Field Testing a Computerized Forecasting System for Rice Blast Disease

Choong-Hoe Kim, D. R. MacKenzie, and M. C. Rush

Graduate assistant and professors, Department of Plant Pathology and Crop Physiology, Louisiana Agricultural Experiment Station, Agricultural Center, Louisiana State University, Baton Rouge 70803.

Portion of a thesis submitted by the first author in partial fulfillment of the requirements for the Ph.D. degree at Louisiana State University, Baton Rouge.

Supported in part by a grant from the College of Agriculture, Louisiana State University, and by the Louisiana Rice Research Board.

Accepted for publication 3 February 1988.

ABSTRACT

Kim, C. H., MacKenzie, D. R., and Rush, M. C. 1988. Field testing a computerized forecasting system for rice blast disease. Phytopathology 78:931-934.

A computer program written to predict blast occurrence based on microclimatic events was tested as an on-site microcomputer in upland and flooded field plots in 1984 and 1985. Two battery-operated microcomputer units continuously monitored air temperature, leaf wetness, and relative humidity and interpreted the microclimate information in relation to rice blast development by calculating daily values (0 to 8) of blast units of severity (BUS). Accumulated daily BUS values were highly correlated with blast development on the two rice cultivars Brazos and M-201 grown under upland conditions. Use of cumulative BUS values to predict the logit of disease proportions gave average coefficients of determination (R^2) of 71 to 91%, depending on cultivar and year, compared to 61 to 79% when days were used as a predictor of logit disease severity. BUS predicted logit disease severity less accurately with Brazos, which showed field resistance at mid-season, than with M-201. Cumulative BUS values in flooded plots were higher than those in the upland plots. No significant correlation was observed between cumulative BUS values and logit disease under flooded conditions because both cultivars were resistant to blast when flooded.

The rice blast disease caused by *Pyricularia oryzae* Cav. is a major constraint on rice production (17). The fungus produces lesions on leaves of rice plants throughout the growing season and attacks the panicle of maturing plants. The management of this disease depends upon the ability to anticipate epidemic outbreaks and schedule appropriate actions for disease control.

The association of specific weather conditions with blast incidence has long been recognized (13), and systems to forecast rice blast disease have been reviewed (10,16). The earlier systems of blast forecasting were based on determining when weather conditions were favorable for disease development. Simple or multiple regression equations often have been generated to relate weather factors for the prediction of blast development (16). Some prediction systems have been based entirely on the number of spores in the air or nutritional content in leaf tissues (4,12). These methods, however, are not available on a timely, regular, and localized basis for use.

Recently a computerized system for rice blast forecasting was jointly developed by the International Rice Research Institute (IRRI) in Los Banos, Philippines, the International Center for Tropical Agriculture in Cali, Colombia, the Rural Development Administration in Suweon, Korea, and The Pennsylvania State University in the United States. The system was designed to predict the initial occurrence and subsequent increase of rice blast disease with an on-site microcomputer by evaluating microclimates.

This research was conducted to test the accuracy of the computerized forecasting system using two commercial rice production methods: flooded and upland conditions. Preliminary reports on portions of this research have been published elsewhere (6–9).

MATERIALS AND METHODS

Forecasting system. The rice blast forecasting system is based on an empirical model to determine periods when microenvironmental conditions were favorable for disease development. The model was derived and synthesized from previous research (3,5,10,16) and uses a combination of mean air temperature, the hours of leaf wetness, and hours of relative humidity above 90% to derive daily rating values of blast units of severity (BUS). As shown in the algorithm for BUS in Table 1, mean temperature outside a range of 15 to 38 C is considered to be unlikely weather for blast occurrence and is assigned a BUS value of 0, regardless of other factors. Within this temperature range, more than 9 hr duration of leaf wetness is required to obtain any BUS; thereafter, the value of BUS increases as leaf wetness hours increase. Temperatures between 19 and 29 C, particularly in the range 23–26 C, and greater than 16 hr of relative humidity above 90% are considered to be highly favorable conditions for blast development. According to this model, the most favorable condition for blast development (BUS value = 8) is a mean temperature between 23 and 26 C, 24 hr of leaf wetness, and 24 hr of high relative humidity.

