Electronic Grape Black Rot Predictor for Scheduling Fungicides with Curative Activity

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ABSTRACT

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A microprocessor programmed to predict grape black rot infection periods was evaluated in the field during two growing seasons. It was effective in determining infection periods and was used to time curative fungicide applications for control of black rot. Triadimefon and CGA-71818 applied 72 or 96 hr after the initiation of an infection period provided excellent control of berry and leaf infection by *Guignardia bidwellii*, causal agent of grape black rot. Fenarimol did not provide satisfactory control. Well-timed curative spray programs of triadimefon and CGA-71818 were as effective as protectant spray programs of ferbam and required four fewer sprays to achieve equal control.

Black rot of grape, caused by the fungus *Guignardia bidwellii* (Ellis) Viala & Ravaz, is one of the most economically destructive grape diseases in the midwestern and northeastern United States. Although the fungus causes little damage to the vine, it can result in fruit losses of 70–100% under conditions favorable for disease development. Before the introduction of effective fungicides, yield losses of 25% were common (1).

Today, black rot is successfully controlled with protectant fungicides in most Ohio vineyards. Although protectant spray programs are generally effective, they can be very costly. In southern Ohio, 10–14 fungicide sprays per season may be necessary to provide adequate black rot control. Additionally, improper timing of midseason to late-season sprays often results in yield loss in spite of a full-season protection program.

An alternative to a protectant fungicide program is a postinfection or curative spray program. In a curative program, the fungicide is applied after initiation of an infection period but before symptom development. Since Spotts (9) published the temperature-wetness relations necessary for leaf infection by conidia of *G. bidwellii*, we have had reliable guidelines for determining infection periods under vineyard conditions. However, these environmental parameters have not been used in disease prediction or forecasting systems.

One factor contributing to the lack of interest in developing a disease forecasting system for black rot has been the lack of fungicides with dependable curative activity when applied 3 or 4 days after the initiation of infection. The introduction of the ergosterol-biosynthesis-inhibiting (EBI) fungicides, which have good curative activity against *G. bidwellii* (8), has made forecast-based control a practical possibility.

Instrumentation has been developed that combines electronic environmental monitoring sensors with a microcomputer to provide simple and rapid on-site determination of apple scab infection periods (2,4,6,7). This apple scab predictor has been validated in the field and is currently being marketed commercially by Reuter-Stokes, Inc., Edison Park, Twinsburg, OH (5). This type of instrumentation combined with EBI fungicides makes disease forecasting systems more practicable.

Our objectives in this study were 1) to program a microprocessor to predict grape black rot infection periods based on the temperature-wetness relations determined by Spotts and 2) to validate the effectiveness of the instrument for timing postinfection (curative) applications of several EBI fungicides for black rot control.

MATERIALS AND METHODS

A microprocessor (Reuter-Stokes Disease Predictor RSS-411) was programmed to predict black rot infection periods from the parameters established by Spotts (9). A detailed description of the disease predictor has been published (5). The unit was installed in a 9-yr-old vineyard (cultivar Aurore) in 1983 at the Ohio Agricultural Research and Development Center, Wooster. A wetness sensor was placed 1.3 m above ground on the second wire of an Umbrella Kniffen training system. The sensor was placed so that it would be within the leaf canopy as sufficient foliage developed. Two temperature sensors (linear thermistors) were attached to the top of the microprocessor, and the unit was enclosed in a weather shelter 1.8 m above ground (5). Temperature sensors were shaded within the shelter. One thermistor measured dry-bulb or ambient temperature; the other, inserted in a wet wick, measured wet-bulb temperature. Temperature and humidity were also measured with a 7-day recording hygrothermograph (Belfort Instrument Co., Baltimore, MD) located in a separate weather shelter next to and at the same height as the disease predictor. Wetness duration was also recorded on a deWit 7-day recording leaf wetness meter (Valley Stream Farms, Orano, Ont., Canada) placed 1.5 m above ground. Calibration of the sensors and hygrothermograph was checked every 2 wk. The disease predictor was visited daily, and values for the wetness and temperature sensors were compared with those of the deWit meter and hygrothermograph and recorded. The criteria used to predict each infection period were retrieved from memory with a keyboard and liquid-crystal display. Infection predictions made by the instrument were compared with predictions calculated from the data of Spotts (9).

The efficacy of three EBI fungicides for curative control of black rot when applied in response to predicted infection periods was studied. Triadimefon (Bayleton 50WP), fenarimol (Rubigan 1EC), and CGA-71818 10WP were applied at the rates of 140, 26, and 97 g a.i./ha, respectively, 72 or 96 hr after the initiation of an infection period. Most curative treatments were applied within 1 hr of the desired time period, and no treatments were made more than 8 hr before or after the desired time. Since the start of our studies, we have assumed that curative applications would provide 7

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days of protectant activity; therefore, infection periods that occurred within that period were disregarded. After 7 days, curative applications were made in response to the next infection period. For comparison, ferbam 76WP (a protectant fungicide) was applied at 2.5 kg a.i./ha in the curative program and a full-season protectant program. All curative treatments were made in response to electronically predicted infection periods, and all predicted infection periods were verified by the deWit wetness meter and hygrothermograph.

