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Assessment of Yield Loss Due to Rice Blast Disease in Iran

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ABSTRACT

Grain yield loss in rice (*Oryza sativa* L.) caused by blast disease, *Magnaporthe grisea* (Hebert) Barr, is a major concern of rice growers worldwide. Blast is considered as the most injurious disease of rice in Iran, resulting in severe loss especially to susceptible rice cultivars. In order to assess yield loss caused by blast pathogen and develop an appropriate model, different disease onsets and levels were simulated in the experimental field in a split-plot experimental design. Independent variables including early diseased leaf area (X_1), final diseased leaf area (X_2), early neck blast index (N_1), final neck blast index (N_2), area under leaf blast disease progress curve ($AUDPC_1$) and area under neck blast disease progress curve ($AUDPC_2$) were taken as predictors and regressed to the loss in yield. Statistics as coefficient of correlation (r), coefficient of determination (R^2), adjusted coefficient of determination (aR^2), standard error (SE), F and Durbin-Watson were considered in evaluating the resulting models. The most appropriate model was the one which predicts rice yield loss based on final diseased leaf area and final neck blast index.

Keywords: Blast, *Magnaporthe grisea*, Rice, Yield loss assessment.

INTRODUCTION

Rice is Iran's second most important crop, providing food for the majority of its population (Javan-Nikkhah, 2001). Every year, various hazardous factors including pests, diseases, weeds, drought, and also during harvestand storing period damages, etc. inflict heavy losses to rice. Blast with the causal agent of *Magnaporthe grisea* (Hebert) Barr, is considered to be the most important disease of rice in Iran resulting in severe losses to susceptible rice cultivars (Javan-Nikkhah, 2001). Despite the availability of resistant varieties to blast and their increased cultivation in recent years, Iranian farmers still prefer the susceptible local varieties, that being due to their more superior qualities.

Modeling and predicting yield loss due to blast disease is necessary as a measure for practical disease management. A mathematical model, through which grain yield loss of rice, due to blast, can be determined, has not yet been developed in Iran. Hence, this study was carried out to develop a predictive crop loss model using various observed disease severities that lead to yield loss.

There are two approaches for predicting yield loss: (1) empirical damage functions and (2) combined blast-crop simulation models. Empirical damage functions are the most common methods of estimating yield losses caused by blast disease. They are derived by applying regression analysis or nonlinear curve fitting techniques to the field data. The first equation is that of Kuribayashi and Ichikawa (1952). Goto (1965) reported several examples of functional disease-yield loss relationships for panicle blast.

Katsube and Koshimizu (1970) determined the relationship as *Y= 0.57X*,

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where Y= percent yield loss and X= percent neck blast incidence 30 days after heading. In India Padmanabhan (1965) reported that the apparent loss associated with neck infection at 1% incidence corresponded to 0.99% yield loss in a resistant variety and 1.22% yield loss in a susceptible one. In Brazil, Prabhu and De Faria (1982) described the relation between time of neck infection in days after milk stages (X) and loss in 1000-grain weight (Y) as $Y= 38.02X^2-0.92$ (r= 0.98).

Kingsolver *et al.* (1984) used data from 24 epidemics gathered by various researchers in different locations, varieties and under different rice spectra to estimate three separate simple linear regression models representing the relationship between percent yield loss (Y) and percent daily increase in lesions (X_1), the highest lesion count observed (X_2), and percent days with weather favorable for infection (X_3). In a multiple linear regression analysis, only X_2 and X_3 were significant.

In the ex-USSR, Klochko *et al.* (1985) developed the formula $Y= 0.3a_1 +0.5a_2 +0.8a_3$, where Y= percent yield loss and a_1, a_2 and a_3 the number of infected panicles in severity groups 1 and 3 per random sample of 100 panicles. At IRRI, Torres (1986) derived an equation linking leaf and panicle blast, $Y= 0.21+1.012X_1+0.51X_2$ (R^2= 0.8).

In Thailand, Surin *et al.* (1986) demonstrated that blast severity during the reproductive stage (75 days after seeding) was most closely related to yield loss with an infected area of 1% corresponding to 3% yield loss. Tsai (1988a, b) analyzed data collected within two years from two varieties and two locations in Taiwan to compute the relationship between percent diseased leaf area (X) and percent yield loss (Y). The regression equations were $Y= -5.89+1.09X$ for Tainung 67 and $Y= -6.65 +1.08X$ for Tainan 5.

