Effect of Powdery Mildew on Apple Yield and Economic Benefits of Its Management in Virginia

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ABSTRACT

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Plots were established in a 'Ginger Gold' apple orchard to test the effects of different powdery mildew levels on cumulative yields. Disease pressure was heaviest in 1997 but yield effects were detected each year. Primary infection in 1997 and 1998 was correlated to previous foliar mildew incidence. Five myclobutanil applications followed by three of triadimefon (M5-T3) reduced primary infections in 1997 to 19% of those on trees not receiving a mildewcide (Ck). M5-T3 gave the most reduction in mildew incidence and severity but a schedule with two less applications (M3-T3) than M5-T3 gave the highest yield. Yields were lowest on trees not receiving a mildewcide. In 1998, the weakest and the strongest treatments had two and four times more flower clusters per tree, respectively, than Ck trees. Yield of the weakest mildew treatment (six applications of sulfur, S6), was about twice that of the Ck trees; several treatments yielded more than 2× S6. Increasing the number of sulfur applications from six to eight increased mildew control and yield. Most of the treatments resulted in yields higher than the nontreated control over a 3-year period. The M3-T3 treatment regime resulted in the highest 3-year yield, whereas a slightly more effective M5-T3 regime yielded slightly less. An economic analysis of cumulative treatment benefits, using local price inputs, is included.

Additional keywords: apple disease management, *Podosphaera leucotricha*

Powdery mildew, caused by *Podosphaera leucotricha* (Ellis & Everh.) E. S. Salmon, is the only disease of apple that thrives during dry spring and summer weather in Virginia (11). The fungus survives the winter in buds, making it difficult to control and, although it can cause fruit russet, its chronic effect on tree vigor and yield is more serious (2). Based on earlier observed yield effects in research plots at Winchester (8,9,11), a special action threshold level at 20% leaf infection was suggested in the *Mid-Atlantic Orchard Monitoring Guide* (12). Because of the chronic effects of the disease, increased control efforts under heavy inoculum conditions are not fully rewarded in just 1 year and growers may become frustrated in their efforts and unconvinced about the importance of routine management programs for highly susceptible cultivars. Cultivars that are moderately or highly susceptible to powdery mildew comprise more than 40% of the apple plantings in Virginia and include 'Ginger Gold', 'Golden Delicious', 'Granny Smith', 'Idared', 'Jonagold', 'Jonathan', 'Paulared', 'Rome Beauty', 'Stayman Winesap', and 'Winesap'. The presence of mildew in an orchard one year, coupled with the normal weather conditions in the Shenandoah Valley region of Virginia, makes the recurrent presence of mildew likely.

Currently, the primary mildewcides are sterol demethylation inhibitors (DMIs) and sulfur. The DMIs have been perceived by many growers as being highly effective, but more expensive than sulfur for mildew control. When either type of fungicide is applied too infrequently to maintain protective coverage in a dry spring, an increase in mildew beyond the suggested action threshold level of 20% infection may result. Three reports cite differing effects of DMI fungicides on return bloom (1,4,7), and several have indicated positive effects on one or more elements of yield by one or more of the DMI fungicides in the presence of mildew (6,8–10).

The objective of this research was to determine the cumulative effect of powdery mildew infection on apple yield on the highly susceptible cultivar Ginger Gold and to compare the effectiveness of various management options. A 2-year preliminary report on this study has been published (10).