Fungicide treatments were applied to two vines (2.1 m between vines and 3 m between rows) in 1,870 L of water per hectare with a 11.3-L CO_2-pressurized hand sprayer at 274 kPa. Treatments were replicated four times. The curative treatments at 72 and 96 hr were applied on 17 and 18 May, 1 and 2 June, 22 and 23 June, 5 and 6 July, 20 and 21 July, and 3 and 4 August, respectively. Application dates for the full-season protectant program were 13, 20, and 27 May; 2, 13, and 22 June; 5, 18, and 28 July, and 8 August.

Black rot berry infection was determined as the mean percentage of infected berries on 10 clusters per vine on 21 July and 26 August. Leaf infection was determined as the mean percentage of leaves with at least one black rot lesion on 10 shoots per vine on 26 August. Ten-cluster weight and total berry weight per vine were also recorded on 26 August.

The predictor was again used during 1984. All infection periods were verified as in 1983. Triadimefon was applied at 140 g a.i./ha in a curative program 72 hr after the initiation of an infection period. For comparison, ferbam was applied in a full-season protectant program. Application dates for the curative program were 22 and 30 May, 14 June, 5 and 27 July, and 6 and 16 August. Application dates for the full-season protectant program were 7, 23, and 31 May; 8 and 19 June; 2, 9, 16, and 30 July; and 10 and 15 August.

Black rot berry infection was determined as described previously on 23 July and 21 August. Percent leaf infection was determined on 23 August. Ten-cluster weight and total berry weight per vine was determined on 4 September.

RESULTS AND DISCUSSION

The times for initiation and duration of wetness periods measured by the microprocessor and the deWit meter were in close agreement. Temperature measurements were also in close agreement. Therefore, only one set of leaf wetness and temperature data is reported for 1983 (Table 1). The microprocessor predicted 18 infection periods. All electronically predicted infection periods agreed with periods calculated from hygrothermograph and deWit meter data using the parameters of Spotts (Table 1). Of the 18 infection periods, six were responded to with curative fungicide applications. The remaining 12 periods fell within the 7-day period after application and were disregarded.

Triadimefon and CGA-71818 provided excellent postinfection control of black rot leaf and berry infection when applied 72 or 96 hr after the initiation of an infection period (Table 2). Postinfection applications of fenarimol significantly reduced berry and leaf infection compared with the untreated control, but the level of control was not commercially acceptable. Incorporation of ferbam into the curative program demonstrated ferbam's lack of curative activity. It is interesting to note that significantly less berry and leaf infection occurred in treatments where ferbam was applied at 72 than at 96 hr after the initiation of an infection period. Although these data might suggest that ferbam has some curative activity against black rot, we believe that ferbam does not have curative activity and that the level of control obtained was probably the result of protectant activity against subsequent infection during the 7-day period after application. Ferbam applied in a full-season protectant program provided excellent black rot control. There were no significant differences in percentage of berry and leaf infection, 10-cluster weight, or total berry weight per vine between any curative treatments of triadimefon and CGA-71818 and the protectant treatments of ferbam. However, by using a curative spray

Table 1. Black rot infection periods predicted by a microprocessor and from Spotts's parameters for 10 selected wetting periods in 1983

Wetting period No.	Wetting period Date	Leaf wetness duration (hr:min)	Mean temperature (C)	Black rot prediction: Microprocessor	Black rot prediction: Spotts's parameters[a]
1	14 May	25:45	20.55	Infection	Infection
2	19 May	8:30	14.44	No infection	No infection
3	23 May	5:10	13.88	No infection	No infection
4	29 May	15:45	16.66	Infection	Infection
5	6 June	10:00	12.77	No infection	No infection
6	19 June	16:00	19.44	Infection	Infection
7	2 July	7:30	21.11	Infection	Infection
8	17 July	18:20	20.00	Infection	Infection
9	21 July	10:10	22.77	Infection	Infection
10	4 August	5:20	23.33	No infection	No infection

[a] Spotts's parameters (9) for temperature and leaf wetness duration for infection of grape leaves by conidia of *Guignardia bidwellii*.

Table 2. Effects of postinfection and protectant applications of various fungicides on black rot control of grapes (1983)

Treatment and rate (a.i./ha)	Timing[x]	Percent berry infection: 21 July	Percent berry infection: 26 August	Percent leaf infection	10-Cluster weight (g)	Total berry weight per vine (kg)
Fenarimol 1EC (26 g)[x]	72	4.4 e[y]	36.1 d	18.7 d	1,089 b	5.7 b
	96	9.9 d	48.5 c	43.7 c	1,180 b	5.6 c
Triadimefon 50WP (140 g)	72	0.2 e	0.8 e	0.4 e	1,816 a	8.7 a
	96	0.1 e	0.3 e	0.4 e	1,952 a	8.9 a
CGA 71818 10WP (97 g)	72	0.1 e	0.9 e	0.2 e	1,861 a	9.2 a
	96	0.4 e	0.8 e	0.1 e	1,861 a	9.3 a
Ferbam 76WP (2.5 kg)	72	17.0 c	45.6 c	42.1 c	1,089 b	5.4 c
	96	23.5 b	57.9 b	52.1 b	998 b	4.8 c
	FS[z]	0.4 e	0.9 e	0.2 e	1,906 a	8.9 a
Unsprayed	···	54.2 a	95.5 a	91.1 a	317 c	1.1 d

[x] Treatments applied in a postinfection (curative) program 72 and 96 hr after the initiation of an infection period. Infection periods that occurred within 7 days of application were disregarded. A total of six sprays were made.
[y] Numbers followed by the same letters within columns do not differ significantly according to Duncan's new multiple range test ($P = 0.05$).
[z] Treatments applied in a full-season protectant program. A total of 10 fungicide sprays were made.