Prediction of yield loss using pest effects combined to a rice crop model has been attempted at IRRI, using the *CERES/RICE* (Torres, 1986; Teng *et al.*, 1989) and the Dutch MACROS models.

Shim *et al.* (2005) introduced some regression equations based on positive correlation between incidence of the panicle blast and rice yield losses. They reported that panicle blast caused deterioration of grain quality, healthy grain rate being reduced by increase in panicle blast infection.

In this study, the objectives were to identify (1) the importance of early *vs.* final diseased leaf area, and (2) the early and final neck blast index in predicting yield loss due to blast disease.

MATERIALS AND METHODS

Plant Material and Cultural Conditions

A rice cultivar, Hashemi, which is one of the most susceptible rice cultivars to blast disease in Iran and is preferred by the farmers for cultivation, because of its superior quality, was studied in the present work. The experiments were conducted at the experimental field of Rice Research Institute of Iran (RRII) using split plot design of two replications during the 2006 and 2007 growing seasons. The different times of disease onset and different levels of disease epidemic were simulated using fungicide application (Tricyclazole, 0.5 kg ha^{-1}) at different stages of the disease. The main plot (A) represented five levels of evaluation including: a_1; evaluating leaf blast 40 Days After Transplanting (DAT) and controlling the disease until harvest, a_2; evaluating leaf blast 50 DAT and controlling the disease until harvest time, a_3; evaluating neck blast 15 days after heading and controlling the disease in the leaf stage as well as after evaluation until harvest, a_4, evaluating neck blast 25 days after heading and controlling the disease in leaf stage, and a_5; evaluating neck blast at harvesting time without controlling the disease in leaf and panicle stages. Subplot (B) involved three levels of timing including b_1: once, b_2:

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twice, and b_3: three times of artificial inoculation at 10^5-10^7 spores ml^{-1}.

The plot size was 3×4 square meters (m^2) in the first year and 4×5 m^2 during the second year. Transplanting was done at 25×25 cm space and such cultural practices as fertilization, irrigation, weed and pest control, etc. were done as practiced for rice in the experimental region. Blast was completely controlled in the control plot using frequent fungicide applications.

Disease Evaluation

For a measurement of diseased leaf area, 15 tillers per plot were randomly selected and diseased leaf area determined using international scale (IRRI, 1996) and then the mean of diseased leaf area calculated. Neck blast incidence and its severity were assessed through randomly selecting 150 panicles per plot with infection type of diseased panicles determined using international scale (IRRI, 1996). Neck blast index was then calculated accordingly.

Plants were harvested excluding three border lines at each plot. The grain yield of each plot was weighted at 14 percent of moisture content. Finally, yields were compared with the yield from control plots (complete control of the disease) and the relationship between different times of disease onset in the field and different levels of leaf and neck blast along with yield loss identified through regression analysis using Stat Graphics plus 3.0. Analysis of variance and mean comparison were carried out using SAS version 6.12 after transforming data to $arcsin\sqrt{X}$. Statistics like r, R^2, aR^2, SE, F and Durbin-Watson were applied to compare the models and to select the most appropriate one.

RESULTS

Disease Severity and Yield Loss

Early and final diseased leaf area and neck blast index along with the extent of yield loss (%) in different treatments during 2006 and 2007 have been presented in Figures 1 and 2, respectively. Variance analysis and mean comparison of the yields revealed a significant difference between different times of evaluation (different times of disease onset) and inoculum levels (α< 0.01) in 2006. Mean comparison, using Duncan's

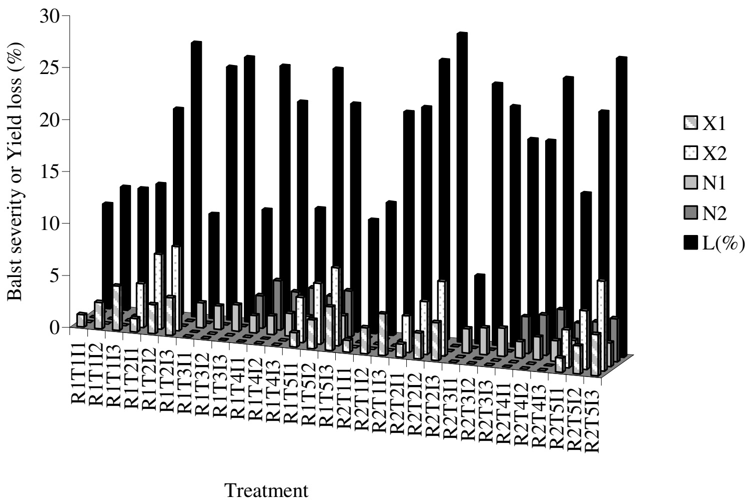

Figure 1. Early and final leaf and neck blast severity (X_1, X_2, N_1 and N_2, respectively) and yield loss (L) in different treatments in 2006 (R, T and I are replication, time of evaluation and inoculum level, respectively).

