Preharvest Peroxyacetic Acid Sprays Slow Decay and Extend Shelf Life of Strawberries

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Abstract. **Strawberry is an important fruit crop in Florida. Yearly losses can be attributed to pre- and postharvest decay incited by *Botrytis cinerea* P. Micheli ex Pers. and postharvest decay resulting from primarily *Rhizopus stolonifer* (Ehrenb. ex Fr.) Vuillemin. In this study, the sanitizer peroxyacetic acid (100 μL·L⁻¹) was sprayed on flowers and developing strawberries 1, 2, and 3 d preharvest. Most of the time, fruit sprayed 3 days before harvest had significantly less decay than fruit sprayed 1 day preharvest or not sprayed when stored at 18 °C. Strawberries sprayed in the field with peroxyacetic acid and then coated postharvest with 1% chitosan coating had reduced decay compared with fruit only treated preharvest with peroxyacetic acid (PAA) for up to 12 days in storage. Sensitivity of *B. cinerea* hyphae and conidia to PAA was shown by the presence of a zone of inhibition using the disc assay method.**

The United States is the largest producer of strawberries (U.S. Dept. of Agriculture, 2005) with Florida second only to California in strawberry production. Strawberries have high levels of antioxidants (Wu et al., 2004) and are under increasing demand by consumers. Strawberries are extremely fragile and perishable necessitating minimal handling after harvest (Mitcham and Mitchell, 2002). For this reason, strawberries are harvested and packed in the field directly into retail clamshell containers that are delivered to the supermarket. Any treatment to reduce decay of strawberries would best be done as a preharvest operation to fit the current industrial harvesting and handling practices. Postharvest decay treatments to strawberries would only be accepted by the industry if decay reduction and resulting shelf life extension were very significant, justifying a change in the current harvesting and handling operation. However, postharvest treatments could increase shelf life of processed strawberries for the cut fruit industry. In most cases, any postharvest handling of strawberries leads to injury, which provides increased opportunity for wound pathogens and enhances decay.

Strawberry losses resulting from diseases are often difficult to quantify because of plant cultivar and cultural practices, which vary with locality, handling, storage, and marketing (Maas, 1980). Fungi are significant pre- and postharvest decay organisms for strawberries. Botrytis berry rot (causal organism, *Botrytis cinerea*) causes both pre- and postharvest disease. It often initiates infection in the field at the flowering or young fruit stage, often remaining latent until postharvest (Blacharski et al., 2001; Maas, 1980; U.S. Dept. of Agriculture, 2005). *Botrytis* is a facultative saprophyte producing a repeating cycle of asexual spores on senescent tissues, diseased flowers or fruit that are dispersed to young plant tissues by rain, wind, or insects (Blacharski et al., 2001; Maas, 1980).

More important as postharvest than preharvest pathogens are *Rhizopus stolonifer* and *Mucor* spp., Zygomycetes, commonly found in soil. These fungi are wound parasites and can become established on ripe fruit within 12 h (Maas, 1980). Although preharvest applications of fungicides have been shown to increase yields and decrease postharvest decay incited by *B. cinerea*, *R. stolonifer* and related opportunistic organisms are not well-controlled by preharvest fungicidal sprays. Most fungicides are residual on the fruit/plant, and because they are still present, fungi can acquire resistance to them rendering them ineffective (Maas, 1980; Maas and Smith, 1972). Additionally, synthetic fungicides are not acceptable for the organic market.

After harvest, refrigeration is most commonly used to slow decay in strawberries and maintain quality (El Ghaouth et al., 1991; Maas, 1980; Nunes et al., 2002). Most fungicides cannot maintain strawberry quality without the aid of refrigeration (Blacharski et al., 2001). In addition to preharvest treatments, postharvest applications of films and coatings such as chitosan act as antimicrobial agents while maintaining fruit quality (El Ghaouth et al., 1991, 1992, 1997; U.S. Dept. of Agriculture, 2005). For organic fruit, use of acidic vapors, food additives, and water dips offer some protection from decay (Karabulut et al., 2004; Park et al., 2005; Sholberg et al., 2000).

