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MODELLING YIELD LOSS IN INDICA RICE IN FARMERS' FIELDS DUE TO MULTIPLE PESTS

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ABSTRACT

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Surveillance data on grain yield and diseases, insect pests and weeds from farmers' fields for two consecutive wet seasons (1981 and 1982) grouped into dwarf *indica* (dwarf) and tall *indica* (tall) rice varieties were subjected to multiple regression analysis. Equations having r^2 or $R^2 \geqslant 0.60$ are reported. Bacterial leaf streak alone explained 70% of yield variation in dwarf varieties, leaf blast and bacterial leaf streak together explained a yield variation of 74%. Brown spot and tungro diseases showed little increase in percentage yield variation in tall varieties. Among the insect pests, yellow stem borer alone could explain 69% yield variation in dwarf and 62% in tall varieties. Narrow-leaf weeds contributed more towards yield variation than did broad-leaf weeds. A combination of pests explained variations in yield better than did any individual pest.

INTRODUCTION

Yield loss estimates in rice due to different pests have been reviewed by Barr et al. (1975). Most of the estimates were based on empirical methods and statistical comparisons between yields obtained at experimental farms and farmers' fields. The other comparisons included those between yields in protected and unprotected plots, between resistant and susceptible varieties and between healthy and artificially mutilated plants. Each of these methods is inadequate in many respects for assessing yield loss in a farm situation. One of the most important criticisms of such methods is the assumption of the empiricity of crop loss estimation. A crop is subject to attack by a number of pests, which estimation of yield loss should take into account. However, for individual rice diseases precise analyses have been made by Reddy

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et al. (1978, 1979a, b). However precise they may be, their prediction is limited to a single variety—single pest interaction. Main (1977) discussed the techniques, opportunities and the problems of statistical methods of determination of yield loss due to multiple diseases. In our view, considering only key diseases in modelling yield loss is unnatural, particularly for tropical rice which is subject to a plethora of pests, which are in a state of flux.

Various methods are available for estimation of yield losses in rice in multiple pest situations (Khosla, 1977; Singh and Khosla, 1981). Surveillance in the farmers' fields and the utilization of multiple regression analysis can be a useful tool for synoptic assessment of the contributions made by different pest variables on yield and in identifying the key pests. Such an exercise is particularly important in determining the threshold levels for pathogens and weeds. Continuing our efforts to develop an appropriate integrated pest management system for rice (Dasgupta and Gangwar, 1983; Gangwar and Dasgupta, 1983, 1984), we have assessed yield loss from surveillance data of rice yield and incidence of various pests in the farmers' fields by multiple regression, with a view to obtaining a simple yet reliable tool which may be applicable in the farmers' fields.

MATERIALS AND METHODS

The incidence of major pests (Table I) and grain yield (Table II) on high yielding dwarf *indica* (dwarf) and indigenous tall *indica* (tall) rice varieties

TABLE I

Diseases, insect pests and weeds surveyed in the rice fields used as independent variables for the development of models

Diseases
Brown spot (BS) (c.o. — *Cochliobolus miyabeanus*) (Ito — Kuribayashi) Drechsler ex. Dastur)
Leaf blast (LB) (c.o. — *Pyricularia oryzae* Cav.)
Node blast (NB) (c.o. — *Pyricularia oryzae* Cav.)
Bacterial leaf blight (BLB) (c.o. — *Xanthomonas campestris* pv. *oryzae* (Ishiyama) Dye)
Bacterial leaf streak (BLS) (c.o. — *Xanthomonas campestris* pv. *translucens* (Jones, Johnson and Reddy) Dye)
Rice tungro disease (RTD) (c.o. — Rice Tungro Virus complex — RTV)
Insect Pests
Yellow stem borer (SB) (*Scirpophaga* (= *Tryporyza*) *incertulas* (Wlk.))
Gundhi bug (GB) (*Leptocorisa acuta* (Thnb.))
Green leaf hopper (GLH) (*Nephotettix virescens* (Dist.))
Leaf cutter (LC) (*Hieroglyphus banian* (F.))
Leaf folder (LF) (*Cnaphalocrocis medinalis* (Gn.))
Weeds
Broad-leaf weeds (BLW)
Narrow-leaf weeds — grasses and sedges (NLW)

