Comparison of Predictive Systems for Timing the Initial Fungicide Application to Control Botrytis Leaf Blight of Onion

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ABSTRACT

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Experiments were conducted in a commercial onion field during 1984–1986 to compare two predictive systems that time the initiation of a fungicide spray program for controlling Botrytis leaf blight of onion. Using the critical disease level (CDL) system, the first fungicide application was called for when lesion counts exceeded 1.0 lesion/leaf. Using BOTCAST, the first application was made when 35 (1984) or 25 (1985–1986) disease severity units had accumulated and rain was indicated in the weather forecast. During the 3 years of field experiments, the CDL system called for the first fungicide application 1–3 wk later than did BOTCAST, resulting in a savings of 1–3 fungicide applications. Lesion levels were slightly, but significantly, higher in the CDL plots in 1985, but no difference was observed in onion yields of the treatments in any of the experiments. Although the CDL system was the more sensitive method for initiating fungicide applications for effective control of Botrytis leaf blight, a combination of the CDL system and BOTCAST may be most efficient in order to reduce grower reliance on intensive field scouting.

Additional keywords: *Allium cepa*, *Botrytis squamosa*, integrated pest management

Several predictive systems are available currently for timing fungicide applications for control of Botrytis leaf blight of onion. Two of these are designed primarily to time the initiation of a fungicide spray program. The critical disease level (CDL) system (5) involves scouting onion fields and counting lesions typical of *Botrytis squamosa* Walker on onion leaves. The current recommendation is that the first application is called for when an average of 1.0 lesion/leaf is reached in a field (3). Subsequent sprays are applied weekly. The CDL system has been in use for a number of years in Cornell University's Onion Integrated Pest Management (IPM) Program (1). Another predictive system called BOTCAST (8) calls for the first fungicide application when a critical number of disease severity units have accumulated; subsequent sprays are applied weekly. The disease severity units of BOTCAST represent estimates of the effects of weather on production of inoculum and infection by *B. squamosa* in the field. Thus, BOTCAST is a weather-based rather than a scouting-based predictive system. A third system, the sporulation index system (2), bases fungicide recommendations on forecasts of sporulation by *B. squamosa*, but not infection. This system can be used to time fungicide sprays throughout the season with the reservation that infection periods are not actually predicted.

It was of interest to determine which predictive system was best for timing the initiation of a fungicide spray program. Since the CDL system and BOTCAST were both designed specifically for this purpose, field experiments that were conducted during 1984–1986 focused primarily on these two predictive systems. The sporulation index system was studied only during 1984.

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MATERIALS AND METHODS

General procedures. The experiments were conducted in commercial onion fields at Ruszkiewicz Farms in Orange County, NY. All cultural and spray operations were performed by the grower-cooperator. All experiments included treatments in which the initial fungicide application was timed according to the CDL system or BOTCAST. All treatments were compared with a "grower schedule," in which the fungicide program was initiated according to the cooperating grower's normal schedule and in which subsequent applications were made at 3–11 day intervals that paralleled the grower's normal schedule.

In the CDL treatment, the first spray was applied when disease reached or exceeded 1.0 lesion/leaf as determined by lesion counts made at 4–7 day intervals. In the BOTCAST treatment, the initial spray was applied when a total of 25–35 cumulative disease severity index (CDSI) units had accumulated, as determined by weather monitoring. The threshold CDSI values used in each experiment are indicated. Once a fungicide program was initiated in a particular treatment, all subsequent applications were made paralleling the grower schedule, unless otherwise indicated. All fungicide treatments were applied by the grower-cooperator using a Ford Model 1900 tractor equipped with a boom sprayer delivering 470 L/ha at 760 kPa using D-2 nozzles (Spraying Systems Co., Wheaton, IL 60187).

