Timing Initial Fungicide Application to Control Botrytis Leaf Blight Epidemics on Onions

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ABSTRACT

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In preliminary studies, the initiation of fungicide application when *Botrytis squamosa* lesions averaged one per 10 leaves resulted in higher yields of onions than when applications were commenced before or after this time. This disease level accordingly was utilized as the critical disease level (CDL) for timing the initiation of weekly fungicide sprays in subsequent studies. Yields from fields in which spray treatments were initiated at or soon after the CDL were equal to yields where weekly sprays were initiated 1-2 wk earlier. Use of the CDL method reduced by one to three the eight (12-38%) recommended spray applications during 3 years of testing. Disease progress curves generally showed slower rates of increase when fungicide sprays were initiated prior to detection of the CDL, but appeared to converge with time for treatments initially sprayed prior to, at, and past detection of the CDL. Analyses of disease progress curves from unsprayed plots in different fields indicated that leaf blight epidemics differed with respect to starting times and rates of development in the same as well as in different years. *Botrytis squamosa* conidia were trapped in a Hirst spore trap 2 wk prior to detection of the CDL and may be useful as an alternative method for timing fungicide initiation.

Additional key words: epidemiology, onion leaf blight, pest management, disease threshold.

Since Newhall and Rawlins reported (4) that the use of dithiocarbamate dusts and sprays increased yields of onion (*Allium cepa* L.), it has become well established that the dithiocarbamates are effective protectant fungicides for the control of Botrytis leaf blight caused by *Botrytis squamosa* Walker in New York (3, 9, 10). Shoemaker and Lorbeer (8) suggested that the initial spray application be made when an average of one lesion per ten leaves is detected, referred to herein as the critical disease level (CDL). The purpose of this paper is to present: (i) the results which led to the formulation of the CDL method; (ii) results of field testing the method; and (iii) analyses of disease progress curves developed from this study.

MATERIALS AND METHODS

Preliminary studies.—During 1967 the initial application of weekly sprays of mancozeb was varied to determine the relation between the initial application date, development of Botrytis leaf blight epidemics, and yields of onions. Seven treatments with four replications in a randomized complete block design were located in a commercial field of onions (cultivar Elba Globe). The initial fungicide application was made on 26 June in the first treatment and was delayed by 1-wk intervals until 7 August in the seventh treatment. Once fungicide application had begun, 1.8 kg actual ingredient (a.i.) mancozeb/hectare (ha) (1.6 lb/A) in 935 liters (100 gal) of water was applied at weekly intervals through 14 August, the final application date for all treatments. Each treatment also received weekly applications of the spreader-sticker Triton B-1956 (Rohm and Haas, Philadelphia, PA, 19105) at the rate of 438 ml/ha (6 fl oz/A) and the insecticide Diazinon 4EC at 1.17 liters/ha (1 pt/A). Treatments were applied to plots 1.6×6.1 m (62 in × 20 ft) containing four rows on 36-cm (14-in) centers using a hand-held CO_2 sprayer operated at a nozzle pressure at 1.76 kg/cm^2 (25 psi). Yields were determined from 5.5 m (18 ft) of the middle two rows of each plot on 28 August. Lesion counts were made weekly on 20 plants collected randomly within an unsprayed plot adjacent to the test area. All lesions typified by necrotic centers, elliptical shape, and size in the range 0.01-0.10×0.05-0.30 cm were counted. The cumulative numbers of conidia were determined daily by collection from a Hirst spore trap.

Field testing the CDL method.—The test of the CDL method was based on comparisons of treatments in which fungicide applications were initiated arbitrarily early and treatments initiated at detection of the CDL. Experiments were conducted in six commercial fields of onions (cultivar Downing Yellow Globe) during 1968 (fields A-C) and 1969 (fields D-F) near Florida, New

