Selection of Components for a Potato Late Blight Forecasting and Fungicidal Control Program

F. W. NUTTER, Jr., Former Graduate Assistant, and W. E. MacHARDY, Associate Professor of Plant Pathology, Department of Botany and Plant Pathology, University of New Hampshire, Durham 03824

ABSTRACT

NUTTER, F. W., Jr., and W. E. MacHARDY. 1980. Selection of components for a potato late blight forecasting and fungicidal control program. Plant Disease 64:1103-1105.

A forecasting system based on BLITECAST was simplified for incorporation into a pest management program for New Hampshire potato growers. In an interactive computer program, field data and 6 yr of weather records from the National Oceanic and Atmospheric Administration were used to identify BLITECAST components not contributing to forecasting accuracy. As a result, severity values were eliminated from the BLITECAST criteria that recommended the first fungicide application, and criteria eliminated from the BLITECAST matrix that recommended subsequent fungicide sprays were: maximum daily temperature $\geq$ 86 F (30 C), 5-day mean temperature $\geq$ 78 F (26 C), and minimum daily temperature $\leq$ 45 F (7 C) that "nulls" a blight-favorable day.

Additional key words: pest management, *Phytophthora infestans*

Climates conducive for potato (*Solanum tuberosum* L.) production generally favor potato late blight development, and several potato late blight forecasting systems have been developed to accommodate the many different potato-growing regions (3,5,7). These systems differ in the environmental variables required for forecasting and the delivery program, eg, the way the system is coupled to fungicide scheduling. A forecasting and delivery program designed for one region may not be successful in other regions because of differences in climate, economic constraints, and grower attitudes. When a forecasting program was considered desirable for New Hampshire, where farms are few and the potato acreage is small, existing forecasting systems were evaluated to develop a delivery program acceptable to potato growers.

Preliminary field evaluations of several late blight forecasting systems indicated that BLITECAST (4) would best predict potato late blight in New Hampshire (8), but this computerized approach is not feasible economically or logistically in New Hampshire. Moreover, growers are skeptical of using remote determinations to schedule fungicide applications, and grower acceptance of the delivery program (computer, calculator, microprocessor, extension agent, etc.) is every bit as important as the precision and reliability of the forecasting system.

BLITECAST is a conservative forecasting system in that it is a union of the Hyre (2) and Wallin (9) systems without removal of extraneous components. Our approach was to use field data and weather records with an interactive computer program to determine if any criteria could be omitted from BLITECAST without adversely affecting the accuracy of the forecast (thereby simplifying the program). Our methods to accomplish this in a relatively short time may be useful to others intent on applying fungicide sprays more efficiently to control a fungal disease.

Present address of senior author: Department of Plant Pathology, The Pennsylvania State University, University Park 16802.

Portion of a thesis submitted by the senior author in partial fulfillment of the requirements for the M.S. degree, University of New Hampshire, Durham.

Scientific Contribution 963 from the New Hampshire Agricultural Experiment Station.

Supported by Hatch Project No. 197.

0191-2917/80/12110303/$03.00/0

MATERIALS AND METHODS

Data from potato fields. The equipment and procedure for collecting environmental data daily were similar to those of BLITECAST (4). Data collection was initiated at green row, the earliest date that distinct green rows were seen, and was terminated at vine kill. A Kramer-Collins 24-hr spore sample (GR Manufacturing Co., Manhattan, KS 66506) was used in 1977 at the Kingman Research Farm in Madbury, NH, to verify and monitor the presence of the late blight fungus. The spore sampler operated for 3-min twice each hour. Slides coated with silicone grease were replaced each day at approximately 8 a.m. and examined for sporangia of *Phytophthora infestans* (Mont.) deBary.

In 1976, weather data were collected from the potato fields of five commercial growers and at the Kingman Research Farm. The five commercial fields were selected to represent the major potato-growing areas of the state. In 1977, weather data were collected at three commercial fields in addition to the Kingman Farm. Data from these locations provided weather information for evaluating the usefulness of the BLITECAST components. The commercial fields were not sprayed according to a forecasting system in 1976 or 1977.

