Computerized Forecasting System (BLIGHTASIRRI) for Rice Sheath Blight Disease in the Philippines

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Abstract

A computerized forecasting system (BLIGHTASIRRI) was constructed to estimate the development of rice sheath blight disease and the yield loss associates with the disease in the Philippines. This system which describes disease development as vertical and horizontal development, was incorporated into all known data acquired from previous epidemiological studies. Vertical development expressed by the relative height of the uppermost lesions to the plant height was estimated on the basis of temperature, relative humidity and the susceptibility of rice sheath to the rice sheath blight fungus. On the other hand, horizontal development expressed by the percentage of diseased hills was determined from the combination of temperature, relative humidity and the number of sclerotia and tillers. Whole disease incidence was calculated from vertical and horizontal development by Hashiba's formula. Furthermore, to estimate the final yield loss, the relation between disease incidence and fully ripened kernels was analyzed. The model curve of vertical and horizontal development estimated by BLIGHTASIRRI was slightly different from actual development in paddy fields in the wet season of 1993 and 1994. Development of this system should enable to determine the need for fungicide application.

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Key words : BLIGHTASIRRI, rice sheath blight disease, vertical development, horizontal development, disease incidence, yield loss.

INTRODUCTION

Rice sheath blight disease caused by *Rhizoctonia solani* Kühn AG-1 IA has recently become one of the major rice diseases in Southeast Asia. High temperature and relative humidity are conducive to the growth of this fungus and it is considered that the characteristics of cultivars and cultural conditions are associated with the increase of its importance. High-tillering and semidwarf rice cultivars are widely grown under heavy fertilizer application and dense planting conditions to achieve high yields. These cultivars and growing conditions are favorable for outbreaks and development of sheath blight reaction^{16,19,22}. It is difficult to develop cultivars resistant to the sheath blight fungus, because the resistance is combined with characteristics that do not enable to achieve high yield. Therefore, various methods of control, both cultural and biological, including crop rotation were applied^{2,3,19,21}. However, chemical control involving the use of fungicides is the most efficient

method to control sheath blight¹. Therefore, accurate forecasting of disease development and yield loss may enable growers to apply fungicides more judicious.

With the appearance of computer, many models have been developed for the forecasting of potato leaf blight, rice blast, etc.^{1,5,9,11,14,15,17,20,24}. Some models have integrated disease development and schedule of fungicide application^{4,5,23}. A large number of epidemiological studies of rice sheath blight disease have been carried out⁶⁻⁸. To construct the computerized forecasting model of rice sheath blight, all known data based on epidemiological studies are incorporated into this model. Spreading of rice sheath blight was classified into vertical and horizontal development. Vertical development is affected by the temperature and relative humidity as meteorological variables and the susceptibility of leaf sheath as host conditions, while horizontal development is influenced by the temperature and relative humidity, as meteorological variables and the number of sclerotia and tillers as host and pathogen conditions³. Hashiba deduced the disease incidence from vertical and horizontal develop-

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ment based on field experiments using 1700 rice cultivars^{8,25}). In this paper, we present the forecasting model for rice sheath blight disease and method of estimating yield loss in the Philippines based on the epidemiological background.

MATERIALS AND METHODS

Cultural conditions. The field experiments were carried out at the International Rice Research Institute (IRRI), Los Baños, Laguna, the Philippines during the wet season of 1993 and 1994 under irrigating. Rice cultivar IR72 was used in this study. Seedlings raised in the nursery for two weeks were transplanted in 5×7-m plots on 15–23 July. Rows spacing was 20-cm and plant spacing 20-cm. The experiment was laid out in a randomized block design with four replications. Basal application of fertilizers was performed at the rate of 40-30-30 kg/ha (N-P₂O₅-K₂O) and additional N fertilization was applied at the rate of 40 kg/ha, 35 days after transplanting and at the rate of 30 kg/ha, 55 days after transplanting.

