Infection Model for Timing Fungicide Applications to Control Cherry Leaf Spot

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ABSTRACT

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A model relating leaf wetness duration and mean air temperature to infection of sour cherry by *Coccomyces hiemalis* was evaluated for timing applications of fungicides dodine and CGA-64251 (1-[[2-(2,4-dichlorophenyl)-4-ethyl-1,3-dioxolan-2-yl]methyl]-1*H*-1,2,4-triazole) for leaf spot control. Infection periods were identified and classified as low, moderate, and high based on predicted environmental favorability indexes of ⩾14, ⩾28, and ⩾42, respectively. In 1979 and 1980, CGA-64251 provided good leaf spot control regardless of application timing, and dodine provided good control when applied after low and moderate but not after high infection periods. In a second trial in 1980, dodine and CGA-64251 applied on an 11-day schedule or as postinfection applications after infection periods with an environmental favorability index ⩾28 gave comparable control. Secondary infection was prevented with eradicant sprays applied against conidial inoculum available during infection periods. Use of the infection model for timing sprays for leaf spot is a promising alternative to fixed time interval spray schedules.

Additional key words: disease forecast, epidemiology, *Prunus cerasus*

Cherry leaf spot, a serious disease of sweet and sour cherry in New York and Michigan, is initiated each spring by ascospores of *Coccomyces hiemalis* Higgins from apothecia in overwintering cherry leaves. Extensive spread of the disease in late spring and summer is caused by the conidial stage of *C. hiemalis* (*Cylindrosporium padi* Karsten).

Protective fungicide programs are used to prevent infection by the leaf spot fungus (2). However, the recent development of a model for identifying environmental periods suitable for infection of cherry trees (1) and the reported control of leaf spot with experimental fungicide CGA-64251 applied 24 hr after inoculation under greenhouse conditions (11) should make eradicant fungicide programs possible as well. This paper assesses the effectiveness of combining predictions and the use of eradicant fungicides for controlling leaf spot.

MATERIALS AND METHODS

Dodine (Cyprex 65% a.i. WP, American Cyanamid Co., Princeton, NJ 08540) and CGA-64251 (1-[[2-(2,4-dichlorophenyl)-4-ethyl-1,3-dioxolan-2-yl]methyl]-1*H*-1,2,4-triazole, 10% a.i. WP, Ciba-Geigy Co., Greensboro, NC 27409) were applied with a handgun sprayer at 24.6 kg/cm^2 (350 psi) at a rate of 0.45 g/L (6 oz/100 gal) of formulation in a 10-yr-old Montmorency sour cherry orchard in 1979 and in 22- and 30-yr-old Montmorency sour cherry orchards in 1980, all near East Lansing, MI. Each treatment was replicated three times using single-tree plots, and each tree was sprayed to the point of drip (approximately 15 L of spray per tree). All eradicant sprays were applied within 48 hr after the inception of wet periods predicted to produce infection, except that no additional sprays were made for 7 days after fungicide was applied.

The model used to identify infection periods of *C. hiemalis* on sour cherry is described elsewhere (1). Hours of wetness from rain and mean air temperature (C) during the wet period are used to compute an environmental favorability index (EFI) from 0 to 100. Under orchard conditions and high inoculum levels, an EFI value of 14 is considered to represent the minimum conditions for infection. In this study, EFI values were computed directly with the model or were taken from a nomogram (Fig. 1). The nomogram was constructed using a computer plotting package (8) and a set of 363 points generated by varying the temperature (T) and leaf wetness (W) values in the model, ie, EFI = f(T,W) where T = 8, 10, 12, ... 28 C and W = 4, 6, 8 ... 68 hr.

Weather data were collected in each orchard each year for determining the EFI values. Air temperature was measured with a 7-day recording hygrothermograph (Bendix Co., Inc., Baltimore, MD 21204) placed in a standard weather shelter 2 m above the ground. A 7-day recording leaf wetness meter (M. deWit, Hengelo, The Netherlands) was placed 1 m above the ground in the drip line of a tree to record the duration of leaf wetness. Rainfall was measured with a 7-day recording tipping bucket rain gauge (Weathermeasure Corp., Sacramento, CA 95841) in 1979 and 1980 and with a dipstick rain gauge at a second location in 1980.

