Influence of Host Resistance and Crop Rotation on Initial Appearance of Potato Early Blight

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ABSTRACT

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The effects of host resistance, frequency of potato cropping, and previous crop on the initial appearance of potato early blight (caused by *Alternaria solani*) were evaluated under natural infestation in upstate New York. Initial lesions were observed at the same time on cultivars resistant to early blight and on those susceptible to early blight. Initial lesions on the current crop occurred earlier if the preceding crop was potato or tomato. In these fields, the earliness of lesion appearance was not affected by the previous frequency of potato production. However, if the preceding crop was not potato or tomato, more frequent potato production was associated with earlier occurrence of first lesions. The previous crop and the frequency of previous potato production were associated with an earlier appearance (6–8 days) of initial lesions. The application of these findings to the scheduling of sprays for early blight suppression is discussed.

Alternaria solani Sorauer, the causal agent of early blight of potato (*Solanum tuberosum* L.), overwinters in the northeastern United States in plant debris and in the soil (10,11,13). The conidia of *A. solani* are capable of surviving freezing weather on the soil surface or when buried to a depth of 5–20 cm (13). The first infections of the new crop are produced from overwintering inoculum. Short rotations and continuous cropping intensify the amount of initial inoculum and contribute to the increasing importance of early blight (11).

Tissues of young potato plants (including those of susceptible cultivars) are resistant to early blight (7,13). This resistance delays disease development even when inoculum is available and weather is favorable for infection by *A. solani* (12). Therefore, early blight foliage infection can be adequately controlled by relatively few applications of fungicide provided that the initial application is properly timed (3–6,12). The best time for initial application is when the secondary spread of *A. solani* conidia is likely, when weather is favorable for dispersal and infection, and when the potato foliage is susceptible to the pathogen—all occurring simultaneously (12). The time of secondary sporulation coincides with the time of first lesion appearance on lower leaves (4,6,7).

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Several simple methods have been developed to predict the time of secondary sporulation or the time when plants become susceptible and have been used to initiate spraying programs. A physiological-days (P-days) model, based on the accumulation of P-days since median emergence, was developed in Wisconsin (12). A degree days (DD) model, based upon accumulation of DD from planting, was developed in Colorado (5). Simple chronological time models have been used in Idaho (4) and in upstate New York (14).

The effect of host resistance and rotation on the initial appearance of early blight (an indicator of secondary sporulation) has not yet been investigated and is unknown. We hypothesized that early blight will appear later on resistant or moderately susceptible cultivars than on susceptible cultivars and that it will appear later on plants growing in fields having lower inoculum potential (because of previous cropping history) than in fields with greater inoculum potential. If our hypotheses are accurate, it may be possible to delay the initiation of sprays on moderately susceptible or resistant cultivars in relation to the initiation of sprays on susceptible cultivars. It may also be possible to delay the initiation of sprays on plants growing in fields that had not recently supported a solanaceous crop relative to those plants growing in fields with immediate preceding history of a solanaceous crop. With these possibilities in mind, we tested our hypotheses in upstate New York.

MATERIALS AND METHODS

The date of initial appearance of early blight was recorded in field experiments conducted at the Homer C. Thompson Research Farm at Freeville, New York. Observations were done on cultivars with different resistances to *A. solani* and in fields with different frequencies of previous potato cropping. The influence of three different frequencies was investigated. In the first rotation system (continuous), potatoes had been grown almost continuously during the last 8 yr. In the second rotation system (intermittent), potatoes had been grown approximately every other year in rotation with other crops (mainly corn). In the third rotation system (occasional), potatoes (or tomatoes, another host of *A. solani*) had been grown only once every 3 or 4 yr. Corn or various other nonsolanaceous vegetable crops were grown in the intermediate years. The closest distance between the continuous and the intermittent rotation systems was approximately 20 m. However, fields were separated by a dense, 5-m-high vegetation hedge. In addition, the common wind direction was from the intermittent to the continuous fields. Therefore, we assumed a negligible dissemination of inoculum from the continuous to the intermittent fields. The occasional fields were isolated (about 1–2 km apart) from the rest of the fields.