Disease assessment. Natural disease development was examined at seven day intervals for two months based on the heading date. The percentage of diseased hills was investigated based on 100 tillers randomly selected in each plot. To calculate the relative height of the uppermost lesions to the plant height, the height of the uppermost lesion (U) and plant height (H) were determined based on ten diseased hills in each plot. The relative height of the uppermost lesions (X) was expressed by the following equation:

$$X = \frac{U}{H} \times 100 \quad (1)$$

Disease incidence was assessed seven days before harvesting from various treatment plots. In each plot on area of 5 m² was harvested and the weight of fully ripened kernels was determined after drying.

Weather observation. Temperature and relative humidity in the field were monitored by on-site data logger every hour. This data logger was installed at the 20-cm height from the water surface in the center of the plot. Measurement of the temperature and relative humidity of the atmosphere were based on the weather data published at Wetland, IRRI Climate Unit.

Estimation of disease incidence. Disease incidence (D) was determined by Hashiba's method as follows:

$$D = \frac{(1.62X - 32.4) \times A}{100} \quad (2)$$

where A is the percentage of diseased hills⁹). Methods of estimation of the percentage of diseased hills and the relative height of the uppermost lesions to the plant height were based on previous studies⁶). Temperature above 23°C and relative humidity above 96% were considered to be favorable conditions for horizontal development of rice sheath blight. Furthermore, the number of sclerotia and tillers were combined with the

temperature and relative humidity to estimate the horizontal development. Vertical development was estimated by the combination of temperature above 19°C, relative humidity above 84% and susceptibility of rice sheath⁹).

Computer and programming language. BLIGHTASIRRI was written in Microsoft FORTRAN. This system can run on most of the computers including compatible personal computers, and the application is based on Disk Operating System (DOS).

RESULTS

Model of vertical development of sheath blight lesions in rice plants

Vertical development of rice sheath blight, in other words, the relative height of the uppermost lesions to the plant height (X) is represented by the formula:

$$X = \frac{(\sum BC)}{H} \times 100 \quad (3)$$

where B indicates the relation between the daily average temperature and vertical development under 100% relative humidity (Table 1). The value of B was modified by taking the daily relative humidity into consideration, and C is the ratio of vertical development at various relative humidities to that at 100% relative humidity (Table 2). Based on the susceptibility of the leaf sheath

Table 1. Vertical and horizontal development of the lesions on rice plants infected by *Rhizoctonia solani* at various daily average temperatures

Daily average temperature (°C)	Vertical and horizontal development in a day ^{a)}
19.0	0.27
19.5	0.40
20.0	0.48
20.5	0.64
21.0	0.70
21.5	0.81
22.0	0.90
22.5	1.02
23.0	1.13
23.5	1.18
24.0	1.24
24.5	1.29
25.0	1.35
25.5	1.39
26.0	1.43
26.5	1.47
27.0	1.51
27.5	1.55
28.0	1.58
28.5	1.56
29.0	1.55
29.5	1.53
30.0	1.50

a) Vertical development is indicated as cm/day and horizontal development is expressed as %/day under 100% relative humidity condition (equations (3) and (4)).

to the sheath blight fungus, there is an upper limit to the daily vertical development. If ΣBC is larger than the values determined from the susceptibility of leaf sheath, the former is replaced by the latter (Table 3). Finally, cumulative values divided by plant height (H) were obtained as the relative height of the uppermost lesions to the plant height. In this formula, weather data were interpreted as temperature and relative humidity between rice hills. However, it appears that monitoring of the microclimate is laborious and costly when this system is used. To facilitate the use of this system, the relation between the weather data published in the Climate Unit and between rice hills was analyzed. Table 4 shows the relation between the relative humidity of atmosphere and relative humidity between rice hills at every six growing stages based on heading date. In this system, the relative humidity converted in Table 4 is considered to be the relative humidity between hills. Temperature of atmosphere was used without conversion, as the differences between these two temperatures were not appreciable.

