A Simulation Model to formulate Iso-lose Curves for Stem Borer and Leaf Rust Incidence in Wheat

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ABSTRACT

Pest scenarios were framed for incidence of stem borer and leaf rust in wheat, presuming lowest to highest pest incidence at different growth stages of the crop. A Crop simulation model, Info Crop-wheat was coupled with damage mechanisms of stem borer (Scirpophaga incertulas) and leaf rust (Puccinia recondite). The model was calibrated and validated with the data of field experiments. The calibrated and validated model was then used for simulating various pest and disease scenarios at three locations viz Delhi, Barrackpore and Varanasi. Simulation results were used to devise iso-loss curves for stem borer and leaf rust individually and jointly for both pests. These curves showed combination of pest incidence and crop age, which resulted in same yield loss during different crop growth stages. These related pest damage levels to yield loss during various growth stages of the crop. Iso loss curves for stem borer revealed that crop became more prone to the pest with increasing crop age. Nitrogen application resulted in reduction of losses due to the pest up to 70-80 days after sowing (DAS). Likewise at Delhi and Varanasi, crop exhibited more proneness to rust incidence upto 60 DAS and nitrogen reduced losses due to disease. However crop showed more tolerance to disease with increasing crop age at Barrackpore. Iso-loss curves for multiple pests (stem borer and leaf rust) were intermediates between the iso-loss curves for stem borer and leaf rust individually. These related pest damage levels to yield loss during various growth stages of the crop. Such curves can be used for pest monitoring and knowing the damage potential of pest population present on the crop at a given crop growth stage. Hence based on economic value of different loss levels such curves can help in deciding the need for control measures. This would be useful in rationalizing pesticide application. These can also be used for monitoring activity of multiple pests on the crop.

Key words: Iso-loss curve, leaf rust, simulation model, stem borer

INTRODUCTION

Yield gaps can be caused by several factors ranging from sub optimal fertilizer and irrigation use, untimely planting, poor crop establishment, pests and disease infestations and their limited control, and harvesting losses. Insect pests and diseases are major yield reducing factors in rice and wheat. The crop losses due to pests in major agricultural crops are estimated at an average of 35% (Youdeowei and Service, 1986). In wheat leaf rust, stripe rust, stem rust, Karnal bunt, foliar blights and loose smut are recognized as major diseases, which cause significant yield losses (Sharma et al., 1998). Similarly aphids, stem borer and Heliothis armigera have shown a tendency to increase in wheat under the rice-wheat system.

The crop yield can be enhanced substantially if losses due to pests are prevented in an efficient manner. This requires quantification of the precise magnitude of yield losses in different regions in relation to the spatial and temporal incidence of yield reducing factors. Synthetic pesticides have contributed significantly towards increasing crop productivity. However their indiscriminate use has led to several problems such as pesticide resistance in pests, pest outbreaks, health hazards and environmental contamination etc. Therefore it is required to regulate pesticide application based on need. The need for pesticides in turn should be ascertained to regular monitoring of pest incidence on the crop. Variable pest incidence may prevail in the field during different crop growth stages. It is necessary to have information on yield-infestation relationship at different crop stages of the crop for judicious pesticide application. It is very tedious to generate such relationships for numerous combinations of pest incidence and crop age through field experiments. The crop-pest simulation models facilitate simulation of innumerable pest scenarios at different crop growth stages under variable input use with in short time.

Outcome of these scenarios can then be used for formulating iso-loss curves, which would be helpful in rationalizing pesticide use. These curves can be used in surveillance monitoring pest population and to determine need for pest control action. In present study, scenarios were visualized for stem borer and leaf rust incidence in wheat, assuming lowest to highest pest incidence at different crop stages. These scenarios were then simulated with Info crop and results are reported below.

MATERIALS AND METHODS

Field experiments were conducted during winter 2000–2001 and HD 2285 variety during winter 2001-2002 in a randomized block design with three replications (Daryaei, 2002). In the first year, HD 2329 variety was sown on 7 December, 2000. Nitrogen was applied at the rate of 150 kg N/ha in three equal splits at sowing, tillering (62 DAS) and panicle initiation (83 DAS). Plot size was 3x1.5m^2 with a row spacing of 25 cm^2. The experiment comprised of 9 treatments. In the second year variety HD 2285 was sown on 7 December, 2001. Nitrogen was applied as urea at the rate of 150 kg N/ha in three equal splits at sowing, tillering (61 DAS) and panicle initiation (84 DAS). Plot size was kept as 3x2 m^2 with a row spacing of 20 cm. There were 8 treatments in the experiment.