The initial appearance of early blight was recorded in field experiments conducted during the 1984, 1985, 1988, and 1989 growing seasons. These experiments were conducted for epidemiological research and employed a variety of experimental designs. However, in each experiment at least 100 plants from each cultivar (not sprayed with fungicides) were examined for early blight appearance. Plants in the experiments were planted during the last two weeks of May every year. If not identified otherwise, methods of planting, fertilizing, and other cultural practices were in accordance with those recommended for central New York (8). Maturity of cultivars and time of natural senescence (defoliation) were recorded in these experiments. The data were not included in this report because we concentrated on the initial appearance of *A. solani*. These events happened much later in the season. Some details concerning the different experiments are presented in Table 1. The resistance of cultivars to early blight is as follows: Chieftain, Norchip, and Superior are susceptible; Katahdin and Kennebec are moderately susceptible; and Bake-King, Elba, Hudson, Rosa, and Sebago are moderately resistant (8).

Table 1. Cultivars, rotation systems, and previous crops in the observations made in 1984, 1985, 1988, and 1989

Year	Experiment number	Cultivar	Rotation system[y]	Previous crop
1984[z]	1	Kennebec, Norchip, Rosa	A	Fallow
1985[z]	2	Kennebec, Norchip, Rosa	A	Fallow
1988	3	Norchip	A	Potato
	4	Hudson, Norchip, Rosa	A	Potato
	5	Chieftain, Elba, Katahdin, Norchip, Sebago, Superior	B	Potato
1989	6	Elba, Norchip, Katahdin	B	Potato
	7	Bake-King, Katahdin, Hudson, Norchip, Rosa, Sebago	B	Potato

[y] A = continuous (i.e., potatoes grown every year); B = intermittent (i.e., potatoes grown every other year).
[z] Data from Pelletier and Fry (*unpublished*).

Table 2. Analysis of variance conducted for identifying the effect of cultivars and experimental sites on the initial appearance of *Alternaria solani* in 1989-II

	Source of variation				
	Cultivar[a]		Experimental site		Error
Forecast method[b]	MS	*F*	MS	*F*	MS
Days since planting	9.3	0.72	50.4	3.93*	12.8
Days since emergence	7.9	0.47	60.4	3.93*	16.6
P-days since planting	786.0	0.83	3,860.0	4.11*	939.0
P-days since emergence	1,417.0	1.28	4,705.0	4.26*	1,103.0
DD since planting	2,111.0	1.01	9,251.0	4.46*	2,070.0
DD since emergence	3,040.0	1.25	12,879.0	5.30*	2,432.0
Julian date	11.1	0.85	51.7	3.97*	13.0

[a] MS = mean square. *F* statistic for difference of the analysis of variance. Analyses were done for each one of the forecast methods separately. Asterisk (*) denotes statistically significant difference at $P = 0.005$. There were no significant differences among cultivars at $P = 0.05$. There were 4 df for cultivars, 9 df for experimental sites, and 36 df for error.
[b] P-days = physiological days, DD = degree days.

Table 3. Effect of host resistance on the initial appearance of *Alternaria solani* in 1989-II employing several forecast methods

	Cultivar resistance[a]			LSD at
Forecast method[b]	S	MS	MR	$P = 0.05$
Days since planting	39[c]	40	41	3.8
Days since emergence	23	25	24	3.5
P-days since planting	317	329	328	24.7
P-days since emergence	193	204	205	46.6
DD since planting	467	486	487	56.9
DD since emergence	308	325	330	68.3
Julian date	195	196	196	4.1

[a] S = susceptible, MS = moderately susceptible, MR = moderately resistant.
[b] P-days = physiological days, DD = degree days.
[c] There were no significant differences among the different groups of cultivars at $P = 0.05$ for any forecast method.

An additional set of experiments was conducted in 1989, identified hereafter as 1989-II. Certified potato seed tubers (whole tubers, each weighing approximately 50 g) of the cvs. Elba, Hudson, Katahdin, Norchip, and Sebago were hand-planted on 5 June 1989 in small plots at 10 different sites (two in the continuous rotation system, four in the intermittent rotation system, and four in the occasional rotation system). In each rotation system, there were plots rotated with potato or tomato and plots rotated with fallow land. Each plot consisted of five 2-m-long rows (a different cultivar in each row), with 1.5 m between rows and about 50 cm spacing within rows. There were two replicates at each experimental site. Fertilizer (175 kg each of N, P, and K per hectare) was applied at planting.