Model of horizontal development of sheath blight lesions in rice plant

Horizontal development of sheath blight disease expressed as the percentage of diseased hills (A) is represented by the equation:

$$A = \Sigma BFS \quad (4)$$

where B is the relation between the daily average temperature and the horizontal development (Table 1) and F is the percentage of the period under favorable conditions for horizontal development in a day. The value of

F is estimated by the analytical program of diurnal variation of temperature and relative humidity from daily average temperature and relative humidity. Cumulative horizontal development was modified by the number of sclerotia floating on the water surface after puddling. S is the ratio of horizontal development to that under 5×10^5 sclerotia per ha (Table 5).

Estimation of yield loss associated with rice sheath blight disease

Disease incidence (D) was negatively correlated with the amount of fully ripened kernels (K : kg) in the 1994 wet season (Fig. 1). Linear regression equation of disease incidence on fully ripened kernels was represented as:

$$K = -16.14D + 5891.05 \quad (r = -0.70) \quad (5)$$

and the relationship was significant. This equation indicates that if the disease incidence increases by 1%, the amount of fully ripened kernels decreases by 16.14 kg/ha. To calculate the yield loss (L) from the relative height of the uppermost lesions to the plant height (X) and the percentage of diseased hills (A), equation (5) was integrated into equation (2). The resulting equation was

$$L = \frac{(1.62X - 32.4) \times A}{100} \times 16.14 \quad (6)$$

where L (kg) is the yield loss per ha.

Table 2. Correction of vertical development of the lesions associated with infection with *Rhizoctonia solani* using various levels of daily average relative humidity

Daily average relative humidity (%)	Index of vertical development ^{a)}
84	0.10
85	0.24
86	0.38
87	0.52
88	0.66
89	0.77
90	0.87
91	0.89
92	0.91
93	0.94
94	0.95
95	0.96
96	0.97
97	0.98
98	0.99
99	1.00
100	1.00

a) Ratio of vertical development of lesions at various levels of daily average relative humidity to that at 100% relative humidity (equation (3)).

Table 3. Correction of vertical development of the lesions associated with infection with *Rhizoctonia solani* based on the susceptibility of leaf sheaths after heading under the most favorable conditions^{a)}

Days after heading	LVD ^{b)} (cm)	15	1.59
		16	1.56
-5	0.71	17	1.56
-4	0.74	18	1.56
-3	0.76	19	1.56
-2	0.79	20	1.56
-1	0.84	21	1.56
0	0.86	22	1.56
1	0.95	23	1.56
2	1.12	24	1.56
3	1.19	25	1.52
4	1.25	26	1.47
5	1.32	27	1.43
6	1.38	28	1.38
7	1.45	29	1.34
8	1.54	30	1.29
9	1.62	31	1.25
10	1.71	32	1.20
11	1.69	33	1.16
12	1.66	34	1.11
13	1.64	35	1.07
14	1.61	36	1.02

a) The most favorable conditions for vertical development of the lesions are 28°C temperature and 100% relative humidity.

b) The upper limit of vertical development after heading in a day (equation (3)).

Construction of BLIGHTASIRRI

This system consists of two major programs, analytical program of diurnal variation of temperature and relative humidity and forecasting program for sheath blight disease (Fig. 2). Each program had approximately 30 subroutines.

Analytical program of diurnal variation of temperature and relative humidity reads the daily average temperature and relative humidity to estimate the value of F (equation (4)). To construct this program, the relation between the daily average temperature, relative humidity and the percentage of the period under favorable conditions in a day was analyzed. The value of F was estimated at 1°C intervals of daily average temperature and 3% intervals of daily average relative humidity every six growing stages based on heading date (Fig. 3). With the rise in the daily average temperature and relative humidity, the percentage of the period under favorable conditions for horizontal development generally increased.

For the forecasting program for rice sheath blight disease, the daily average temperature, relative humidity and the value of F were used to calculate A , X , D

and L (equations (4), (3), (2) and (6)). This program is constructed by applying the uniform-increment method so that time is taken into account (Fig. 4). First, the initial date and weather data in that day are read. Next, A and X are calculated on the basis of weather data and host-pathogen factors. Finally, D and L are deduced from A and X . The calculations are continued until the final date. Furthermore, 20 iterative calculations are carried out to obtain an unbiased estimator of the mean.