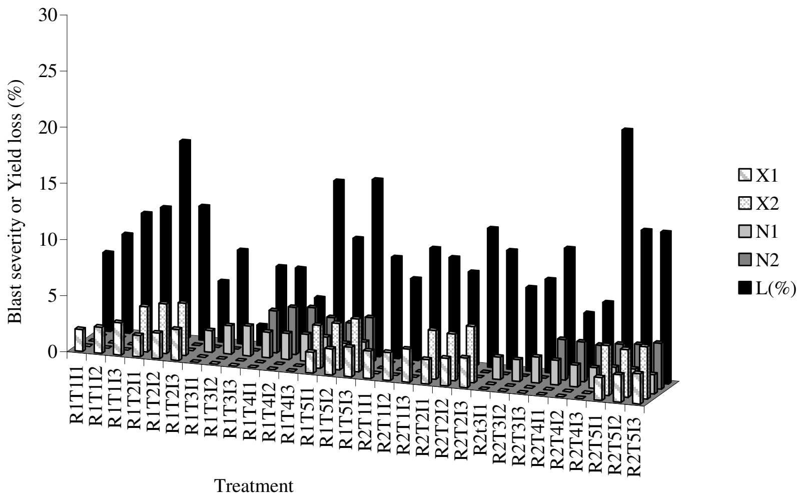

Figure 2. Early and final leaf and neck blast severity (X_1, X_2, N_1 and N_2, respectively) and yield loss (L) in different treatments in 2007 (R, T and I are replication, time of evaluation and inoculum level, respectively).

multiple range test (α= 0.05), divided times of evaluation and inoculum levels into two groups (A and B). During the second year of the experiment, significant difference has been only observed for different times of evaluation (α< 0.01) and mean comparison based on Duncan's multiple range test (α= 0.05) divided times of evaluation into two major groups (A and B) and minor group (AB) (data not shown). Variance analysis also showed significant differences between the yield loss data obtained for the two years. From Figures 1 and 2 it is revealed that neck infection alone caused yield loss as much as did leaf blast. When the disease was not controlled till harvest, maximum amount of yield loss occurred.

Model Development

Model development for yield loss assessment was done using the data of each year and the pooled data of two years. For modeling, early and final diseased leaf area (X_1 and X_2), early and final neck blast index (N_1 and N_2) and also area under leaf blast disease progress curve ($AUDPC_1$) and area under neck blast disease progress curve ($AUDPC_2$) regressed to the percent yield loss as simple or multiple regression models (Table 1). Statistics like r, R^2, aR^2, SE, F and Durbin-Watson were applied to compare the models and select the most appropriate one. When single regression analysis of 2006 data was used, only N_2 had high correlation with percent yield loss. In 2007, high correlation was observed for X_1. When pooled data of the two years were used, no significant correlation was observed between these independent variables and percent yield loss. There was also a significant correlation observed between $AUDPC_1$ and yield loss based on two years of pooled data. The most appropriate models for predicting yield loss due to blast disease were found to be the ones when early or final diseased leaf area along with final neck blast index applied in multiple regression equations of:

$L= 37.41+5.51X_1 -7.98N_2$ (R^2= 85.25) (2006 data)

$L= 36.13+3.84X_2 -9.63N_2$ (R^2= 94.04) (2006 data) and

$L= 20.90+3.77X_2 -5.81N_2$ (R^2= 69.86) (two years data)

Table1. Resulted models for forecasting yield loss (%) based on 2006 and 2007 data.