A Crop simulation model, Info Crop-wheat (Aggarwal et al., 2002) was coupled with damage mechanisms of stem borer and leaf rust. The model was calibrated for yield and yield contributing factors with the data of healthy crop of each cultivar. Pest damage mechanisms were calibrated with the data of three pest incidence treatments. The model was validated with the data of remaining pest incidence treatments. The calibrated and validated model was then used for simulating various pest and disease scenarios. Different insect and disease scenarios were formulated by presuming lowest to highest pest incidence at various growth stages of wheat crop. The scenarios were envisaged for stem borer and leaf rust incidence on the crop. Stem borer incidence @ 10, 20, 30, 40, 50, 60, 70, 80 and 90% at each of 50, 60, 70, 80, and 90 DAS was assumed. Similarly leaf rust infection @ 10, 20, 30, 40, 50, 60, 70, 80 and 90 % at each of the 10, 20, 30, 40, 50 and 60 DAT was assumed. The effect of pests on crop was simulated with Infocrop-wheat individually as well as jointly at 0 and 150 Kg nitrogen for Delhi, Varanasi and Barrackpore. The results on yield loss were then used to plot Iso-loss curves for pests at each of the stations. The yield loss with and without nitrogen was compared to find out the effect of nitrogen on crop-pest interaction. Similarly changes in crop response to pest attack with crop age were also studied.

RESULTS AND DISCUSSION

Stem borer: Iso-loss curves for stem borer incidence in wheat at Delhi showed that 5% loss was caused by 35, 25, 25, 10, 10 and 10% tiller cutting and 10 % loss was inflicted by 60, 50, 40, 20, 15 and 15% tiller cutting at 40, 50, 60, 70, 80, and 90 DAS, respectively (Fig.1a). Similarly 20 % loss was seen at 90, 80, 70, 45, 35 and 30% cutting at 40, 50, 60, 70, 80 and 90 DAS, respectively. Therefore, crop became more prone to stem borer damage with increasing crop age and less and less tiller cutting resulted in same amount of yield loss. At relatively higher damage levels crop showed continuous increase in proneness to pest damage up to 90 DAS while at lower damage levels, increase in crop susceptibility was observed only up to 80 DAS.

Iso-loss curves at Barrackpore (Fig. 1) revealed that crop response to pest attack did not differ up to 60 DAS but then there was sudden increase in crop susceptibity between 60 and 70 DAS. However, after 70 DAS, crop response to pest damage did not vary. On the other hand, at Varanasi (Fig. 1) crop became more prone to pest attack with increasing crop age up to 80 DAS at all damage levels.Yield infestation relationship differed at different locations, e.g. at 50 DAS, 10% loss was caused by 50 % damage at Delhi while same loss was inflicted by 20 and 30 % pest damage at Barrackpore and Varanasi, respectively. On the other hand, at 70 DAS 10 % loss was recorded with 20 % damage at Delhi and Varanasi both and with 15 % damage at Barrackpore. Therefore crop was found to be most sensitive to pest damage at Barrackpore. Comparison of yield loss without nitrogen and with nitrogen (150 Kg) showed (Fig.2 a,b,c) that at Delhi nitrogen application reduced loss due to stem borer incidence upto 60 DAS while at Varanasi and Barrackpore reduction in loss with nitrogen application was found up to 70 DAS. After this nitrogen did not influence crop-pest interaction at different locations. The difference between crop losses with and without nitrogen was maximum at Barrackpore. With nitrogen application, crop produces more tillers than without nitrogen, which then compensate the stem borer damage with comparatively less reduction in yield.

Leaf rust: Iso loss curves for leaf rust severity at Delhi indicated that 5% loss was caused by 45, 35, 30, 25, 20 and 25% disease severity while 10% loss was recorded at 70, 60, 50, 40, 40 and 40 % severity at 30, 40, 50, 60, 70 and 80 DAS, respectively (Fig. 3a). On the other hand 20% yield loss was incurred by 90, 80, 70, 70 and 70% severity at 40, 50, 60, 70 and 80 DAS, respectively. Therefore, with increasing age, crop became more prone to rust upto 60 DAS and afterwards crop response to pest attack did not vary with crop age. At Varanasi crop showed increase in susceptibility to disease up to 50 DAS at severity levels less than 70 % (Fig.3c). At more than 70% severity levels, crop exhibited comparatively less sensitivity to disease than at lower severity levels. At Barrackpore, on the contrary, crop showed increase in tolerance to disease with increasing age and therefore same yield loss was witnessed with more and more disease severity (Fig.3b). Differences in crop sensitivity to disease at different stages were more at higher loss levels than at lower ones.