While postharvest surface treatments may delay decay, keeping spores from developing on plant tissues while in the field is most efficacious (Blacharski et al., 2001; Maas, 1980; Maas and Smith, 1972; U.S. Dept. of Agriculture, 2005). Our primary objective was to lengthen shelf life of strawberries by using the nonresidual commercial disinfectant, peroxyacetic acid (PAA) as an antimicrobial preharvest spray to reduce postharvest decay. Postharvest coatings were also applied to the fruit surface to enhance the antimicrobial control of the preharvest application of PAA. This disinfectant/sanitizer is soon to be approved for the organic market and has been shown to be effective against postharvest decay when applied postharvest on mango and citrus (Narciso, 2005; Narciso and Plotto, 2005).

Materials and Methods

Experimental strawberry plants, *Fragaria ×ananassa* Duchesne, variety 'Strawberry Festival', were located at the Florida Strawberry Growers Research and Education Center in Dover, Fla. Plants were in a commercial field in a double-row bed with 30.5-cm spacing between rows. Water and fertilizer were provided through drip tape after initial overhead irrigation after transplanting. The rows were ≈74 m long and each row was divided into six blocks with 54 to 57 plants in each block. A buffer area of ≈0.61 m at the start and the end of each row was used to better isolate experimental plants from open areas. Studies on strawberry plants in this field began in Jan. 2006.

Spraying. Before spraying, ripe strawberries were harvested from all plants in the experimental areas including control (nonsprayed) blocks. This left only flowers and very young strawberries, which would result in fruit that were synchronized in ripening. Commercial PAA (OxiDate; BioSafe Systems, Glastonbury, Conn.) was mixed on-site (100 μL·L⁻¹) in 8-L hand-sprayers (Chapin, Batavia, N.Y.). Spraying took place 3 d, 2 d, and 1 d (3S, 2S, and 1S) before harvesting the fruit from the experimental rows (e.g., 3S fruit were harvested the morning of the fourth day after spraying, leaving plant in "contact" with the spray for 3 d). Three days before the first harvest, the first blocks of each of two experimental rows was sprayed (3S) with 14 L of PAA per one block area using a heavy mist setting and completely covering all surfaces and all parts of the plant. Plants were not resprayed during the course of each

experiment. Handheld plastic barriers were used to prevent spray from drifting to unsprayed areas. The next day, the spray protocol was repeated and again on the third day. Three days after the initial spray, all the ripe strawberries in the experimental spray and nonsprayed areas were harvested. The strawberries were picked with gloved hands and placed directly into polyethylene terephthalate 325-mL vented clamshell containers (Pactiv Corp., Lake Forest, Ill.), 10 fruit per container, six to 15 containers per treatment, similar to commercial operations. The clamshells were packed in plastic crates and taken back to the Citrus and Subtropical Products Laboratory in Winter Haven. The strawberries were stored at 5 °C overnight to remove field heat and then moved to an 18 °C storage room with 95% relative humidity (RH). Temperature and humidity were monitored by dataloggers (Dickson Pro Series; Dickson, Addison, Ill.). Decay was evaluated every few days; strawberries were considered decayed when 30% or more of the surface was covered with lesions or there was visible mycelium. This process of spraying and evaluating decay was repeated three times in Jan., Feb., and Mar. 2006.

Determination of microbial load on immature fruit. A study of the effect of PAA on the microbial load of developing fruit was made concurrently with the Mar. 2006 spray experiment. On the first day of spraying (3 d before harvest), immature strawberry samples (green to white color stage) were randomly picked from each of the three experimental blocks (spray areas) and placed into sterile WhirlPak bags (Nasco, Modesto, Calif.), five fruit per bag, four bags per experimental block. The bags were placed in a cooler and taken back to the laboratory where they were weighed. After weighing, 99 mL of sterile phosphate buffer (pH 7.2) was added to each bag and the strawberries and the buffer were manually agitated for 2 min to remove the microflora from the surface of the fruit. The buffer was analyzed for presence of any microorganisms removed from fruit surfaces by using the protocol described by Narciso and Plotto (2005).

Weather. Averages of weather parameters during the duration of each study such as air temperatures (60 cm above the surface of the soil), precipitation, wind speeds, and solar radiation were evaluated to better understand differences in field results. Weather data were obtained from the Florida Automated Weather Service, Dover Station (State of Florida, 2006).