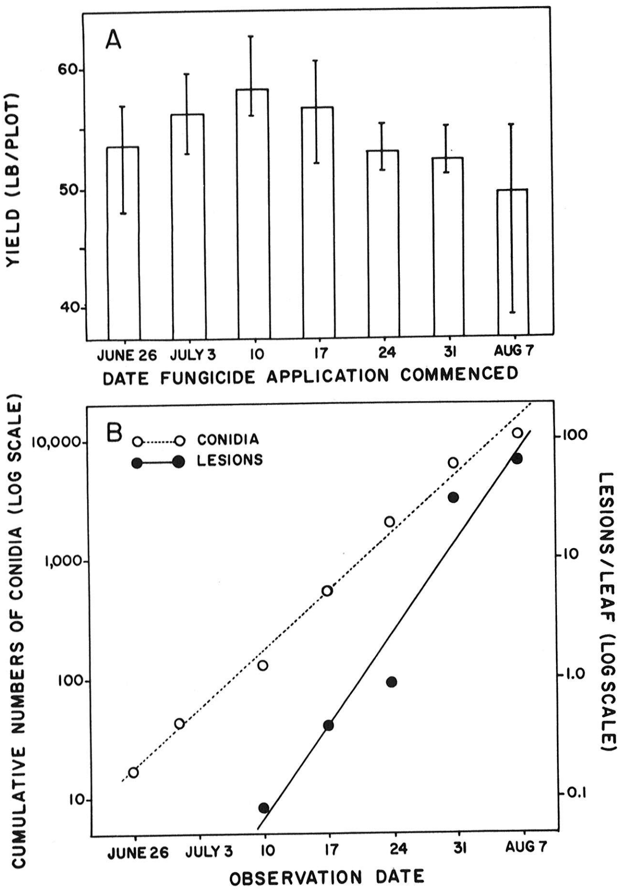

Fig. 1-(A, B). Relation of the 1967 Botrytis leaf blight epidemic to onion yields and the cumulative number of conidia of *B. squamosa*. **A**) Average yields for fungicide treatments initiated at different weekly intervals; dates of initial application are at base of each bar and lines through the tops of the bars indicate the range of variation. **B**) Regression lines for cumulative spore numbers collected in a Hirst spore trap adjacent to the plots and average weekly lesion numbers for a random sample of 20 plants from a nearby nonsprayed subplot.

York. The fields were located 1.6-3.2 km (1-2 mi) apart and ranged in size from 0.61-1.4 ha (1.5-3.5 A). Plant and row spacings differed slightly between fields, but all plantings were in four row beds approximately 1.7 m (69 in) wide with rows approximately 38 cm (15 in) apart. Cultural operations, except spraying, were performed by the grower cooperators.

The six fields were laid out in a randomized complete block design with four blocks and three treatments. Blocks were five beds wide (20 rows) and were divided into three equidistant lengthwise sections 52-91 m (170-300 ft) long depending on the length of the fields; treatments were assigned to a section at random. Treatments consisted of: (i) a "control" or standard in which the initial fungicide spray was applied in mid-June when growers normally begin to spray; (ii) a "detection" treatment in which the initial fungicide spray was applied at time of detecting the CDL; and, (iii) an optional treatment in which sprays either were initially applied at time of detection of the CDL, but at a different fungicide rate or were delayed 1-2 wk after detection of the CDL. The initial spray date, rate, and total number of applications for each treatment are listed in Table 2. Once application was initiated, maneb plus zinc sulfate (1968) and mancozeb (1969) were applied at weekly intervals. All plots were sprayed weekly with Triton B-1956 and Diazinon at rates previously indicated beginning when the control was first sprayed. Once fungicide application had begun in a given treatment, the spreader-sticker and insecticide were tank-mixed with the fungicide. Sprays were applied by a tractor-mounted, 20-row, commercial boom sprayer in 468 liters H_2O/ha (50 gal/A) at a pressure of 7 kg/cm^2 (100 psi) with one spray nozzle over each row.

Within each main (treatment) plot, various subplots were randomly allocated: one for lesion counts and three (1968) or four (1969) for yield determinations. The subplots were four rows wide by 9.1 m (30 ft) long and were located in the second and fourth bed of each treatment plot; the two outside beds were left as buffers and the center bed for tractor wheels. One subplot within each main plot was left unsprayed as an internal check (no fungicide) in 1968, but the unsprayed checks were located outside the test area in 1969. To detect the CDL, 20 plants per subplot (80 plants per field) were randomly collected each week from the four detection treatment plots.