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MATERIALS AND METHODS

This 3-year study was designed to compare the economics of mildew control programs based on either DMI fungicides or sulfur. Ginger Gold was chosen as the test cultivar because of its susceptibility to mildew, its discovery in Virginia, and its extensive planting in recent years. Beginning in April 1996, four treatments were applied at two selected spray intervals (1-week versus 2-week) from tight cluster stage through first cover. Then, all treatments were applied on the same interval for midseason sprays, as deemed appropriate (Table 1). Two additional treatments (T3-S3 and M3-S3) representing intermediate, less expensive serial applications of DMI fungicides and sulfur were also included, giving a total of six treatments plus a control (Table 2). The products used were myclobutanil (Nova 40W; Rohm and Haas Co., Philadelphia, PA), triadimefon (Bayleton 50WDG; Bayer Co., Kansas City, MO), and sulfur (Microfine Sulfur 90W; United Agri Products, Greeley, CO). Test plots were established in a 4-year-old commercial orchard in a randomized block design with five double-tree replicates separated by single border trees in the treatment row and by a border row between treatment rows. The test planting contained 193 trees/ha spaced at 6.1 by 8.5 m. This design permitted an entire replicate block, including all treatments, to be placed in a separate tree row along the side of a hill to statistically minimize the effects of frost injury on yield as affected by elevation. Treatments were applied to both sides of the tree on each indicated application date with an airblast sprayer (Swanson Model DA-400; Durand-Wayland, Inc., La Grange, GA) at 935.4 liters/ha. The amounts of fungicide per hectare were adjusted for tree-row-volume (TRV), based on 40% of the standard for full-sized mature trees (3,742 liters/ha) for the young trees in 1996, 50% TRV in 1997 (Table 3), and 75% in 1998 (Table 4) (5).

Maintenance sprays with little or no effect on powdery mildew were applied as needed to the entire test orchard to provide broad spectrum disease and insect protection. These sprays included the fungicides dodine and ziram, streptomycin, and commercial insecticides. Border rows were protected from mildew with dilute handgun treatments of myclobutanil at 6 g a.i. per 100 liters applied at approximately biweekly intervals.

Data collection. Temperature, relative humidity, and wetting event data were recorded on a Weathertronics Hygrothermograph Model 5021. Rainfall volume was measured with a Taylor rain gauge. The percentage of leaves and percent leaf area infected were determined by assessing all leaves on 10 terminal shoots from each of five double-tree replicates on 12 June 1996, 11 June 1997, and 9 June 1998. Overwintering infection was rated on 10 June 1997 and 18 June 1998 by recording primary infections (infected shoots arising from dormant bud infection) observed near the tree periphery to a distance up to 2.1 m. Fruit weight was recorded at harvest from each of five double-tree replications on 1 August 1996, 13 August 1997, and 29 July 1998. Estimated yields per hectare were calculated from yield from each test tree expanded to 193 trees/ha planted at 6.1 by 8.5 m for the test planting. Fruit finish (russeting) was evaluated by estimating the percent area affected on individual fruit each year, and fruit were downgraded to No. 1 grade if more than 15% of the surface area was russeted. Data were subjected to analysis of variance and means were separated using the Waller-Duncan k-ratio t test ($P \leq 0.05$). Percent data were transformed using the arcsine transformation prior to analysis.

Economic analysis. The 3-year benefits of treatments were calculated from cumulative 3-year yields, value of fresh-market or processing-market fruit (assuming that all fruit went to one market or the other), and total mildewcide treatment costs during the test period. Costs of six applications for all treatments were not included because it was assumed that most orchards would be sprayed on a regular schedule of similar frequency for management of insects and other diseases. However, application costs were included for treatments that had two additional early-season applications (S8 and M5-T3) because those would likely be supplemental applications beyond the regular commercial spray schedule. Fruit finish is a major determinant to market suitability. Mildew damage to fruit finish (russeting presumed to be related to mildew infection) was found to be significant only in 1998. To project a worst-case scenario for russeting of cv. Ginger Gold, significant treatment effects on fruit finish were incorporated in an analysis where the total 3-year yield of fruit would be downgraded (to U. S. No. 1) according to 1998 russeting data, with some going to fresh market and some to processing (depending on their appearance). The value and cost assumptions for these analyses were based on \$0.42/kg for fresh market fruit and \$0.22/kg for processing market fruit; mildewcide costs of \$0.551/kg for sulfur, \$0.133/g for triadimefon, and \$0.120/g for myclobutanil; and a cost of \$13.59/ha/application for a commercial sprayer and operator.

RESULTS AND DISCUSSION

Although mildew inoculum was initially abundant in the test orchard, daily rains that occurred from 30 April to 11 May and 40 of 53 days from 30 April to 21 June reduced 1996 disease incidence and severity. The longest interval without any rainfall during the entire growing season was 6 days, a situation that had not occurred in the previous 20 years. Based on the assumption that wetting inhibits infection, that rain removes conidia from the leaf surface, and that only immature conidia would be available the following day, only 7 days would have been favorable for mildew infection during the active secondary development period of 1 May to 21 June. A late spring frost on 14 May reduced the crop in the test orchard by more than 50%.