Observations of weather, crop phenology, and disease were made every year in each experiment. Weather data were recorded (starting at planting) via a hygrothermograph installed in a weather station resting about 25 cm above the ground. Median emergence was estimated in each experiment by linear interpolation of emergence counts over time. Every 2–3 days after median emergence, plants were carefully examined for early blight lesions. The presence of early blight was verified in the field by observing typical lesions (with concentric targetlike markings; 10) and in the laboratory by microscopic examination of spores isolated from the lesions.

In previous studies, several simple forecasting methods have been used to predict the initial appearance of early blight (4,5,12,14). Most of them have not been tested in New York state. Because we did not know beforehand which one of them would best resolve the effects of host resistance and rotation on the initial appearance of early blight, we examined all of them. These included the number of days passed since planting or since median emergence, the accumulation of P-days since planting or since median emergence, the accumulation of DD since planting or since median emergence, and the Julian date of disease

Table 4. Effects of rotation system and previous crop on the initial appearance of *Alternaria solani* in 1989-II employing several forecast methods

	Rotation system and preceding crop[w]					
	Continuous		Intermittent		Occasional	
Forecast method[x]	Potato[y]	Fallow	Potato	Fallow	Tomato	Fallow
Days since planting	35[z] a	39 ab	39 ab	40 b	39 ab	45 c
Days since emergence	19 a	24 ab	24 ab	24 ab	23 ab	30 c
P-days since planting	286 a	309 ab	304 ab	327 b	319 ab	372 c
P-days since emergence	151 a	185 ab	187 ab	210 ab	195 b	252 c
DD since planting	425 a	459 ab	463 ab	481 b	471 ab	556 c
DD since emergence	244 a	296 ab	192 ab	327 b	321 b	401 c
Julian date	191 a	194 ab	195 ab	196 ab	195 ab	201 c

[w] Continuous = potatoes grown every year, intermittent = potatoes grown every other year, occasional = potatoes grown every 3–4 yr.
[x] P-days = physiological days, DD = degree days.
[y] Previous crop.
[z] Numbers followed by different letters in each row differ significantly ($P < 0.05$) as determined by Fisher's protected LSD test.

appearance. The growth response of the potato plant to temperature was used to calculate the accumulation of P-days for a 24-hr period. P-days accumulated most rapidly at 21 C and declined to zero at temperatures of 7 C and 30 C (12). The daily accumulation of DD was calculated by subtracting a base value of 7.2 C from the daily average temperature (5).

Analyses of variance were performed for identifying the effect of cultivars and various cropping systems on the initial appearance of *A. solani*. The computer software package MINITAB (Minitab Inc., State College, PA) was used to perform all statistical analyses.

RESULTS AND DISCUSSION

First, we analyzed the results of the set of experiments conducted in 1989-II. Then we compared the conclusions derived from these experiments with results recorded in the observations done in 1984, 1985, 1988, and 1989. Because there was no difference in the conclusions derived from analysis using any of the seven forecast methods in most cases, we will refer to the results of all of them simultaneously.

Host resistance had no significant effect ($P = 0.05$) on the initial appearance of early blight (Tables 2 and 3). The initial lesions in the different resistance groups of cultivars occurred over a narrow range: 1 day, 12 P-days, or 22 DD after emergence (Tables 2 and 3). (In 1989, an average chronological day was equivalent to 8.2 P-days and 12.6 DD.) Therefore, in further analyses, data for different cultivars (within each experimental site) served as subsamples for this site. Our results confirm previous observations of the initial appearance of *A. solani* on different cultivars (5,6,9). These previous observations, however, included fewer cultivars than the study reported here. We concluded that sprays should be initiated at the same time for all cultivars, regardless of their resistance to the pathogen.