TABLE 1. Numbers of *Botrytis squamosa* lesions per leaf from weekly sampling to detect the critical disease level (CDL) and dates of initial fungicide application in the CDL detection treatments during 1968 and 1969 in six onion fields near Florida, New York

Field[a]	Sampling date	Number of lesions/leaf[b]	Sampling date	Number of lesions/leaf[b]	Initial spray date
A	18 June[c]	0.083	24 June	1.544	18 June
B	19 June	0.004	24 June[c]	0.202	28 June
C	19 June	0.021	27 June[c]	3.300	29 June
D	16 June	0.008	23 June[c]	0.108	24 June
E	17 June	0.030	24 June[c]	0.128	25 June
F	19 June	0.026	26 June[c]	0.754	26 June

[a]Fields A-C (1968); D-F (1969).
[b]Lesion counts are sample averages based on all the leaves of 20 plants randomly collected from each of four subplots (range: 215-336 leaves/sample).
[c]Detection date of the CDL (one lesion per 10 leaves). Fungicide (maneb + zinc) application was initiated in the detection treatments when there were at least .08 lesions per leaf. Because of weekly sampling, the detection treatments in fields B, C, and F were sprayed initially after the date indicated by the CDL.

Because sampling was done weekly, the exact day the CDL was reached was not determined. Therefore, it was decided that fungicide spraying be initiated when 0.08 lesions per leaf were observed in the detection treatments (Table 1). This procedure resulted in a delay of several days in the initial application after the CDL had been exceeded in three of the fields [fields B, C, and F (Table 1)]. The progress of the epidemic in all treatments was