Table 1. Treatment application dates and approximate tree growth stages in test years 1996 to 1998 in ‘Ginger Gold’ apple powdery mildew (*Podosphaera leucotricha*) test plots in Winchester, VA

	Date for indicated application number and approximate growth stage[z]								
	1	2	3	4	5	6	7	8	9
Year	TC-Pink	Bloom	Petal fall	…	1st C	2nd C	3rd C	4th C	5th C
1996	22 April	26 April	2 May	10 May	15 May	30 May	13 June	26 June	…
1997	3 April	16 April	30 April	7 May	17 May	29 May	23 June	9 July	…
1998	2 April	11 April	21 April	29 April	7 May	21 May	4 June	18 June	9 July

[z] Growth stage abbreviations: TC = tight cluster; 1st to 5th C = first to fifth cover sprays

Table 2. First-year effects of selected treatment regimes on apple powdery mildew (*Podosphaera leucotricha*) and fruit yield of ‘Ginger Gold’ apple in Winchester, VA in 1996

		Application for indicated number and growth stage[v]								Mildew infection[w]			
	Mildewcide	1	2	3	4	5	6	7	8	Leaves	Leaf	Mean	Yield/tree
Code	rate/ha (40% TRV)[x]	P	Bl	PF	…	1C	2C	3C	4C	(%)	area (%)	fruit/tree	(kg)[y]
Ck	No mildewcide	…	…	…	…	…	…	…	…	41.5 d[z]	11.9 d	15.0 b	2.7 b
S6	Sulfur 90W 5.4 kg	X	…	X	…	X	…	…	…	17.2 c	3.2 c	26.8 ab	4.9 ab
	Sulfur 90W 4.5 kg	…	…	…	…	…	X	X	X				
S8	Sulfur 90W 5.4 kg	X	X	X	X	X	…	…	…	8.3 b	1.7 b	36.4 ab	5.8 ab
	Sulfur 90W 4.5 kg	…	…	…	…	…	X	X	X				
M3-T3	Myclobutanil 40W 112 g	X	…	X	…	X	…	…	…	0.5 a	0.1 a	50.4 a	8.2 a
	Triadimefon 50WDG 56 g	…	…	…	…	…	X	X	X				
M5-T3	Myclobutanil 40W 112 g	X	X	X	X	X	…	…	…	0.2 a	0.1 a	27.3 ab	4.2 ab
	Triadimefon 50WDG 56 g	…	…	…	…	…	X	X	X				
T3-S3	Triadimefon 50WDG 56 g	X	…	X	…	X	…	…	…	5.6 b	1.4 b	22.8 ab	3.8 ab
	Sulfur 90W 4.5 kg	…	…	…	…	…	X	X	X				
M3-S3	Myclobutanil 40W 112 g	X	…	X	…	X	…	…	…	4.3 b	1.1 b	30.0 ab	5.1 ab
	Sulfur 90W 4.5 kg	…	…	…	…	…	X	X	X				

[v] Material applied = X. Growth stage abbreviations: P = pink; Bl = bloom; PF = petal fall; 1C to 4C = first to fourth cover sprays.
[w] Counts of leaves on 10 terminal shoots on 12 June from each of five double-tree replications.
[x] Amounts of fungicide per hectare were adjusted for tree-row-volume (TRV) based on 40% of the standard for full-sized, mature trees.
[y] Fruit yield recorded at harvest 1 August 1996 from each of five double-tree replications.
[z] Mean in columns followed by the same letter are not significantly different according to Waller-Duncan k-ratio t test ($P \leq 0.05$).

The temperature was below freezing for more than 3 h with a low of –3°C.

