Usefulness of Vineyard Fungicides as Antioxidants for Grapevines

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ABSTRACT

Musselman, R. C., and Taschenberg, E. F. 1985. Usefulness of vineyard fungicides as antioxidants for grapevines. Plant Disease 69:406-408.

The fungicides benomyl and triadimefon applied for powdery mildew (*Uncinula necator*) control to *Vitis labruscana* 'Concord' or 'Ives' in New York vineyards significantly reduced oxidant stipple injury on foliage. Both fungicides were similar in their effectiveness in reducing oxidant stipple injury. Increasing the number of applications of the fungicides reduced injury further, with best control obtained with weekly applications. The fungicides were more effective in controlling oxidant stipple injury on Concord than on Ives foliage.

Additional key words: dinocap, etaconazole, ozone

Oxidant stipple injury to grapevine foliage in the northeastern United States is a problem caused by exposure to ambient concentrations of ozone. Methods of ameliorating the effects of ozone on grapevines have been reviewed (2–4). These include maintaining high levels of nitrogen in leaf tissue and avoiding vine stresses induced by overcropping, weed competition, insects, diseases, or winter injury. Vineyard cultural practices are more important in determining severity of injury than are ambient levels of ozone (3,4). Research has shown that frequent applications of the fungicide benomyl will reduce the severity of oxidant stipple injury on Concord foliage (2,3).

Benomyl has had widespread use in northeastern U.S. vineyards as a fungicide to protect grapevines against infection by *Uncinula necator* (Schw.) Burr., the cause of powdery mildew; however, benomyl-resistant strains of *U. necator* have occurred in some vineyards (6–8,10). Benomyl-resistant isolates of *Botrytis cinerea* Pers. ex Fr. have also been identified in New York vineyards, even though benomyl is not recommended for *Botrytis* control on grapevines (5). Benomyl resistance in common vineyard pathogens suggests that its usefulness as a vineyard fungicide may become limited.

Although benomyl remains effective in reducing the severity of oxidant stipple injury on grapevine foliage, its cost-effectiveness becomes much reduced if applied only as an antioxidant rather than for dual use as fungicide and antioxidant. The effectiveness of other vineyard fungicides in reducing the severity of oxidant stipple on grapevine foliage should be examined.

The purpose of these experiments was to compare the effectiveness of triadimefon and other fungicides with that of benomyl in reducing oxidant stipple injury and/or *U. necator* infections on grapevine foliage.

MATERIALS AND METHODS

Five field experiments were conducted in 1979 and 1980 in mature vineyards at Fredonia, NY, to determine if triadimefon reduced oxidant stipple injury to Concord and Ives grapevines. Plots were replicated and arranged in a completely randomized block design. All sprays were applied to vineyard plots with a hydraulic sprayer operating at 3,450 kPa and equipped with a hooded boom that carried seven nozzles on each side of the grape row (9). Early postblossom sprays were applied at a rate of 1,170 L/ha, and later sprays were increased to 2,335 L/ha. This procedure gave good coverage of both leaf surfaces. The spray unit also minimized drift, which otherwise is likely to create some problem when using single-row plots.

Initial experiments were conducted during 1979 in two commercial Concord vineyards to determine if triadimefon applied as a fungicide for powdery mildew control would reduce oxidant stipple injury. One experiment examined the effectiveness of triadimefon at 0 and 0.14 kg/ha; the other, at 0, 0.14, and 0.42 kg/ha, the highest recommended rate of application for powdery mildew control. Triadimefon sprays were applied on 3 and 13 July and 22 August to conform with a recommended commercial fungicide spray program for mildew control. Ozone injury was estimated as the percentage of leaf surface area with oxidant stipple necrosis at the six basal nodes (averaged for all shoots on a vine).

Three additional experiments were conducted in 1980 to compare triadimefon with benomyl and other vineyard fungicides in reducing oxidant stipple injury to grapevine foliage. Sprays were applied with the equipment used in 1979, and oxidant stipple injury was evaluated as in 1979. The percentage of leaf surface area chlorotic at the six basal nodes was estimated in the last experiment. Estimates of powdery mildew injury on the vines were also made in the 1980 Concord experiments. Ives was less susceptible to powdery mildew than Concord and was not seriously infected by *U. necator* in 1980.

The first 1980 experiment compared triadimefon with benomyl in a commercial Ives vineyard to examine their effectiveness on a cultivar more susceptible to oxidant stipple injury than Concord. Triadimefon 50W or benomyl 50W was applied at weekly intervals with equipment described previously to obtain maximum coverage of the foliage during ozone episodes. Because of equipment problems, benomyl sprays were begun 1 wk later than triadimefon sprays, and one of the weekly benomyl sprays was not applied in September.

An experiment in a commercial Concord vineyard (the vineyard where the second 1979 experiment was conducted) compared triadimefon with benomyl, dinocap, a mixture of triadimefon and benomyl, and etaconazole (Vangard). All fungicides except etaconazole were applied at rates currently labeled for powdery mildew control on grapes. Etaconazole, not registered for grapes, was being tested as a potential vineyard fungicide. Sprays were applied to 24 vine plots on 7 and 18 July and 19 August. Plots were examined for oxidant stipple injury on 14 October.