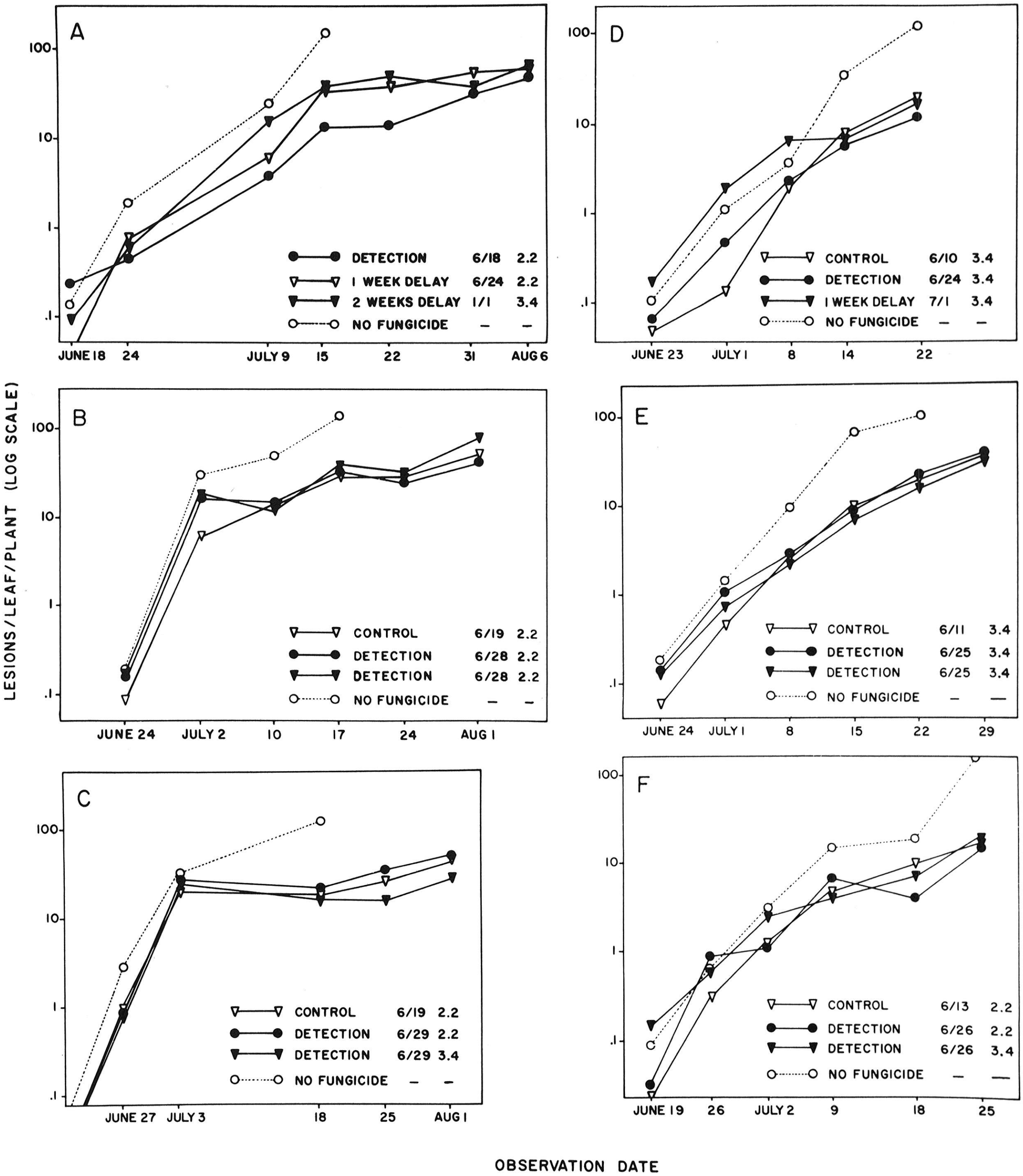

Fig. 2. Disease progress curves resulting from fungicide treatments with different initial spray dates for control of Botrytis leaf blight of onion. The first column in legend indicates treatments, the 2nd indicates initial date of fungicide application, and the 3rd the rate in kilograms of formulation per hectare (formulation in fields A-C was maneb + $ZnSO_4$ 80WP, and in fields D-F mancozeb 80WP). Initial fungicide application was arbitrarily early in the "controls", based on the CDL method in the "detection" and 1-2 wk later in the "delay" treatments. Graph labels A-F correspond to field location designations in Tables 1 and 2.

followed by counting lesions on five plants collected at random per subplot once a week. Yield data were obtained from 6.1 m (20 ft) of the center two rows of the subplots assigned for yield determinations.

Analysis of disease progress curves.—Chi-square tests were used to determine whether epidemics begin uniformly within a field by comparison of lesion numbers from the four CDL detection subplots. Analyses of covariance (6) of lesion data from the check (no fungicide) plots were used to determine whether the epidemics progressed differently between years 1967, 1968, and 1969 and to determine whether there were differences between fields in the same year.

RESULTS

Preliminary studies.—During 1967, the fungicide treatment which was initiated on 10 July had the largest average yield (Fig. 1-A) and yields progressively were less in treatments wherein fungicide application had been initiated before or after 10 July. Inasmuch as an average of one lesion per 10 leaves had been observed in an adjacent unsprayed plot on 10 July (Fig. 1-B), we

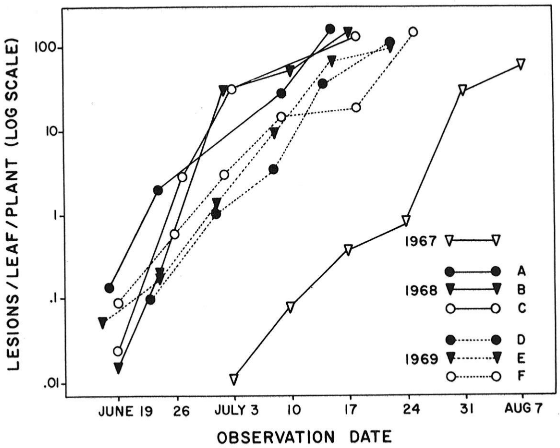

Fig. 3. Disease progress curves for Botrytis leaf blight of onions from check (no fungicide) treatments for 1967-69. Data points are the average number of lesions per leaf per plant from random samples of five plants from each of four plots in different locations for each of seven different fields. In 1968 and 1969, each of the three fields was 1.6-3.2 km (1-2 mi) apart.