All treatments gave significant reduction in mildew incidence and severity (Table 2). Extending the early spray interval significantly reduced control by sulfur (S6). Extending the early spray interval of myclobutanil followed by triadimefon (M3-T3 versus M5-T3) did not significantly reduce control ($P \leq 0.05$). At the more extended early spray interval, triadimefon and myclobutanil both gave significantly better control than sulfur (T3-S3 and M3-S3 versus S6). Triadimefon also provided better control than sulfur when compared with the second to fourth cover sprays following early season myclobutanil application at the extended interval (M5-T3 versus M3-S3). There was no significant difference where myclobutanil and triadimefon were compared directly (T3-S3 versus M3-S3).

Initially, 1996 yields were recorded the first year of the study because of their potential effect on “return bloom” for 1997 and the 1997 crop, but there was a significant first-year reduction in yield of control (Ck) trees compared to those protected by a strong mildew treatment (Ck versus M3-T3).

In 1997, drier weather greatly increased mildew pressure in the test block. Twenty days were favorable for mildew infection (no rain for at least 2 days; daily high of >10°C) during its period of active secondary development from 1 May to 21 June, compared with only seven favorable days in 1996. The rank order of treatment effectiveness was similar for mildew incidence in 1996 and primary mildew infections for 1997. All treatments resulted in a reduction of mildew incidence and severity (Table 3). The most intense spray schedule, five applications of myclobutanil followed by three of triadimefon (M5-T3), reduced the

Table 3. Second-year effects of selected treatment regimes on apple powdery mildew (*Podosphaera leucotricha*) and yield of ‘Ginger Gold’ apple in Winchester, VA in 1997

		Applications for indicated number and growth stage[u]									Mildew 1997[v]		
	Mildewcide and	1	2	3	4	5	6	7	8	No. infections	Leaves	Leaf	Yield/tree
Code	rate/ha (50% TRV)[w]	P	Bl	PF	…	1C	2C	3C	4C	1996–1997[x]	(%)	area (%)	(kg)[y]
Ck	No mildewcide	…	…	…	…	…	…	…	…	32.5 c[z]	72.4 e	40.4 d	37.1 b
S6	Sulfur 90W 6.7 kg	X	…	X	…	X	…	…	…	17.0 abc	48.8 d	6.9 bc	55.2 ab
	Sulfur 90W 5.6 kg	…	…	…	…	…	X	X	X				
S8	Sulfur 90W 6.7 kg	X	X	X	X	X	…	…	…	19.4 bc	43.6 d	9.2 c	54.9 ab
	Sulfur 90W 5.6 kg	…	…	…	…	…	X	X	X				
M3-T3	Myclobutanil 40W 140 g	X	…	X	…	X	…	…	…	9.5 ab	5.7 ab	0.9 a	63.0 a
	Triadimefon 50WDG 70 g	…	…	…	…	…	X	X	X				
M5-T3	Myclobutanil 40W 140 g	X	X	X	X	X	…	…	…	6.1 a	2.5 a	0.6 a	51.2 ab
	Triadimefon 50WDG 70 g	…	…	…	…	…	X	X	X				
T3-S3	Triadimefon 50WDG 70 g	X	…	X	…	X	…	…	…	15.4 abc	12.6 bc	1.9 ab	54.6 ab
	Sulfur 90W 5.6 kg	…	…	…	…	…	X	X	X				
M3-S3	Myclobutanil 40W 140 g	X	…	X	…	X	…	…	…	14.0 ab	16.2 c	2.1 abc	57.9 a
	Sulfur 90W 5.6 kg	…	…	…	…	…	X	X	X				

[u] Material applied = X. Growth stage abbreviations: P = pink; Bl = bloom; PF = petal fall; 1C to 4C = first to fourth cover sprays.
[v] Foliar infection based counts of all leaves on 10 terminal shoots from each of five double-tree replications on 11 June.
[w] Amounts of fungicide per hectare were adjusted for tree-row-volume (TRV) based on 50% of the standard for full-sized mature trees.
[x] Number of primary infections, rated 10 June by recording overwintering primary infections observed near the tree periphery to a distance up to 2.1 m.
[y] Fruit yield recorded at harvest 13 August 1997 from each of five double-tree replications.
[z] Mean in columns followed by the same letter are not significantly different according to Waller-Duncan k-ratio *t* test ($P \leq 0.05$).

