer storage temperatures, e.g. 36-37°F. However, only relatively low volumes of fruit are available because production is still limited. Separate storage facilities to those maintained at 32°F to maintain quality of other varieties in air storage are not always a realistic option, and increasing storage temperatures would compromise quality of the other varieties. In addition, even higher storage temperatures do not control soft scald in fruit that are highly susceptible to development of the disorder.

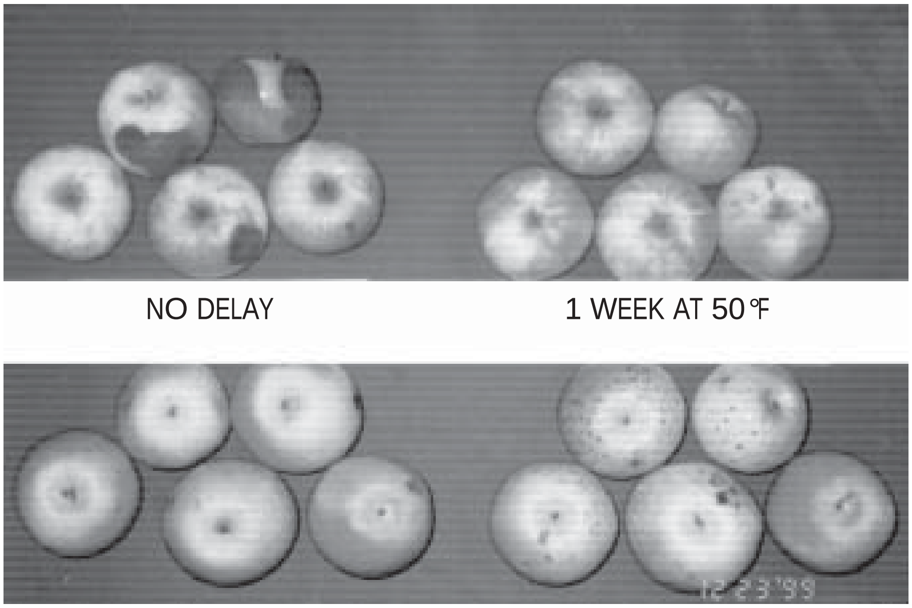


Figure 1. Effect of delay treatment on increasing the incidence of bitter pit in Honeycrisp apple fruit.

DPA has been shown to reduce soft scald development in other varieties, but was not effective enough to prevent the disorder in Honeycrisp when fruit were stored at 33°F. Higher DPA concentrations might allow better control of soft scald and soggy breakdown, but may still be less effective for a highly susceptible cultivar such as Honeycrisp.

We have found that the most effective treatment for control of soft scald is a short storage at 50°F for a week before cold storage, even if the subsequent storage temperature is 33°F. We did not investigate a wider range of delay periods at 50°F, but fruit susceptibility was reduced markedly by as little as one day at 68°F in trials in Massachusetts. The mechanism by which delays before cold storage inhibit development of soft scald is not known.

In general, delays at warmer temperatures before cold storage of apple fruit is discouraged because softening rates and therefore loss of marketable quality can increase. Honeycrisp is a remarkable apple however, with slow softening characteristics. Its firmness is maintained for long periods even under air storage. Our data indicate that firmness and other quality factors were not affected negatively by a 1-week delay at 50°F before cold storage. Informal taste panels using grower groups also indicated that no effects of treatment could be detected during these storage periods. However, the effect of delays before cold storage on quality characteristics for longer storage periods are not known. Therefore, this method should be considered only if fruit will be stored for less than several months in air.

Our greatest concern about use of delay treatments, as well as warmer storage temperatures, is increased bitter pit development as illustrated by Figure 1. Bitter pit incidence is generally increased by postharvest treatments that increase fruit metabolic rates. Therefore, unless the susceptibility of fruit can be decreased by preharvest factors such as calcium spray regimes *(Rosenberger, this issue)* losses of fruit due to bitter pit may be as high as those resulting from soft scald development. Nevertheless, several New York storage operators who sustained major fruit losses due to soft scald development in the past have utilized a delay procedure in their operation. Fruit have been kept in the corridor outside storage rooms for a week prior to cold storage with good results.

Acknowledgements

This research was supported by the New York Apple Research and Development Program, and by Federal Formula Funds, Regional Project NE-103.

Christopher Watkins is a research and extension professor who leads Cornell's postharvest research and extension in fruit crops. Jackie Nock is a research support specialist who works with Watkins.

Join the New York State Horticultural Society

Become a part of our Society.
Yearly membership includes
HortSense Newsletter, Hort Flash Updates,
and the New York Fruit Quarterly.
Join us today and support the NYSHS mission to educate, promote and protect the NY fruit industry!
Fill out and mail the Membership Application below.

Mission Statement

The mission of the New York State Horticultural Society, founded in 1855, is to foster the growth, development and profitability of the fruit industry in New York State. It accomplishes this by:

1) Supporting educational opportunities for members
2) Promoting the industry
3) Representing the industry in matters of public policy

NYSHS Membership Dues

NY Fruit Growers (Individual membership)	$95
Additional (Voluntary Contribution)	$________
Industry Professionals	$95
Academic Professionals	$45
Out of State	$45
Fruit Industry Sponsors	
NYSHS Supporter	<$500
Bronze	$500
Silver	$1250
Gold	$2500
Platinum	$5000+

NYSHS Issues

Pesticide Registrations
Food Quality Protection Act
Integrated Pest Management
Agricultural Labor and Immigration
Fruit Industry Economic Development
Cornell Research and Extension
Educating Public Officials
Educating Industry
Food Safety

New York State Horticultural Society Membership Application

Become a part of our Society. Yearly memberships include HortSense Newsletter, Hort Flash Update, and the New York Fruit Quarterly.
Join us today!

Please Print

NAME ____________________
FIRM NAME ____________________
STREET ADDRESS ____________________
CITY ____________________ COUNTY ____________________
STATE ____________________ ZIP ____________________
PHONE ____________ FAX ____________ E-MAIL ____________

PLEASE FIND THE ENCLOSED DUES FOR THE FOLLOWING:

$__________ NYS Horticultural Society Membership Dues

$__________ $20 per year NY Fruit Quarterly Subscription ONLY

$__________ TOTAL

PLEASE MAKE CHECK PAYABLE TO:
New York State Horticultural Society

MAIL TO: New York State Horticultural Society
PO Box 462 • Hedrick Hall
Geneva, NY 14456

Questions? Call the NYSHS office at 315-787-2404

For non-NY residents: Are you interested in the latest research news from New York?

Subscribe to the informative

NEW YORK FRUIT QUARTERLY

for $20* per year.

Please use the subscription form at left.

*__Membership__ in the NYS Horticultural Society **includes** a subscription to the New York Fruit Quarterly.