Temperature and relative humidity were monitored with a Bendix hygrothermograph (model 594, Science Associates, Princeton, NJ 08540) located within a weather shelter placed on the soil surface within or adjacent to the experimental area. In 1985 and 1986, leaf wetness and temperature within the crop canopy were monitored with a Datapod model 223 micrologger (Omnidata International, Inc., Logan, UT 84321). An unpainted printed-circuit board (Wong Laboratories, Cincinnati, OH) was used to detect leaf wetness. This sensor was found to estimate the onset and cessation of leaf wetness episodes to within 30 min.

1984 experiment. The 1984 experiment was conducted in cooperation with Cornell University's Integrated Pest Management Program. Experimental plots measured 8.5 × 250 m, with one plot per treatment in each of two contiguous fields. Treatments within fields were randomized so that individual fields were regarded as blocks in a randomized complete block design. Onions were sown 27 April, 1984 (cv. Spartan Banner).

To determine lesion levels, 50 plants were sampled at random from within CDL plots and lesions typical of *B. squamosa* were counted on the three oldest leaves (≥80% green). The initial fungicide application was made to the CDL plots when the lesion level reached 1.0 lesion/leaf. The CDL system as originally formulated (5) calls for subsequent applications to be made on a weekly basis. In 1984, subsequent sprays were made in CDL plots when lesion counts exceeded 3.0 lesions/leaf rather than on a regular basis. Consequently, a modification of the original CDL system was being tested.

Leaf wetness data, necessary for implementing BOTCAST, were unavailable for the 1984 experiment. Therefore, duration of leaf wetness episodes was estimated using hygrothermograph data. For the period from crop emergence (9 May) until placement of the weather equipment in the field (6 June), leaf wetness episodes were estimated from hygrothermograph data collected at the Orange County Vegetable Improvement Cooperative Research Laboratory (near the experimental area). From 6 June onward, leaf wetness episodes were estimated from hygrothermograph data collected in the weather shelter in the field. Leaves were considered to be wet if the relative humidity (RH) equalled or exceeded 90%. Subsequent data confirmed a close association between wetness on onion leaves and RH ≥90%.

The initial fungicide application was made when 35 CDSI units were estimated to have accumulated, using the 1984 version of BOTCAST (6). Subsequent applications were made according to the grower schedule. The BOTCAST system calls for subsequent applications to be made on a regular basis (6,7). Since fungicide applications following the grower schedule were made at 3–10 day intervals, a strictly regular schedule was not followed.

In addition to the above treatments, a third treatment was examined in 1984 in which fungicide applications were made only when there was a forecast for sporulation by *B. squamosa* using the sporulation index predictive system (2). This predictive system was programmed into an Epson HX-20 microcomputer, and hygrothermograph data were used to generate a daily sporulation index (2). Sprays were applied when the sporulation index equalled or exceeded 50, if at least 5 days had elapsed since the last application.

Yields of the field plots were assessed by harvesting the bulbs from six 1.0-m sections of row that were randomly selected from among the two onion rows not adjacent to tractor wheel rows. Treatment means were compared using Fisher's least significant difference (LSD) test if an analysis of variance indicated a significant ($P < 0.10$) treatment effect (4).

1985 and 1986 experiments. Experiments in 1985 and 1986 were designed to compare the CDL and BOTCAST as methods of timing the initiation of a fungicide spray program. Further work with the sporulation index system was not conducted because it failed to forecast 44% of the spore episodes recorded in a commercial onion field in New York (9). Experimental plots measured 8.5 × 82 m (1985) or 8.5 × 65 m (1986) and were arranged as a randomized complete block design with three replicates per treatment. Cultivars used were Sentinel, planted 4 April 1985, and ALR44 (an early homegrown variety), planted 3 April 1986.