Table 4. Third-year effects of selected treatment regimes on apple powdery mildew (*Podosphaera leucotricha*) and fruit yield of ‘Ginger Gold’ apple in Winchester, VA in 1998

		Applications for indicated number and growth stage[u]											Mildew 1998[v]		
	Mildewcide and	1	2	3	4	5	6	7	8	9	1998 primary	Flower	Leaves	Leaf area	Yield/tree
Code	rate/ha (75% TRV)[w]	P	Bl	PF	…	1C	2C	3C	4C	5C	infections (%)[x]	clusters/tree	(%)	(%)	(kg)[y]
Ck	No mildewcide	…	…	…	…	…	…	…	…	…	79.3 e[z]	27.4 c	59.2 e	50.5 c	9.0 c
S6	Sulfur 90W 10.1 kg	X	…	X	…	X	…	…	…	…	50.0 d	54.4 bc	42.5 d	9.8 b	18.1 bc
	Sulfur 90W 8.4 kg	…	…	…	…	…	X	X	X	X					
S8	Sulfur 90W 10.1 kg	X	X	X	X	X	…	…	…	…	38.8 d	79.6 ab	32.2 c	5.5 b	41.9 a
	Sulfur 90W 8.4 kg	…	…	…	…	…	X	X	X	X					
M3-T3	Myclobutanil 40W 210 g	X	…	X	…	X	…	…	…	…	13.3 b	91.6 ab	5.2 ab	1.1 a	37.2 a
	Triadimefon 50WDG 105 g	…	…	…	…	…	X	X	X	X					
M5-T3	Myclobutanil 40W 210 g	X	X	X	X	X	…	…	…	…	3.0 a	120.1 a	2.7 a	0.7 a	41.2 a
	Triadimefon 50WDG 105 g	…	…	…	…	…	X	X	X	X					
T3-S3	Triadimefon 50WDG 105 g	X	…	X	…	X	…	…	…	…	25.5 c	63.6 b	7.4 b	1.5 a	19.9 bc
	Sulfur 90W 8.4 kg	…	…	…	…	…	X	X	X	X					
M3-S3	Myclobutanil 40W 210 g	X	…	X	…	X	…	…	…	…	17.3 bc	59.0 b	6.9 b	1.2 a	26.3 ab
	Sulfur 90W 8.4 kg	…	…	…	…	…	X	X	X	X					

[u] Material applied = X. Growth stage abbreviations: P = pink; Bl = bloom; PF = petal fall; 1C to 5C = first to fifth cover sprays.
[v] Foliar infection based counts of all leaves on 10 terminal shoots from each of five double-tree reps 9 June.
[w] Amounts of fungicide per hectare were adjusted for tree-row-volume (TRV) based on 75% of the standard for full-sized mature trees
[x] Rated 18 June by recording overwintering primary infections observed near the tree periphery up to a distance of 2.1 m.
[y] Fruit yield recorded at harvest 29 July 1998 from each of five double-tree reps.
[z] Mean in columns followed by the same letter are not significantly different according to Waller-Duncan k-ratio *t* test ($P \leq 0.05$).

number of primary infections to 19% of those on trees that had not received a mildewcide in 1996. Order of treatment effectiveness was similar for mildew incidence and severity. M5-T3 was again the most effective treatment. The schedule involving three applications of myclobutanil followed by sulfur (M3-S3) was significantly less effective than treatments M3-T3 and M5-T3 ($P \le 0.05$) for percent leaves infected.

Although M5-T3 was again the most effective treatment, the more extended schedule M3-T3 resulted in the highest yield. A schedule with three applications of myclobutanil followed by sulfur (M3-S3) was significantly less effective for mildew control but resulted in the second highest yield in 1997. Control trees had the lowest yield.

In 1998, frequent rains in early May were not conducive to mildew development. In all, 9 days were favorable for mildew (no rain for at least 2 days; daily high of >10°C) during the normal period of active secondary development from 1 May to 21 June, compared with only 7 in 1996 and 20 in 1997. The rank order of treatment regime effectiveness was again similar for mildew incidence in 1997 and primary mildew infections in 1998. The most intense spray schedule, M5-T3, reduced the number of primary infections to only 4% of those on trees that had not received a mildewcide in 1997. There was a significant difference in the number of flower clusters per tree with the weakest mildew treatment (S6) having twice as much bloom as nontreated trees and the strongest mildew treatment having more than a fourfold increase over nontreated trees (Table 4). Other treatments provided a two- to threefold increase in bloom. All treatments again resulted in significantly lower mildew incidence and severity. In 1998, mildew incidence in the test block was intermediate between 1996 and 1997.