Postharvest treatments. In Mar. 2006, experimental blocks were sprayed 3 d pre-harvest with a 100 μL·L^{-1} solution of PAA following the protocol previously described. On harvest day, ≈300 strawberries from plants sprayed 3 d earlier were picked and placed in a clean container. Three hundred fruit were also picked from the corresponding no-spray (control) group of plants and placed in a separate container. Strawberries were taken back to the laboratory, sorted, and stored at 5 °C until treated.

Previously sprayed and nonsprayed stored strawberries were divided into four groups of 10 per treatment. Postharvest treatments were manually sprayed onto fruit using 250-mL misters (Fisher Scientific, Atlanta). There were five treatments applied to strawberries harvested from sprayed and nonsprayed sections of the field: no-treatment, distilled water, 50 μL·L^{-1} PAA (a formulation of PAA rated for postharvest use; StorOx; Bio-Safe Systems, Glastonbury, Conn.), chitosan (0.1% in 0.5% glacial acetic acid; France-Chitine, Orange, France), and sodium propionate (0.5%; Avocado Research Chemicals, Ltd., Lancashire, U.K.). The strawberries were spread on plastic mesh (commercial mesh size 0.9 × 1.3 cm) stretched between 30.5 × 30.5-cm polyvinyl chloride frames to allow the treatments to drain and the fruit to dry. After drying, strawberries were placed into containers as described previously, 10 fruit per container. The fruit were stored at 18 °C at 95% RH. Decay was logged as previously described.

Determination of pathogen sensitivity to peroxyacetic acid and chitosan. To test the effect of PAA on *B. cinerea* and *R. stolonifer* spores, the disc assay method was used. Spores were collected from plates of *B. cinerea* or *R. stolonifer*. Organisms were grown on potato dextrose agar for 5 to 7 d at 25 °C. Spores were removed from the colony surface with a solution of sterile water and 0.1% Tween 20 while gently rubbing the plate surface with a sterile glass rod. Spores were filtered through three layers of cheese-cloth and adjusted to ≈3.0 × 10^5 spores/mL with a hemocytometer (Hausser Scientific, Horsham, Penn.). Two hundred fifty microliters of inoculum of either *B. cinerea* or *R. stolonifer* was placed on the surface of potato dextrose agar plates and evenly spread with a sterile glass rod. Four sterile filter paper discs (10.5 mm) (Ace Glass, Vineland, N.J.) were placed in a container with a

solution of 100 μL·L^{-1} PAA and swirled for 30 s. The discs were drained, removed with sterile forceps, and placed on the surface of the inoculated plates. Plates were incubated at 25 °C for 10 to 14 d.

Determination of sensitivity of Botrytis *to chitosan coating.* Effect of chitosan on growth of *B. cinerea* was determined using the same method described previously. The discs were placed in 0.1% chitosan in 0.5% glacial acetic acid for 30 s and placed on plates coated with the *B. cinerea* inoculum. The chitosan buffer was also tested.

Statistical analysis. The Wilcoxon rank-sum test for difference in medians and equal variance (*t* test) and the Kruskal-Wallis test were used to determine significance between decay rates of the different spray groups and the average decay of the nonspray group. Tests were based on data distribution (Number Cruncher Statistical System, Kaysville, Utah; and SAS System Software Version 9.1; SAS Institute, Cary, N.C.) with $P \leq 0.05$ designated as significance of difference.

Results and Discussion

Designations are S for sprayed NS for nonsprayed strawberries. The 3S fruit were sprayed 3 d before harvest, 2S fruit were sprayed 2 d before harvest, and 1S fruit were sprayed the day before harvest.

In January, two experimental groups were picked within 3 d of each other and designated as harvest 1 and 2. Decay rates over the postharvest storage period (days after harvest) are summarized for the two January harvests. For harvest 1, 16 d postharvest, 3S strawberries had significantly (Figs. 1 and 2A) less decay (20%) than NS strawberries (50%), whereas 2S and 1S strawberries had 35% and 63% decay, respectively, and were not significantly different from the average NS decay rate of 50%. However, 17 d after harvest, both 3S and 2S strawberries had

