Using Phosphite Fungicides to Control Apple Diseases

David A. Rosenberger and Kerik D. Cox
Dept. of Plant Pathology,
New York State Ag. Exp. Station, Cornell University
Highland, NY and Geneva, NY

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

The first phosphite fungicide registered in the U.S. was fosetyl-Al. It is currently marketed as Aliette WDG, is primarily labeled for managing *Phytophthora* root rot diseases and has proved effective for numerous crops where *Phytophthora* root rots had been difficult to control. In apples, Aliette is also labeled for fire blight and blister spot management. Of these two diseases, it is most effective against blister spot on 'Mutsu' or 'Crispin' where it is a viable option for streptomycin resistance management (Ellis et al., 2000). For many years, Aliette was the only phosphite fungicide available, but less expensive generics became available after the Aliette patent expired a few years ago. Today's phosphite fungicides are available under a variety of brand names such as ProPhyt, Agri-Fos, Phostrol, and Fosphite.

> **"Extensive testing provided no evidence that phosphite fungicides have value for controlling apple scab. However, when added into summer sprays, ProPhyt enhanced the residual activity of Captan, Topsin M and Pristine against flyspeck and sooty blotch."**

In Australia, phosphite fungicides have been applied by air to large forested areas to protect endangered native species of trees that were being threatened by newly introduced *Phytophthora* species (Hardy et al., 2001). In California, the outbreak of sudden oak death caused by *Phytophthora ramorum* led to increased use of phosphite fungicides and new methods for applying them (Garbelotto, 2007). Particularly intriguing was the discovery that phosphite fungicides, when combined with a patented penetrant/surfactant spray adjuvant, could be applied to the basal trunk section of large oak trees and would protect the entire tree from infection.

Although used primarily for managing *Phytophthora* diseases, phosphite fungicides also proved effective for controlling flyspeck and sooty blotch on apples in North Carolina (Sutton et al., 2006). In 2006, initial studies in several states suggested that phosphite fungicides applied as trunk sprays to apples at green tip might suppress apple scab infections throughout the tree from green tip to petal fall. If such trunk sprays could control apple scab, this approach would reduce the total pesticide load applied to apples by decreasing the need for prebloom sprays.

With funding from the USDA Pesticide Management Alternatives Program, we established research plots to determine if phosphite fungicides applied as trunk sprays at bud break would control apple scab during the interval from bud break to petal fall without adversely affecting fruit set and total yield. At the same time, the NY Apple Research and Development Program funded research to determine if phosphite fungicides could be integrated into summer fungicide programs to control flyspeck, sooty blotch, and summer fruit rots.

Background on Phosphite Fungicides

Phosphite fungicides have also been called phosphorous acids, phosphonic acids, phosphonates, or just "phosphites." Phosphite fungicides are transported through plants in both the xylem and the phloem, a unique property that allows the phosphites to move both upward and downward from the point of application (Ouimette & Coffey, 1989). Phosphites have been shown to stimulate host defense mechanisms in plants, but at high concentrations phosphites are also directly toxic to some pathogens (bacteria and fungi). The mode of action by which phosphites inhibit plant diseases under field conditions is still largely unknown.

Phosphites are relatively inefficient as phosphorus fertilizers and therefore are not useful for phosphorus nutrition (Landschoot & Cooke, 2005). Some researchers have reported that the phosphites become available to plants in a usable form only after the phosphites leach out of plant roots, are modified by soil bacteria into a usable form of phosphorus, and then are then taken back into the roots. Despite the fact that phosphites have little nutritional value, some phosphites are labeled as plant nutritional sprays rather than as fungicides. Using these so-called "nutritional" formulations for disease control is illegal because they are not labeled as fungicides. Furthermore, it is often impossible to compare the fungicidal capabilities of "nutritional" phosphites with those that are labeled as fungicides because the "nutritional" product labels do not report the amounts of active ingredient in a way that would allow them to be compared with phosphite fungicides. Phosphites labeled as fungicides report their activity as pounds per gallon of phosphorous acid equivalent.