Yield in 1998 probably reflects both the effects of mildew incidence and 1997 crop load. The weakest treatment (S6) had the lowest yield, about twice that of the Ck trees; several treatments yielded more than twice the amount of the S6 treatment, including treatment S8, which gave significant increases in mildew control and yield. The best mildew treatments (M3-T3 and M5-T3) resulted in high yields, whereas treatments T3-S3 and M3-S3, which resulted in moderate mildew incidence and good yields in 1997, yielded less in 1998.

Economic analysis. Yield data are presented as 3-year totals to offset the variability of irregular or alternate bearing of the test trees. All treatments resulted in a greater 3-year yield than the control, and differences of all but S6 and T3-S3 were statistically significant ($P \le 0.05$; Table 5). One of the most effective mildew treatments, M3-T3, also resulted in the highest yield. A slightly more effective schedule (M5-T3) resulted in slightly reduced yields compared to M3-T3. Two additional applications of sulfur in the early-season portion of the schedule (S8) significantly increased yield compared to the sulfur schedule with fewer applications (S6).

When the economic analysis was conducted (assuming that all fruit would be marketed fresh or that all would go to the processing market), the highest yielding treatments, M3-T3 and S8, resulted in the highest 3-year fruit values (Table 5). The slight increase in production by M3-T3 over S8 more than offset the increased expense of this program to give the highest 3-year treatment benefit, $4,556/ha for fresh market fruit and $2,259/ha for processing fruit. Treatment benefit per hectare of treatment M3-T3 was almost twice that of the least effective mildew treatment, six applications of sulfur (S6), whether fruit went to the fresh or processing market. Treatment M5-T3, which gave the best control of powdery mildew, did not yield as well and, being more expensive, had a lower treatment benefit. When treatment benefits were estimated with all fruit going for fresh market, 3-year treatment benefits ranged from $2,226 to $4,556/ha; when all fruit were considered only for the processing market, treatment benefits ranged from $1,127 to $2,259/ha (Table 5).

Treatment effects on fruit finish (russeting presumed to be related to mildew infection) were minimal in 1996 and 1997. However, in 1998, significant treatment effects on fruit finish were observed; they were projected into an analysis where the 3-year yield of fruit was downgraded according to 1998 russeting data, with some going to fresh market and some to processing, depending on their appearance (Table 6). Treatment S8 provided benefits on fruit finish with significantly fewer fruit downgraded by russeting than treatments S6, T3-S3, and M3-S3. Treatment benefits ranged from $2,172 to $4,628/ha over the 3-year study. The high yield and good fruit finish of fruit from treatment S8 provided treatment benefits of $4,628/ha for the 3-year study. In treatment S8 versus S6, two additional applications of sulfur per year in the early season at a total additional 3-year

Table 5. Three-year yield and estimated value (assuming all fruit was marketed as fresh or all as processing) of yield from 'Ginger Gold' apple trees treated with selected powdery mildew (*Podosphaera leucotricha*) management regimes in Winchester, VA

