Control of *Alternaria* Infection of Fruit of Apple Cultivar Nittany with Calcium Chloride and Fungicides

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ABSTRACT

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Calcium chloride ($CaCl_2$) was tested for its efficacy in reducing the incidence and severity of infection of the apple cultivar Nittany by *Alternaria* spp. In 1989, eight biweekly applications of flake (referred to as $CaCl_2$) or liquid $CaCl_2$ reduced the incidence of rot from 61% in the controls to 27 and 33%, respectively. Dip treatments alone reduced rot incidence to 17 and 12% for the $CaCl_2$ and liquid $CaCl_2$ treatments, and seasonal sprays followed by dip treatment reduced incidence to 5%. Nine $CaCl_2$ sprays, applied biweekly, reduced the incidence of the disease from approximately 44% in the controls to 12 and 18% in 1990 and 1991, respectively. Disease severity was reduced from 27 and 14 lesions per fruit in the controls to nine and six lesions per fruit in 1990 and 1991, respectively. In postharvest tests, fruit treated with $CaCl_2$ alone and in combination with iprodione exhibited the lowest incidence and severity of Alternaria rot after 3 and 6 mo in refrigerated storage. Best control of Alternaria rot was achieved with nine seasonal applications of $CaCl_2$ followed by a postharvest dip of $CaCl_2$ alone or in combination with iprodione. Fruit were sampled biweekly beginning in July through harvest to determine the frequency and pathogenicity of *Alternaria* spp. In 1991, isolation of epiphytic *Alternaria* spp. was uniform through the growing season, with isolation frequency of 52–72%. Isolation of *Alternaria* spp. from the same fruit that had been surface-disinfested yielded approximately 1–2% in July and increased gradually through the remainder of the season. At harvest, isolation frequency from surface-disinfested fruit averaged 34%. In 1992, isolation of epiphytic *Alternaria* spp. increased over the season from 22% in July to 69% at the end of September. Isolation of *Alternaria* spp. from surface-disinfested fruit was 2% in July and 11–16% in September.

Alternaria rot occurs on apple (*Malus* × *domestica* Borkh.) and pear (*Pyrus communis* L.) in most areas of the world where these fruits are grown. Although the disease seldom causes major losses, the apple cultivar Nittany appears to be very susceptible to Alternaria rot. Nittany, a cross of York and probably Golden Delicious, has very good dessert and processing qualities (12). Alternaria rot, caused by *Alternaria* spp., of Nittany apple results in significant losses in some years and is one of the major factors preventing more widespread planting of this cultivar. Alternaria rot cannot be controlled with the fungicides that are currently available for use on apple, and none is registered for control of *Alternaria* diseases. Iprodione is moderately effective for control of Alternaria blotch in North Carolina (7).

On most apple cultivars, Alternaria rot is characterized by round, brown to black, dry, firm, shallow lesions, often located around skin breaks, and symptoms often appear within 2 mo after the fruit are placed in refrigerated storage (11). On Nittany, initial infections may take place in the orchard, with lesions appearing either before harvest or during storage. These initial infections may be visible as small red freckles, usually located around lenticels. It is not certain at what time during the growing season *Alternaria* infections occur on Nittany fruit. Lesions may expand rapidly after fruit are harvested, often with over 50% of fruit exhibiting symptoms.

Calcium-related tissue disorders such as bitter pit, cork spot, and lenticel spot are thought to provide avenues of entry into the fruit for *Alternaria* spp. (8). Given the nature of the infection court and the relatively weak pathogenicity of *Alternaria* spp. on apple fruit, enhancement of fruit resistance to decay is a viable alternative to fungicide treatments. Consequently, the research reported here was conducted to examine the effectiveness of pre- and postharvest calcium chloride applications and postharvest fungicide applications on the incidence and severity of Alternaria rot of Nittany apple. In addition, we examined the time during the growing season that *Alternaria* spp. were present on fruit surfaces and when infection was initiated.

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MATERIALS AND METHODS

All experiments were conducted at the West Virginia University Experiment Farm, Kearneysville, with trees of the cultivar Nittany on M.7a rootstock planted during 1979–1982. Trees used in these experiments were located in three separate blocks of 36 trees each (six rows with six trees per row) planted at 6.5 × 6.5 m spacing.