Dependent variable	Independent variable	Model	r [h]	R^2 [i]	aR^2 [j]	SE [k]	F [l]	DW [m]
L [a]	X_1 [b]	$L= 7.99+1.97X_1$	0.62	38.5		3.72	2.50	
		$L= 7.42+2.5X_1-0.09X_1^2$ (2006 data)	0.62	38.57	0.00	4.29	0.94	1.39
		$L= 0.037+3.49X_1$	0.84	71.71		0.90	10.14*	
		$L= 6.75-2.01X_1+1.10X_1^2$ (2007 data)	0.85	72.49	54.16	1.02	3.95	1.54
		$L= 5.33+2.20X_1$	0.54	29.58		3.33	4.20	
		$L= 13.46-4.62X_1+1.27X_1^2$ (two years data)	0.65	42.27	29.44	3.18	3.30	2.04
L	X_2 [c]	$L=13.27+1.63X_2$	0.48	23.71		6.06	1.24	
		$L= 8.27+3.51X_2-0.16X_2^2$ (2006 data)	0.48	23.96	0.00	6.99	0.47	0.34
		$L= 0.44+2.56X_2$	0.28	8.02		3.42	0.35	
		$L= -140+65X_2-6.90X_2^2$ (2007 data)	0.37	13.77	0.00	3.82	0.24	1.32
		$L= 0.76+3.21X_2$	0.63	40.88		5.99	6.92*	
		$L= 20.27-3.98X_2+0.61X_2^2$ (two years data)	0.65	42.40	29.61	6.24	3.31	0.86
L	N_1 [d]	$L= -38.81+23.37N_1$	0.48	23.09		8.32	1.20	
		$L= 277.05-230.79N_1+50.91N_1^2$ (2006 data)	0.49	24.97	0.00	9.49	0.50	2.60
		$L= 16.39-4.22N_1$	-0.45	20.49		3.02	1.03	
		$L= -188.10+178.81N_1-40.25N_1^2$ (2007 data)	0.84	71.43	52.39	2.09	3.75	2.30
		$L= -15.02+11.91N_1$	0.37	14.40		8.50	1.68	
		$L= -50.22+42.90N_1-6.72N_1^2$ (two years data)	0.38	14.65	0.00	8.95	0.77	1.73
L	N_2 [e]	$L= -11.13+8.08N_2$	0.90	81.20		2.62	17.29*	
		$L= -114.49+61.17N_2-6.68N_2^2$ (2006 data)	0.96	93.73	89.55	1.75	22.43*	3.01
		$L= 15.12-2.10N_2$	-0.35	12.71		2.34	0.58	
		$L= -186.92+102.79N_2-13.50N_2^2$ (2007 data)	0.58	34.64	0.00	2.34	0.79	2.94
		$L= -13.87+7.18N_2$	0.43	18.53		7.66	2.28	
		$L= 97.88-50.10N_2+7.23N_2^2$ (Two years data)	0.47	22.40	5.16	7.88	1.30	0.71
L	X_1, N_2	$L= 37.41+5.51X_1-7.98N_2$ (2006 data)	0.92	85.25	75.41	3.16	8.67	1.56
		$L= 0.26-10.29X_1+10.45X_2$ (2007 data)	0.71	51.06	18.43	3.60	1.57	1.47
		$L= 14.80+4.73X_1-2.29N_2$ (Two years data)	0.63	40.49	27.27	5.06	3.06	1.85
L	X_2, N_2	$L= 36.13+3.84X_2-9.63N_2$ (2006 data)	0.96	94.04	90.07	2.01	23.70*	2.25
		$L= 2.32+1.11X_2+2.13N_2$ (2007 data)	0.22	5.07	0.00	5.01	0.08	2.20
		$L= 20.90+3.77X_2-5.81N_2$ (Two years data)	0.83	69.86	63.16	3.60	10.43**	2.40
L	$AUDPC_1$ [f]	$L=7.77+0.2\ AUDPC_1$ (Two years data)	0.66	44.45		5.05	17.60**	
		$L=10.88-0.052AUDPC_1+0.0034AUDPC_1^2$	0.70	49.00	44.15	4.95	10.09**	0.63
L	$AUDPC_2$ [g]	$L=12.26+0.046\ AUDPC_2$ (Two years data)	0.08	0.66		8.42	0.15	
		$L=7.83+0.52\ AUDPC_2-0.0089\ AUDPC_2^2$	0.01	1.39	0.00	8.58	0.15	1.20
L	$AUDPC_1$ and $AUDPC_2$	$L=-8.22+0.23\ AUDPC_1+0.36\ AUDPC_2$ (Two years data)	0.73	53.56	43.24	4.47	5.19*	2.43

[a] Grain yield loss (%); [b] Early diseased leaf area; [c] Final diseased leaf area; [d] Early neck blast index; [e] Final neck blast index; [f] area under leaf blast disease progress curve; [g] Area under neck blast disease progress curve; [h] Correlation coefficient; [i] Coefficient of determination; [j] Adjusted R^2; [k] Standard error; [l] F statistic, [m] Durbin-Watson statistic.