TABLE II

Mean values of grain yield, pest scores with their standard deviation (SD) in the farmers' fields of *indica* rice around Sriniketan, during the rainy seasons of 1981 and 1982

	Dwarf varieties		Tall varieties	
	Mean	SD	Mean	SD
Yield (t ha^{-1})	3.92	0.52	2.57	0.46
Diseases				
Bacterial leaf streak	3.06	1.73	2.48	2.28
Leaf blast	3.00	1.44	2.96	2.23
Brown spot	2.77	1.52	2.36	2.00
Bacterial leaf blight	2.06	1.31	2.20	2.90
Node blast	1.58	1.54	2.20	1.80
Rice tungro disease	0.58	0.76	1.32	1.07
Insect pests				
Gundhi bug	5.00	2.91	7.68	2.56
Leaf folder	3.55	1.48	3.20	2.68
Green leaf hopper	3.39	1.48	5.68	3.34
Stem borer	3.13	1.36	6.44	2.99
Leaf cutter	2.45	1.73	3.88	2.13
Weeds				
Broad-leaf weeds	3.77	2.89	2.88	2.24
Narrow-leaf weeds	3.22	2.74	2.80	2.08
Number of observations	31		25	

during rainy seasons of 1981 and 1982 were recorded weekly at the University Experimental Farm, Sriniketan and in farmers' fields 5, 10 and 15 km from the site in four directions (N, S, E and W). Multiple regression (MR) analysis with step-wise forward selection of variables was applied for different sets of data taking grain yield as a dependent variable and the maximum scores of pests as independent variables.

Diseases were recorded on a 0—9 scale (0 for no incidence; 1 for 1–5%; 2 for 6—10%; 3 for 11—20%; 4 for 21—30%; 5 for 31—40%; 6 for 41—50%; 7 for 51—60%; 8 for 61—70%; 9 for 71—100% incidence). Insect pests (per m^2) were evaluated by counting affected plants (dead hearts for yellow stem borer, cut leaves for leaf cutters and folded leaves for leaf folders) or the number of adults and nymphs trapped in 10 random sweeps per plot (green leaf hopper, and gundhi bug (*Leptocorisa acuta*)). Weeds were grouped into broad-leaf weeds and narrow-leaf weeds. Grasses and sedges were evaluated by visual observation of the proportional area covered as compared with the crop and the other group of weeds, respectively. This proportion was converted into a 0—9 scale as in diseases. Data for diseases, insect pests and weeds were examined separately and were also pooled to study the additive effects between the pests of different comparable groups. Thus, the following data sets were used in regression analysis: (1) diseases only; (2) insect pests only; (3) weeds only; (4) all pests in combination.

RESULTS

An average difference of 1.35 t ha^{-1} grain yield was noted between dwarf and tall varieties. This might be partially due to variation in yield potential and partially due to variation in proneness of these two types of varieties to various pests (Table II). For the purpose of this analysis, the key pests have been identified as those which have contributed towards yield variation in any of the data sets. While incidence of some diseases was found more on dwarf varieties, others had a greater incidence on tall varieties (Table II). Both narrow-leaf and broad-leaf weeds had more impact on dwarf varieties. Stem borers were the fourth most frequent pest on dwarf varieties, but the second on tall ones. Leaf folders were the second most frequent pest on dwarf varieties, but the least frequent on tall ones. While Table II permits comparison between the incidence levels of individual pests on dwarf and tall varieties, because of difference in the methods of scoring it does not permit comparison of scores among the groups of pests (diseases, insect pests and weeds). It is possible that the growth of weeds was favoured in dwarf varieties due to the lack of sunlight. The experimental area was more affected by traditional insect pests. Brown plant hopper, tungro complex and gall midge were not endemic. Tall varieties were more affected by pests.

Correlation of yield with pests

Transformation (arc-sine) of the scores of diseases and weeds was done, and analysis showed there was no difference in correlation coefficient between these pests and yields using either transformed or untransformed data. Yield of both dwarf and tall varieties was negatively correlated with all diseases, insect pests and weeds except node blast which seemed to affect the yield of dwarf varieties only (Table III).

Regression models

Table IV presents the regression models with one or more variables having $r^2/R^2 \geqslant 0.60$ (assuming this explains sufficient yield variation) for dwarf and tall varieties.