Comparison between actual disease development in the field and model curve by BLIGHTASIRRI

Figure 5 indicates the relative height of the uppermost lesions to the plant height observed in the field and that estimated by the model curve use of BLIGHTASIRRI in the wet season of 1993 and 1994. There were no appreciable differences in the vertical development of the lesions between 1993 and 1994, and the vertical development estimated by BLIGHTASIRRI was very close to the actual one in 1993 and 1994. Although the relative humidity in 1994 was higher than in 1993 (data not shown), these model curves was similar because the susceptibility of the rice sheath was taken into consider-

Table 4. Relation between relative humidity of atmosphere and relative humidity between rice hills

Relative humidity of atmosphere (%)	Days after heading		-6 to 0	+1 to +11	+12 to +21	+22 to +31
	-31 to -17	-16 to -7				
75	93 ^{a)}	94	83	95	94	90
76	93	95	86	96	95	91
77	93	95	88	96	95	92
78	93	95	90	97	96	93
79	93	95	92	97	97	94
80	94	95	94	97	98	95
81	94	96	95	98	98	95
82	94	96	96	98	99	96
83	94	96	98	98	99	98
84	95	97	99	98	100	98
85	95	97	100	99	100	99
86	95	97	100	99	100	100
87	95	97	100	99	100	100
88	96	98	100	99	100	100
89	96	98	100	99	100	100
90	97	99	100	99	100	100
91	97	99	100	99	100	100
92	98	100	100	100	100	100
93	98	100	100	100	100	100
94	98	100	100	100	100	100
95	99	100	100	100	100	100
96	99	100	100	100	100	100
97	100	100	100	100	100	100
98	100	100	100	100	100	100
99	100	100	100	100	100	100
100	100	100	100	100	100	100

a) Relative humidity between rice hills at 20 cm height from the soil surface in paddy fields.

Table 5. Relation between the horizontal development of the lesions associated with infection with *Rhizoctonia solani* and the number of floating sclerotia on the water surface after puddling in paddy field

Number of sclerotia ^{a)}	Index of horizontal development ^{b)}
5	1.0
10	1.4
20	2.3
30	3.2
40	4.1
50	5.0

a) Hundred thousand per ha in paddy field.

b) Index indicates the ratio of the horizontal development under various densities of sclerotia to that under five hundred thousand sclerotia per ha (equation (4)).

Fig. 1. Linear regression between disease incidence (D) and fully ripened kernels (K) at International Rice Research Institute, in the wet season of 1994. Solid line shows the relationship expressed as equation (5).

Fig. 2. Construction of BLIGHTASIRRI.

Fig. 3. Relation between the percentage of period under favorable conditions for the horizontal development of sheath blight disease (F), daily average temperature and relative humidity from 16 to 7 days before heading date (equation (4)). Both the temperature above 23°C and relative humidity above 96% between rice hills are favorable conditions for horizontal development.

ation (Table 3). On the other hand, Fig. 6 shows the relation between the actual increase of the percentage of disease hills in the field and that indicates in the model curve estimated by BLIGHTASIRRI. In view of the high relative humidity in 1994, the percentage of diseased hills in 1994 had increased compared with 1993. Both actual values were in agreement with those estimated by BLIGHTASIRRI in 1993 and 1994. In addition, there was a good agreement between disease incidence based on observed value and estimated one (data not shown).

DISCUSSION

Forecasting models of plant diseases based on weather, host and pathogenic factors have been developed for potato leaf blight and several other pathosystems^{1,5,9,11,14,15,17,20,24}. We attempted to construct a computerized forecasting model for rice sheath blight disease that could be conveniently used. BLIGHTASIRRI requires the monitoring of temperature and relative humidity, and since it can use and read the meteorological variables from a weather station, this system is considered to be practical for application.