The model was expressed as a computer algorithm for rapid and accurate data analyses. The algorithm was incorporated into an on-site, water-tight, battery-operated microcomputer (model BC-560, Omnidata International, Inc., Logan, UT). Microcomputer instrumentation included a leaf wetness sensor, a temperature sensor, and a lithium chloride relative humidity sensor. When positioned in the rice field, the microcomputer sampled its sensors eight times per hour and updated the following daily variables: hours of leaf wetness; hours of relative humidity above 90%; average temperature (based on maximum and minimum temperature measurements); and BUS values. The microcomputer continuously displayed the cumulative BUS values for the season.

Cultural conditions. Two rice cultivars, M-201, susceptible to blast, and Brazos, partially resistant to blast, were used in the study. The experiments were carried out at the Rice Research Station, Crowley, LA, during the 1984 and 1985 growing seasons. Seeds were drill planted in Crowley silt loam soil with 18-cm row spacing at 112 kg seed/ha on 11 May 1984, and 6 May, 1985. Fertilizer was applied at planting at a rate of 672 kg/ha of 20-10-10 (N-P_2O_5-K_2O). The herbicide propanil was applied at the recommended rate (3.7 kg active ingredient/ha) before the permanent flood.

A split-plot design was employed with three replications. Two irrigation practices, flooded and unflooded, were used in the main plots and the two cultivars were assigned to subplots. Each subplot consisted of 28 rows 4.6 m long in 1984, and 18 rows 6.1 m long in 1985. The subplots were separated by a 0.9-m alley. Main plots were isolated from each other by earthen levees 1.5 m wide and levee ditches on each side with a total width of 3.1 m so that each main plot could be separately treated as flooded or unflooded to simulate commercial flooded or upland rice production. After planting, all plots were flushed periodically by opening or closing a water gate on a PVC pipe connected to each ditch to facilitate germination and growth of 5–15 cm until 10 days before maturity. The upland plots were flooded and drained (flushed) as necessary to maintain plant growth during prolonged dry periods (seven times in 1984 and six times in 1985). Irrigation treatments were begun at 33 days after planting in 1984 and and at 29 days after planting in 1985.

Monitoring the microclimate. Microclimate in flooded and upland plots was monitored by separate on-site microcomputer units, each placed in a wooden weather shelter. The shelters were located in adjacent subplots of the flooded and upland main plots and 25 to 30 cm above ground in the center of the experimental area. The microcomputers were installed at 17 and 24 days after planting in 1984 and 1985, respectively. Temperature, relative humidity, and leaf wetness sensors were calibrated according to recommendations in the operator's manual. Weather data and BUS values were recorded at 1- to 2-day intervals from the microcomputer.

Inoculation and disease assessment. A single M-201 plant, inoculated with isolate 74L2 of race IH-1 of *P. oryzae* and having four susceptible-type lesions (1), was transplanted into the center of each subplot at 8 days before initiation of irrigation in 1984 and at 6 days before initiation of irrigation in 1985.

In 1984, disease progress was examined at 3- to 4-day intervals during the first month and at 7- to 14-day intervals thereafter. In 1985, disease progress was recorded at 7-day intervals. During the early part of the epidemic, the number of susceptible-type lesions per tiller was counted based on 30 tillers randomly selected in each subplot. The number of lesions per tiller in the early examination period was converted into percentage of diseased leaf area per tiller by the method of Villareal et al (19). As disease progressed, the percentage of diseased leaf area per tiller was visually estimated using a scale of 0 (0%) to 10 (100%).

Data analysis. Cumulative BUS values were used as the independent variable to predict the logit of the proportion of disease severity (X) with linear regression. Time in days also was used to predict logit (X) (18). The slopes and coefficients of determination were used as criteria for determining the accuracy of the independent variables to predict the logits of disease severity.