Disease occurrence in unsprayed plots of the potato cultivar Green Mountain at the Kingman Farm was used to evaluate the accuracy of the Hyre (2) and Wallin (9) systems for predicting the initial outbreak of blight. BLITECAST recommended the first fungicide application when either the Hyre or Wallin system first predicted blight outbreak. We wanted to evaluate each system to determine if only one system, rather than both, could be used to time the initial spray.

Weather data. Records of daily rainfall and maximum and minimum daily temperatures were obtained from the National Oceanic and Atmospheric Administration (NOAA), Environmental Data Service, Ashville, NC, for six locations in New Hampshire for 1972 through 1977. Lancaster, Hanover, Concord, Durham, Keene, and Nashua

were chosen because they represented the major potato-growing areas in the state.

Daily maximum and minimum temperatures (F) and rainfall (mm) from 1 May through 30 September for each year and location were entered and stored on a DEC-10 system computer. These data were used in conjunction with a computer model of Hyre's temperature-rainfall system (2) to predict the initial occurrence of late blight and to generate the date of the initial spray recommendation. Hyre's system does not require that temperature and rainfall be recorded within the plant canopy; thus NOAA data can be used to evaluate components of this system. The NOAA weather records were also used with a computer program to evaluate the usefulness of each BLITECAST component in New Hampshire.

Evaluation of BLITECAST forecasting components. An interactive computer program patterned after BLITECAST (4) was written to evaluate the following BLITECAST components: minimum temperature that defines a "null" day, maximum temperature that will cancel the previous day's severity value, Hyre's and Wallin's systems for timing the first fungicide application, and the 5-day mean temperature value. Field data and weather records were entered in the computer, each component was altered or omitted, and the resultant spray schedule generated by the computer program was compared to the spray schedule generated by the unaltered BLITECAST program and the fungicide schedule recommended to commercial growers (1). The computer program was designed to identify components that could be eliminated from BLITECAST without changing its message.

RESULTS

Timing initial fungicide application. Late blight lesions were first noted in unsprayed plots at the Kingman Research Farm on 19 August 1976. Hyre's system accurately predicted the initial outbreak of blight, and a BLITECAST spray schedule initiated by Hyre's system would have omitted seven fungicide sprays that would have been applied before 19 August according to the calendar schedule recommended to growers (Table 1). Wallin's system (severity values) indicated that the initial fungicide application be applied on 29 June, 5 wk earlier than Hyre's system. Because BLITECAST recommends an initial spray when either Hyre's or Wallin's criteria are satisfied, a grower using the intact BLITECAST program would initiate fungicide applications on 29 June.

Late blight did not appear in unsprayed plots at the Kingman Research Farm in 1977. Hyre's system did not issue a forecast to initiate sprays for late blight that year, but Wallin's system indicated that sprays were required beginning 14 July. Thus, the seven sprays recommended by the BLITECAST matrix that followed the first spray recommended by Wallin's system and the 11 sprays recommended by the growers' schedule were unnecessary (Table 1). Sporangia of *P. infestans* were trapped at the Kingman Research Farm on 13 days during the 1977 growing season, indicating that lack of initial inoculum did not hinder blight development: apparently environmental conditions were unfavorable for infection and blight development when sporangia were trapped.

In most years the initial fungicide application was later by Hyre's system than by the current growers' schedule. According to the NOAA weather data, Hyre's system would have delayed the first fungicide application in 31 of 36 forecasting seasons (each location each year is considered a separate growing season). Field data indicated a delay in the initial fungicide application in eight of 10 forecasting seasons. Hyre's system recommended a mean of four less early-season sprays in 1976 and 1977 than the schedule recommended to growers and two less sprays than recommended by Wallin's system.

Timing subsequent fungicide applications. BLITECAST uses a matrix to schedule sprays after the initial warning by Hyre's or Wallin's system (4). A computer program was used to determine if inclusion of each component of the matrix was necessary in New Hampshire.