To test EFI values for timing fungicides, we applied sprays in 1979 following wet periods when EFI values were ⩾14, ⩾28, and ⩾56, and in 1980 when EFI values were ⩾14, ⩾28, and ⩾42. Infection periods corresponding to these categories of EFI values were designated as low, moderate, and high, respectively. In 1979, a protective schedule (2) with sprays on a 10-day interval starting at petal fall, concluded by a spray 1 wk after harvest, was included for comparison. In 1980, a second trial consisted of applying the fungicides after primary, secondary, and all infection periods with EFI values ⩾28. A protective schedule with sprays on an 11-day interval starting at petal fall, concluded by a spray 1 wk after harvest, was included for comparison. Timing of the sprays in relation to predicted infection periods and rainfall is shown in Figures 2A–C for each fungicide trial.

Leaf spot incidence and severity were assessed by examining 20 shoots per tree in 1979 and counting the numbers of nodes, leaves, and lesions per shoot. In 1980, the numbers of nodes, leaves, lesions, and diseased leaves were recorded on 30 shoots per tree. Lesions per leaf, percentage of defoliation, and percentage of remaining leaves infected were calculated, transformed to ensure homogeneity of variance, and subjected to analysis of variance. Differences between treatment means were detected at $P = 0.05$ using the Duncan or Student-Newman-Keuls multiple range procedures.

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RESULTS

In 1979, 3 of 18 infection periods identified were high, 10 moderate, and 5 low (Fig. 2A). Lesions were first observed on 19 June resulting from rainy periods during 9–11 June. Analysis of data taken 15 July indicated that infection in all spray treatments was significantly less than infection on untreated trees (Table 1). Infection in the dodine treatment applied after infection periods with EFI ⩾56 was significantly higher than infection in the CGA-64251 treatment applied after the same infection periods, and it was significantly higher than infection in the other dodine and CGA-64251 schedules. On 31 August, defoliation from leaf spot was significantly greater on untreated trees than on treated trees. Defoliation and infection in the dodine treatment applied after high infection periods were identified were more severe than in the other fungicide treatments.

Table 1. Use of an infection model in scheduling fungicide applications for cherry leaf spot on Montmorency sour cherry at East Lansing, MI, in 1979

		Leaf spot on terminal leaves					
		15 July		31 August			
		Lesions/leaf		Defoliation (%)		Lesions/leaf	
Schedule Fungicide[u]	Sprays (no.)	Mean	Std. error	Mean	Std. error	Mean	Std. error
10-day schedule[v]							
Dodine	6	0.07 a[w]	0.004	2.5 a	2.06	3.82 a	1.97
CGA-64251	6	0.003 a	0.001	0.0[x]	0.0	0.009 a	0.009
EFI[y] ⩾14							
Dodine	6	0.121 a	0.103	0.3 a	0.28	0.239 a	0.237
CGA-64251	6	0.002 a	0.001	0.0[x]	0.0	0.019 a	0.017
EFI ⩾28							
Dodine	6	0.012 a	0.012	0.1 a	0.14	0.038 a	0.038
CGA-64251	6	0.001 a	0.001	0.0[x]	0.0	0.003 a	0.003
EFI ⩾56							
Dodine	2	0.435 b	0.111	8.6 b	1.9	6.44 b	2.62
CGA-64251	2	0.012 a	0.006	0.9 a	0.46	1.09 a	0.78
Untreated	0	1.56 c	0.257	80.5 c	16.9	...[z]	...

[u] Fungicides, both at 0.45 g/L (6 oz/100 gal), were applied within 48 hr of the inception of wetting.
[v] Five sprays applied on a 10-day interval and one spray applied 1 wk after harvest.
[w] Values followed by the same letter are not significantly different from each other at $P=0.05$ using the Student-Newman-Keuls multiple range test.
[x] Information was not used in range test.
[y] Environmental favorability index (EFI) was calculated with an infection model from duration of leaf wetness and mean air temperature.
[z] Data not taken because of heavy defoliation.

In 1980, 6 of 20 infection periods identified were high, 10 moderate, and four low (Fig. 2B). On 31 May the first lesions were observed resulting from a high infection period on 17 May. Analysis of disease assessment data taken on 1 August indicated that infection in all spray treatments was significantly less than infection on untreated trees (Table 2). Infection in the dodine treatment applied after infection periods with EFI ⩾42 was not significantly different from the other schedules. On 5 September, defoliation from leaf spot was significantly higher on untreated trees than on treated trees. Defoliation and infection in the dodine treatment applied after high infection periods were significantly higher than in the other schedules.

