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.

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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 formulated product per 100 gal	May 16	May 24	May 30	June 13	June 20	July 11	July 17	July 24	Aug 1	Aug 8	Aug 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.

Spray programs	% fruit with bitter pit at harvest 29 Aug	2 Nov	Maturity ratings at harvest 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.

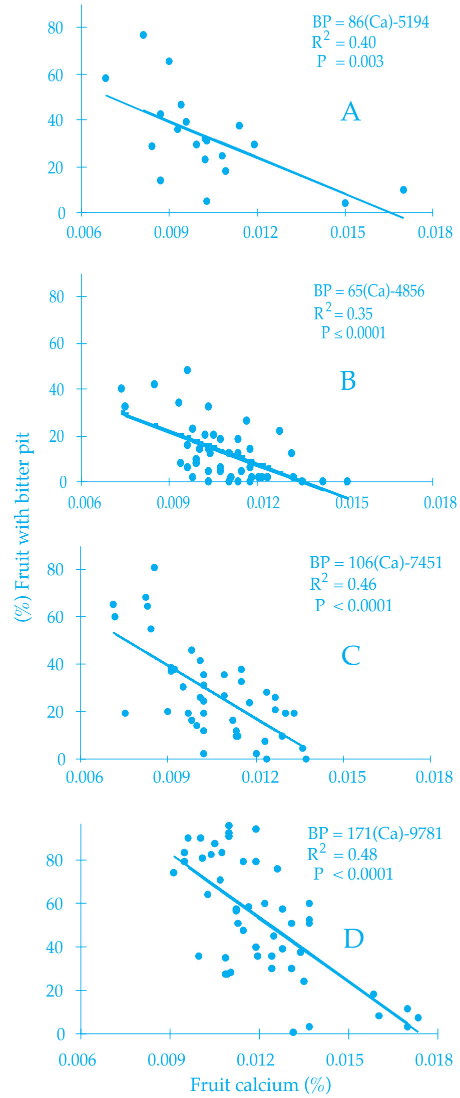

Fig. 1. Linear regressions showing effects of fruit calcium concentrations on incidence of bitter pit after cold storage for the experiments conducted at Lyons in 2000 (A), Lyndonville in 2001(B) and Milton in 2000 (C) and 2001 (D).

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.

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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.