Validation of an Early Blight Forecasting System for Tomatoes

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ABSTRACT

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A forecasting system (FAST) for *Alternaria solani* on tomato (*Lycopersicon esculentum*) was validated during the 1978 and 1979 growing seasons. Early blight epidemics that developed on plants sprayed according to a FAST-generated schedule were compared with early blight epidemics that developed on plants sprayed according to the following schedules: 7-day (7D) in both years, 14-day (14D) in 1978, and a no-spray check (0D) in both years. One cultivar was used in 1978, whereas four were used in 1979. The 7D treatment rows were sprayed nine times in each year, 14D treatment rows were sprayed five times, and the FAST treatment rows received only two and five sprays in 1978 and 1979, respectively. Analysis of variance indicated no cultivar × spray schedule interaction for either final disease severity or infection rate. There were no significant differences in disease severity or infection rates for the FAST and the more frequent spray schedules; the amount of disease resulting in the check plots was, however, significantly ($P = 0.05$) different from the other treatment plots. In summary, FAST produced a spray schedule that resulted in efficient and reliable early blight control.

A computerized forecasting system for tomato (*Lycopersicon esculentum* Mill.) early blight (caused by *Alternaria solani* (Ell. & G. Martin) Sor.) was developed at The Pennsylvania State University during 1976 and 1977 (7–9). The system identifies periods when environmental conditions are favorable for early blight development and then schedules fungicide applications (9). Spraying according to the forecaster resulted in reduced numbers of spray applications while maintaining early blight control (3,9). For such a management scheme to be considered for commercial use, it should be tested and validated for several years and on several cultivars. To be accepted, a forecasting scheme should also possess economic and/or ecological advantages.

Our study was conducted to evaluate FAST (Forecaster of *Alternaria solani* on Tomato) on four cultivars. A portion of the results were reported previously (10).

MATERIALS AND METHODS

Cultural conditions. In 1978, an experiment was established in a field planted to potatoes (*Solanum tuberosum* L.) in 1977 and not planted to tomatoes since 1971 or earlier. Treatment plots consisted of two rows of tomatoes (cultivar Merit) 9.1 m long; rows were placed 1.8 m apart and plants were at 30.5-cm spacings within the rows. Treatment plots were separated by single nonsprayed rows of Merit tomatoes. Five-week-old seedlings of this cultivar (Speedlings, Speedling Corp., Sun City, FL) that were grown in 1-in. (2.54-cm) cells were planted on 30 May 1978.

In 1979, an experiment was established in a field planted to tomatoes in 1978. Each treatment consisted of a single 16-m row of tomatoes planted with one of the following cultivars: 1) Merit, 2) Dorchester, 3) Red Rock, and 4) 77B38, a USDA line considered resistant to early blight. Seedlings of each cultivar were grown in a local greenhouse in 1-in. (2.54-cm) cells in plastic trays similar to Speedling trays. The seedlings were transplanted to the field on 15 May 1979. Rows were spaced 1.8 m apart and plants were at 23-cm spacings within the row. All treatment rows were separated by a nonsprayed row of Merit tomatoes. All rows received equal fertilization, cultivation, and weed and insect control.

Fungicide application. Chlorothalonil, a flowable protectant fungicide (BRAVO 500, Diamond Shamrock Corp., Painesville, OH 44077), was applied at a rate of 4.9 L/ha to the tomatoes according to specific schedules or according to FAST. The fungicide was applied with a one-row, tractor-mounted boom sprayer. Tee-Jet hollow cone nozzles (Spraying Systems Co., Wheaton, IL 60187) fitted with D3-23 orifice disk and core components delivered the fungicide at a pressure of 17.6 kg/cm^2.

Early blight assessment. In each treatment row, early blight severity was estimated at 2.5-m intervals in 1978 and 4-m intervals in 1979. The Horsfall-Barratt (2) rating scale was used initially to estimate disease severity per plant and later for a 30-cm-long row section when individual plants were no longer distinguishable. In 1978, assessments were started on 19 July and continued at about 14-day intervals until 7 September; in 1979, assessments began on 7 July and continued at about 10-day intervals until 21 August.