In a second orchard in 1980, 7 of 19 infection periods identified were high, 9 moderate, and 3 low (Fig. 2C). Lesions were first observed on 31 May resulting

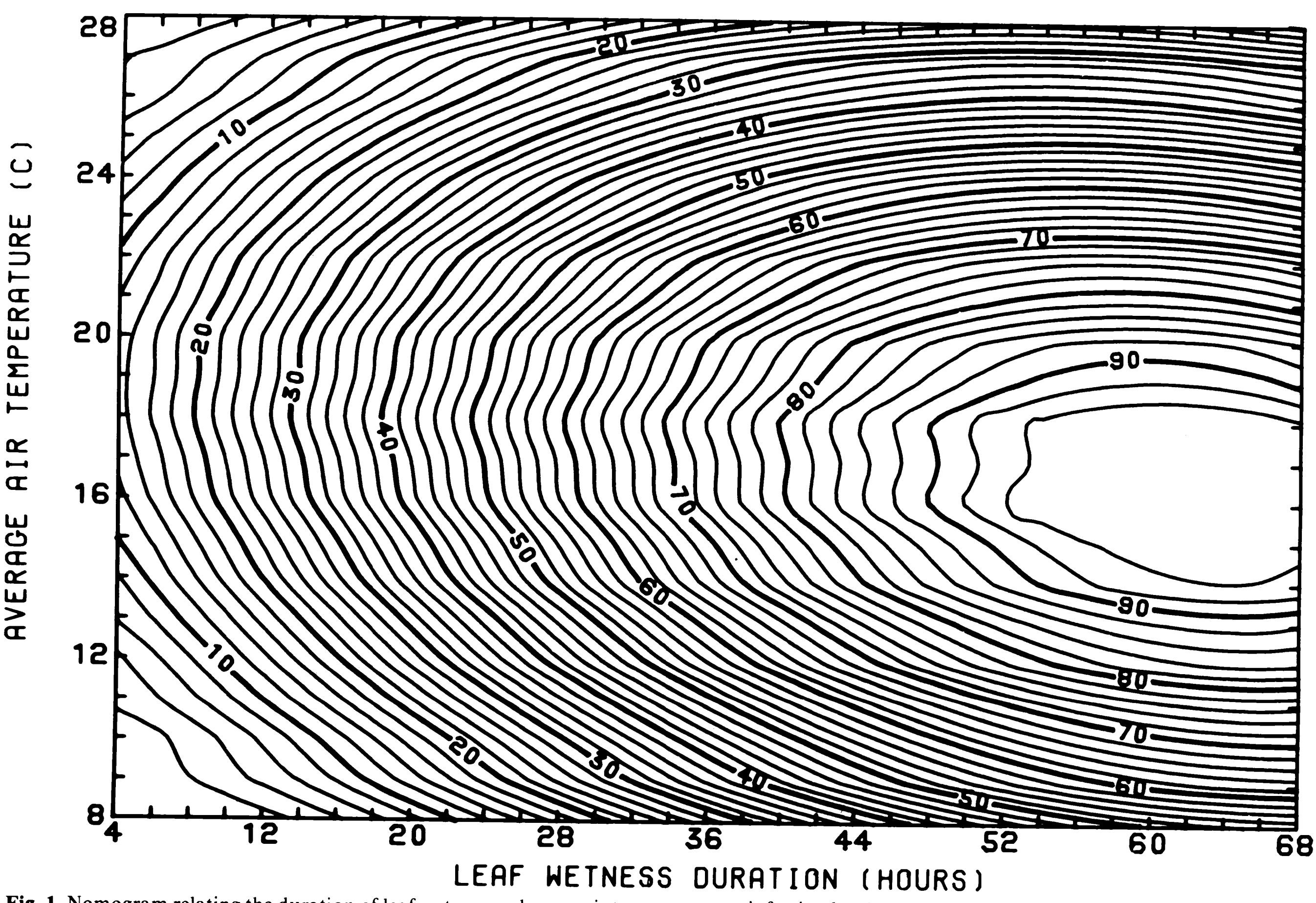

Fig. 1. Nomogram relating the duration of leaf wetness and mean air temperature to infection by *Coccomyces hiemalis* of Montmorency sour cherry leaves. Intervals are values of an environmental favorability index from 0 to 100 generated from an infection model.