RESULTS

Blast development. Disease progressed rapidly in upland plots but was greatly reduced in flooded plots regardless of cultivar in both seasons (Fig. 1). Final disease severity was greater on M-201 than on Brazos in upland plots (Fig. 1). In flooded plots, no appreciable disease was observed for either cultivar in 1984. In 1985, blast development on M-201 in flooded plots increased to 4.8% 21 days after inoculation and decreased thereafter.

BUS accumulations. In 1984, 98 and 108 BUS values were accumulated in upland and flooded plots, respectively, for the 57-day period following inoculation (Fig. 2). During the same time period in 1985, 53 and 120 values were recorded in upland and flooded plots, respectively. Daily BUS values ranged from 0 to 6, but were commonly from 1 to 2. The rate of BUS accumulation over time varied with year and irrigation practice and ranged from 1.0 to 2.2 per day. The rate was somewhat similar between upland and flooded plots in 1984, but cumulative BUS values were significantly higher in flooded plots in 1985.

TABLE 1. Algorithm of blast units of severity (BUS) values as a function of ambient air temperature, leaf-wetness period, and relative humidity[a]

I. If Tem. $<$ 15 C or Tem. $>$ 38 C, then BUS = 0.
II. If LW $<$ 9 hr, then BUS = 0.
III. If Tem. $>$ 14 C, then BUS = LW/4 hr.
IV. If RH $>$ 16 hr, then BUS = (III) + (RH − 12 hr)/6.
V. If Tem. $<$ 23 C or Tem. $>$ 26 C, then BUS = (IV) − 2.
VI. If Tem. $<$ 19 C or Tem. $>$ 29 C, then BUS = (V) − 2.
VII. If BUS $<$ 0, then set BUS = 0.

[a] Tem. = temperature (C); LW = hours of leaf wetness; RH = hours of relative humidity above 90%.

Relationships between BUS accumulation and blast development. Under upland conditions, both cumulative blast units of severity (CBUS) and days were correlated with logit (Table 2). Coefficients of determination for individual epidemics, when time in days was used as the independent variable, ranged from 0.678 to 0.795 for M-201 and from 0.610 to 0.680 for Brazos. The accuracy of estimates of logit in the model was appreciably improved, regardless of cultivar, when CBUS was used as the predictor of logit rather than days as indicated by the greater values for the coefficients of determination associated with the model using CBUS. The coefficients of determination for individual epidemics in this model ranged from 0.735 to 0.913 for M-201 and from 0.710 to 0.825 for Brazos. The coefficient of determination for CBUS in the logistic model improved from 1984 to 1985. The coefficients of determination were less with Brazos than with M-201. The coefficients of regression slopes obtained from the linear model using days were significantly correlated with the slopes of the regressions using CBUS ($r = 0.656$). Differences in unit change of logit per CBUS between the two seasons were in some cases considerable within a cultivar. Under flooded conditions, no relationship was found between logit and either CBUS or days with either cultivar (Table 3).