Reliability of early blight assessments was evaluated by having four observers on 21 August 1979 estimate disease severity at 4-m intervals in each of 24 tomato rows (six rows per cultivar). The degree of association among observers was determined by calculating Kendall's coefficient of concordance (1). Kendall's coefficient (K) is analagous to a multiple correlation coefficient ($0 \leq K \leq 1$).

Data analyses. In 1978, experiment treatments consisted of a no-fungicide check (0D) and fungicides applied at 7-day intervals (7D), 14-day intervals (14D), and according to the early blight forecaster (FAST). Treatments were replicated three times in a randomized complete block design.

The 1979 experiment consisted of two factors—cultivar and spray schedule, ie, four cultivars and three spray schedules. The fungicide treatments were a no-fungicide check (0D) and fungicides applied at 7-day intervals (7D) and according to FAST. All 12 treatments (four cultivars × three fungicide schedules) were replicated four times in a randomized complete block design.

The 1978 disease progression data were fitted with a first-difference regression model (6,13) after first taking the square-root of the severity values expressed as a percentage. This transformation resulted in the best fit of the data as indicated by residual plots and coefficients of determination. The logit transformation (15) was made on the 1979 early blight disease severity data; this transformation gave the best fit of the data when using the first-difference regression model.

Final disease severity and the rate parameter from regression analysis were analyzed by analysis of variance to evaluate early blight control. When using the logit transformation, the rate parameter is equivalent to Vanderplank's apparent infection rate (15).

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RESULTS

1978. There were no differences ($P = 0.05$) among final disease severity ratings for the FAST, 14D, and 7D scheduled fungicide treatments, but these three treatments resulted in significantly less early blight disease than had occurred on nonsprayed (0D) plants (Table 1). Timing fungicide applications on the basis of local weather data (FAST) required only two sprays for managing early blight disease to levels not significantly different from those achieved with five and nine sprays applied at 14- and 7-day intervals, respectively.

1979. An analysis of variance indicated there was no cultivar × spray interaction for final disease severity and infection rate for the 1979 epidemics. Therefore, comparison can be restricted to main effects without loss of information (11). There were no significant differences in disease severities (Table 2) and infection rates (Table 3) for the FAST and 7D treatments; however, values for these treatments were significantly lower than values for the check (0D) treatment. The USDA line (77B38) exhibited significantly less defoliation on 21 August than Merit and Dorchester (Table 2) and significantly lower apparent infection rates for the season than Merit, Dorchester, and Red Rock (Table 3). Negative apparent infection rates corresponding to the FAST and 7D schedules on 77B38 (Table 3) can be attributed to the rate of plant growth exceeding the rate of disease progression.

Kendall's coefficient of concordance for the degree of association among the four observers in 1979 equaled 0.914. This indicated a highly significant ($P < 0.001$) reliability of early blight assessment.

DISCUSSION

The spray schedule produced by the forecasting system provided efficient and effective control of tomato early blight at the test site in central Pennsylvania during the 1978 and 1979 growing seasons. Spray reductions that resulted following the FAST schedule rather than a 7-day schedule when used in six consecutive years were 70% in 1976 (8), 50% in 1977 (3), 78% in 1978, 44% in 1979, 50% in 1980 (4), and 67% in 1981 (5). The number of sprays recommended by FAST is entirely dependent on ambient temperature and moisture conditions (9) and therefore the number of fungicide applications recommended by FAST may vary among individual fields and from season to season. If environmental conditions are very favorable for early blight development, the number of sprays recommended could equal or exceed those applied according to a 7-day schedule. This condition has not occurred during the 6 yr we have been developing and verifying the forecast system; however, in 1979, the system recommended a spray be applied 2 wk before fruit set, ie, the plant growth stage when the 7-day schedule normally is initiated.