The first fungicide application in the CDL treatment was made when the disease level reached 1.0 lesion/leaf. Lesion counts were made by randomly sampling 10 plants per plot and counting lesions typical of *B. squamosa* on the three oldest leaves (≥80% green). The first application in BOTCAST plots was applied when 25 CDSI units had accumulated and rain was indicated in the weather forecast. CDSI units were determined using the 1985 version of BOTCAST (7,8). For the period 3–16 May 1986, leaf wetness data were unavailable due to malfunctioning of the Datapod unit. For this 14-day period, durations of leaf wetness episodes were estimated using the following regression equation ($R^2 = 0.933$) developed from data for 1985: $HRLW = 1.12\ HIRH - 0.55$, where HRLW = no. hr leaf wetness and HIRH = no. hr in which RH ≥90%. In both the BOTCAST and the CDL treatments, once a fungicide program was initiated, all remaining fungicide applications in that treatment were made according to the grower schedule.

To assess treatment effects, lesions were counted on the three oldest leaves (≥60% green) on 20 randomly selected plants per plot at 2–4 wk before harvest. Yields were measured and data were analyzed as indicated previously.

RESULTS

1984 experiment. Eight fungicide applications were made in the grower schedule, beginning 30 June (Table 1). Thirty-five CDSI units were estimated to have accumulated by 30 June, so BOTCAST plots received a total of eight sprays beginning 30 June and following the grower schedule thereafter. Seven sprays were made in the sporulation index treatment, beginning 2 July. In the modified CDL treatment, the 1.0 lesion/leaf action threshold was not reached in this field until 10 July, thus delaying the first fungicide application by 10 days. The lesion count in the modified CDL plots exceeded 3.0 lesions/leaf on two occasions in 1984, resulting in a total of three fungicide applications being made to these plots. Application dates and the fungicides used in all four treatments are listed in Table 2.

There was no significant treatment effect on yield in this experiment, indicating that mean yields for these treatments did not differ significantly in 1984 (Table 1). No visual differences between plots in disease severity or plant size were noted.

1985 experiment. Nine applications were made in the grower schedule beginning 9 June (Table 3). The BOTCAST protocol indicated that 25 CDSI units had accumulated by 6 June. The first application in the BOTCAST plots was applied on 9 June and subsequent applications followed the grower schedule, resulting in a total of nine applications being made for this treatment. The 1.0 lesion/leaf level was not reached in this field until 1 July, resulting in a delay of the first fungicide application by 23 days. Since subsequent sprays in the CDL treatment were applied following the grower schedule, a total of six fungicide applications were made to the CDL plots. Application dates and fungicides used in all treatments are listed in Table 4.

Lesion levels were slightly, but significantly ($P < 0.05$), higher in the CDL plots than in the BOTCAST or grower-schedule plots, although the three treatments did not differ significantly in yield (Table 3). No visual differences between plots were noted in either disease severity or in plant size.

1986 experiment. Seven applications were made following the grower schedule, beginning 10 June (Table 5). Twenty-five CDSI units were accumulated by 9 June, so BOTCAST plots also received a total of seven applications beginning 10 June and followed the grower schedule thereafter. The 1.0 lesion/leaf level was reached on 16 June. Subsequent sprays in the CDL treatment were applied following the grower schedule, so that CDL plots received a total of six applications beginning 19 June. Application dates and fungicides used in all treatments are given in Table 6.

No differences between treatments in disease control or in yield were detected (Table 5). Likewise, no visual difference between plots were noted in either disease severity or plant size.

Table 1. Comparison of the modified critical disease level,[a] BOTCAST,[b] and sporulation index[c] predictive systems for timing fungicide applications for control of Botrytis leaf blight of onion in 1984

Spray schedule	Date of first application	Total no. of applications	Yield (kg/m of row)[d]
Grower	30 June	8	10.6
BOTCAST	30 June	8	10.2
Sporulation index	2 July	7	10.6
Critical disease level	10 July	3	10.9

[a] First fungicide application made when lesion count ≥ 1.0 lesion/leaf. Subsequent applications made when lesion count ≥ 3.0 lesion/leaf.