According to Model 3, bacterial leaf streak explained 70% variation in yield while the yellow stem borer (Model 2) and narrow leaf areas (Model 1) showed 69 and 60% variation in yield, respectively. Model 4 showed the combined effect of leaf blast and bacterial leaf streak. Regression coefficients (Models 1—3) and partial regression coefficients in Model 4 were significant.

For tall varieties, the variables which satisfactorily explained yield varia-

TABLE III

Coefficient of correlation (*r*) between *indica* rice yield and major diseases, insect pests and weeds in the farmers' fields around Sriniketan during the rainy seasons of 1981 and 1982

	Dwarf	Tall
Diseases		
Bacterial leaf streak	−0.836***[1]	−0.650***
Brown spot	−0.736***	−0.601***
Leaf blast	−0.711***	−0.718***
Node blast	−0.594**	−0.120
Bacterial leaf blight	−0.489**	−0.505**
Rice tungro disease	−0.468**	−0.613***
Insect Pests		
Stem borer	−0.887***	−0.786***
Green leaf hopper	−0.882***	−0.611***
Gundhi bug	−0.825***	−0.632***
Leaf cutter	−0.794***	−0.477*
Leaf folder	−0.731***	−0.676***
Weeds		
Narrow-leaf weeds	−0.773***	−0.817***
Broad-leaf weeds	−0.701***	−0.674***
Number of observations	31	25

[1] * Significant at $P = 0.05$; ** Significant at $P = 0.01$; *** Significant at $P = 0.001$.

TABLE IV

Description of models with their coefficient of determination (r^2/R^2)

Number	Model	r^2/R^2
Dwarf varieties		
(1)	Y[1] = 4.389 − 0.145 NLW[3] (0.022)[2]	0.60
(2)	Y = 4.947 − 0.289 SB (0.036)	0.69
(3)	Y = 4.683 − 0.249 BLS (0.030)	0.70
(4)	Y = 4.802 − 0.195 BLS − 0.094 LB (0.040) (0.048)	0.74
Tall varieties		
(5)	Y = 3.354 − 0.122 SB (0.020)	0.62
(6)	Y = 3.078 − 0.182 NLW (0.027)	0.67
(7)	Y = 3.325 − 0.176 RTD − 0.138 NLW − 0.112 BS − 0.069 BLS (0.051) (0.044) (0.039) (0.028)	0.85

[1] Y = Observed rice yield ($t\ ha^{-1}$).
[2] Figures in parentheses refer to standard errors.
[3] Initials for pests used as independent variables are mentioned in Table I.

tion were yellow stem borer (Model 5) and narrow leaf weeds (Model 6). Model 7 showed the combined effect of rice tungro disease, narrow-leaf weeds, brown spot and bacterial leaf streak. The regression coefficients for Models 5 and 6 and the partial regression coefficients for Model 7 were significant.

DISCUSSION

The simulation helps to understand yield loss due to multiple pests (Table IV). In nature, a pest at a critical level often limits other pests (indirectly through the host, or sometimes directly), a situation which is reflected by Models 1—3. More often, sub-critical levels of one pest may additively contribute towards yield loss due to critical level of a more serious pest; Model 4 reflects this.

In tall varieties Model 7 expresses a situation where yield loss due to the critical level of one pest (narrow-leaf weeds) is worsened by the effects of a number of other sub-critical pests (brown spot, bacterial leaf streak and rice tungro disease).

While the regression models explain a proportion of the variance in yield, constraints of pests taken as independent variables give a measure of their weightage on yield loss, either alone or when partitioned into a number of critical or sub-critical incidences of multiple pests. Thus, it is reasonable to assume that the models explain variation in yield loss as well (Main, 1977).

Among all pests, on dwarf varieties the order of importance seems to be bacterial leaf streak, yellow stem borer, narrow-leaf weeds and leaf blast. On tall varieties, the order is narrow-leaf weeds, yellow stem borer, rice tungro disease, brown spot and bacterial leaf streak.

Additional data would be useful for improving these models. Further precision may be expected from sub-models considering each group of pests (diseases, insects and weeds) and using information on weather and other factors. In the absence of process-based models, multiple regression analysis can be used to adequately predict yield loss and to choose appropriate plant protection measures.

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