Preharvest and postharvest calcium application, 1989. This study used 24 7-yr-old trees and included six treatments with four single-tree replications: 1) control, 2) calcium chloride sprays at 1.27 g of 77% flake per liter of water (hereafter referred to as $CaCl_2$), 3) liquid calcium chloride (Stopit 6, 12% Ca, Shield-Brite, Kirkland, WA) sprays at 8.2 ml/L of water, 4) $CaCl_2$ postharvest dip (4%, w/v), 5) liquid $CaCl_2$ dip (4% $CaCl_2$, w/v), and 6) $CaCl_2$ sprays and dip. The sprays were applied to runoff, with a hydraulic handgun sprayer at 2,070–2,760 kPa, eight times beginning on 25 May 1989 (24 days after full bloom) and continued at 2-wk intervals. For dip treatments prior to storage, fruit were dipped in a solution containing 2,700 mg/L of ethoxyquin (a scald inhibitor) + 300 mg a.i./L of benomyl (Benlate 50WP) + 960 mg a.i./L of captan (Captan 80WP), amended with 40 g/L of $CaCl_2$ or 120 mg/L of liquid $CaCl_2$. Total treatment volume was 10 L and fruit were dipped for 1 min. Fruit were then placed in open 5-kg paper bags and moved into storage at 0–2 C and 90–95% relative humidity. Fruit were examined for bitter pit lesions and rot infections, and subsamples of 10 fruit per treatment were taken for determination of firmness and tissue calcium concentrations.

Firmness was determined with a drill-press-mounted Effegi penetrometer with an 11-mm-diameter probe. Two readings (reported in newtons) per fruit were made on opposite peeled sides. Calcium concentrations of washed, harvested, and stored fruit were measured from the peel, the 1-mm layer of flesh just beneath the peel, and flesh located 1–4 mm beneath the peel. Calcium concentrations (ppm dry weight) were determined with an atomic absorption spectrophotometer (Perkin-Elmer Model 5000). All data were analyzed with analysis of variance, and means were separated with Duncan's multiple range test (10). Pearson correlation coefficients were determined for the relationships among firmness, tissue calcium concentrations, and percentage of fruit with rot. Simple linear regression was used to describe the association between incidence of rots and calcium

concentration of peel tissue.

Preharvest calcium application, 1990 and 1991. Experiments were initiated in 1990 on the use of seasonal calcium sprays to control Alternaria rot. Trees were sprayed to runoff with calcium chloride (1.8 g of $CaCl_2$ [74–77% food-grade flake]) + 0.026 ml of di-1-*p*-menthene 96% (NuFilm 17) per liter of water, beginning on June 14 (about second cover) and continuing at 2-wk intervals for programs of zero, nine, six, or three sprays over the remainder of the season. Trees were arranged in a completely randomized design with four replicate trees per treatment. At harvest, 100 fruit were collected from each tree, stored in wooden crates at 0–2 C, and evaluated after 3 mo for symptoms of Alternaria rot. Identity of the causal fungus was confirmed by isolation from lesion margins on potato-dextrose agar (PDA). Fruit were evaluated for proportion of fruit with symptoms of Alternaria rot (incidence), numbers of lesions per fruit (severity), and mean lesion size. The experiment was repeated in 1991 with an additional evaluation of fruit after 6 mo of storage. In 1991, fruit also were rated by the modified Russo-Rajotte grading scheme (9) for packout quality according to USDA grade standards. Data were subjected to analysis of variance and means separated with Duncan's multiple range test (10).

Fruit from the control and six-application treatments were used in both years to test the hypothesis that rot incidence is related to the proportion of fertilized ovules. At the end of the 6-mo storage period, three replicates of 40 fruit were examined for the proportion of locules with seeds in relation to the incidence of rot. Fruit were halved transversely and locules were examined for the presence of seeds. Data were assessed with the chi-square test (10).

Calcium content was determined in peels from fruit taken from the 1990 preharvest calcium application experiment. Three fruit from each replicate tree were collected from the storage crate, washed with mild detergent, rinsed in distilled water, and allowed to air-dry before peeling. The entire peel was removed from each fruit, frozen, then dried at 65 C and sent to the Pennsylvania State University Agricultural Analytical Services Laboratory for ICP emission spectroscopy analysis.