Fig. 1. Chart showing significance between decay rates in sprayed and control (unsprayed) strawberries during 17 to 24 d in storage. **NS** means no significance and **X** shows significance between the sprayed and nonsprayed populations of the same day: 3S = sprayed 3 d preharvest; 2S = sprayed 2 d preharvest; 1S = sprayed 1 d preharvest; NS = not sprayed.
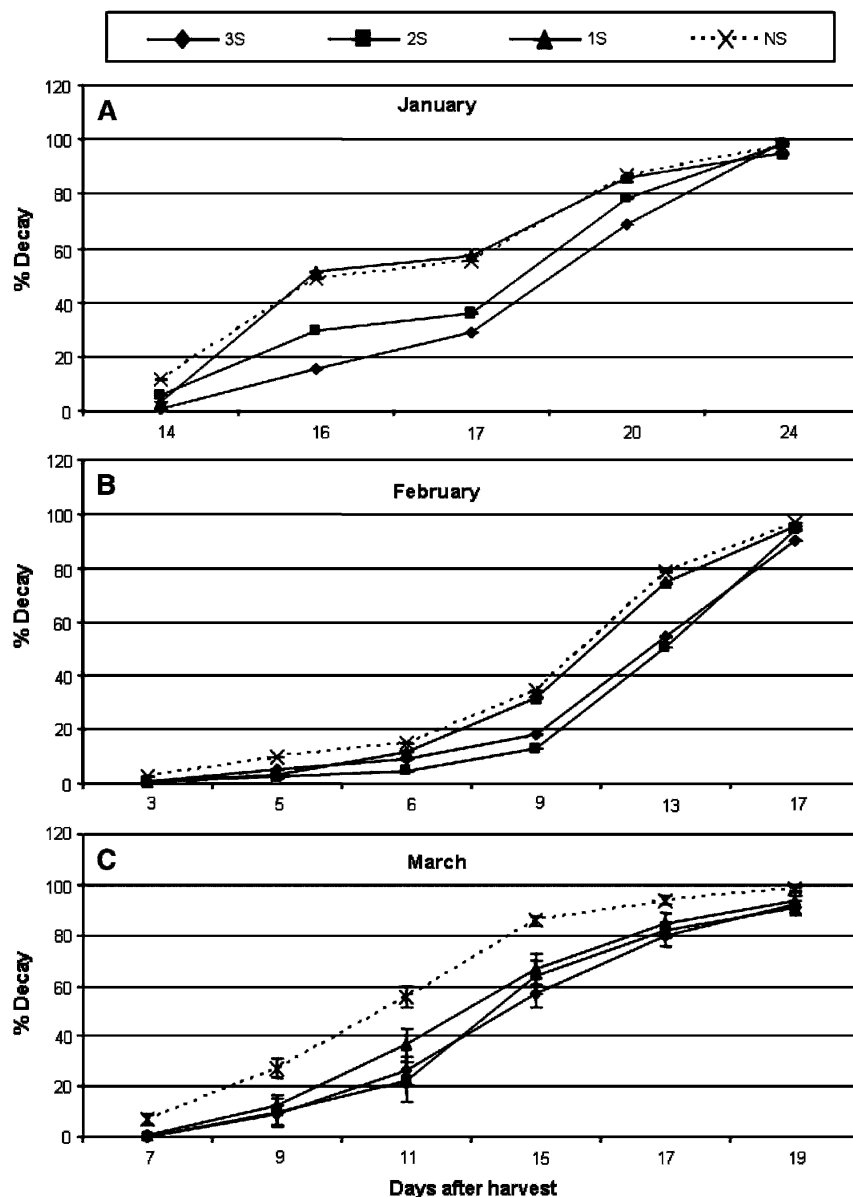
Fig. 2. Decay rates of strawberries in clamshells stored at 18 °C for up to 24 d: 3S (sprayed 3 d preharvest); 2S (sprayed 2 d preharvest,); 1S (sprayed 1 d preharvest); NS = not sprayed. Data ± SE (if error bars are not visible then are under the symbol) are a summary of duplicated experiments in (**A**) January for two harvest dates (20 and 23 Jan. 2006) and (**B**) 24 Feb. 2006 for two areas of the field and a (**C**) single experiment on 10 Mar. 2006. Six to 12, 11 to 15, and 14 to 17 clamshells with 10 strawberries each for January, February, and March, respectively, were counted per treatment in each experiment.

significantly less decay (37% and 42%, respectively) than the NS group (60%). Twenty days postharvest, all sprayed groups had decay that was not different from the NS group.