In this study, we analyzed the relation between yield and disease incidence based on Hashiba's formula⁶⁻⁸. As

Fig. 4. Flow chart of forecasting program for rice sheath blight disease. Weather conditions show stored daily average temperature, relative humidity and the percentage of period under favorable conditions for horizontal development in a day.

the yield was negatively correlated with the disease incidence, it became possible to predict the final yield loss based on a linear relationship. It was considered that the prediction of the final yield loss would enable to determine for use of fungicides^{4,5,12,23}. It was confirmed that the vertical and horizontal development estimated by BLIGHTASIRRI was very close to the actual development in the case of rice sheath blight. This forecasting system may thus be applied to determine whether fungicide application is necessary.

It appeared that the equation for predicting the yield loss may be limited to cultivar IR72. If other cultivars are used, the equation will be reformulated based on the relation between disease incidence and yield. Furthermore, BLIGHTASIRRI is constructed in assuming that primary inoculation is reflected by the presence of floating sclerotia on the water surface after puddling. Factors other than floating sclerotia may play an important role in the initiation of sheath blight disease, because the sclerotial density in the field is much lower than density usually observed in Japan^{3,10,13,18}. To confirm the presence of inoculum of mycelium in plant debris, we examined the percentage of diseased hills in an artificial field when various amounts of plant debris were added.

Fig. 5. Comparison between the vertical development of the lesions observed on rice plant infected with *Rhizoctonia solani* in the field and that estimated by BLIGHTASIRRI (equation (3)). This experiments were carried out in the wet season of 1993 and 1994. Heading time occurred on 25 September 1993 and 20 September 1994.

Fig. 6. Comparison between the horizontal development of the lesions observed on rice plant infected with *Rhizoctonia solani* in the field and that estimated by BLIGHTASIRRI (equation (4)).

The plots containing plant debris showed a significantly higher percentage of diseased hills than plots without plant debris, and the larger the amount of plant debris, the higher percentage of diseased hills (data not shown). In temperate countries such as Japan, mycelium in plant debris loses its viability due to the dry and cold conditions prevailing in winter after harvest. However, in the tropics, mycelium in plant debris may play a role in inoculum without losing its viability though floating sclerotia are the major source of inoculum.

The prediction accuracy of BLIGHTASIRRI will be further improved based on the data collected in the field and weather reports.

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和 文 摘 要

小林 隆・井尻 勉・Twng Wah MEW・Gerard MANINGAS・羽柴輝良：フィリピンにおけるコンピューターを用いたイネ紋枯病発生予測システム(BLIGHTASIRRI)の作成

フィリピンなどの熱帯地方で近年深刻な問題となっているイネ紋枯病の効率的な防除を行うために本病の発生予測モデルの作成を試みた。本システムはイネ紋枯病の進展を水平進展と上位進展の2つの面からとらえ、それぞれをこれまで推定されている気象因子または植物・病原体因子と結びつけることにより推定した。上位進展は病斑高率として表され、気温、湿度、イネ体の紋枯病菌に対する感受性および茎数をパラメーターとして算出された。一方、水平進展は発病株率として表され、気温、湿度、茎数、菌核数および1日の内にどれだけ水平進展可能な時間が存在するかを考慮に入れて算出された。さらに、これら2つの進展度から羽柴の式を用いて被害度を算出した。日本で既に確立しているイネ紋枯病発生予測システム BLIGHTAS をフィリピンで使用したところ気象条件の大きな違いから高い適合性が得られなかった。そこで、フィリピンの気象データを観測、解析してプログラムを修正し BLIGHTASIRRI を作成した。さらに被害度と収量との関係について検討し、上位進展と水平進展から最終的な減収量を推定する式を作成した。次に、BLIGHTASIRRI の精度について検討するため、本システムに1993年と1994年の雨期作の実測の気象データおよび菌核数等を入力して水平進展と上位進展のモデル曲線を作成した。これらのモデル曲線は、実際に圃場で観察されたイネ紋枯病の推移と非常によく一致したことから、本システムはフィリピンで使用可能と考えられた。