Postharvest application of calcium and fungicides, 1990 and 1991. In 1990, fruit from the above experiment that had received either no $CaCl_2$ or nine seasonal sprays were utilized to evaluate postharvest dip treatments of $CaCl_2$ (4%, w/v) alone or in combinations with 210 mg a.i./L of iprodione (Rovral 50W) and 1.5 g a.i./L of captan (Captan 50W). For each treatment, 100 fruit, divided into five replicates of 20 fruit each, were dipped. Fruit were evaluated for incidence and severity of Alternaria rot as described above after 3 and 6 mo of storage at 0–2 C. The experiment was repeated in 1991 with the following changes: Fruit were divided into five replicates of 10 fruit each, $CaCl_2$ was not added to the captan + iprodione treatment, and fruit were evaluated once after 4 mo of storage. Data were subjected to analysis of variance and means separated with Duncan's multiple range test (10).

Isolation experiments, 1991 and 1992. Beginning on 6 June 1991 and continuing every 2 wk thereafter until harvest, 35 symptomless fruit from each block were collected and brought into the laboratory. Small samples (one per fruit from the side) from the peel and underlying tissues (about 1 mm wide × 3 mm long × 1 mm deep) were excised and placed on 2% PDA in 9-cm-diameter petri dishes. Fruit were then surface-disinfested with 0.5% NaOCl for 2 min (time based on preliminary experimentation) and rinsed in sterile distilled water, and a second set of samples was excised and placed on PDA. All cultures were incubated at room temperature (22–25 C) for approximately 7 days prior to being examined for the presence of *Alternaria* spp. The percentage of isolations yielding *Alternaria* spp. was calculated at each date. The experiment was repeated in 1992, but only 45 fruit were collected at each date from one block because of poor return bloom and fruit set related to drought conditions in 1991. Data on proportion of isolations yielding *Alternaria* spp. were regressed against time (10). A mixture of five isolates of *Alternaria* spp. from nondisinfested fruit surfaces was tested for pathogenicity by making mycelial inoculations on mechanically wounded, mature Golden Delicious fruit. Fruit were incubated at 24 C and examined after 1 wk for rot symptoms.

RESULTS

Preharvest and postharvest calcium application, 1989. At harvest and prior to dip treatments, fruit firmness ranged from 57.8 to 63.6 N. The firmness of fruit in all calcium treatments did not differ significantly from the control except for the liquid $CaCl_2$ spray, which produced the firmest fruit (*data not shown*). After

Table 1. Effect of calcium treatments in 1989 on percentage of fruit with rots and bitter pit lesions and number of bitter pit lesions per fruit after 5 mo of storage

Treatment[x]	Total rots (%)	Fruit with bitter pit lesions (%)	Mean number of bitter pit lesions/fruit
Control	60.9 a[y,z]	32.2 a	2.7 a
$CaCl_2$ spray	26.6 bc	36.7 a	2.4 a
Liquid $CaCl_2$ spray	33.3 b	30.0 a	2.2 a
$CaCl_2$ dip	16.6 bcd	35.0 a	2.3 a
Liquid $CaCl_2$ dip	11.7 cd	28.3 a	3.7 a
$CaCl_2$ spray + dip	5.0 d	16.7 a	2.4 a

[x] $CaCl_2$ at 1.27 g of 77% flake per liter of water and liquid $CaCl_2$ at 9.34 L/ha applied to runoff, with a hydraulic handgun sprayer at 2,070–2,760 kPa, eight times beginning on 25 May 1989 (24 days after full bloom) at 2-wk intervals to four single-tree replicates. For 1-min dip treatments, $CaCl_2$ was used at 40 g/L of water and liquid $CaCl_2$ was used at 120 mg/L of water in 10 L of dip solution. Fruit were stored in open paper bags at 0–2 C and 90–95% relative humidity.

[y] Mean values from four replications with a minimum of 10 fruit per replication.

[z] Means within a column followed by the same letter are not significantly different according to Duncan's multiple range test ($P \leq 0.05$).