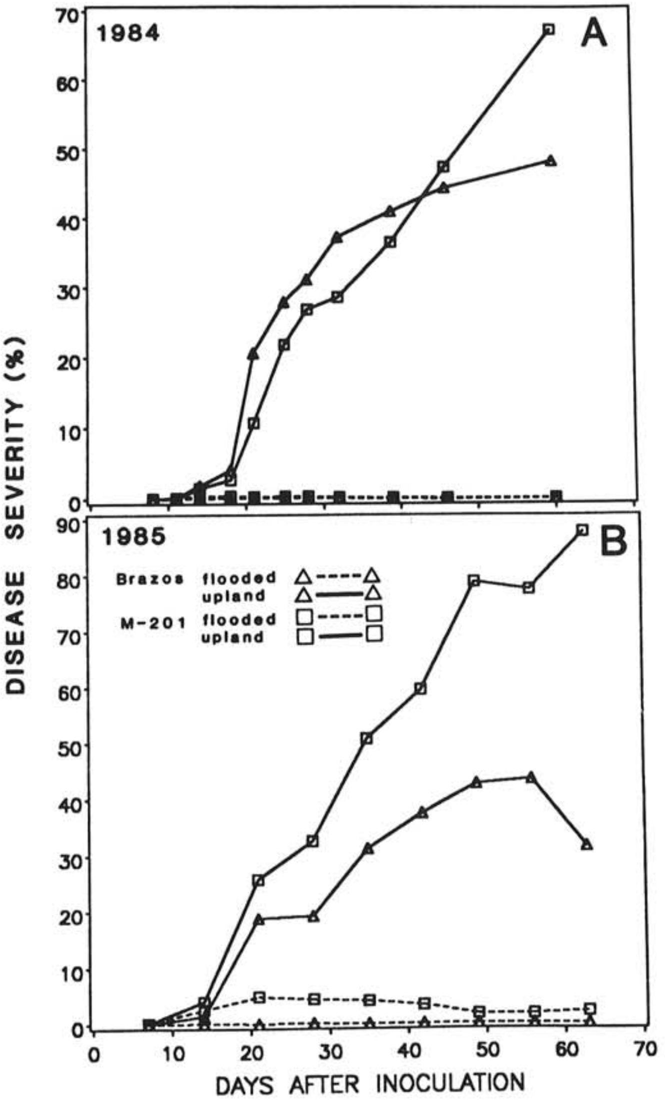

Fig. 1. Progress of rice blast disease on the rice cultivars M-201 and Brazos grown in flooded and upland (unflooded) field plots at Crowley, LA, in 1984 (**A**) and 1985 (**B**). A point source of inoculum of *Pyricularia oryzae* was introduced into each plot at the mid-tillering stage of plant development.

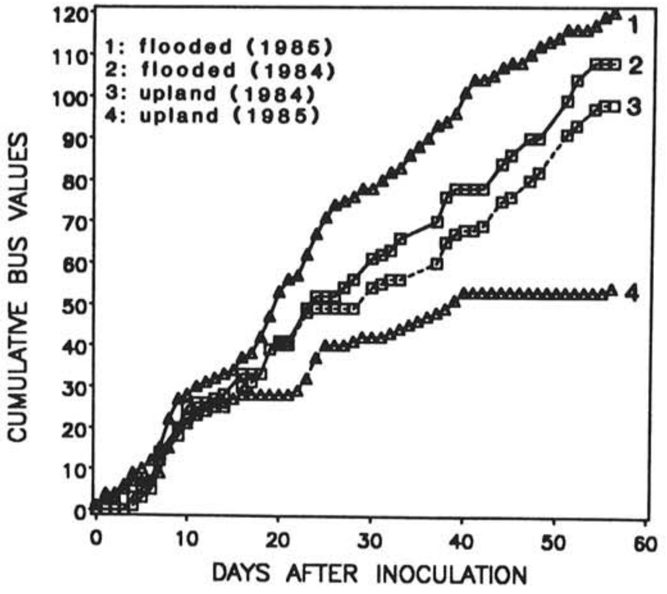

Fig. 2. Accumulation of daily blast units of severity (BUS) values in flooded and upland rice plots for the 57-day period following inoculation (June 21 to August 17 in 1984 and June 10 to August 6 in 1985) at Crowley, LA.

TABLE 2. Comparison of regression coefficients and model coefficients of determination between the logistic models using time in days and those using cumulative blast units of severity (CBUS) values as an independent variable for the development of epidemics in upland plots

			Logit (X)[b]		Slope[c]		R [2d]	
Cultivar	Year	Rep.[a]	Minimum	Maximum	Days	CBUS	Days	DBUS
M-201	1984	I	−9.43	0.90	0.164	0.106	0.693	0.735
		II	−9.90	0.21	0.162	0.105	0.705	0.746
		III	−8.22	1.13	0.156	0.101	0.747	0.788
	1985	I	−6.98	1.05	0.144	0.163	0.795	0.913
		II	−9.90	1.11	0.179	0.210	0.678	0.840
		III	−8.18	1.61	0.164	0.187	0.753	0.885
Brazos	1984	I	−7.07	0.40	0.134	0.087	0.680	0.721
		II	−6.61	0.34	0.124	0.081	0.678	0.720
		III	−9.03	−1.03	0.136	0.088	0.678	0.710
	1985	I	−6.78	−0.16	0.105	0.125	0.610	0.784
		II	−11.51	−0.08	0.192	0.224	0.671	0.825
		III	−9.72	−0.56	0.156	0.182	0.667	0.823

[a] Replicated plots.