Data from harvest 2 in January showed similar results. Thirteen days postharvest, 3S and 2S spray strawberries had significantly (Fig. 1) less decay (12% and 21%, respectively) than the 1S (43%) or the NS group (48%). Seventeen days postharvest, only the 3S group had less decay than the NS group. For both January trials, those strawberries sprayed 3 d (3S) before harvest had slightly less decay than the 2S group and significantly slower rates of decay than the 1S and NS groups.

For the combined January data, the 2S and 3S strawberries exhibited less decay for 16 to 20 d in storage compared with the 1S and NS fruit, with the 3S group being most resistant to postharvest decay. Weather parameters for these trials showed temperatures at 60 cm above the surface of the soil with an average high of 22.6 °C and average low temperature of 5.9 °C with negligible rain and intermittent sun (163 w·m⁻²).

In February, there were two experimental groups picked from different sectors of the commercial field: Expt. 1 contained interior blocks protected from open spaces and Expt. 2 contained exterior blocks at the edge of the field. Decay rates over the postharvest storage period (days after harvest) are summarized for the two field locations for February in Figure 2B. Data for Expt. 1 (blocks from the interior of the field) showed no significant difference in decay between sprayed and nonsprayed strawberries until 13 d after harvest (Fig. 1). After 13 d, 3S and 2S groups had less decay (67% and 48%, respectively) than the 1S (80%) and the NS (81%) groups (Fig. 1). After 17 d, all groups had decay greater than 90%.

Data for Expt. 2 (blocks from the edge of the field) were comparable to Expt. 1 with the exception that decay was slower in all groups. Nine days postharvest, 3S and 2S had less decay (8% and 4%, respectively) than the 1S (27%) and the NS (27%) groups. Thirteen days postharvest, the 3S and 2S groups remained significantly (Fig. 1) less decayed (39% and 53%, respectively) than the 1S (68%) and NS (77%) groups.

For the combined February data, the 2S and 3S strawberries exhibited less decay for 9 and 13 d in storage compared with the 1S and NS fruit. Weather data for this time period showed temperatures with an average high of 20.0 °C and average low of 16.0 °C at 60 cm above the soil surface with negligible rain and intermittent sun (159 w·m⁻²). Wind speeds, as would have affected the exterior block, were between 0.9 and 1.8 m·s⁻¹. Although the actual decay rates were different between the January and February experimental groups, the strawberries that were sprayed 3 d before harvest had the slowest decay rates followed by the 2S group. Those strawberries sprayed the day before harvest did not show any difference in decay rates when compared with the nonsprayed group.

Data for March show decay rates for all three spray groups (3S, 2S, and 1S) were significantly less than those of the NS group (Figs. 1 and 2C). Nine days postharvest, percent decay of 3S, 2S, and 1S was 9%, 10%, and 13%, respectively, whereas the NS group was 28%. At 17 d postharvest, decay for the sprayed fruit was still less (3S = 80%, 2S = 82%, and 1S = 85%) than the NS group (94%). Temperatures for March at 60 cm above the soil surface ranged from an average high of 25 °C to a low of 10 °C. One cold night (4.6 °C) offset a general increase in temperatures. Precipitation was minimal but there were several sunny days (244 w·m⁻²).

In summary, data for the months of January and February show that strawberries sprayed 3 d preharvest had reduced decay when compared with strawberries sprayed 1 d preharvest or not sprayed, and all sprayed treatments had reduced decay compared with those not sprayed in March.

Microflora on immature fruit. To understand what seemed to be a residual effect of PAA on strawberry decay organisms, green fruit were daily assessed for surface microflora populations. Data show a continuing decline in microbial populations after the initial spray when compared with the initial nonsprayed plants (Fig. 3). Microorganisms on the surface of the immature strawberries were significantly reduced in the 3S, 2S, and the 1S groups up to 3 d postspray (Fig. 3).

PAA is volatile, breaking down to release oxygen and acetic acid, but as a compound is

not residual on fruit surfaces. The data from the immature strawberry study suggest that it continues to reduce microbial populations after initial application. This would indicate that over time, the number of organisms on the fruit surfaces decrease as a result of cell death when exposed to PAA. Sublethal cells would be unable to make repairs while remaining on the now acidified environment of the strawberry surface. Immature strawberries showed a continued decline in the microbial population after spraying, which corresponds with ripe strawberry studies. Strawberries sprayed 3 or 2 d preharvest had significantly lower rates of decay than fruit sprayed just before harvest or not sprayed, likely as a result of a reduction in microorganisms and, subsequently, their growth.