Table 2. Effect of calcium treatments in 1989 on calcium concentrations (ppm dry weight) in different tissue depths of Nittany apple fruit at harvest and after dip treatments plus 5 mo of storage

	Harvest			Storage for 5 mo		
Treatment[x]	Peel	0–1 mm	1–4 mm	Peel	0–1 mm	1–4 mm
Control	652.5 ab[y,z]	257.5 a	310.0 a	566.5 d	126.2 c	219.5 a
$CaCl_2$ spray	710.0 ab	267.5 a	200.0 a	752.5 cd	376.7 a	207.0 a
Liquid $CaCl_2$ spray	795.0 a	387.5 a	242.5 a	834.5 bc	231.7 abc	290.0 a
$CaCl_2$ dip	452.5 b	262.5 a	137.5 a	1,134.2 a	264.2 abc	274.5 a
Liquid $CaCl_2$ dip	615.0 ab	245.0 a	362.6 a	1,072.2 ab	158.2 bc	221.0 a
$CaCl_2$ spray + dip	670.0 ab	302.5 a	285.0 a	1,184.5 a	348.5 ab	195.2 a

[x] $CaCl_2$ at 1.27 g of 77% flake per liter of water and liquid $CaCl_2$ at 9.34 L/ha applied to runoff, with a hydraulic handgun sprayer at 2,070–2,760 kPa, eight times beginning on 25 May 1989 (24 days after full bloom) at 2-wk intervals to four single-tree replicates. For 1-min dip treatments, $CaCl_2$ was used at 40 g/L of water and liquid $CaCl_2$ was used at 120 mg/L of water in 10 L of dip solution. Fruit were stored in open paper bags at 0–2 C and 90–95% relative humidity.

[y] Mean values from four replications with a minimum of 10 fruit per replication.

[z] Means within a column followed by the same letter are not significantly different according to Duncan's multiple range test ($P \leq 0.05$).

dip treatments and after 5 mo of storage, fruit sprayed with the liquid $CaCl_2$ were significantly firmer at 58.9 N ($P \leq 0.05$) than those of the other treatments (mean of all other treatments = 53.9 N). After 5 mo of storage, a decrease in the incidence of rots occurred with all the calcium treatments (Table 1). Among the calcium treatments, the incidence of rots from the $CaCl_2$ spray + dip treatment was the lowest, although it did not differ significantly from the $CaCl_2$ dip or the liquid $CaCl_2$ dip. The effects of all treatments on the incidence of fruit with bitter pit and the number of bitter pit "lesions" per fruit were not significant (Table 1).

At harvest and after 5 mo of storage, calcium levels were higher in fruit peels than in underlying tissues (Table 2). At harvest and prior to dip treatment, fruit treated with eight liquid $CaCl_2$ or $CaCl_2$ sprays had calcium levels that did not differ significantly from the control. The effect of calcium dip treatments was significant after 5 mo of storage, especially in the peel (Table 2), where all the calcium-treated fruit, except those sprayed with $CaCl_2$, contained higher calcium amounts than the nonsprayed fruit. In the 0- to 1-mm tissue layer, calcium concentrations were highest from the $CaCl_2$ spray and the $CaCl_2$ spray + dip treatments (Table 2), although these treatments were not significantly different from the liquid $CaCl_2$ spray and the $CaCl_2$ dip treatments. No significant differences were found among treatments in the 1- to 4-mm layer of stored fruit.

Correlations of fruit calcium concentrations, firmness, and incidence of rots showed no relationship between firmness and peel calcium ($r = -0.23$) or firmness and incidence of rots ($r = -0.25$). However, incidence of rots was correlated significantly with calcium in both the peel and the 0- to 1-mm layer ($r = -0.84$ and -0.52, respectively; $P \leq 0.01$). As calcium concentration of these tissues increased, percentage of fruit with rots decreased. The association between peel calcium concentration and rot incidence was described by the regression equation $Y = -0.068X + 93.17$, where Y is the incidence of rots (%) and X is peel calcium in ppm ($R^2 = 0.70$).