In contrast to the effect of host resistance, experimental site (= effects of rotation system and previous crop) had highly significant effects ($P < 0.005$) on the initial occurrence of early blight (Table 2). Analyses of these data enable us to make preliminary estimates of the effect of rotation system and previous crop on the initial appearance of *A. solani*. In general, early blight was observed first on potatoes grown on sites with recent histories of frequent potato production. Early blight lesions were recorded earlier if potato or tomato had been grown in the previous year than if the land had been left fallow (Table 4). However, the interaction between rotation systems and the previous crop was significant ($P < 0.05$), so comparisons were made for all levels of these factors. If potato or tomato immediately preceded the current crop, the frequency of previous potato production in this field (rotation system) made no significant difference ($P < 0.05$) in the date of early blight appearance (Table 4). When fields had previously been fallowed, those with only occasional plantings of potato or tomato supported later occurrence of early blight on the current crop than did fields with histories of more frequent potato or tomato production (Table 4).

In general, initial lesions in the experiments conducted in 1984, 1985, 1988, and 1989 were recorded later than in the set of experiments done in 1989-II (Tables 4 and 5). This is probably because the plants were examined more carefully for early blight appearance in 1989-II. However, the conclusions derived from the 1989-II experiments were corroborated by these previous observations: 1) early blight lesions were observed at the same time on all cultivars regardless of their susceptibility to *A. solani*; 2) early blight appeared early when the previous crop was tomato or potato; and 3) an effect of the frequency of previous potato or tomato production was obscured by the immediately preceding crop (Table 5).

Several lines of evidence now indicate that host resistance and previous cropping history of a field influence the need for fungicide application for suppression of potato early blight. Authors of several studies have concluded that the frequency of application can be safely reduced on moderately resistant cultivars and still maintain disease levels at or below those of susceptible cultivars receiving more applications (1,2,15). Our study indicates that the history of potato production and the immediate preceding crop affect the earliness of early blight appearance. In general, if potatoes or tomatoes are grown only occasionally (for example, once every 3 or 4 yr) and if neither potato nor tomato preceded the current crop, lesions appear about 1 wk later than when potato or tomato was the preceding crop (Table 4). In upstate New York, potato plants generally become susceptible to early blight about 6 or 7 wk after planting (14), and we have previously recommended that fungicide applications be initiated at this time. If this strategy is adequate for fields in which the preceding crop was potato or tomato, then it seems likely that when other crops preceded the current season, initial fungicide applications could be delayed until 8 wk after planting. In fields where potato or tomato are grown more frequently, or when potato or tomato precede the current crop, fungicide applications should be initiated 6 or 7 wk after planting (14). The obvious next

Table 5. Effect of host resistance, rotation system, and previous crop on the initial appearance of *Alternaria solani* in 1984, 1985, 1988, and 1989[a]

	Cultivar resistance to early blight			Rotation system and preceding crop[b]		
				Continuous		Intermittent
Forecast method[c]	Susceptible	Moderately susceptible	Moderately resistant	Potato[d]	Fallow	Potato
Days since planting	49	51	50	46	48	50
	(1)[e]	(3)	(1)	(1)	(1)	(1)
Days since emergence	30	31	30	27	30	31
	(1)	(4)	(1)	(1)	(1)	(1)
P-days since planting	353	383	362	336	366	371
	(10)	(12)	(11)	(15)	(17)	(6)
P-days since emergence	219	238	224	202	229	234
	(8)	(18)	(10)	(12)	(15)	(6)
DD since planting	519	552	535	492	516	523
	(54)	(32)	(13)	(38)	(17)	(10)
DD since emergence	351	383	367	311	333	358
	(20)	(41)	(17)	(17)	(15)	(12)
Julian date	192	195	194	189	192	194
	(2)	(4)	(1)	(1)	(4)	(1)

[a] Numbers are means of data observed in 25 crops in 1984, 1985, 1988, and 1989. At least 100 plants were examined in each crop.
[b] Continuous = potatoes grown every year, intermittent = potatoes grown every other year.
[c] P-days = physiological days, DD = degree days.
[d] Previous crop.
[e] Numbers in parentheses are standard errors.

step is to evaluate this strategy under both field plot conditions and on commercial farms.

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