from a wet period on 17 May. Analysis of data taken 6 August indicated that defoliation was significantly greater on untreated than on treated trees (Table 3). Infection and defoliation in treatments sprayed only during secondary infection periods were significantly greater than in other schedules. Differences in defoliation and infection between trees sprayed with dodine and CGA-64251 on the same schedule were not significant. On 5 September, differences in defoliation from leaf spot between trees sprayed with dodine and CGA-64251 on similar schedules were not significant, but trees sprayed with dodine on a protective schedule had significantly more infection than those sprayed with CGA-64251 on a protective schedule. Dodine and CGA-64251, when applied to control secondary infection on trees with primary infections, substantially reduced further increase in disease. A marked increase in disease was observed in trees sprayed after primary but not secondary infection periods.

DISCUSSION

Forecasting systems to time fungicides have been developed for late blight of potato (5), early blight of tomato (6), Cercospora leafspot on peanut (9), and apple scab (7). In all these systems except that for apple scab, disease control is achieved by limiting inoculum increases by timely applications of fungicides. The success of these systems indicates that fungicide applications timed by monitoring the environment often control disease with fewer sprays and as effectively as fixed time interval schedules.

Our data also showed that disease was controlled with fewer sprays. Two applications of CGA-64251 resulted in disease levels statistically equivalent to those resulting from six sprays on a fixed time interval schedule in 1979 (Table 1). In the assessment of 6 August 1980 (Table 2), disease control was statistically equivalent with six 11-day sprays or with three sprays after primary infection periods. Moreover, if the goal of the disease management program is to keep disease below a threshold that the tree can tolerate without affecting its potential yield, adequate control should be achieved with a reduction in spray number by applying dodine or CGA-64251 only after secondary infection periods (Table 2).

Use of infection models in timing fungicide sprays increases the effectiveness of disease control during moderately wet or dry seasons but not in very wet years. Rainfall during June through August in 1979 and 1980 was above the 1940–1969 normal for East Lansing. Therefore, the potential increase in effectiveness of using the infection model for disease control was not demonstrated. Drawbacks to the use of infection models to time fungicide sprays are the inability