Determination of pathogen sensitivity to peroxyacetic acid. Evidence of sensitivity of *B. cinerea* hyphae and conidia to PAA was shown by the presence of a zone of inhibition (≈1 cm) around each of the discs after 5 d growth. After 10 d, the inhibition area was still obvious, although *B. cinerea* hyphae were beginning to move closer to the discs (Fig. 4). *R. stolonifer* was not as sensitive as *B. cinerea* to the presence of PAA. After 10 d, *R. stolonifer* growth in PAA plates was almost as dense as in the control. The only indication that PAA had any effect on *R. stolonifer* was decreased sporulation over parts of the plate that had exposure to PAA (Fig. 5). The disc assay study served as an indicator of the possible reduction of growth of *B. cinerea* and *R. stolonifer* by PAA when applied on strawberries in the field.

Postharvest treatments. To determine if postharvest antidecay treatments could enhance the decay reduction obtained with the preharvest PAA sprays, strawberries sprayed with PAA 3 d preharvest and strawberries from corresponding nonsprayed blocks were harvested, brought to the laboratory, and treated with postharvest antidecay compounds or coatings, including a lower (approved for postharvest application) concentration of PAA (Table 1). The preharvest PAA-sprayed strawberries with the postharvest spray treatment had generally less decay than nonsprayed fruit with postharvest treatments, except for sodium propionate, after 12 d (Table 1). This was significant for "no postharvest treatment" day 6; postharvest water treatment, day 12; and the postharvest chitosan treatment, days 6 to 12. Chitosan coating on presprayed fruit significantly reduced decay (17.5% decay) for 8 d longer than the control (no preharvest spray or postharvest treatment, 62.5% decay) (Table 1). Potato dextrose plates containing 10 d *B. cinerea* cultures and filter discs with chitosan or its buffer showed no difference in fungal growth when compared with the control plates (Fig. 4), indicating that chitosan did not have a direct effect on the pathogen but may have protected the fruit by eliciting a plant defense response (Kendra and Hadwigr, 1984). Other studies have reported chitosan to damage fungal hyphae (El Ghaouth et al., 1997).

Studies by other workers have also shown that chitosan is effective in extending the shelf life of strawberries (El Ghaouth et al., 1991; 1992; Park et al., 2005). Data in Table 1 show that on some strawberries, exposure to PAA preharvest before further treatment reduced postharvest decay. PAA reduces microflora populations on the fruit. As an additional postharvest treatment,

however, PAA has no effect or may even be damaging to ripe strawberries. If trichomes of the strawberries were damaged, it would result in increased infection. The high acidity of the combined pre- and postharvest PAA treatments may have damaged these structures. Discs with PAA in *B. cinerea* plates maintained areas of reduced or no growth (zones of inhibition) even after 10 d (Fig. 4).

Significance of results. All strawberries in these experiments were held at abusive temperatures (warmer than commercial storage) (Mitcham and Mitchell, 2002) to accelerate decay and simulate possible temperature abuse in transit or in consumer kitchens. Many studies have shown that cooling after harvest and in storage is important for extending shelf life (El Ghaouth et al., 1991; Maas, 1980; Nunes et al., 2002). In this study, at temperatures above storage optimum, strawberries sprayed 3 d preharvest had significantly less decay than strawberries sprayed 1 d before harvest or nonsprayed at some point of time in storage. The majority of decay in the stored fruit in this study was incited by *B. cinerea* followed by *R. stolonifer*. These organisms are the most problematic postharvest pathogens on strawberries (Blacharski et al., 2001; Bristow, 1986; Maas, 1980; Maas and Smith, 1972). Studies suggest that *B. cinerea* gains entrance into the strawberries in the field, remains latent, and causes decay after harvest (Bristow, 1986; Maas, 1980). Suggested controls include preharvest fungicide sprays at the prebloom, flowering, or young fruit stage (Blacharski et al., 2001; Maas, 1980; Maas and Smith, 1972). The prophylactic activity of the fungicide decreases the spores of *B. cinerea* that can invade young tissues. *R. stolonifer* is more difficult to control with field sprays because it is a wound pathogen and ripe fruit offer a good substrate (Maas, 1980).