Evaluating Phosphites for Controlling Scab

In spring of 2007, phosphite fungicides were applied to trunks of mature apple trees in research orchards at both Highland and Geneva, New York. In both trials, we evaluated trunk sprays of Agri-Fos, ProPhyt, and Phostrol, products containing phosphorous acid equivalents of 3.35, 4.2, and 4.32 lb per gallon, respectively. Agri-Fos was tested at four different rates in an attempt to discover the lowest effective dose that might control scab. All of the trunk sprays were applied in combination with Pentra-Bark, the adjuvant that had been successfully used to enhance uptake of phosphite fungicides through the bark of oak trees in California. The trunk sprays were also compared to weekly foliar applications of Agri-Fos and to a standard weekly calendar spray with contact fungicides (mancozeb and/or Captan).

For trunk sprays, hand-held CO_2-pressurized sprayers were used to treat the bottom three feet of each apple trunk plus the first foot of each scaffold limb that branched from the trunk less than three feet above ground. The trunks were sprayed until completely wet. Plots were replicated four times at each test site. The test orchards used in 2007 contained the apple cultivars 'Jerseymac', 'Ginger Gold', 'McIntosh', and 'Golden Delicious'. Treated trees were observed for phytotoxicity throughout the season, and detailed data on disease incidence was collected at regular intervals through the season and from fruit at harvest.

Unfortunately, none of the phosphite trunk treatments provided a commercially acceptable level of apple scab control at Highland or Geneva in 2007. The foliar sprays of Agri-Fos were more effective against scab than trunk treatments, but the foliar sprays were still far less effective than standard protectant fungicides applied on the same schedule.

Field trials for 2008 were redesigned to determine if other application methods and/or application times might enable phosphites to control apple scab. Because trunk sprays were totally ineffective in 2007, most of the phosphite treatments in 2008 involved either crown drenches or soil surface applications within the herbicide strip. The crown drench was meant to mimic the original method used to apply Ridomil to apple trees to control *Phytophthora* crown rot, and the soil sprays were meant to facilitate uptake via roots. In addition, some of the trunk sprays, crown drenches, and soil-surface sprays were applied at tight cluster rather than at green tip to determine if trees with active leaves might take up and translocate the phosphite better than trees that were treated at green tip.

In the coordinated 2008 trial at Highland and Geneva, a three-way factorial design was used to assess effects of two phosphite rates, two different timings (either green tip or tight cluster), and two application methods (either a crown drench or as an application to the soil surface within the herbicide strip beneath trees). In a another 2008 field trial at the Hudson Valley Lab, a variety block containing 20 apple cultivars was used to compare untreated controls, a regular mancozeb spray program, phosphite crown drenches at green tip, and phosphite treatment of soil surfaces at green tip. The phosphite soil treatment involved application of ProPhyt at rates equivalent to 6 gal of ProPhyt per treated acre. Trees were observed carefully to determine if phosphite applications would cause phytotoxicity on any of the 20 cultivars in this test orchard.

In summary, over the course of the two years in which these trials were conducted, we applied phosphite fungicides to control apple scab in a total of eight different field trials that involved 39 separate phosphite treatment programs in Highland and 20 treatment programs at Geneva. Products tested included Phostrol, Agri-Fos, and ProPhyt, but most of treatments involved Agri-Fos in 2007 and ProPhyt in 2008. The phosphites were tested as trunk sprays at green tip, crown drenches at both green tip and tight cluster timings, soil surface applications at both green tip and tight cluster timings, as a single high-rate foliar spray at green-tip in combination with oil, weekly foliar sprays of phosphites alone, and weekly foliar sprays in combinations with Captan and with mancozeb.

None of the phosphite applications caused observable phytotoxicity on any cultivars, and detailed blossom and fruit set counts in 2007 showed that phosphite trunk sprays and weekly foliar sprays had no effect on fruit set. We did not detect any effects on total yield or fruit size, although our ability to detect fruit size and yield effects was limited by high tree-to-tree variability within our test blocks due to previous disease control and cropping histories.

