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[Short Communication]

Assessment of Yield Loss in Rice due to Yellow Stem Borer, *Scirpophaga incertulas*, Using Simulation Models

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ABSTRTAC

The yield loss simulation (YLS) and the MACROS LIQ.CSM models were used to simulate the effect of stem borer damage at a detillering rate of 5, 15, 30, 60% at vegetative, panicle initiation and grain filing stages, on yield of rice cultivar's Ratna. This stem borer damage during vegetative and panicle initiation stages was not simulated appropriately by both the models. Relatively MACROS simulated pest effects better than YLS at this stage. The predicted reduction in yield due to detillering at grain filling stage varied from 10.93-62.5 and 2.59-57.2% with the YLS and MACROS models, respectively in comparison to observed reduction of 4.8-56.1%. The simulated and observed pest effects on crop yield during grain filling stage were found to be comparable.

Keywords: *Scirpophaga incertulas*, Simulation Models, Stem borer, Yield loss

INTRODUCTION

The yellow stem borer, *Scirpophaga incertulas* (Walker) is one of the most injurious amongst stem borer species (Walker, 1975; Panda *et al.*, 1976) inflicting 1-80% yield loss (Khan, 1967). Its damage causes dead hearts and white heads in the crop during vegetative and reproductive stage, respectively. The plants can compensate for a low intensity of early dead hearts by producing additional tillers (Dale, 1994). Nevertheless every percent white head leads to 1-3% loss in yield (Pathak, 1975). Accurate, quantitative estimates of yield loss due to insect pests are necessary for research prioritization and decision making in pest management. Several empirical models have been developed to quantify the relationship between pest damage and yield loss. However, their application is limited to the specific environmental condition, genotype and soils etc. (Kropff *et al.*, 1993). On the other hand, crop growth simulation models are based on the quantitative understanding of the effect of weather, genotype, soil and management on dynamic crop growth. Several crop-pest simulation models have been developed by linking pest effects through damage mechanisms at the physiological level to dynamic crop simulation models (Boote *et al.*, 1983; Rabbinge *et al.*, 1989). The yield-infestation relations established through simulation model are more stable and can be extrapolated. A validated simulation model can also be used for various applications such as development of economic thresholds, rationalizing pesticide use, predictive pest zoning and analyzing effect of climate change (Nordh *et al.*, 1988; Teng and Savary, 1992). Simulation models, however, can predict different magnitudes of yield loss depending upon the damage mechanisms included in them. It is important to quantify this uncertainty before models could be meaningfully used for yield loss assessment and other application. The objective of this study was to compare two simulation models viz. The yield loss simulation model (YLS) and the MACROS LI Q.CSM model for simulating the effect of stem borer damage on growth and yield of rice.

MATERIALS AND METHODS

The models were calibrated and validated with the data collected from field experiment, designed to study the effect of artificial yellow stem borer (*Scirpophaga incertulas)* damage i.e. detillering on growth and yield of rice cultivar Ratan (Prasad *et al.*, 1992). The experiment was conducted at the Central Rice Research Institute (CRRI), Cuttack. The row to row and plant to plant spacing was maintained at 20 × 20 cm and plot size was

28.5 m^2. Nursery was sown in first week of January and transplanting was carried out in last week of January. Recommended doses of fertilizers were applied and other operations like irrigation and weeding were done whenever needed.

The treatments constituted, tiller removal at the rate of 0, 5, 15, 30, and 60% at each of the vegetative stage, panicle removal was done to ensure sufficient pest damage, which sometimes does not happen under natural conditions. However to avoid the yellow stem borer natural infestation, the crop was treated with carbofuran rate 2 kg a.i./ha at an interval of 30 days till harvest. The models were calibrated with the experimental data for the healthy crop. Sowing transplanting, anthesis and physiological maturity dates and weather data were used for calibration of the models. The models were then validated for various detillering treatments.

Yield loss simulation model (YLS): It considers all the main processes of rice growth (Willocqet *et al.*, 1998). The daily accumulation of biomass is simulated by a rate of growth. The rate of growth is proportional to an intrinsic rate of growth, the daily solar radiation and the light intercepted by the crop canopy. The intrinsic rate of growth embeds the efficiency of several processes gross photosynthesis, respiration, and transportation of photosynthesic and synthesic of complex molecules from photosynthesic. The biomass is then distributed to different rice organs (leaves, stem, roots and panicles) according to partitioning coefficients that vary over time depending upon the developmental stages of the crop. Tillering depends on the amount of biomass partitioned daily into the stems and leaves.

The effect of white heads on crop yield is simulated by reducing panicle weight in proportion to the white head fraction. During reproductive stage compensation mechanisms are not deemed to exist in the crop. The white head injury is input as the uniform rate corresponding to maximum white head fraction recorded during the season.

MACROS LIQ.CSM model (de Vries *et al.*, 1989) operates in a series of quarter day time steps for the duration of the crop-growing season with all the requirements at optimum level. The damage fraction due to stem borer is calculated as a function of tiller number and time. The effect of stem borer damage on maintenance respiration of the plant is also considered. The stem borer damage is input as fraction dead hearts and white heads recorded in the crop. The stem borer injury then gets reflected in reduction of leaf, stem and panicle weights.