TABLE 2. Onion yield averages from treatments with various initial spray dates for Botrytis leaf blight control in experiments conducted during 1968 and 1969 near Florida, New York

Field[a]	Treatment[b]	Initial spray date	Rate[c] (kg/ha)	Total applications	Average yield[d] (kg)	LSD ($P = .05$)
A	Detection	6/18	1.8	9	24.9	
	1-week delay	6/24	1.8	8	22.9	4.9
	2-week delay	7/1	2.7	7	21.9	
	Check			0	17.4	
B	Control	6/19	1.8	8	20.6	
	Detection	6/28	1.8	7	20.3	4.1
	Detection	6/28	1.8	7	20.5	
	Check			0	16.3	
C	Control	6/19	1.8	8	23.5	
	Detection	6/29	1.8	7	23.8	6.6
	Detection	6/29	2.7	7	25.4	
	Check			0	17.1	
D	Control	6/10	2.7	8	25.4	
	Detection	6/24	2.7	6	26.2	2.9
	1-week delay	7/1	2.7	5	25.1	
	Check			0	22.0	
E	Control	6/11	2.7	8	31.6	
	Detection	6/25	2.7	6	30.8	4.1
	Detection	6/25	2.7	6	31.5	
	Check			0	24.9	
F	Control	6/13	1.8	7	21.2	
	Detection	6/26	1.8	5	21.7	1.5
	Detection	6/26	2.7	5	21.5	
	Check			0	19.8	

[a]Fields A-C (1968); D-F (1969).
[b]Initial fungicide application was at an arbitrary early date for treatments designated "control," as close as feasible to the time of detecting an average of one lesion per 10 leaves (CDL) for those designated "detection," and one to two weeks later for those designated "delay." The "checks" received no fungicide and were not true treatments within the experimental design.
[c]Rates are kilograms a.i. fungicide per hectare. Maneb + $ZnSO_4$ and mancozeb were used in 1968 and 1969, respectively.
[d]Yield averages were based on 12 observations for fields A-C and 16 observations for fields D-F except for the check averages which were based on four observations each.

hypothesized that maximum yields should be obtained by initiating fungicide application when this level of infection was detected; this was designated as the CDL.

Results from spore trapping indicated that significant numbers of conidia of *B. squamosa* had been collected approximately 2 wk before the time of CDL (Fig. 1-B).

Field testing the CDL timing method.—In fields A, D, and E, sampling once a week resulted in application of the initial fungicide sprays at a time very close to the CDL (Table 1). However, in fields B, C, and F, the detection spray treatments were initiated late according to the CDL criterion. In fields B, C, D, E, and F, the average yields for treatments in which spraying was initiated at or soon after detection of CDL were not significantly different from that in treatments in which spraying was initiated 1 or 2 wk earlier (Table 2). Where weekly applications of 1.8 and 2.7 kg a.i. fungicide/ha were compared in plots initiated at detection of the CDL, the treatments sprayed with 2.7 kg/ha yielded highest in field C, but there was no difference between the two rates in field F. In field A, the first spray was applied at the CDL and resulted in higher yields than treatments where the initiation date was delayed 1 or 2 wk. In all cases, the check (no fungicide) plots had lower yields than the fungicide-treated plots.

Analysis of disease progress curves.—The disease progress curves indicate that, in general, the controls (fungicide treatment initiated before detection of the CDL) had the least incidence of disease during the first week or two (Fig. 2). The treatments initiated at the CDL or later had a higher initial incidence of disease, but by midseason there was little difference among treatments, although in all cases leaves had been completely destroyed in the unsprayed checks. Chi-square analysis of lesion numbers from four random locations at the time of detection of the CDL in the different fields indicated that leaf blight began nonuniformly within each field ($P = 0.05$). Analysis of variance of the original data summarized in Fig. 2-A and 2-D (excluding data from the check plots) indicated that lesion number means for the different spray treatments were significantly different ($P = 0.05$) for the early dates, but were not different for the later dates. Results from these analyses suggest that the disease progress curves for the fungicide treatments in fields A and D initially were divergent but converged with time.