Mean temperature. By the 5-day mean temperature criterion, a day is considered unfavorable to blight when the 5-day mean temperature is ≥ 78 F (26 C). The NOAA data indicated that 41 days had a 5-day mean temperature ≥ 78 F (26 C) for all six locations during the 1972 through 1977 growing seasons; of these 41 days, 22 would have been unfavorable to blight because the 10-day cumulative rainfall was less than 1.21 in. (30.73 cm). Thus, this criterion could have affected the forecasting system only 19 days during 36 forecasting seasons. According to field data, elimination of the 5-day mean temperature criterion affected the initial forecast issued by Hyre's system in two of 10 forecasting seasons but did not alter any of the subsequent spray messages generated by the matrix. Thus, this criterion has been removed from the BLITECAST matrix that times subsequent sprays, but it remains a component of Hyre's system.

Maximum daily temperature. By this criterion, a maximum temperature of ≥ 86 F (30 C) cancels the severity value of the previous day. The NOAA weather data showed that this criterion was involved an average of only 13 to 16 days after the first spray recommended by Hyre's system. One exception was Lancaster, which averaged only 6 days per season when this criterion was met after the initial spray recommendation.

Only five of 75 spray messages issued from the 1976 and 1977 field data were changed when this criterion was omitted, and each change resulted in a more conservative spray schedule; eg, two messages were changed from a warning to a 7-day schedule, two were changed from a 7-day to a 5-day schedule, and one was changed from no spray to a 7-day schedule. Thus, this criterion was rarely met through the 6- yr examined against the NOAA weather data. In the few instances when it was met,the field data suggest that its removal from the BLITECAST matrix would result in increased fungicidal protection. For these reasons, this criterion is not considered necessary for forecasting late blight in New Hampshire.

Cumulative 10-day rainfall. This criterion was effective in forecasting the initial outbreak of potato late blight at the Kingman Research Farm in 1976 and 1977 when the rainfall value was set at ≥ 1.21 in. (30.73 cm). Altering this component in the computer program led to inaccurate timing of the initial and subsequent fungicide applications.

Minimum temperature. The null day criterion states that a day is unfavorable for blight development if the minimum daily temperature falls below 45 F (7 C). A null day does not however interrupt the

Table 1. Comparison of Hyre's or Wallin's forecasting systems for predicting the initial outbreak of potato late blight

Forecasting system	Initial outbreak of potato late blight predicted accurately		Unnecessary sprays recommended[a] before first appearance of late blight[b]		Total fungicide applications recommended	
	1976	1977	1976	1977	1976	1977
Hyre/BLITECAST[c]	yes	yes	0	0	5	0
Wallin/BLITECAST[d]	no	no	4	7	9	7
None[e]	...	...	7	11	13	11

[a] By forecasting system or grower's schedule.
[b] No late blight was observed in 1977.
[c] Hyre's system determined the date of the first fungicide application; a BLITECAST matrix determined dates of later sprays.
[d] Wallin's system determined the date of the first fungicide application; a BLITECAST matrix determined dates of later sprays.
[e] Sprays were applied according to the schedule recommended to commercial potato growers (1).

sequence of consecutive blight-favorable days: the day is simply omitted.

According to NOAA weather data, the null day criterion would have delayed the initial fungicide application 3 of 6 yr in Durham, 2 of 6 in Lancaster, and 1 of 6 in Concord, Keene, Hanover, and Nashua. The field data indicated that the null day criterion delayed the date of the first fungicide application in two of 10 forecasting seasons in 1976 and 1977. With both the field data and the NOAA weather data, this criterion omitted a mean of only 2 blight-favorable days per location per season after the initial spray recommendation date. Only one spray message of 75 was altered when the null day criterion was omitted from the BLITECAST computer program, and the change was conservative; eg, the spray message changed from a 7-day to a 5-day schedule. Thus, the null day criterion should be used when recommending the first spray application but should not be used in recommending subsequent applications.

DISCUSSION

Hyre's system to predict the first fungicide application and a modified BLITECAST matrix to time subsequent sprays is a combination that appears to be well-suited for controlling potato late blight in New Hampshire. Other researchers have also found Hyre's system to be more reliable than Wallin's for timing the first spray application in the northeastern United States (3).