Three processing tomato cultivars (Merit, Dorchester, and Red Rock) were equally susceptible to early blight (Tables 2 and 3). The USDA line 77B38 was the most tolerant cultivar tested as indicated by having the lowest apparent infection rate and the lowest final disease severity value. The lack of a cultivar × spray schedule interaction indicated, however, that the increase in early blight control resulting from substituting a FAST-generated schedule for a no-spray schedule was no greater with cultivar 77B38 than with the other more susceptible cultivars.

The FAST-generated spray schedule resulted in early blight control not significantly different from that obtained with the more frequent spray schedules (Tables 1–3). These results, together with the results of 1976, 1977, 1980, and 1981 (3–5,9), indicate that FAST could be an efficient and reliable fungicide scheduling system for the control of tomato early blight in commercial fields in Pennsylvania. FAST may work equally well in other geographical areas with similar weather patterns. Application of fungicide treatments based on the FAST system also have been evaluated in North Carolina (12) and Indiana (W. R. Stevenson and R. Bundy, *unpublished*).

It is anticipated that commercial growers will consider using this forecast system only if it provides sufficient labor and financial savings and if the forecast is reliable so their crop will not be jeopardized by an omitted spray. In our study area, we noted that in certain years the reduced number of sprays may lead to a potential reduction in crop yield, not because of the early blight disease but as a result of fruit rot epidemics. Apparently, weather conditions unfavorable for early blight development may favor certain fruit-rotting organisms. Therefore, the reduced number of fungicide sprays may no longer provide protection against fruit-rotting organisms, eg, *Colletotrichum coccodes* (Wallr.) Hughes and *Alternaria alternata* (Fr.) Keissler (14).

Table 1. Early blight disease severity on 7 September 1978 and first difference rate parameters (rp) for epidemics resulting from four fungicide treatments applied to the tomato cultivar Merit

Treatment[y]	Number of sprays	Disease severity[z] (%)	rp
0D	0	61 a	0.0148 a
FAST	2	4 b	0.00396 b
14D	5	4 b	0.00297 bc
7D	9	2 b	0.00233 c

[y] 0D = Nonsprayed check, FAST = early blight forecaster generated schedule, 14D = 14-day schedule, and 7D = 7-day schedule.
[z] Means followed by the same letter within a column are not significantly different according to Fisher's least significant difference test ($P = 0.05$).

Table 2. Early blight disease severity estimates (%) on 21 August 1979 for four cultivars and three fungicide timing schedules

Spray schedule[x]	Number of sprays[y]	Cultivar				
		Merit	Dorchester	Red Rock	77B38	Mean[z]
0D	0	88	91	59	51	72 A
FAST	5	11	16	13	5	11 B
7D	9	23	10	11	5	12 B
Mean[z]		41 a	39 a	28 ab	20 b	

[x] 0D = Nonsprayed check, FAST = early blight forecaster generated spray schedule, and 7D = 7-day schedule.
[y] Spray timing: FAST = 3, 17, 24 July and 6, 14 August and 7D = weekly from 17 July through 8 September.
[z] Means followed by the same letter (either capital or lowercase) are not significantly different according to Fisher's least significant difference test ($P = 0.05$).

Table 3. Apparent infection rates (first-difference regression rate parameters) for early blight epidemics from 7 July to 21 August 1979

Spray schedule[y]	Number of sprays	Cultivar				
		Merit	Dorchester	Red Rock	77B38	Mean[z]
0D	0	0.131	0.136	0.088	0.074	0.107 A
FAST	5	0.029	0.035	0.031	−0.004	0.023 B
7D	9	0.042	0.015	0.029	−0.005	0.020 B
Mean[z]		0.067 a	0.062 a	0.049 a	0.022 b	

[y] 0D = Nonsprayed check, FAST = early blight generated spray schedule, and 7D = 7-day schedule.
[z] Means followed by the same letter (either capital or lowercase) are not significantly different according to Fisher's least significant difference test ($P = 0.05$).

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