		Yield (kg/ha)[u]				Estimated ($/ha)[v]			Estimated ($/ha)[w]	
Code	Mildewcide rate/ha (50% TRV)[x]	1996	1997	1998	Total[y]	Fresh	Process	Cost ($/ha)[z]	Fresh	Process
Ck	No mildewcide	517 b	7,160 b	1,743 c	9,420 c	3,957	2,072	0.00	…	…
S6	Sulfur 90W 6.7 kg, 3 apps. Sulfur 90W 5.6 kg, 3 apps.	946 ab	10,654 ab	3,493 bc	15,093 bc	6,339	3,320	66.54	2,315	1,181
S8	Sulfur 90W 6.7 kg, 5 apps. Sulfur 90W 5.6 kg, 3 apps.	1,121 ab	10,601 ab	8,089 a	19,811 a	8,321	4,359	170.72	4,193	2,116
M3-T3	Myclobutanil 40W 140 g, 3 apps. Triadimefon 50WDG 70 g, 3 apps.	1,575 a	12,159 a	7,178 a	20,912 a	8,783	4,601	270.27	4,556	2,259
M5-T3	Myclobutanil 40W 140 g, 5 apps. Triadimefon 50WDG 70 g, 3 apps.	814 ab	9,884 ab	7,950 a	18,648 ab	7,832	4,102	462.77	3,412	1,567
T3-S3	Triadimefon 50WDG 70 g, 3 apps. Sulfur 90W 5.6 kg, 3 apps.	726 ab	10,532 ab	3,843 bc	15,100 bc	6,342	3,322	122.74	2,262	1,127
M3-S3	Myclobutanil 40W 140 g, 3 apps. Sulfur 90W 5.6 kg, 3 apps.	990 ab	11,171 a	5,078 ab	17,239 ab	7,240	3,793	199.03	3,084	1,522

[u] Yield recorded at harvest from five double-tree replications. Means in columns followed by the same letter are not significantly different according to Waller-Duncan k-ratio *t* test ($P \le 0.05$).
[v] Estimated 3-year value if all fruit marketed as fresh or process. Fresh market value estimates assume no treatment effect on fruit russeting. Assumed fruit values: $0.42/kg for fresh market Extra Fancy/Fancy grade and $0.22/kg for processing grade.
[w] Estimated 3-year treatment benefit if all fruit sold as fresh or process. Treatment benefit for fresh or processing marketed fruit = estimated value of treated fruit minus value of control fruit minus cost of treatment.
[x] Applied at 40% tree-row-volume (TRV) rate in 1996, 50% TRV in 1997, and 75% TRV in 1998.
[y] Total for 3 years.
[z] Estimated treatment cost for 3 years. Assumptions: prices of $0.551/kg for sulfur, $0.133/g for triadimefon, $0.120/g for myclobutanil, and $13.59/ha application cost.

cost of $104/ha were estimated to return additional benefits of $2,394/ha.

A significant difference in the 3-year yields of S8 and T3-S3 (a direct comparison of five applications of sulfur versus three of triadimefon during the early part of the season) was primarily a result of the 1998 yield component and is not readily explained by deleterious mildew levels. Yield may be somewhat related to bloom level, but the small difference in bloom of these two treatments in 1998 was much less than that for bitertanol plus triadimefon (4) or bitertanol and flusilazole versus captan (1) in earlier reports.

It should be noted that the treatments and analyses conducted in this study were aimed specifically at powdery mildew and that, in commercial practice in the eastern United States, numerous diseases and insects are managed with the spray program most appropriate for that part of the growing season. Scab and rusts were controlled in this orchard by timely applications of dodine and ziram, which would have had little impact on mildew incidence. In commercial practice, sulfur and triadimefon must be supplemented by another fungicide for early-season disease management. Sulfur is considered to be weak against apple scab and, therefore, would usually need to be supplemented for improved scab control and management of rust diseases. Triadimefon controls rusts but not scab. Myclobutanil controls rusts and is a strong scab protectant-eradicant that could provide additional benefits on most cultivars beyond those shown here for mildew management alone. Another minor consideration not included in the economic analysis is the effect of a heavy sulfur program on acidification of the soil and the need for some additional lime application to offset reduction in soil pH. This could cost $5/ha/year for a loam soil (3) at current local prices.

The difference in reduced 3-year yield of M5-T3 versus M3-T3 was not statistically significant ($P \leq 0.05$), but resulted in substantially diminished profit returns, although M5-T3 had the least amount of mildew in all rating categories each year. In some heavy disease pressure situations, the more intense schedule may be useful to reduce initial mildew pressure or for management of other diseases, but it was not economically justified in this study. Also, in addition to its diminished economic returns, the more intense schedule involving eight consecutive applications of DMI fungicides may represent a greater possibility for development of DMI-resistant mildew strains.