The delivery portion of our forecasting program, designated BLIGHT FORECAST, is grower-centered; eg, the grower is solely responsible for the final decision-making (6). It is important to eliminate any unnecessary criteria that would only complicate the program if the grower, rather than a computer, is to analyze the environmental data to deliver the forecasting spray schedule. Thus, each component of BLITECAST was computer-analyzed using field and NOAA weather data to identify components not contributing to the forecasting system for New Hampshire.

As a result, the following criteria have been eliminated from the BLITECAST matrix that recommends subsequent sprays: a minimum daily temperature $\leq$ 45 F (7 C), a 5-day average temperature $\geq$ 78 F (26 C) is blight-unfavorable day, and a maximum daily temperature $\leq$ 86 F (30 C) cancels the previous day's severity value. These criteria were seldom realized, and when one was met, it rarely altered the spray recommendation. Thus, their removal simplifies decision-making without loss of reliability.

Grower-centered forecasting programs have seldom been fully used in the past, because the decision-making procedures were slow, complex, and imprecise. Calculations and mathematical tables have been minimized in BLIGHT FORECAST to make the program acceptable to growers (6). The procedure for reaching a decision to spray requires only 2–3 min of nonmathematical interpretation of weather data by a potato grower.

BLIGHT FORECAST was tested in four commercial potato fields in 1978 and 1979. Potato late blight outbreaks were prevented in potato fields receiving fungicide applications timed according to BLIGHT FORECAST or the grower's regular spray schedule, although the fields included in the BLIGHT FORECAST program received less fungicide (*unpublished data*). Potato late blight was reported in the areas of the state where the tests were conducted.

In summary, the forecasting portion of BLIGHT FORECAST was selected after only 2 yr of field research, because weather data from NOAA and an interactive computer program provided an additional 6 yr of pertinent weather information for analysis from several locations in the state. The delivery portion of BLIGHT FORECAST circumvents the economic and logistic problems of implementing a computer-based potato late blight control program, and our experience suggests that New Hampshire potato growers will use a program if they are involved in the decision-making and the program is tailored to accommodate their needs and attitudes.

ACKNOWLEDGMENTS

We are grateful to Gerard Pregent, state climatologist, Geography Department, University of New Hampshire, and to Henry Van Cotter, Department of Botany and Plant Pathology, for technical assistance with the computer programming.

LITERATURE CITED

1. BOWMAN, J. S., and W. E. MacHARDY. 1976. Insect and Disease Control Guide for Commercial Vegetable Growers. Ext. Bull. 177. Coop. Ext. Serv. Univ. of New Hampshire, Durham. 30 pp.
2. HYRE, R. A. 1954. Progress in forecasting late blight of potato and tomato. Plant Dis. Rep. 38:245-253.
3. KRAUSE, R. A., and L. B. MASSIE. 1975. Predictive systems: Modern approaches to disease control. Annu. Rev. Phytopathol. 13:31-47.
4. KRAUSE, R. A., L. B. MASSIE, and R. A. HYRE. 1975. BLITECAST: A computerized forecast of potato late blight. Plant Dis. Rep. 63:21-25.
5. LARGE, E. C. 1955. Methods of plant disease measurement and forecasting in Great Britain. Ann. Appl. Biol. 42:344-354.
6. MacHARDY, W. E. 1979. A simplified, non-computerized program for forecasting potato late blight. Plant Dis. Rep. 63:21-25.
7. MILLER, P. R., and M. J. O'BRIEN. 1957. Prediction of plant disease epidemics. Annu. Rev. Microbiol. 11:77-110.
8. NUTTER, F. W. 1978. A forecasting program for chemical control of late blight and early blight of potato in New Hampshire. M.S. thesis, Univ. of New Hampshire, Durham. 129 pp.
9. WALLIN, J. R. 1967. Ground level climate in relation to forecasting plant diseases. Pages 149-163 in: Ground Level Climatology. Am. Assoc. Adv. Sci. Washington, DC. 395 pp.