PAA is a strong oxidizer and reduces microbial spore populations on fruit surfaces (Narciso, 2005). When PAA was sprayed on flowers and young fruit, spore numbers were reduced on surfaces, so fewer spores germinated and infected young tissue, reducing decay in fruits that were allowed to ripen (Fig. 3). Plants that were sprayed 3 d preharvest had only flowers and very young fruit (all ripe strawberries were harvested before the initial spraying). Our storage data show that decay was generally significantly reduced when PAA was sprayed on flowers and young fruit when compared with PAA sprays on ripe (1S groups) or nonsprayed strawberries (Figs. 1 and 2). Differences in results in onset of decay for storage studies from January through March could be attributed to changes in disease pressure in the field and the aging strawberry plants stressed by the increase in nighttime temperatures.

Other studies have also shown that *B. cinerea* and *R. stolonifer* spread in storage with fruit-to-fruit contact (Maas, 1980). In our clamshells, we found disease development on one or two stored strawberries that spread from the point of contact until all fruit
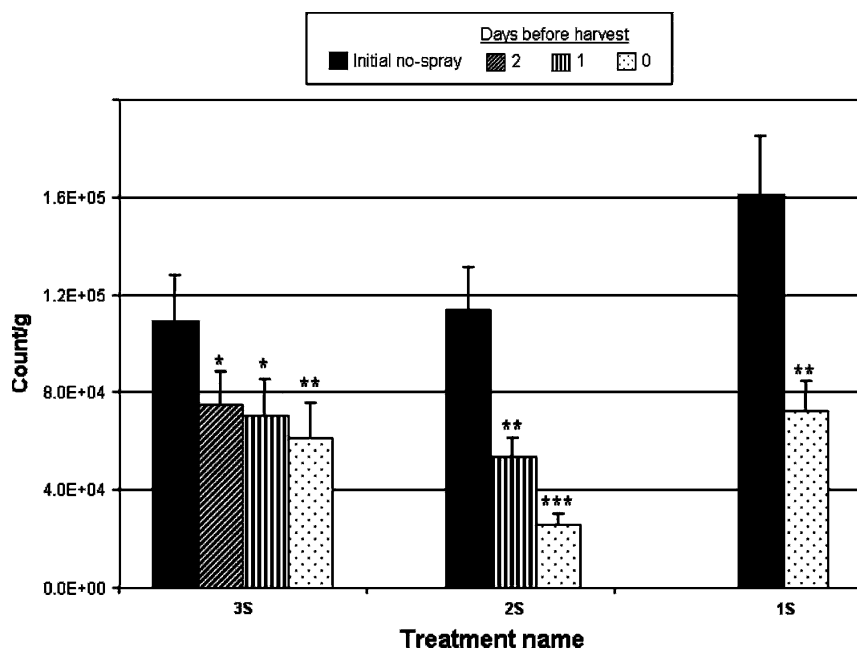