Yield- infestation relationship varied at different locations e.g. at 40 DAS, 10% loss was caused by 60% severity at Delhi and Varanasi while same loss was done by 45% severity at Barrackpore. On the other hand, at 70 DAS, 10% loss was inflicted by 40, 50 and 55% severity at Delhi, Varanasi and Barrackpore respectively. Among three locations, the crop showed maximum susceptibility to disease during early stages and least susceptibility at later stages at Barrackpore. Comparison of yield loss at 0 and 150 kg N (Fig.4a,b,c) demonstrated that at Delhi, nitrogen application reduced crop loss due to disease upto 30 DAS while afterwards crop loss increased with nitrogen application. At Varanasi, nitrogen application reduced losses due to disease infection up to 70 DAS. On the other hand, nitrogen application did not show any clear influence on crop-pest interaction during different growth stages of the crop at Barrackpore.

Multiple pests (Stem borer and rust): It is clear from (Fig. 5a) that at Delhi 10% loss was caused by 30, 30, 20, 15, 15 and 10% severity and tiller cutting each and 15% yield loss was inflicted by 40, 35, 25, 20, 10 and 15% severity and tiller cutting at 40, 50, 60, 70, 80 and 90 DAS respectively. Similarly, 20% loss was caused by 50, 40, 35, 30, 20 and 20 % disease severity and tiller cutting both at 40, 50, 60, 70, 80 and 90 DAS, respectively. Therefore, crop became more susceptible to pests with increasing crop age upto 70-80 DAS. Iso-loss curves for multiple pests at Varanasi and Barrackpore also showed increase in crop sensitivity to multiple pests up to 80 DAS (Fig. 5b,c). The magnitude of pest incidence resulting in same yield loss differed at three locations, e.g. at 50 DAS, 10% loss was caused by 30, 10 and 20% incidence of each pest at Delhi, Varanasi and Barrackpore, respectively. On the other hand, at 70 DAS same loss was inflicted by 20% incidence at Delhi and 10% incidence at Varanasi and Barrackpore. Iso loss curves for multiple pests intermediates of that for rust and stem borer individually.

At Delhi, nitrogen reduced loss due to multiple pests at high severity during 40-60 DAS (Fig 6a,b,c). Afterwards nitrogen did not influence loss due to multiple pests. Nitrogen was found to reduce crop loss due to multiple pests during 40-60 DAS at Varanasi also. On the other hand, nitrogen application did not influence crop-pest interaction at Barrackpore up to 60 DAS but later on it was found to cause decline in yield loss due to pests.

There were differences in crop-pest interactions at three stations. However, following conclusions can be drawn from perusal of iso-loss curves for pests of wheat:

I. Crop was found to be more prone to stem borer damage with increasing crop age. Nitrogen application resulted in reduction of losses due to stem borer damage in wheat up to 70-80 DAS.
II. At Delhi and Varanasi, crop exhibited more proneness to rust incidence upto 60 DAS and nitrogen reduced losses due to disease. However, crop showed more tolerance to disease with increasing crop age at Barrackpore.
III. Iso-loss curves for multiple pests (stem borer and leaf rust) were intermediates between the iso-loss curves for stem borer and leaf rust individually.

Iso-loss curves exhibited combination of pest incidence and crop age, which resulted in same yield loss during different crop growth stages. These thus related pest damage levels to yield loss during various growth stages of the crop. Such curves can be utilized for pest monitoring and perceiving damage potential of pest population encountered on the crop during at a given crop growth stage. Hence based on economic value of different loss levels these can help in ascertaining the need for control action. This would facilitate rationalization of pesticide application on the crop. Besides reducing cost of pest control it would also reduce environmental contamination due to pesticides. These curves also showed the relative response of crop to pest stress during different crop growth stages. These can also be used for monitoring activity of multiple pests on the crop. Pest models when linked to crop models can be used to devise iso-loss curves (Teng and Savary,1992). Such curves may then be used in a pest monitoring programme, in which pre-decided levels of acceptable loss are used to decide the need and timing of control action. Heong (1990) used simulation models to devise strategies for insecticide use against pests. Likewise Teng et al. (1978) predicted disease epidemics with the help of simulation models. Simplified pest models or simplified decision rules from crop-pest models based on economic value of their outputs have been used to manage rice blast (Surin et al., 1991), wheat diseases (Zadoks, 1984, 1989), sugarbeet *Cercospora* leafspot (Shane et al., 1985) and sweet corn common rust (Teng, 1988).

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