The last experiment, conducted in a Concord vineyard at the Vineyard Laboratory, Fredonia, NY, compared the effectiveness of triadimefon or benomyl applied at weekly intervals for maximum protectant coverage with that of chemicals applied during ozone

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Supported in part by grants from Mobay Chemical Corporation and E. I. du Pont de Nemours & Company.

Approved by the director of the New York State Agricultural Experiment Station for publication as Journal Paper 3564.

Accepted for publication 23 October 1984.

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episodes. A treatment using benomyl at the recommended commercial rate for powdery mildew control was also included in this study to examine the effectiveness of common grower application of the fungicide for oxidant stipple control.

The effectiveness of fungicide application was determined using analysis of variance (ANOVA) for all experiments with more than two treatments. Where ANOVA showed significant treatment effects, means were separated using Waller-Duncan's BSD test at $k = 100$ (11). The difference between means of the experiment with only two treatments was determined by standard t test. There were four or more replications of each treatment, with three to 12 grapevines per experimental plot.

RESULTS

The 1979 experiments demonstrated that triadimefon effectively reduced oxidant stipple injury of grapevines. Triadimefon at a concentration of 0.14 kg a.i./ha applied as infrequently as three times during the season in a spray program to control powdery mildew significantly reduced oxidant stiple injury to Concord foliage to about half that observed on unsprayed controls (Table 1). Increasing the application rate of triadimefon to 0.42 kg a.i./ha resulted in a further significant reduction in oxidant stipple injury (Table 1).

The 1980 Ives experiment showed triadimefon similar to benomyl in reducing oxidant stipple injury (Table 2). Both fungicides significantly reduced average oxidant stipple on leaves at the six basal nodes as evident from the August and September estimates of injury. The amount of injury still remained severe on this sensitive cultivar, however, with 75% of the leaf surface at the six basal nodes affected by oxidant stipple necrosis at harvesttime at the end of September.

Oxidant stipple injury seemed more severe on Concord grapevines in 1980 than in 1979, which can be seen by comparing controls of experiments conducted both years (Tables 1 and 3). Injury on the controls also appeared to vary among vineyards in the same year (Tables 3 and 4), possibly a result of differences in microclimate or cultural practices (4,5). The actual significance of these apparent differences cannot be determined statistically. All fungicides applied at rates recommended for powdery mildew control were similar to benomyl in effectiveness in reducing oxidant stipple injury to grapevines in 1980 (Table 3). However, only etaconazole and a mixture of benomyl and triadimefon were significantly better than the control. Although all fungicides reduced powdery mildew on grapevine foliage, triadimefon and etaconazole were most effective. A similar ranking for these fungicides for powdery mildew control was measured independently in the same vineyard and reported previously (8).

Triadimefon or benomyl applied during ozone episodes at recommended rates for powdery mildew control significantly reduced oxidant stipple injury below that for unsprayed controls (Table 4). As in the previous experiments, benomyl applied for powdery mildew control also reduced oxidant stipple injury. Best control of oxidant stipple injury and powdery mildew was obtained with weekly sprays of triadimefon or benomyl. Triadimefon at 0.07 kg/ha was not as effective as benomyl at 0.56 kg/ha in controlling oxidant stipple injury, even though they had been similar in effectiveness at higher rates (Table 3).

DISCUSSION

It is evident from these experiments that triadimefon or benomyl applied at rates recommended for powdery mildew control was generally effective in reducing oxidant stipple injury on Concord and Ives grapevines. Increasing the concentration of triadimefon to 0.42 kg/ha further reduced oxidant stipple injury, suggesting that still higher concentrations may increase the effectiveness of triadimefon.

Although frequent application of triadimefon or benomyl significantly reduced oxidant stipple injury on Ives (Table 2) and Concord (Table 4), the reduction in injury at harvest may be too small to justify application of the fungicides on Ives for oxidant stipple control alone. Data from the earlier experiments (Table 1) suggest that higher concentrations of triadimefon might be more effective, but labeling restricts triadimefon application to no more than 1.12 kg per season. Our data indicate that the reduction in oxidant stipple obtained with fungicides would justify their use for that purpose on Concord; however, weekly applications of fungicide for oxidant stipple control may not be economically feasible.

Application of benomyl or triadimefon during ozone episodes shows promise for reducing oxidant stipple injury to Concord with limited applications of fungicide. However, our experience has indicated that prediction of episodes is difficult; some sprays were applied when episodes did not materialize or sprays were applied after the episode occurred. Coordination with air-quality personnel in predicting ozone episodes would increase the usefulness of this treatment.