RESULT AND DISCUSSION

Both YLS and MACROS models overestimated the crop yield in detillering treatments during vegetative stage by 7.3-25.6 and 4.7-15.6%, respectively (Table 1). The estimated reduction due to detillering varied from 0.08-1.78 and 0.32-11.7% with the YLS and MACROS, respectively as compared to 0.3-16.3% observed reduction. Both models thus underestimated the effect of stem borer damage on rice yield and simulation was not satisfactory at all. However MACROS simulated stem borer damage better especially at 60% detillering.

In panicle initiation stage, detillering treatments, the YLS over predicted the yield by 11.2-68.8% while MACROS over predicted it by 6.9-19.5% at 5-30% detillering and under predicted it by 16.6% at 60% detillering (Table1). The simulated reduction due to detillering ranged from 0.21-6.25 and 1.93-52.6% with the YLS and the MACROS, respectively while observed decline in yield varied from 3.9-40.5%. The YLS thus always under predicted the effect of stem borer damage at all levels of tiller removal and simulation results with this model were not acceptable. The MACROS under predicted yield reduction at 5, 15 and 30% detillering whereas it exceeded observed reduction at 60% detillering. Comparatively the MACROS simulated the stem borer damage much better than the YLS at panicle initiation stage of the crop.

In grain filling detillering treatments, the observed and simulated yields were found to be close to each other (Table 1). The simulated yields varied from 0.1-8.42 and 2.1-13.8% over the observed yield in case of the YLS and MACROS, respectively. The simulated reduction due to detillering ranged from 10.93-62.5 and 2.59-57.2% with the YLS and the MACROS, respectively in comparison to observed reduction of 4.8-56.1%. The YLS overestimated the effects of stem borer damage by 4-6% at all their removal levels. On the other hand, the MACROS underestimated the pest effect by 2-6% at 5, and 30% while at 60% detillering, observed and simulated reduction varied by just 1%. The simulation of stem borer damage by both models at grain filling stage was thus comparable to observed effects on

Table 1. Observed and simulated yields of rice cultivars Ratna under artificial stem borer damage

Crop stage	Detillering (%)	Yield (kg / ha)		
		Observed	YLS	MACROS LIQ
Vegetative	5	5287	5675 (7.3)*	5370 (4.7)
	15	4953	5663 (14.3)	5531(11.7)
	30	4656	5643 (21.2)	5384 (15.6)
	60	4440	5579 (25.6)	4905 (10.5)
Panicle Initiation	5	5095	5668 (11.2)	5448 (6.9)
	15	4628	5641(21.9)	5041 (8.9)
	30	3643	5582 (53.2)	4354 (19.5)
	60	3155	5325 (68.8)	2632 (16.6)
Grain filling	5	5050	5059 (0.1)	5411 (7.12)
	15	4532	4526 (0.13)	4901 (8.14)
	30	3575	3727 (4.25)	4068 (13.8)
	60	2326	2506 (8.42)	2376 (2.1)
No detillering		5303	5680	5555

* Numbers in parentheses indicate percent variation of simulated yields over the observed yield.

the crop yield. Overall, the MACROS reflected the effect of stem borer damage better than the YLS.

Yield data revealed that at any given developmental stages, the simulated reduction in both models as well as observed decline in yield increased with increase in detillering percentage. Further, with advancing developmental stage, the same level of tiller removal caused more reduction in yield. At vegetative and panicle initiation stage, the YLS did not simulate the stem borer damage properly perhaps due to difference in actual tillering behavior of the crop and tillering mechanism considered in the model. Kropff *et al*. (1994) found differences between observed and simulated dry matter with ORYZA1. The rice crop may of course compensate for tiller loss due to stem borer injury (Rubia and de Vries, 1990). However, the YLS might overcompensate for tiller loss and thus even detillering as high as 60% during vegetative and panicle initiation stage did not result in yield decline comparable to observed one. On the other hand, simulated reduction in yield with the same model at all detillering levels of during grain filling stage was comparable to observed effects. During grain filling i.e. after flowering, due to cessation of tillering, compensation cannot take place. At vegetative and panicle initiation stages, the simulation of stem borer damage by the MACROS was also not proper but it was much better than the YLS. The tillering mechanism in the MACROS is perhaps more realistic thus detillering showed somewhat logical decline in yield. At grain filling stage the simulation of stem borer damage by the MACROS was comparable to observed effects. The models differed in prediction of losses due to stem borer damage because of differences in the pest damage mechanisms incorporated into them.

Despite differences in simulated and observed pest effects on crop yield, the simulation models have potential for different applications in pest management. The lacunae in the models can be overcome by more appropriate concepts of crop growth and pest damage mechanisms. Once such models are validated for a pest, they can be applied for determining economic injury levels, iso-loss curves, pest risk analysis and effect of climate change on pests and crop production, etc. Simulation models can thus enhance the efficiency of field experiments greatly.

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