Unfortunately, we found no evidence that phosphites are useful as apple scab fungicides. Where phosphites were combined with Captan or mancozeb sprays, disease control was similar to that provided by Captan or mancozeb used alone. When phosphites were applied alone, the best treatment was that of weekly foliar sprays of Agri-Fos, but even that treatment provided only 76% control of early season scab as compared 99% control with a mancozeb fungicide applied on the same schedule. For most of the other application methods and timings, the phosphite fungicides were only about half as effective as standard contact fungicides applied weekly.

Effectiveness of Phosphite Fungicides for Controlling Summer Diseases on Apples

Phosphite fungicides were applied to control sooty blotch and flyspeck (SBFS) in six field trials in the Hudson Valley during the 2007 and 2008 growing seasons. In all of the trials, treatments were replicated four times and all sprays were applied dilute using a handgun to spray trees to drip. Many of the trials employed two-way or three-way factorial designs wherein various fungicides or fungicide combinations were applied either alone or in combinations with ProPhyt or other spray adjuvants.

In one trial, ProPhyt, LI-700 (a surfactant and acidifier), and Tactic (a synthetic latex and organosilicone sticker, surfactant, and deposition agent) were applied alone, with Captan, or in three-way combinations with Topsin M plus Captan. Treatments were applied to 'Golden Delicious' trees on 1 September using a handgun sprayer. The test trees had received no fungicide sprays after 21 July, so we anticipated that the fruit would have many incubating but still invisible flyspeck infections at the time the fungicides were applied. When fruit were evaluated 33 days later, 96 percent of unsprayed fruit had flyspeck. ProPhyt applied alone suppressed flyspeck by 51% whereas LI-700 and Tactic had less effect (Table 1). Fruit sprayed with Topsin M plus Captan plus Tactic had the least flyspeck (14%), but ProPhyt plus Captan provided statistically equivalent control with 31% of fruit affected. Results from this trial suggested that ProPhyt activity against SBFS involves more than spray acidification or surfactant activity.

In 2007 and 2008, extensive trials were conducted in an orchard composed of three-tree plots that each contained a 'Honeycrisp', a 'Royal Court' and a 'Cameo' tree. ProPhyt was applied at two rates either alone or in mixtures with Captan, Topsin M, or Pristine. In 2007, treatments were applied on 7 June, 3 July, 23 July, and 14 August. Applications in 2008 were made on 16 July, 31 July, 13 August, and, to Royal Court and Cameo only, on 16 September. Each cultivar was harvested when mature and fruit were assessed for incidence of flyspeck, sooty blotch, and fruit decays. Most of the latter were caused by the black rot fungus, *Botryosphaeria obtusa*. In cases where disease incidence in the unsprayed controls was relatively low at harvest, fruit were evaluated immediately after harvest, then incubated at room temperature with 100% relative humidity for two to three weeks to allow incubating lesions on fruit surfaces to become visible. Fruit were then rated a second time after the postharvest incubation period and both harvest and postharvest datasets were used in our final analyses.

The objective of these trials was to determine if, when, and at what use-rate ProPhyt might enhance control of summer diseases. We opted to test ProPhyt at 8 and 16 fl oz per 100 gal of dilute spray, rates that would be equivalent to 1.5 pint/A and 3 pt/A on trees requiring 300 gal/A in tree-row volume calculations. The label rate for ProPhyt is 2 qt/A, so the rates tested in these trials were lower than the label rate. However, results from an earlier field trial in the Hudson Valley led us to suspect that the rates that we tested would be adequate for enhancing control of summer diseases.