Preharvest calcium applications, 1990 and 1991. Six and nine $CaCl_2$ sprays reduced disease incidence significantly below that of the control in 1990, and nine sprays reduced disease levels below those of the control in 1991 (Table 3). As few as three sprays resulted in significantly fewer lesions per fruit (severity) relative to the nonsprayed control fruit in both years, with six and nine sprays resulting in even fewer lesions in 1991. Mean lesion diameter (*data not shown*) was not affected by application of calcium sprays in 1990. In 1991, however, the mean diameter of the largest lesion was significantly smaller ($P \leq 0.05$) in the nine-spray treatment (mean diameter = 1.0 cm) when compared with the control (mean diameter = 2.1 cm). Packout rating according to USDA grade standards, as judged by the modified Russo-Rajotte grading scheme (9), showed that fruit receiving nine calcium applications were rated significantly higher (mean rating = 9.7) than control fruit (mean rating = 8.6). The proportion of fertilized ovules, which exhibited large variation among the sampled fruit, showed no relationship to the incidence or severity of Alternaria rot (chi-square = 30.0, $P \leq 0.22$ for incidence).

Postharvest application of calcium and fungicides, 1990 and 1991. In the 1990 experiment, one postharvest treatment of 4% $CaCl_2$ appeared as effective at reducing incidence of Alternaria rot as did nine seasonal sprays when the fruit were examined after 3 mo of storage (Table 4). These two treatments, however, were not significantly different from any of the other fungicide or $CaCl_2$ + fungicide treatments. Only the iprodione + $CaCl_2$ treatment showed reduced severity levels relative to the control. After 6 mo of storage, the lowest rot incidence was observed in the iprodione + $CaCl_2$ and the $CaCl_2$ treatments when compared with the control. Extreme variability of rot development after prolonged storage precluded further separation among the treatments. The postharvest treatments with $CaCl_2$ and $CaCl_2$ + iprodione also showed lowest severity levels after 6 mo of storage. The fruit from treatment with nine seasonal sprays exhibited relatively high severity levels after 6 mo of storage, and the severity was no different from that on fruit with no treatment.

Fruit given nine seasonal sprays of $CaCl_2$ in 1990 showed a reduced incidence of Alternaria rot 3 mo after postharvest treatment with $CaCl_2$ and iprodione + $CaCl_2$ dips. Likewise, severity after 3 mo was reduced by these two treatments, as well as by captan + iprodione + $CaCl_2$ (Table 5). After 6 mo, disease incidence was lowest compared with the control in the iprodione + $CaCl_2$ treatment, although the data from this treatment could not be separated statistically from those of captan + iprodione + $CaCl_2$, captan, and $CaCl_2$ treatments, all of which reduced the incidence of Alternaria rot. Severity after 6 mo was reduced relative to the control by iprodione + $CaCl_2$, captan + iprodione + $CaCl_2$, $CaCl_2$, and captan (Table 5). In 1990, spray application of $CaCl_2$ during the growing season did not significantly increase the amount of calcium present in the fruit peel. Calcium concentration ranged from 597 ppm for the control to 452 ppm for the six-spray treatment (*data not shown*).

In 1991, the best postharvest treatments for reducing disease incidence were captan + iprodione + $CaCl_2$ (when no seasonal $CaCl_2$ was applied) and iprodione + $CaCl_2$ when combined with nine seasonal sprays (Table 6). Lowest severity of Alternaria rot was observed in fruit treated with captan + iprodione + $CaCl_2$. For fruit given nine seasonal applications of $CaCl_2$, incidence and severity of Alternaria rot were lowest for those treated with iprodione + $CaCl_2$

Table 3. Effect of seasonal calcium chloride sprays in 1990 and 1991 on incidence and severity of Alternaria rot of Nittany apple fruit after 3 mo in storage[x]

No. of sprays	Fruit with lesions[y] (%)		No. of lesions/fruit	
	1990	1991	1990	1991
0	44.7 a[z]	43.5 a	26.6 a	14.4 a
3	24.4 ab	39.5 ab	13.8 b	9.5 b
6	21.9 b	30.5 ab	12.9 b	5.9 c
9	12.8 b	18.0 b	8.7 b	5.5 c

[x] $CaCl_2$ at 1.8 g/L applied to runoff with a hydraulic handgun sprayer at 2,070–2,760 kPa.
[y] Mean values of 400 observations from four replications of 100 fruit per tree.
[z] Means within a column followed by the same letter are not significantly different according to Duncan's multiple range test ($P \leq 0.05$).