[b] First fungicide application made when cumulative disease severity index units ≥35. Subsequent applications made according to grower schedule.

[c] All fungicide applications made when sporulation index ≥50, given at least 5 days since previous application.

[d] No significant treatment effect was detected in an analysis of variance ($P > 0.10$).

Table 2. Application dates and fungicides used in comparison of three predictive systems for control of Botrytis leaf blight of onion in 1984

Date	Plots treated[a]	Fungicides used (per ha)
30 June	G, B	1.5 kg chlorothalonil + 0.9 kg mancozeb
2 July	S	1.5 kg chlorothalonil + 0.9 kg mancozeb
8 July	G, B	1.5 kg chlorothalonil + 0.6 kg mancozeb
10 July	C, S	1.5 kg chlorothalonil + 0.9 kg mancozeb
19 July	G, B	1.2 kg chlorothalonil + 0.9 kg mancozeb
20 July	S	1.2 kg chlorothalonil + 0.9 kg mancozeb
25 July	G, B	1.2 kg chlorothalonil + 0.9 kg mancozeb
26 July	S	1.2 kg chlorothalonil + 0.6 kg maneb + 0.3 kg iprodione
30 July	G, B	1.2 kg chlorothalonil + 0.6 kg maneb
1 August	S	1.2 kg chlorothalonil + 0.6 kg maneb
3 August	C	1.7 kg chlorothalonil + 1.4 kg mancozeb
6 August	G, B, S	1.2 kg chlorothalonil + 0.6 kg maneb
11 August	G, B	1.2 kg chlorothalonil + 0.6 kg maneb
14 August	S	1.2 kg chlorothalonil + 1.2 kg maneb
15 August	G, B	1.2 kg chlorothalonil + 1.2 kg maneb
16 August	C	1.2 kg chlorothalonil + 1.2 kg maneb

[a] G = Grower schedule, B = BOTCAST, S = sporulation index, and C = modified critical disease level.

Table 3. Comparison of the critical disease level[a] and BOTCAST[b] predictive systems for timing the initial fungicide application for control of Botrytis leaf blight of onion in 1985

Spray schedule	Date of first application	Total no. of applications	Mean no. of lesions/leaf	Yield[c] (kg/m of row)
Grower	9 June	9	2.5 a[d]	14.0
BOTCAST	9 June	9	2.6 a	13.3
Critical disease level	2 July	6	3.4 b	13.5

[a] First fungicide application made when lesion count ≥1.0 lesion/leaf. Subsequent applications made according to grower schedule.

[b] First fungicide application made when cumulative disease severity index units ≥25. Subsequent applications made according to grower schedule.

[c] No significant treatment effect was detected in an analysis of variance ($P > 0.10$).

[d] Means followed by the same letter are not significantly different according to a protected LSD test ($\alpha = 0.05$).

DISCUSSION

In all three years in which these experiments were conducted, the CDL of 1.0 lesion/leaf was not reached until 1–3 wk after the grower-cooperator began his fungicide program. Consequently, savings of 1–3 fungicide applications were achieved in the CDL treatment with minimal effect on disease development and no effect on yield. Although a slightly higher disease level was noted in the CDL treatment in 1985 as compared with the grower schedule or the BOTCAST treatment, this difference of 0.8 lesions/leaf was minor and had no detectable impact on yield.

In all 3 years of this study, BOTCAST called for the first application 1–3 wk before the CDL was reached. Since yields of these treatments did not differ significantly, this may indicate that the BOTCAST predictive system as it is currently formulated (7,8) calls for the initial application too early for growing conditions in Orange County, NY, where the present research was conducted. While this may be the case, further evaluation of BOTCAST in fields throughout the state may be appropriate. A threshold of 25 CDSI units was taken to represent a call for the initiation of a fungicide program before the next significant rainfall, as indicated in the description of BOTCAST (6–8), although a higher threshold may be more appropriate for Orange County and elsewhere in New York. BOTCAST is sufficiently flexible that different thresholds could easily be evaluated.