For each cultivar and disease evaluated, the dataset was subjected to a two-way analysis of variance that allowed us to compare differences among simple means (i.e., all of the individual treatments) as well as differences among grand means (i.e., effects of fungicides across the +/- ProPhyt treatments and effects of ProPhyt across the various fungicide treatments). Results from one of these datasets are shown numerically in Table 2 and graphically in Figure 1. Two years of field testing resulted in a total of 24 different datasets like the one shown in Table 2, with datasets varying by year of the test, cultivar evaluated, disease evaluated (i.e., flyspeck, sooty blotch, or fruit rots), and the time of the evaluation (at harvest or after postharvest incubation).

Table 1. Effects of different treatments applied on 1 September 2007 on flyspeck incidence on Golden Delicious fruit harvested on 3 October as determined by observing 75 fruit per tree.

Fungicide and rate of formulated product applied per 100 gal of dilute spray	Percent of fruit with flyspeck: Combination products — None: fungicide used alone	ProPhyt 4.2E 20 fl oz	LI-700 16 fl oz	Tactic 8 fl oz	Grand means for effects of fungicides
Control	96 e	47 b	84 de	74 cd	77 C*
Captan 80WDG 15 oz	42 ab	31 ab	45 b	45 b	41 B
Topsin M 70WSB 4 oz plus Captan 80WDG 15 oz	26 ab	21 ab	47 bc	14 a	24 A
Grand means for effects of combination products	**55 B***	**32 A**	**61 B**	**44 AB**	

*Simple means followed by the same lower-case letter are not significantly different (P ≤ 0.05), and grand means within the last column or the bottom row that are followed by the same capital letter are not significantly different (P ≤ 0.05) as determined by applying Fisher's Protected LSD test to results from a 3x4 two-way analysis of fungicides and combination products. P-values for effects of fungicides, combination products, and interactions were <0.001, 0.010, and 0.059, respectively.

Table 2. Flyspeck incidence on Royal Court fruit incubated at 100% RH for 19 days following harvest on 19 September 2007.

Fungicide and rate of formulated product applied per 100 gal of dilute spray	Percent fruit with flyspeck (%): Fungicide alone	Mixed with ProPhyt 4.2L: 8 fl oz	Mixed with ProPhyt 4.2L: 16 fl oz	Grand means for effects of fungicides
No fungicide	95 j	82 hi	73 gh	83 D
Captan 80WDG 10 oz	87 ij	50 ef	44 def	60 C
Topsin M 70WDG 4 oz	58 fg	38 cde	35 cd	44 B
Pristine 38WDG 5 oz	29 c	15 b	6 a	17 A
Grand means for effects of ProPhyt	**67.0 C**	**46 B**	**39 A**	

*Any of the 12 simple means followed by the same small letter are not significantly different (P≤0.05) as determined by applying Fisher's Protected LSD to results from a 3x4 two-way analysis of fungicides and ProPhyt. Similarly, grand means within columns or within rows that are followed by the same capital letter are not significantly different. P-values for effects of fungicides, ProPhyt, and their interaction were <0.001, <0.001, and 0.245, respectively.

Results from the 16 datasets involving flyspeck and sooty blotch are summarized in Table 3. The datasets in Table 3 were ordered from left to right based on a "disease severity index" that was determined for each dataset by averaging disease incidence in the unsprayed control and the treatment involving Captan applied alone. The latter was consistently the weakest of the treatments that involved Captan, Topsin M or Pristine. The severity index allowed us to rank the datasets according to the severity of the test (Table 3). In most cases, fungicides have longer residual activity against sooty blotch than against flyspeck, so for any given cultivar and harvest date, the dataset for sooty blotch always had a lower severity index than the corresponding dataset for flyspeck. Disease severity was also affected by the timing of sprays applied during summer, the number of days and the weather conditions between the last spray and harvest, and the cultivar. The complexity of these interactions is still not fully understood and goes beyond the scope of this report. Nevertheless, ranking datasets by the severity index as shown in Table 3 allows certain patterns of activity to emerge.