[b] The value of ln [X/(1 − X)], where X is a disease severity proportion. Disease severity was examined 11 times in 1984 and 9 times in 1985.

[c] Regression coefficients obtained from the regressions ln [X/(1−X)] = days and ln [X/(1 − X)] = CBUS.

[d] Coefficients of determination from regressions (c). All models were statistically significant at $P = 0.05$.

DISCUSSION

Systems for disease forecasting based on weather indexing in relation to the likelihood of disease development have been developed with potato late blight and several other crop diseases (2,11,14,15). In those systems, daily severity values, obtained from the evaluation of some key environmental data, functioned as epidemiological units of time for scheduling fungicide applications. Other units of time are needed because all days are not equally favorable for disease development.

MacKenzie (14) proposed the use of severity values for standardization of epidemics that occur under variable weather conditions. Because epidemics may vary from year to year and from location to location, the use of severity value rather than days as an independent variable in calculating the apparent infection rate may provide a standardized predictor for epidemics.

TABLE 3. Comparison of regression coefficients and model coefficients of determination between the logistic models using time in days and those using cumulative blast units of severity (CBUS) values as an independent variable for the development of epidemics in flooded plots

			Logit (X)[b]		Slope[c]		R [2d]	
Cultivar	Year	Rep.[a]	Minimum	Maximum	Days	CBUS	Days	CBUS
M-201	1984	I	−9.11	−5.27	−0.002	−0.000	0.001	0.000
		II	−7.88	−5.48	−0.019	−0.010	0.084	0.080
		III	−10.13	−5.42	0.014	0.008	0.022	0.026
	1985	I	−8.68	−3.27	0.046	0.023	0.205	0.267
		II	−6.39	−2.47	0.026	0.015	0.128	0.213
		III	−9.43	−5.09	0.039	0.019	0.158	0.194
Brazos	1984	I	−8.95	−6.19	−0.013	−0.006	0.033	0.021
		II	−11.51	−6.23	−0.005	−0.002	0.002	0.002
		III	−9.11	−6.20	−0.025	−0.014	0.197	0.191
	1985	I	−10.82	−7.82	0.011	0.006	0.032	0.049
		II	−10.41	−8.25	−0.010	−0.003	0.031	0.018
		III	−10.41	−7.82	−0.005	−0.001	0.006	0.002

[a] Replicated plots.

[b] The value of ln [X/(1−X)], where X is a disease severity proportion. Disease severity was examined 11 times in 1984 and 9 times in 1985.

[c] Regression coefficients obtained from the regressions ln [X/(1−X)]=days and ln [X/(1−X)]=CBUS.

[d] Coefficients of determination from regressions (c). All models were statistically nonsignificant at $P = 0.05$.

In this study, the logistic model using BUS as a predictor of epidemics explained a relatively large portion of the statistical variability when plants were grown under upland conditions, but it did not explain variability under flooded conditions because plants apparently became resistant to blast under flooded conditions. Accumulated BUS values calculated from air temperature, leaf wetness period, and relative humidity were higher under flooded conditions in both seasons, suggesting that blast development should be favored by flooded conditions; however, little disease was observed in the flooded plots. This suggests that soil moisture may be an important environmental factor for predicting blast severity.

The inclusion of effects of soil moisture on development of the blast epidemic might improve the accuracy of the current model for upland conditions and enable the successful application of this forecasting system to flooded conditions. Once the effects of soil moisture on blast development are quantified, the microcomputer units could be retrofitted with soil moisture probes and the algorithm for BUS could be adjusted correspondingly.