Table 4. Application dates and fungicides used in comparison of the critical disease level system and BOTCAST for control of Botrytis leaf blight of onion in 1985

Date	Plots treated[a]	Fungicides used (per ha)
9 June	G, B	1.2 kg chlorothalonil + 1.1 kg maneb
17 June	G, B	1.2 kg chlorothalonil + 1.1 kg maneb
25 June	G, B	1.2 kg chlorothalonil + 1.1 kg maneb
2 July	G, B, C	1.2 kg chlorothalonil + 1.1 kg maneb
7 July	G, B, C	1.2 kg chlorothalonil + 1.1 kg maneb
10 July	G, B, C	1.2 kg chlorothalonil + 1.1 kg maneb
17 July	G, B, C	1.2 kg chlorothalonil + 1.1 kg maneb
24 July	G, B, C	1.2 kg chlorothalonil + 1.1 kg maneb
30 July	G, B, C	1.2 kg chlorothalonil + 1.1 kg maneb

[a] G = Grower schedule, B = BOTCAST, and C = critical disease level.

Table 5. Comparison of the critical disease level[a] and BOTCAST[b] predictive systems for timing the initial fungicide application for control of Botrytis leaf blight of onion in 1986

Spray schedule	Date of first application	Total no. of applications	Mean no. of lesions/leaf[c]	Yield[c] (kg/m of row)
Grower	10 June	7	1.6	18.2
BOTCAST	10 June	7	1.8	16.3
Critical disease level	19 June	6	1.7	18.0

[a] First fungicide application made when lesion count $\geqslant$1.0 lesion/leaf. Subsequent applications made according to grower schedule.
[b] First fungicide application made when cumulative disease severity index units $\geqslant$25. Subsequent applications made according to grower schedule.
[c] No significant treatment effect was detected in an analysis of variance ($P > 0.10$).

Table 6. Application dates and fungicides used in comparison of the critical disease level system and BOTCAST for control of Botrytis leaf blight of onion in 1986

Date	Plots treated[a]	Fungicides used (per ha)
10 June	G, B	1.2 kg chlorothalonil + 1.1 kg maneb
19 June	G, B, C	1.2 kg chlorothalonil + 1.1 kg maneb
22 June	G, B, C	1.2 kg chlorothalonil + 1.1 kg maneb + 0.1 kg iprodione
30 June	G, B, C	1.1 kg maneb + 0.3 kg iprodione
7 July	G, B, C	1.2 kg chlorothalonil + 1.1 kg maneb
15 July	G, B, C	1.1 kg maneb + 0.6 kg iprodione
22 July	G, B, C	0.6 kg maneb

[a] G = Grower schedule, B = BOTCAST, and C = critical disease level.

Lesion counts in the field provide a sound empirical measure of relative amounts of inoculum production and infection that have occurred before sampling. Because they are made in individual fields or small groups of contiguous fields (scouting blocks), lesion counts can be expected to reflect local differences in climate and weather, amounts of primary inoculum, etc. However, without considerable training, lesions of *B. squamosa* can be difficult to distinguish from leaf spots resulting from other foliar pathogens, windblown rain or dust, herbicide damage, and other causes. Furthermore, if injury from herbicides, rain, dust, or hail is severe, counting lesions of *B. squamosa* can be impossible. BOTCAST is a flexible and logically constructed predictive system that has the advantage of not relying on scout training or visibility of lesions on leaf surfaces. However, BOTCAST assumes that amounts of primary inoculum are constant from field to field (8), and as such, it is not sensitive to differences between fields or farms in amounts of, or proximity to, sources of primary inoculum. Since the two predictive systems seem somewhat complementary, the best approach for the future may be to implement them concurrently or to combine them into a single predictive system for timing the initial fungicide application for controlling Botrytis leaf blight of onion.

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