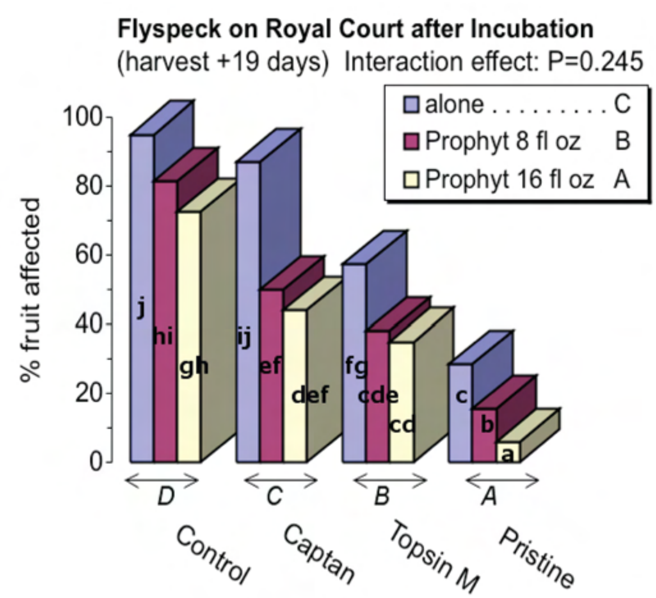

Figure 1. Effects of fungicides applied either alone or with Prophyt on incidence of flyspeck following field sprays in 2007. Upper-case letters show statistical separations (P≤0.05) for effects of grand means (overall fungicide effects) and lower case letters show separations among the 12 simple means.

The dataset shown in Table 2 and Fig. 1 is displayed as dataset #15 in Table 3. Detailed data from each dataset like the one in Table 2 was summarized in Table 3 by answering a series of questions about the treatment means. First, we asked if disease incidence for the lower rate of ProPhyt used alone (82% in top

Table 3. Effectiveness of ProPhyt used alone or combined with Captan, Topsin M, or Pristine as determined from disease incidence for sooty blotch and flyspeck observed either at harvest or after postharvest incubation. Columns in the table show comparisons from 16 datasets from field trials conducted in 2007 and 2008 at Cornell's Hudson Valley Lab.

	Dataset number (1-16), harvest date, cultivar (Honeycrisp, Royal Court, Cameo), evaluation time (harvest or after postharvest incubation), and disease evaluated (sooty blotch or flyspeck) [z]															
ProPhyt treatment comparisons	#1 9/5 2007 HC hvst SB	#2 9/25 2008 RCt hvst SB	#3 9/18 2007 RCt hvst SB	#4 9/5 2007 HC incb SB	#5 9/18 2007 RCt incb SB	#6 9/11 2008 HC hvst SB	#7 9/5 2007 HC hvst FS	#8 9/5 2007 HC incb FS	#9 10/29 2007 Cam hvst SB	#10 8/10 2008 Cam hvst SB	#11 9/18 2007 RCt hvst FS	#12 9/11 2008 HC hvst FS	#13 10/8 2008 Cam hvst FS	#14 9/25 2008 RCt hvst FS	#15 9/18 2007 RCt incb FS	#16 10/29 2007 Cam hvst FS
Test severity index [y]	8	12	19	22	28	37	39	48	56	56	70	73	87	87	91	91
ProPhyt 8 fl oz —																
Better than unsprayed	Y [x]	0	Y	Y	Y	Y	Y	Y	0	Y	Y	Y	Y	Y	Y	0
Improved Captan	-	Y	-	Y	Y	Y	0	0	Y	Y	Y	Y	Y	Y	Y	0
Improved Topsin M	-	-	-	-	Y	-	-	-	0	0	0	0	Y	Y	Y	0
Improved Pristine	-	-	-	-	-	0	-	-	-	0	0	0	Y	Y	Y	0
ProPhyt 16 fl oz —																
Better than unsprayed	Y	Y	Y	Y	Y	Y	Y	Y	0	Y	Y	Y	Y	Y	Y	0
Improved Captan	-	Y	-	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	0
Improved Topsin M	-	-	-	-	Y	-	-	-	0	Y	0	Y	Y	Y	Y	0
Improved Pristine	-	-	-	-	-	0	-	-	-	0	0	Y	Y	Y	Y	0
% fruit affected in the best treatment	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**1.9**	**0.6**	**0.0**	**4.0**	**1.1**	**4.2**	**9.2**	**6.0**	**12.6**