* and **, Significant at the 5% and 1% probability level, respectively.

DISCUSSION

It is evident that, the effects of blast on the host plant can be better simulated with quantitative information on all important pathways of disease-host interactions than with empirical damage functions. But the advantage of empirical damage functions may be that they are simple and easy to use. However, almost none of them are transferable across years, locations, varieties and cultivation practices. This suggests that, for any possible combination of the major components of the agroecosystem (such as variety, cultivation practices and location) a separate forecasting formula would have to be developed, with some possible interactions of the system components still not accounted for.

The task in the study was to identify the importance of early and final diseased leaf area and early as well as final neck blast index in forecasting yield loss and to introduce a suitable model for rice yield loss prediction due to blast disease. It was observed that, independent variables like early diseased leaf area (X_1), final diseased leaf area (X_2), final neck blast index (N_2) and also $AUDPC_1$ are in high correlation with yield loss. It is evident that an early occurrence of blast in tillering stage can cause high damage to the leaves and finally cause high yield loss during harvest while the infection occurring after this stage has lower damaging effects. Sometimes blast occurrence is delayed to late tillering stage, so it was preferred to apply final diseased leaf area in the multiple regression models in addition to early diseased leaf area.

The best models for forecasting yield loss due to blast disease were the ones that early or final diseased leaf area and final neck blast index were applied in multiple regression equations. At IRRI, Torres (1986) also derived an equation linking leaf and panicle blast. Surin *et al.* (1986) also reported a model to predict yield loss from diseased leaf area. Okhovat *et al.* (1989, 1990) also estimated rice yield loss due to blast disease. All of these researches show that final leaf and neck blast severity are the most important predictors of yield loss due to blast disease and the existing difference between the models is related to either different locations, varieties or cultivation practices.

The model $L= 36.13+3.84X_2-9.63N_2$ (R^2= 94.04) which is of a high coefficient of determination, will be introduced for forecasting yield loss in Guilan province, following validation and determination of the model capability for forecasting. A yield loss forecasting model helps plant pathologists and farmers to have more information concerning the disease and its ability to inflict losses. It also affects their decisions in IPM programs to apply suitable fungicides when they are facing a specific blast disease level. It also can help the government to have information about the extent of rice production each year which can ultimately influence and guide the programs for any needed rice import.

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ارزیابی خسارت ناشی از بیماری بلاست برنج در ایران

ص. موسی نژاد، ع. علیزاده و ن. صفایی

چکیده

خسارت برنج ناشی از بیماری بلاست از نگرانی‌های کشاورزان در ایران و دیگر کشورها است. بیماری بلاست برنج مهمترین بیماری برنج در ایران است که خسارت زیادی را به ارقام حساس برنج وارد می‌نماید. به منظور دستیابی به مدلی برای ارزیابی خسارت ناشی از این بیماری، زمان های مختلف شروع بیماری و همچنین سطوح مختلف آن از طریق اجرای طرح آزمایشی در قالب کرتهای نواری خرد شده شبیه‌سازی شدند. متغیرهای مستقلی نظیر شدت اولیه بلاست برگ (X_1)، شدت نهایی بلاست برگ (X_2)، شاخص اولیه آلودگی گردن خوشه (N_1)، شاخص نهایی آلودگی گردن خوشه (N_2)، سطح زیر منحنی پیشرفت بیماری بلاست برگ ($AUDPC_1$) و سطح زیر منحنی پیشرفت بیماری بلاست گردن خوشه ($AUDPC_2$) به عنوان متغیرهای پیش‌بینی‌کننده در نظر گرفته شده و به خسارت عملکرد (L) مرتبط

شدند. آماره‌هایی نظیر r، R^2، aR^2، SE، F و دوربین- واتسون برای ارزیابی مدل‌های حاصل مورد استفاده قرار گرفتند. بهترین مدل، مدلی بود که خسارت عملکرد را براساس شدت نهایی بلاست برگ و شاخص نهایی آلودگی گردن خوشه پیش‌بینی می‌کرد.