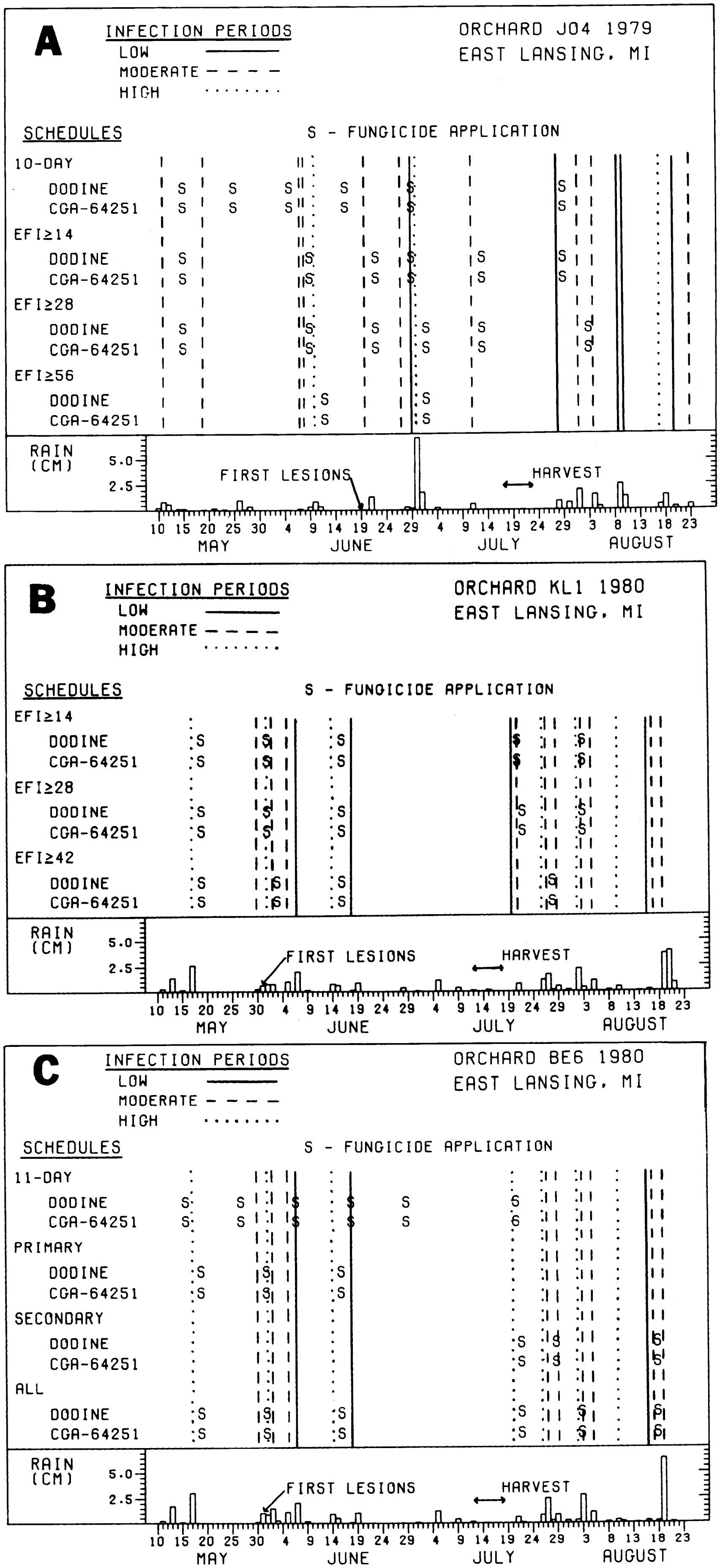

Fig. 2. Timing of spray schedules for control of cherry leaf spot in relation to predicted infection periods and rainfall in three orchards (**A, B, C**) near East Lansing, MI. Predicted sprays were not applied when a fungicide had already been applied within 7 days.

Table 2. Use of an infection model in scheduling fungicide applications for cherry leaf spot on Montmorency sour cherry at East Lansing, MI, in 1980: Orchard KL 1

Schedule Fungicide[w]	Sprays (no.)	Leaf spot on terminal leaves			
		1 August		5 September	
		Defoliation (%)	Infected leaves (%)	Defoliation (%)	Infected leaves (%)
EFI[x] ⩾14					
Dodine	5	0.0	0.47 a[y]	0.0 a	5.85 a
CGA-64251	5	0.0	0.17 a	0.0 a	2.69 a
EFI ⩾28					
Dodine	5	0.0	0.0 a	3.06 a	7.44 a
CGA-64251	5	0.0	0.0 a	0.65 a	2.82 a
EFI ⩾42					
Dodine	4	0.0	0.22 a	20.0 b	54.7 b
CGA-64251	4	0.0	0.62 a	1.34 a	20.8 a
Untreated	0	0.95	24.5 b	88.2 c	...[z]

[w] Fungicides, both at 0.45 g/L (6 oz/100 gal), were applied within 48 hr of the inception of wetting.
[x] Environmental favorability index (EFI) was calculated with an infection model from duration of leaf wetness and mean air temperature.
[y] Values followed by the same letter are not significantly different from each other at $P=0.05$ using Duncan's multiple range test.
[z] Data not taken because of heavy defoliation.

Table 3. Use of an infection model in scheduling fungicide applications for cherry leaf spot on Montmorency sour cherry at East Lansing, MI, in 1980: Orchard BE 6

Schedule Fungicide[t]	Sprays (no.)	Leaf spot on terminal leaves			
		6 August		5 September	
		Defoliation (%)	Infected leaves (%)	Defoliation (%)	Infected leaves (%)
11-day schedule[u]					
Dodine	6	0.45 ab[v]	0.75 a	1.52 abc	34.0 cd
CGA-64251	6	0.0 a	0.10 a	0.31 a	7.70 ab
Primary infection[w]					
Dodine	3	0.0 a	1.68 a	6.64 bcd	64.5 d
CGA-64251	3	1.14 ab	1.93 a	26.3 d	72.4 d
Secondary infection[x]					
Dodine	3	2.15 bc	30.0 b	6.50 cd	29.0 cd
CGA-64251	3	4.06 c	29.6 b	4.34 bcd	20.3 bc
All infection periods[y]					
Dodine	6	0.89 ab	0.19 a	0.68 ab	2.56 a
CGA-64251	6	0.16 a	0.19 a	0.97 abc	2.11 a
Untreated	0	13.5 d	58.1 b	70.6 e	...[z]