[z] HC = Honeycrisp; RCt = Royal Court; hvst = harvest; incb = after postharvest incubation; SB = sooty blotch; FS = flyspeck.
[y] Test severity index is the mean of disease incidence in unsprayed control and the treatment with Captan alone.
[x] Y = Yes: the addition of ProPhyt caused significant reductions ($P \leq 0.05$) in disease incidence compared to the unsprayed control or to the other fungicides used alone. A dash means that disease incidence with Captan, Topsin M or Pristine used alone was less than 5%, thereby making detection of improved performance with ProPhyt unlikely. A zero (0) indicates that neither of the previous criteria was met and ProPhyt therefore provided no benefit compared to the unsprayed control or to the other fungicides used alone.

data line of Table 2) was significantly less than disease incidence in the unsprayed control (95% in the top data line of Table 2). Since the answer in this case was yes, we entered a "Y" in the top data line in Table 3 in the column designated for dataset #15. We then asked if ProPhyt at 8 fl oz, when added to Captan, resulted in significantly less disease than Captan applied alone, and we continued that process for all of the potential combinations with ProPhyt using responses as noted in the footnote for Table 3.

When results from all of the 16 SBFS datasets were compiled (Table 3), certain trends emerged. First, ProPhyt applied alone at either the low rate or the high rate suppressed sooty blotch and flyspeck in most of the datasets. However, as illustrated in Table 2, the degree of control was almost never commercially acceptable. Second, for datasets 1 to 8 where the disease severity index was low, ProPhyt usually improved the activity of Captan, but ProPhyt could not enhance activity of Topsin M and Pristine, both of which provided nearly complete disease control when used alone. Within the mid-range for disease severity in Table 3 (datasets 6 to 12), adding ProPhyt to standard fungicides sometimes improved fungicide efficacy and sometimes it did not. Within this group, there was some evidence that the higher rate of ProPhyt was more effective than the lower rate.

Under the high disease severity conditions represented by datasets 13 to 15, the addition of ProPhyt always enhanced activity of the standard fungicides. Although this group had high disease severity indices, disease incidence in the best treatment (usually Pristine plus ProPhyt) was still below 10% (bottom data line in Table 3). Moreover, the majority of infections in the Pristine-plus-ProPhyt treatment were so small that fruit would not have been downgraded at packing. Thus, datasets 13-15 in Table 3 are representative of disease incidence levels that would frequently occur in Hudson Valley orchards.

Dataset #16, from late-harvested Cameo that were last sprayed 76 days prior to the 29 October harvest date, was the only dataset wherein no benefits from ProPhyt were detected. Within that dataset, mean disease incidence for all treatments involving Pristine was 13% and for all treatments involving Topsin M it was 35% whereas treatments that included neither Pristine, Topsin M, nor Captan averaged 97%. Thus, while the standard fungicides still impacted disease incidence 76 days after the last application, the benefits of adding ProPhyt had apparently dissipated before the Cameo fruit were harvested.

The eight datasets not shown in Table 3 summarized effects of ProPhyt on control of summer fruit decays and lenticel spots. Whereas ProPhyt clearly improved control of sooty blotch and flyspeck in many of the comparisons shown in Table 3, there was not a single comparison where adding ProPhyt resulted in a reduction of fruit decays and lenticel spots. By contrast, there were two cases where fruit treated with ProPhyt applied alone had significantly higher incidence of decay and lenticel spots than occurred in the corresponding unsprayed controls. Across all of these eight datasets, the mean incidences of decays and lenticel spots for treatments involving Captan, Topsin M, Pristine, or none of the previous three products were 18, 9, 7, or 18%, respectively.