Best oxidant stipple and powdery

Table 1. Effectiveness of triadimefon in reducing oxidant stipple injury on leaves at six basal nodes of Concord grapevines in a commercial vineyard at Fredonia, NY, at harvest in 1979

Fungicide	Rate (kg a.i./ha)	Oxidant stipple[x] (%)
Vineyard 1[y]		
Control	0.00	58.7
Triadimefon 50W	0.14	30.8
Vineyard 2[z]		
Control	0.00	54.7 a
Triadimefon 50W	0.14	27.9 b
	0.42	21.1 c

[x] Leaves at six basal nodes scored 10 October.
[y] Treatments applied on 3 and 13 July and 23 August. Means significantly different at $P = 0.05$.
[z] Treatments applied on 6 June and 12 July and 17 August. Means separated by Waller-Duncan's BSD test at $k = 100$.

Table 2. Comparison of the effectiveness of triadimefon and benomyl in reducing oxidant stipple injury on Ives grapevines in 1980[x]

Fungicide	Rate (kg a.i./ha)	No. of applications[y]	Oxidant stipple (%)[z] 21 August	Oxidant stipple (%)[z] 30 September
Control	0.00	0	41 a	91 a
Triadimefon 50W	0.07	18	35 b	76 b
Benomyl 50W	0.56	16	35 b	75 b

[x] Means separated by Waller-Duncan's BSD test at $k = 100$.
[y] Triadimefon: weekly applications 5 June to 29 September. Benomyl: weekly applications 12 June to 29 September (except 11 September).
[z] Leaves at six basal nodes.

Table 3. Comparison of the effectiveness of dinocap, triadimefon, benomyl, and etaconazole in reducing oxidant stipple injury and powdery mildew infection on Concord grapevines in 1980[w]

Fungicide[x]	Rate (kg a.i./ha)	Oxidant stipple[y] (%)	Powdery mildew rating[z]
Control	0.00	81 a	7.2 a
Dinocap 19.5W	1.68	71 ab	3.5 c
Triadimefon 50W	0.14	71 ab	1.9 d
Benomyl 50W	1.12	69 ab	5.6 b
Benomyl + triadimefon	0.56 + 0.07	66 b	3.2 c
Etaconazole 10W	0.21	64 b	2.0 d
	0.11	62 b	2.9 cd

[w] Means separated by Waller-Duncan's BSD test at $k = 100$.
[x] Fungicides applied 7 and 18 July and 19 August.
[y] Leaves at six basal nodes scored 9 October.
[z] Scale of 1–10, where 10 = severely infected with powdery mildew, scored 9 October.

Table 4. Effectiveness of benomyl and triadimefon sprays applied at different intervals in reducing oxidant stipple injury and powdery mildew infection on Concord grapevines in 1980[w]

Fungicide treatment[x]	Rate (kg a.i./ha)	No. of applications	Date of application	Oxidant stipple[y] (%)	Chlorosis[y] (%)	PM rating[z]
Control	0.00	0	...	63 a	61 a	6.6 a
Benomyl for PM	1.12	2	5 Aug., 3 Sept.	46 b	51 ab	4.5 b
Benomyl for OS	1.12	3	25 June, 14 and 29 July	45 b	58 a	6.2 a
Triadimefon for OS	0.14	3	25 June, 14 and 29 July	39 bc	52 ab	3.0 c
Triadimefon weekly	0.07	16	25 June–18 Sept.	35 c	46 bc	0.2 e
Benomyl weekly	0.56	16	25 June–18 Sept.	24 d	36 c	1.4 d

[w] Means separated by Waller-Duncan's BSD test at $k = 100$.
[x] PM = powdery mildew, OS = oxidant stipple.
[y] Injury rating 14 October on leaves at six basal nodes.
[z] Scale of 1–10, where 10 severely infected with powdery mildew, scored 14 October.

mildew control still occurs with frequent application of the fungicides, which suggests that a nearly continuous coverage of fungicide is necessary to protect against ozone injury and powdery mildew.

Although dinocap and etaconazole were similar to triadimefon and benomyl in their effect on oxidant stipple injury to Concord grapevines, only etaconazole and a mixture of triadimefon and benomyl were significantly better than controls. Since etaconazole is not labeled for use on grapes, further testing of this chemical may not be useful. In these experiments, we have identified fungicides other than benomyl that are useful in reducing oxidant stipple on grapevine foliage. Fungicides may also be useful to protect grapevines from injury caused by other air pollutants. For example, fungicides (but not benomyl) have protected grapevines from hydrogen fluoride injury (1). Other vineyard fungicides should be tested as antioxidants.

The relationship between protection from powdery mildew infection and susceptibility to oxidant stipple injury remains unclear. Previous observations have indicated that grapevines suffering from environmental stresses such as fungal infection were more susceptible to oxidant stipple injury (3). Our data demonstrate that grapevines receiving fungicide sprays have reduced powdery mildew injury and are less susceptible to oxidant stipple injury.

ACKNOWLEDGMENTS

We wish to thank Richard C. McMinn and Richard E. Melious for technical assistance and Janice Scalza of du Pont and Richard Ackerman of Mobay for suggestions and assistance.

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