[t] Fungicides, both at 0.45 g/L (6 oz/100 gal), were applied within 48 hr of the inception of wetting.
[u] Five sprays applied on an 11-day interval and one spray applied 1 wk after harvest.
[v] Values followed by the same letter are not significantly different from each other at $P=0.05$ using Duncan's multiple range test.
[w] Sprays were applied when infection model predicted an EFI ⩾28 between 15 May and 1 July.
[x] Two sprays were applied 1 wk apart when 5% defoliation was observed, and remaining spray was applied when infection model predicted an EFI ⩾28 between 1 July and 31 August.
[y] Sprays were applied when infection model predicted an EFI ⩾28 between 15 May and 31 August.
[z] Data not taken because of heavy defoliation.

to plan applications, the necessity of monitoring the environment, the inability of the grower to apply chemicals within the postinfection activity period of the compound, and the necessity of complete spray coverage of susceptible host tissue.

In our study, the experimental fungicide CGA-64251 possessed the postinfection control activity needed for use in an eradicant schedule for cherry leaf spot. However, the apparent lack of persistence may mandate the use of a more persistent fungicide if a single postharvest spray is expected to control leaf spot for the remainder of the season. Fungicide CGA-64251 could replace benomyl, now ineffective because of resistance by the fungus (4), as a highly effective, broad-spectrum compound for the combined control of leaf spot, brown rot (*Monilinia fructicola* (Wint.) Honey), and powdery mildew (*Podosphaera oxyacanthae* (DC.) DeBary). CGA-64251 could also replace cycloheximide, which was formerly used to suppress sporulation in established lesions (3). Our field results are consistent with Szkolnik's greenhouse work with CGA-64251 (11) and should allow for the use of other eradicant fungicides for leaf spot when they become available (10).

The nomogram relating leaf wetness duration and mean air temperature to the favorability of the environment (Fig. 1) offers several potential advantages to growers. It is faster to use than an equation, there is less chance of error because no mathematical calculations are required, and the high operating and maintenance costs of computerized pest management delivery systems are avoided. Use of the infection model is a promising alternative to fixed time interval schedules and may be used by growers who prefer not to apply sprays until they can predict whether and to what extent infection from leaf spot has occurred during a natural wet period.

ACKNOWLEDGMENT

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LITERATURE CITED

1. Eisensmith, S. P., and Jones, A. L. 1981. A model for detecting infection periods of *Coccomyces hiemalis* on sour cherry. Phytopathology 71:728-732.
2. Flore, J. A., Jones, A. L., and Olson, L. G., eds. 1979. Fruit Pesticide Handbook. Mich. State Univ. Ext. Bull. E-154. 86 pp.
3. Hamilton, J. M., and Szkolnik, M. 1953. Factors involved in the performance of cycloheximide (Actidione) against *Coccomyces hiemalis*. (Abstr.) Phytopathology 43:109.
4. Jones, A. L., and Ehret, G. R. 1980. Resistance of *Coccomyces hiemalis* to benzimidazole fungicides. Plant Dis. 64:767-769.
5. Krause, R. A., Massie, L. B., and Hyre, R. A. 1975. Blitecast: A computerized forecast of potato late blight. Plant Dis. Rep. 59:95-98.
6. Madden, L., Pennypacker, S. P., and MacNab, A. A. 1978. FAST, a forecast system for *Alternaria solani* on tomato. Phytopathology 68:1354-1358.
7. Mills, W. D. 1944. Efficient use of sulfur dusts and sprays during rain to control apple scab. N.Y. Agric. Exp. Stn. (Ithaca) Ext. Bull. 630. 4 pp.
8. Sampson, R. J. 1975. Surface II Graphics System. Series on Spatial Analysis #1. Kans. State Geol. Surv. 240 pp.
9. Smith, D. H., Crosby, F. L., and Ethredge, W. J. 1974. Disease forecasting facilitates chemical control of Cercospora leaf spot of peanuts. Plant Dis. Rep. 58:666-668.
10. Szkolnik, M. 1974. Unusual post-infection activity of a piperazine derivative fungicide for the control of cherry leaf spot. Plant Dis. Rep. 58:326-329.
11. Szkolnik, M. 1979. Broad-spectrum after-infection activity by CGA-64251 against tree fruit diseases. (Abstr.) Phytopathology 69:1047.