Table 4. Effect of calcium chloride (4%, w/v) and other postharvest treatments on Alternaria rot of Nittany apple fruit harvested in October 1990 after 3 and 6 mo in storage

Treatment	Storage for 3 mo (16 January 1991)		Storage for 6 mo (8 April 1991)	
	Fruit with lesions (%)	No. of lesions/fruit	Fruit with lesions (%)	No. of lesions/fruit
Control	46.9 a[x,y]	139.0 ab	51.7 a	174.4 ab
Captan	42.0 ab	90.6 abc	45.3 abc	117.2 abc
Iprodione	40.6 ab	72.4 abc	50.0 ab	93.2 abc
$CaCl_2$	20.5 b	32.8 bc	27.6 bc	35.2 c
Captan + $CaCl_2$	42.2 ab	174.2 a	41.9 abc	187.6 a
Iprodione + $CaCl_2$	26.9 ab	20.6 c	26.0 c	26.2 c
$CaCl_2 \times 9$[z]	24.2 b	34.2 bc	35.8 abc	70.8 abc
Captan + iprodione + $CaCl_2$	26.5 ab	48.6 bc	36.8 abc	54.8 bc

[x] Mean values from five replications of 20 fruit per replication per treatment.
[y] Means within a column followed by the same letter are not significantly different according to Duncan's multiple range test ($P \leq 0.05$).
[z] Fruit treated with nine seasonal applications of 1.8 g of $CaCl_2$ + 0.026 ml of di-1-*p*-menthene 96% per liter of water.

(Table 6). Results from other treatments receiving nine seasonal calcium applications did not differ significantly from those of the control.

Isolation experiment, 1991 and 1992. *Alternaria* spp. were recovered at high frequencies from the surface of healthy appearing apple fruit sampled biweekly from mid-June through harvest in mid-October 1991 (Fig. 1). The relative frequency of isolation from non-surface-sterilized fruit was uniform across the 16-wk sampling period, ranging from approximately 52 to 72% (slope of linear regression not significantly different from 0, $P \leq 0.05$). When fruit surfaces were disinfested, isolation frequency was less than 2% early in the season, began to increase about 12 wk before harvest, and climbed gradually to approximately 33% just prior to harvest. The proportion of surface-disinfested peels yielding *Alternaria* isolates was best described by the equation $Y = -0.222 + 1.04 \times 10^{-5}X^2$, where Y is the proportion of fruit yielding *Alternaria* isolates and X is the day of the year ($R^2 = 0.74$, $P \leq 0.001$). Approximately 63% of fruit inoculated with epiphytic isolates of *Alternaria* spp. exhibited Alternaria rot symptoms within 1 wk, whereas the remainder later showed signs and symptoms of infection by *Penicillium expansum*.

In 1992, the frequency of *Alternaria* isolation from non-surface-disinfested fruit increased linearly ($P \leq 0.10$) from 22% on 6 July to 69% on 28 September (Fig. 2). Frequency of *Alternaria* isolation from surface-disinfested fruit was initially similar to that in 1991 (2–4% in July and early August). In 1992, however, fruit infection increased to approximately 16% for the rest of the season (Fig. 2), compared with 33% in 1991. In 1992, the proportion of isolates from surface-disinfested peels was best described by the equation $Y = -0.092 + 3.48 \times 10^{-6}X^2$, where Y is the proportion of fruit yielding *Alternaria* isolates and X is the day of the year ($R^2 = 0.57$, $P \leq 0.05$).

DISCUSSION

These results show that $CaCl_2$ applications, applied either as sprays or as a postharvest drench, reduced significantly the incidence and severity of Alternaria rot on fruit of Nittany apple. A calcium program consisting of nine applications during the growing season appears to be advantageous to growers of Nittany apples, particularly since many do not have the facilities for dipping large volumes of fruit. Similar calcium programs are effective against side rot of pear, caused by *Phialophora malorum* (13). No effective fungicide alternatives for control of Alternaria fruit rot are available currently. Fungicides used in this study appear to have no beneficial effect on disease control, with none of these treatments significantly reducing incidence and severity relative to treatment with $CaCl_2$ alone.