LITERATURE CITED

1. Anonymous. 1965. The Rice Blast Disease. Proc. Symp. IRRI, July 1963. Johns Hopkins Press, Baltimore, MD. 507 pp.
2. Castor, L. L., Ayers, J. E., MacNab, A. A., and Krause, R. A. 1975. Computerized forecasting system for Stewart's bacterial disease on corn. Plant Dis. Rep. 59:533-536.
3. Hashioka, Y. 1965. Effects of environmental factors on development of causal fungus, infection, disease development, and epidemiology in rice blast disease. Pages 153-161 in: The Rice Blast Disease. Proc. Symp. IRRI, July 1963. Johns Hopkins Press, Baltimore, MD. 507 pp.
4. Hori, M., Uchino, K., and Kijima, Y. 1957. Correlation between the number of silicified cells in uppermost leaves of rice plants and neck blast. Plant Prot. (Tokyo) 11:333-336.
5. Kahn, R. P., and Libby, J. L. 1958. The effect of environmental factors and plant age on the infection of rice by the blast fungus, *Pyricularia oryzae*. Phytopathology 48:25-30.
6. Kim, Choong-Hoe, MacKenzie, D. R., and Rush, M. C. 1985. Testing a computerized forecasting system for rice blast disease. (Abstr.) Phytopathology 75:1319.
7. Kim, Choong-Hoe, Rush, M. C., and MacKenzie, D. R. 1985. Effect of water management on the epidemic development of rice blast. (Abstr.) Phytopathology 75:501.
8. Kim, Choong-Hoe, Rush, M. C., and MacKenzie, D. R. 1985. Flooding dependent resistance to rice blast. (Abstr.) Phytopathology 75:1342.
9. Kim, Choong-Hoe, Rush, M. C., and MacKenzie, D. R. 1986. Flood-mediated resistance to the rice blast disease. Pages 151-160 in: The Wetlands and Rice in Subsaharan Africa. A. S. R. Juo and J. A. Lowe, eds. International Institute of Tropical Agriculture, Ibadan, Nigeria.
10. Kingsolver, C. H., Barkdale, T. H., and Marchetti, M. A. 1984. Rice

blast epidemiology. Pa. Agric. Exp. Stn. Bull. 853. 25 pp.

11. Krause, R. A., Massie, L. B., and Hyre, R. A. 1975. BLITECAST: A computerized forecast of potato late blight. Plant Dis. Rep. 59:95-98.
12. Kuribayashi, K., and Ichigawa, H. 1952. Studies on forecasting of the rice blast disease. Nagano Agric. Exp. Stn. Spec. Rep. 13:1-229.
13. MacKenzie, D. R. 1981. Breeding for disease resistance in cereals. Pages 63-69 in: Proc. 28th Annu. Meet. Can. Pest Manage. Soc., St. Catharines, Ontario. 129 pp.
14. MacKenzie, D. R. 1981. Scheduling fungicide applications for potato late blight with BLITECAST. Plant Dis. 65:394-399.
15. Madden, L., Pennypacker, S. P., and MacNab, A. A. 1978. FAST, a forecast system for *Alternaria solani* on tomato. Phytopathology 68:1354-1358.
16. Ono, K. 1965. Principles, methods, and organization of blast disease forecasting. Pages 173-194 in: The Rice Blast Disease. Proc. Symp. IRRI, July 1963. Johns Hopkins Press, Baltimore, MD. 507 pp.
17. Ou, S. H. 1972. Rice Disease. Commonwealth Mycological Institute, Kew, Surry, England. 369 pp.
18. Vanderplank, J. E. 1963. Plant Disease: Epidemics and Control. Academic Press, New York. 349 pp.
19. Villareal, R. L., MacKenzie, D. R., Nelson, R. R., and Coffman, W. R. 1980. Apparent infection rates of *Pyricularia oryzae* on different rice cultivars. Phytopathology 70:1224-1226.