Table 3. Effects of postinfection and protectant applications of various fungicides on black rot control in grapes (1984)

Treatment, rate (a.i./ha), and timing[y]	Percent berry infection		Percent leaf infection	10-Cluster weight (g)	Total berry weight per vine (kg)
	23 July	21 August			
Triadimefon 50WP (140 g) (curative program)	1.6 b[z]	4.8 b	5.4 b	1,407 b	7.6 b
Ferbam 76WP (2.5 kg) (protectant program)	0.1 b	0.5 c	0.6 c	1,725 b	7.9 b
Unsprayed	50.6 a	72.4 a	84.4 a	204 a	2.3 a

[y] Fungicide in the postinfection (curative) program was applied 72 hr after the initiation of an infection period. Infection periods that occurred within 7 days of application were disregarded. A total of seven and 11 applications were made for the curative and protectant programs, respectively.
[z] Numbers followed by the same letter within columns do not differ significantly according to Duncan's new multiple range test ($P = 0.05$).

program based on predicted infection periods, four fewer applications were made to obtain an equal level of disease control. The protectant program of ferbam did provide significantly better disease control than the curative program of fenarimol (Table 2)

Results obtained in 1984 were very similar to those of 1983. The microprocessor predicted 14 infection periods, and all agreed with periods calculated from hygrothermograph and deWit meter data using the parameters of Spotts. Of the 14 infection periods, seven were responded to with curative fungicide applications. The remaining seven fell within the 7-day period after application and were disregarded. In 1984, the protectant program of ferbam did provide significantly better control of berry and leaf infection than the curative program of triadimefon (Table 3). However, the level of control in the curative program was commercially acceptable and required four fewer applications. There were no significant differences in 10-cluster weight and total berry weight per vine between the curative and protectant treatments.

Spotts (8) reported that fenarimol and Bay Meb 6447 (triadimefon) provided significant postinfection control of leaf infection by conidia of *G. bidwellii*. Our results suggest that postinfection activity is also effective against berry infection. This is an important observation considering that most damage from black rot is due to berry infection. The significant reductions in 10-cluster weight and total berry weight per vine in the untreated controls clearly demonstrates the adverse effects of berry infection on yield (Tables 2 and 3).

Since the start of our studies, we have assumed that curative applications would provide 7 days of protectant activity, and we have disregarded infection periods that occur within that time. Although this assumption is not based on established data, our curative program, using triadimefon and CGA-71818 with a minimum of 7 days between applications, has provided excellent disease control during 2 yr of testing in plots with high disease levels in the controls.

During 2 yr of testing, the predictor accurately predicted black rot infection periods. The development of rapid, on-site, and dependable disease predictive units such as the one studied here, combined with the fact that triadimefon (Bayleton) is presently labeled for black rot control, makes disease predictive or forecasting systems coupled with curative spray programs an alternative to prophylactic fungicide applications in standard protectant spray programs.

During dry growing seasons, a curative spray program for black rot could reduce the number of fungicide applications necessary for disease control. In wet seasons, a curative program may not reduce the number of applications but may be beneficial in improving the timing of fungicide applications by warning growers on protectant programs when the potential for black rot infection is high. If they are concerned that their protection is inadequate, they can still apply a curative fungicide.

One limitation with the predictor is that it can only predict infection periods for *G. bidwellii*. At present, accurate models for the other important grape diseases are not available. In the midwestern and eastern United States, downy mildew, caused by *Plasmopara viticola*, and powdery mildew, caused by *Uncinula necator*, can be equally as important as black rot. The fungicide spray program must be capable of controlling all these diseases.

Our black rot program is based on environmental parameters for infection by conidia. In Michigan, ascospores have been shown to be an important source of inoculum for black rot. The wetness-temperature parameters necessary for grape leaf infection by ascospores appear to fall within the parameters required for infection by conidia (3). Our results suggest that the curative program is controlling ascospore infection or that ascospores are not an important source of inoculum in Ohio.

In summary, the data from these studies indicate that 1) the electronic black rot predictor was effective in monitoring temperature and wetness duration and in predicting black rot infection periods in the vineyard, 2) the environmental parameters developed by Spotts for grape leaf infection by *G. bidwellii* are also valid for berry infection, and 3) triadimefon and CGA-71818 provided postinfection control of grape black rot for up to 96 hr after the initiation of an infection period and appeared to be useful in curative spray programs for black rot.

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