The disease progress curves for the check plots in the 3 years 1967-69 are similar in shape, but differ in their position on the graph (Fig. 3). In 1967, the epidemic began 2 wk later than in 1968 and 1969 and the rate of development apparently was faster in 1968 than in 1969 (Fig. 3). Analyses of covariance of the original data summarized by the seven curves in Fig. 3 indicated that the slopes of regression lines fitted to the data are significantly different ($P = 0.05$) both for different years and for different fields within the same year. These analyses indicate that the epidemics progressed differently in each of the 3 yr, and also progressed differently in different fields within the same year.

DISCUSSION

Yields were equivalent in plots in which fungicide spray treatments were initiated 1 wk and 2 wk before, at and past detection of the CDL. The conclusion is that the CDL method for timing initiation of weekly mancozeb sprays for Botrytis leaf blight control is effective and that there is some latitude if the first spray is applied a few days later than indicated by the CDL. At first glance, these results appear to contradict the principle which Van der Plank (11, p. 271) says theory and experience dictate; i.e., protectant fungicides, to be most effective, must be applied before arrival of inoculum. The disease progress curves show this principle clearly during the early stage of the epidemic. The standard treatments (controls) in which spray applications were begun before the date of the CDL initially had slower rates of disease development, but did not produce greater yields than those treatments initiated at the CDL. This apparent discrepancy is explainable as follows: (i) The differences in the disease progress curves occurred when lesion counts were low, and thus would have a negligible effect on final yields. (ii) New leaves are formed in onions at the rate of about one per week during the growing season (2); therefore, new leaves that developed after the CDL in the detection treatments were protected as well as the new leaves that formed in the control plots. Furthermore, the older leaves (the source of early data) naturally senesce and slough off with age. This may explain the convergence of the disease progress curves for the control and detection treatments. (iii) Bulbing usually starts in mid-July, and by this time the new growth in the control and detection treatments had received equal protection for about 3 wk. This later growth presumably contributes to the enlargement of the bulb and thus the final yield.

Efforts to avoid interplot interference (7, 11) included: (i) comparison of treatments that were similar in effectiveness; (ii) use of relatively large main (treatment) plots (450-770 m^2) in which subplots, approximately 16 m^2, were located for sampling away from the borders of the main plot; and (iii) unsprayed checks were located outside of the plot areas in 1969 and had negligible effect on the spray treatments. However, one unsprayed check subplot (16 m^2) was located within each treatment main plot in 1968 and, therefore, interfered equally with all treatments. Since the unsprayed checks were surrounded by protected foliage, they presumably were interfered with negatively (7) and had less disease and greater yields than otherwise.

Use of the CDL method in a pest management production scheme for onions could provide for the elimination of unnecessary early fungicide applications. Inasmuch as weekly fungicide sprays are usually begun in early to mid-June, use of the CDL method would have delayed the initial application so that one or two sprays would have been eliminated in 1968 and 1969. In 1967, when the CDL was detected on 10 July, three of eight of the fungicide applications would have been eliminated. Should the epidemic start later in the season or fail to occur altogether, even more fungicide applications could be eliminated.

Practical application of the CDL method, however, would require sampling in a number of locations within a field as well as in different fields, because our findings showed that epidemics do not begin uniformly within a field nor at the same time in different fields. However, there apparently is some latitude when sprays can be initiated with respect to the CDL; yields were not decreased when spray applications were initiated a few days or even 1 wk after the CDL.

Spore trap counts of *B. squamosa* conidia could possibly be used for timing the initiation of spray applications (see Fig. 1-B). This alternative method would have the advantage that a developing epidemic could be detected approximately 2 wk before detection of the CDL, and thus provide more time for advising growers of the initial date to spray. These findings are contrary to Schenck's (5) results with watermelon downy mildew *(Pseudoperonospora cubensis)* in which spores were not trapped until the appearance of symptoms in the field. However, Harrison et al. (1) concluded that spore trap data were useful for basing spray schedule initiation for control of potato early blight *(Alternaria solani)*. Spore trapping, however, may be impractical because the area sampled is generally very limited, and considerable time is required for examination of slides.

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