Conclusions

Extensive testing over two years and in two locations provided no evidence that phosphite fungicides are useful for controlling apple scab. However, ProPhyt added to Captan in summer fungicide sprays almost always resulted in improved control of sooty blotch and flyspeck. ProPhyt also appeared to strengthen the residual activity of Topsin M and Pristine against these diseases, but ProPhyt did not show any activity against *Botryosphaeria* species that cause summer fruit decay and lenticel spots.

ProPhyt is labeled (including in New York State) for applications against sooty blotch and flyspeck. Some of the other phosphites have similar labels. Although we tested only ProPhyt in our summer spray programs, we suspect that other phosphite formulations would provide similar results.

In most of our trials, the combination of ProPhyt plus Captan provided control of sooty blotch and flyspeck that was comparable to control provided by Topsin M or Topsin M/Captan combinations. (Although we tested Topsin M alone in some of our research plots, Topsin M should always be combined with Captan in summer sprays both for resistance management and because Topsin M applied alone does not control bitter rot caused by *Colletotrichum acutatum.*) The combination of Captan plus a phosphite fungicide might fit best for sprays applied in late June and early July when infection risks from fruit rot fungi are usually lower than later in the summer. Growers who wish to reserve Topsin M for late summer applications could use a Captan/phosphite combination in late June and/or early July so that late summer sprays with Topsin M will not be limited by the annual maximum usage limit of 64 oz/A/yr that is specified on the Topsin M.

Alternatively, Captan/phosphite combinations might be used for later season sprays in situations where apple buyers have placed restrictions on late-season use of Topsin M. However, Captan/phosphite combinations will be less effective than Topsin M/Captan combinations for controlling summer fruit rots. One way to compensate for that deficiency might be to use higher rates of Captan in the Captan/phosphite combination sprays. All of our testing was done with relatively low rates of Captan.

Finally, results suggest that adding a phosphite to end-of-season Pristine or Topsin M/Captan combinations might help to extend residual activity of these fungicides for those varieties that are picked in October or early November.

Acknowledgements

This work was supported by the New York Apple Research and Development Program, the USDA Pest Management Alternatives Special Grants Program, and several companies that market phosphite fungicides.

Literature Cited

Ellis, M.A., Madden, L.V., Burr, T.J. 2000. Effectiveness of Fosetyl-Aluminum and Streptomycin Alone and In Combination for Control of Blister Spot on 'Mutsu' Apples in Ohio and New York. PHP-2000-1204-01-RS

Hardy, G. E. St. J., Barrett, S. and Shearer, B. L. 2001. The future of phosphite as a fungicide to control the soilborne plant pathogen *Phytophthora cinnamomi* in natural ecosystems. *Australasian Plant Pathology* 30: 133-139.

Garbelotto, M. 2007. Agri-Fos Use Guidelines and Application Protocol. On-line at: http://nature.berkeley.edu/garbelotto/english/treatment.php

Landschoot, P., and Cook, J. 2005. Sorting out the phosphonate products. *Research Science for the Golf Course.* November 2005: 73-88.

Ouimette, D. G., and Coffey, M. D. 1989. Comparative antifungal activity of four phosphonate compounds against isolates of nine *Phytophthora* species. *Phytopathology* 79: 761-767.

Sutton, T.B., Brown, E., Anas, O., and Meister, C.W. 2006. Efficacy of phosphorus-containing fungicides on summer diseases of apples, 2005. Fungicide and Nematicide Tests (online.) Report 61:PF004. DOI:10.1094/FN61. The American Phytopathological Society, St. Paul, MN.

David Rosenberger is a research and extension professor of Plant Pathology and superintendent of New York State Agricultural Experiment Station's Hudson Valley Lab. Kerik Cox is an assistant professor of Plant Pathology at the Geneva Experiment Station who specializes in diseases of apple, pear, berry crops and stone fruit.