Fig. 3. Numbers of microorganisms counted (cfu/g) on immature fruit surfaces before (solid bar) and after spraying 3 (3S), 2 (2S), and 1 (1S) d preharvest. Data are means of four bags containing five strawberries each. Stars indicate significant differences between initial unsprayed plants (first column, solid bar) and sprayed berries 2, 1, and 0 d before harvest of ripe berries: *,**,*** significant at $P \leq 0.05$, 0.01, 0.001, respectively.
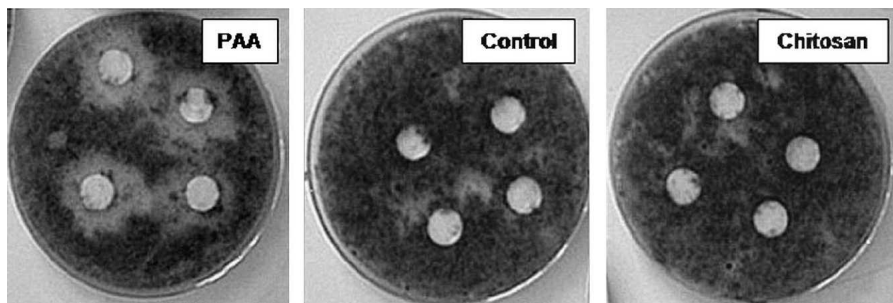
Fig. 4. Ten-day-old *Botrytis cinerea* cultures growing on potato dextrose agar plates with discs containing peroxyacetic acid, chitosan, and sterile water (control).
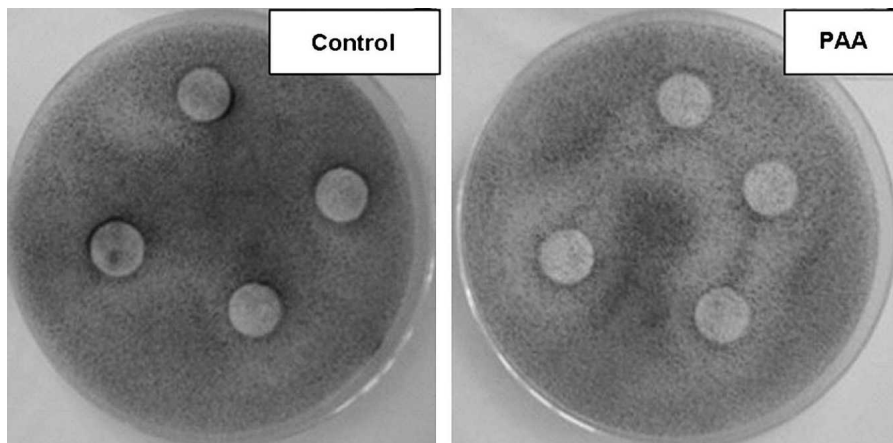

Fig. 5. Ten-day-old *Rhizopus stolonifer* cultures growing on potato dextrose agar plates with discs containing peroxyacetic acid and sterile water (control).

Table 1. Percent decayed fruit treated or not with a preharvest peroxyacetic acid (100 µL·L^{-1} PAA) spray and treated postharvest with water, PAA, chitosan, or sodium (Na)-propionate.[z]

Preharvest PAA	Postharvest treatment	Days in storage at 18 °C			
		4	6	8	12
No	Nothing	2.5	55.0*	62.5	80.0
Yes	Nothing	0.0	15.0*	42.5	72.5
No	Water	0.0	57.5	72.5	100.0*
Yes	Water	2.5	52.5	77.5	87.5*
No	PAA	0.0	25.0	42.5	82.5
Yes	PAA	10.0	40.0	52.5	67.5
No	Chitosan	0.0	77.5*	87.5*	97.5*
Yes	Chitosan	0.0	12.5*	17.5*	55.0*
No	Na-propionate	5.0	52.5	70.0	72.5
Yes	Na-propionate	0.0	22.5	40.0	80.0

[z]Numbers are percent decay of 40 fruit. Means followed by an asterisk indicate significant differences ($P \le 0.05$) between preharvest PAA-treated and nontreated fruit within a postharvest application treatment and day in storage using the Wilcoxon two-sample test (or the Kruskal-Wallis test).
PAA = peroxyacetic acid.

in the clamshell were involved. A preharvest treatment to reduce spores and a postharvest antimicrobial treatment to reduce in-storage spread of decay organisms would seem an ideal system to lengthen shelf life of these fragile fruit.

At a 100 µL·L^{-1} solution, PAA was not phytotoxic on leaves, flowers, or fruit. Pollinating insects were not deterred from flowers just sprayed (data not shown). Because U.S. Environmental Protection Agency field allowances for PAA are higher than what we used in this study, future work will involve testing increasing concentrations of preharvest PAA applications for better postharvest decay control. Times of applications, as well as assessing ripening strawberries for

both their microbial loads and the effectiveness of PAA on these loads, will be further studied. Peroxyacetic acid could be used to complement other methods of decay control presently in use by reducing the use of fungicides in the field if they were alternated with PAA sprays.

Studies with postharvest treatments on strawberries previously sprayed with PAA showed variable results. In most cases, the addition of a coating or surface treatment did not lengthen storage time of the fruit with the exception of the chitosan coating. The activity of the PAA and surface treatments needs further analysis to identify combined pre- and postharvest treatments that will most effectively maintain strawberry quality.

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