The isolation data indicate that a control program based on spray applications for *Alternaria* spp. on Nittany apple could be initiated at about 10–12 wk before harvest, presuming that an effective fungicide could be registered for

Table 5. Effect of calcium chloride (4%, w/v) and other postharvest treatments on Alternaria rot of Nittany apple fruit sprayed in 1990 with $CaCl_2$ nine times in the field after 3 and 6 mo in storage

Treatment	Storage for 3 mo (16 January 1991)		Storage for 6 mo (8 April 1991)	
	Fruit with lesions (%)	No. of lesions/fruit	Fruit with lesions (%)	No. of lesions/fruit
Control[x]	24.2 a[y,z]	34.2 a	35.8 a	70.8 a
Captan	10.6 ab	10.4 ab	15.5 bc	13.4 b
Iprodione	15.0 ab	26.0 ab	23.4 ab	31.0 ab
$CaCl_2$	10.2 b	8.0 b	19.0 bc	13.2 b
Captan + $CaCl_2$	19.0 ab	28.4 ab	25.8 ab	29.5 ab
Iprodione + $CaCl_2$	6.7 b	3.4 b	3.7 c	4.0 b
Captan + iprodione + $CaCl_2$	13.1 ab	7.2 b	13.0 bc	7.0 b

[x] Fruit treated with nine seasonal applications of 1.8 g of $CaCl_2$ + 0.026 ml of di-1-*p*-menthene 96% per liter of water.
[y] Mean values from five replications of 20 fruit per replication per treatment.
[z] Means within a column followed by the same letter are not significantly different according to Duncan's multiple range test ($P \leq 0.05$).

Table 6. Effect of calcium chloride (4%, w/v) and other postharvest treatments on Alternaria rot of Nittany apple fruit receiving no calcium chloride during the growing season in 1991 or sprayed with calcium chloride nine times in the field after 4 mo in storage[x]

Treatment	No $CaCl_2$		Nine $CaCl_2$ sprays	
	Fruit with lesions (%)	No. of lesions/fruit	Fruit with lesions (%)	No. of lesions/fruit
Control	31.7 ab[y,z]	10.5 a	26.7 a	4.3 a
Captan	36.0 ab	11.6 a	16.0 ab	1.3 ab
Iprodione	24.0 bc	9.2 ab	10.0 ab	4.6 a
$CaCl_2$	42.0 a	5.9 ab	12.0 ab	2.3 ab
Captan + $CaCl_2$	40.0 a	4.8 ab	18.0 a	2.6 ab
Iprodione + $CaCl_2$	28.0 abc	3.9 ab	0 b	0 b
Captan + iprodione + $CaCl_2$	16.0 c	2.5 b	14.0 ab	0.6 ab

[x] Fruit harvested on 3 October 1991 and evaluated on 10 February 1992.
[y] Mean values from five replications of 10 fruit per replication per treatment.
[z] Means within a column followed by the same letter are not significantly different according to Duncan's multiple range test ($P \leq 0.05$).

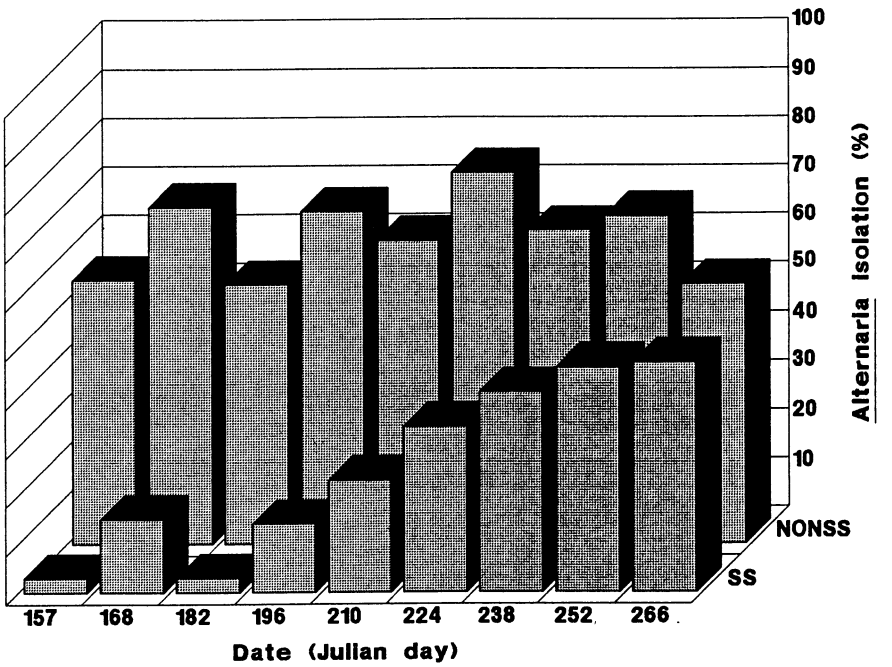

Fig. 1. Percent *Alternaria* isolation from surface-disinfested (SS) and non-surface-disinfested (NONSS) fruit of apple cultivar Nittany from June through September 1990. Each bar represents the mean of 105 fruit from three replicates.