In commercial practice in the mid-Atlantic region, fungicides are often applied from just one side of the tree on each application date with a slightly shorter interval between application dates. Although the overall chemical costs might be reduced and effectiveness improved by this application practice, the changes should be relative with all treatments, and it is assumed that this practice would not significantly change the economics of the study.

The cumulative value of fungicide applications for mildew management on Ginger Gold apple has been clearly demonstrated by test regimes applied to the same trees for three consecutive years. At higher mildew levels, benefits were proportional to the level of mildew control achieved. However, the most effective treatment, which reduced annual mildew incidence to less than 5%, gave diminishing returns when considering mildew as the only disease to be managed. The mildew levels and yields observed resulting from the range of experimental treatments indicate that the action threshold level of 20% leaf infection in the *Mid-Atlantic Orchard Monitoring Guide* (12) is also appropriate for this highly susceptible cultivar.

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Table 6. Three-year yield and estimated value of 'Ginger Gold' apples intended for fresh market considering potential fruit finish effects of selected powdery mildew (*Podosphaera leucotricha*) management regimes (russet down-grading based on 1998 data only) in Winchester, VA

Code	Mildewcide rate/A (50% TRV)[t]	Yield (kg/ha)[u]	Grade (%)[v]	Estimated (kg/ha)[r]		Estimated ($/ha)[s]		Value ($/ha)[w]	Cost ($/ha)[x]	Adj. Value ($/ha)[y]	Benefit ($/ha)[z]
				Fresh	Process	Fresh	Process				
Ck	No mildewcide	9,420 c	50.0 c	4,710	4,710	1,978	1,036	3,015	0.00	3,015	…
S6	Sulfur 90W 6.7 kg, 3 apps. Sulfur 90W 5.6 kg, 3 apps.	15,093 bc	33.9 bc	9,976	5,116	4,190	1,126	5,316	66.54	5,249	2,235
S8	Sulfur 90W 6.7 kg, 5 apps. Sulfur 90W 5.6 kg, 3 apps.	19,811 a	12.8 a	17,276	2,536	7,256	559	7,814	170.72	7,643	4,628
M3-T3	Myclobutanil 40W 140 g, 3 apps. Triadimefon 50WDG 70 g, 3 apps.	20,912 a	28.4 ab	14,973	5,939	6,289	1,307	7,595	270.27	7,325	4,310
M5-T3	Myclobutanil 40W 140 g, 5 apps. Triadimefon 50WDG 70 g, 3 apps.	18,648 ab	25.6 ab	13,874	4,774	5,827	1,050	6,877	462.77	6,414	3,400
T3-S3	Triadimefon 50WDG 70 g, 3 apps. Sulfur 90W 5.6 kg, 3 apps.	15,100 bc	34.2 bc	9,936	5,164	4,173	1,136	5,309	122.74	5,187	2,172
M3-S3	Myclobutanil 40W 140 g, 3 apps. Sulfur 90W 5.6 kg, 3 apps.	17,239 ab	35.3 bc	11,153	6,085	4,684	1,339	6,023	199.03	5,824	2,810

[r] Estimated 3-year yield for fruit marketed as fresh or process. Total yields separated into fresh market or processing grade canners according to United States Department of Agriculture grades for russeting.
[s] Estimated 3-year value for fruit marketed as fresh or process.
[t] Mildewcides (1997 rate) applied at 40% tree-row-volume (TRV) rate in 1996, 50% TRV in 1997, and 75% TRV in 1998.
[u] Total 3-year yield. Yield recorded at harvest from five double-tree replications. Means in columns followed by the same letter are not significantly different according to Waller-Duncan k-ratio *t* test ($P \leq 0.05$).
[v] Percentage of fruit U. S. #1 or utility.
[w] Total 3-year fruit value. Assumed fruit values: $0.42/kg for fresh market Extra Fancy/Fancy grade and $0.22/kg for processing grade.
[x] Estimated treatment cost. Assumed prices of $0.551/kg for sulfur; $0.133/g for triadimefon and $0.120/g for myclobutanil and $13.59/ha application cost.
[y] Estimated fruit value minus treatment cost.
[z] Treatment benefit for fresh or processing marketed fruit = estimated value of treated fruit minus value of control fruit minus cost of treatment.

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