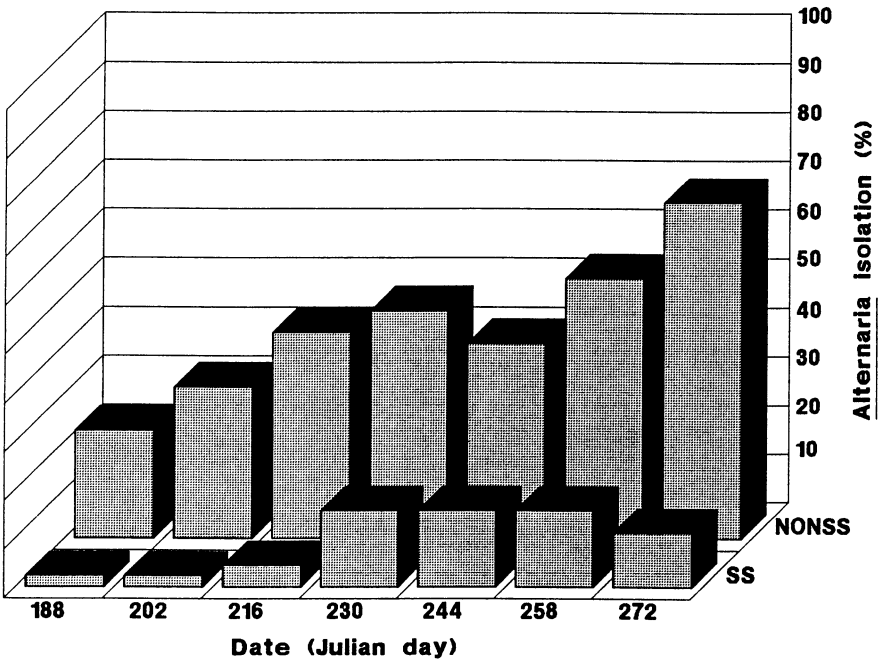

Fig. 2. Percent *Alternaria* isolation from surface-disinfested (SS) and non-surface-disinfested (NONSS) fruit of apple cultivar Nittany from July through September 1991. Each bar represents the mean of 45 fruit from three replicates.

this use on apple. Beginning the $CaCl_2$ sprays at this time was beneficial in 1990 but not in 1991. Preliminary field studies with iprodione, which is registered for use against Alternaria blotch on Red Delicious in North Carolina (7), indicate that the fungicide may not reduce the superficial and subepidermal populations of *Alternaria* spp. on Nittany fruit (A. R. Biggs, *unpublished*). The isolation data should be interpreted with caution. It is possible that the 2-min exposure to hypochlorite solution, which was very effective initially in suppressing isolation of *Alternaria* spp., could have become less effective gradually over the course of the growing season because of changes in cuticle structure or thickness in the developing fruit.

A proposed mechanism of fungal inhibition in $CaCl_2$-treated fruit suggests some impediment of fungal pectolytic enzyme activity by Ca^{++} ions associated with intercellular pectic substances in fruit (1–5). Although this proposed mechanism may be operative for the Nittany apple/Alternaria rot system (i.e., in reducing lesion size), it is possible also that disease incidence is reduced via the beneficial effects of calcium on reducing the incidence of calcium-related fruit disorders that serve as infection courts for the fungus. The cultivar Nittany is prone to develop bitter pit and lenticel spot, both of which are thought to be calcium-related fruit disorders, although their real cause or causes remain unknown (6). The lack of significant differences in bitter pit incidence among treatments, along with the significant differences in disease incidence among treatments in 1989, suggest that incidence of bitter pit is not necessarily required for Alternaria rot to occur nor is it correlated with the level of Alternaria rot at harvest or after storage. The possible fungicidal activity of $CaCl_2$ solutions against *Alternaria* spp. should be investigated.

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