



Integrated Pest Management in Rice

Chitta Ranjan Satpathi

Among the different biotic stresses some insect pests *viz.*, stem borers, leaf folder, gall midge, leaf roller, gundhi bug, green leaf hopper and brown plant hoppers have become major constraints in rice production. Considering the yield loss the farmers rely on chemical pesticides which directly affects health of human and environment. Different strategies have been developed by the farmers among which some cultural practices might be adopted to combat the initial insect pest problem before application of chemical pesticide. Consequently, the natural enemies especially parasitoids and predators play an important role in long term control of the pest and even their population could be enhanced by adopting different ecological engineering techniques over the non-crop areas in rice field. Synthetic pheromones and allelochemicals are now being used as modern tool to control the borer pest. For development of sustainable management practices different strategies have been combined in suitable proportion which are now designed as Integrated Pest Management practices in rice crop.

Keywords: *Insect pest, Diversity, Biological control, Cultural control, Parasitoid, Predator, Pheromone, Insecticide, Ecological engineering*

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Introduction

With the introduction of high yielding varieties, developing improved water management, fertilization and adopting modern mechanization, rice plants become susceptible to insect pests. Sometime climate change may also accelerate the growth and development of insect pest. Considering the crop losses farmer rely only on chemical pesticide but cannot be denied the adverse effect of health of animal and environment. Sometime the insecticide is used either on natural enemies or pollinators at the wrong time, or both which can be considered to be misuse of chemical. Recently restrictions have been imposed on export of rice due to high level of pesticide residues. Conversely the massive applications of same insecticide in rice crop some of the

insects become resistance to pesticides. Therefore, more sustainable practices are needed to minimize the environmental pollution. Augmentation of existing parasitoids and predators keep the natural balance of pest but sometime damage exceeds the economic threshold level due to rapid multiplication of particular group of insects. Beside the effect of natural enemies, killing the dormant stage of insect by tillage as well as burning of stubble, selection of resistant variety, crop rotations and adjusting the planting times should be part of the cultural practice to combat the pest problem. Here all the strategies are combined in suitable proportion to develop integrated insect pest management in rice crop which is ecologically safe, socially acceptable, economically viable to the farmers.

Diversity of insect pests of rice



Leaf folder larva



YSB adult



Pink borer adult



GLH adult



GLH adult



BPH and WBPH colony



Rice hispa



Gundhi bug adult



Leaf roller adult

Figure 1. Some important insect pests of rice crop at RRSS, Chakdaha, BCKV, WB, India

Although numbers of insect pests were recorded in rice crop but the incidence of mealy bug, termite, stem borer complexes, leaf folder, gall midge, leaf roller, hispa, gundhibug, green leaf hopper and brown plant hoppers are predominant (Figure 1) and causing considerable damage to the (Figure 2) crop in Eastern India (Pasalu et al., 2004, Mukhopadhyay & Satpathi 2004). Both brown plant hopper (*Nilaparvata lugens* Stål and whitebacked planthopper *Sogatella furcifera* Horvath are gradually becoming alarming pest in Gangetic Alluvial zone of West Bengal. Different biotic and abiotic factors influence to make population buildup of brown plant hoppers in rice crop (Satpathi & Mukhopadhaya 2002)

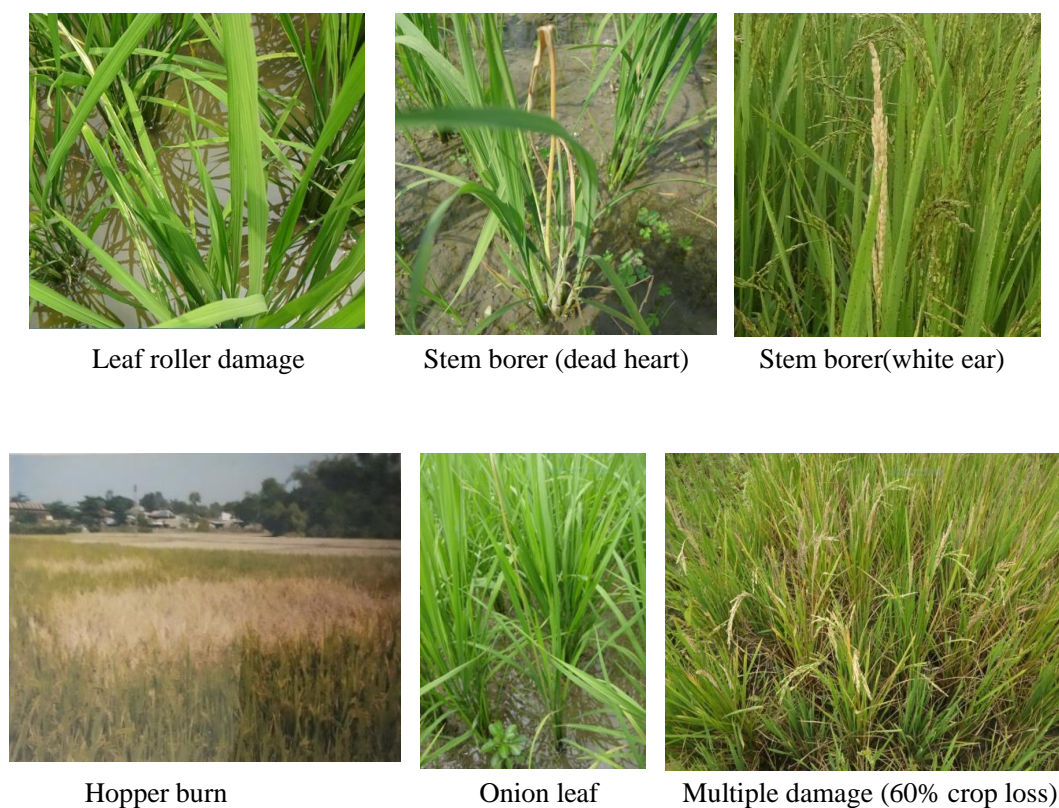


Figure 2. Damaging stages of rice crop at RRSS, Chakdaha, BCKV, West Bengal, India.

Diversity of natural enemies in rice ecosystems

Insect predator: About 15 taxa of insect predators are found in rice ecosystem of which *Ischnura aurora aurora* (Brauer) (Coenagrionidae, Zygoptera, Odonata), *Orthetrum sabina sabina* (Drury) Libellulidae, *Brachythemis contaminata* (Fab.) (Libellulidae, Anisoptera, Odonata), *Forficularia decipiens* (Gene), *Doru aculeatum* (Scudder) (Forficulidae, Dermaptera), *Cleptocoris atromaculatus* (Satal) (Reduviidae, Hemiptera), *Andrallus spinidens* (Fabricius) (Pentatomidae, Hemiptera), *Cyrtorhinus lividipennis* (Reuter) Miridae, *Ophionea nigrofasciata* (Scht-Gobel) (Carabidae, Coleoptera), *Paederus fuscipes* (Curtis) (Staphylinidae, Coleoptera), *Coccinella transversalis* (Fabricius), *Micraspis discolor* (Fab.) (Coccinellidae, Coleoptera), *Diacomma vaganas* (Smith), *Camponotus compressus* (Fab.), *Solenopsis geminata* (Fb.) (Formicidae, Hymenoptera), were recorded as some of the important predator in rice crop in Eastern India. Among the Odonata both damselfly *Ischnura aurora* (Brauer), and dragonfly *Orthetrum sabina sabina* (Drury), *Brachythemis contaminata* (Fab.) are usually appeared in rice field right from the first observation

from 15 days after transplanting but very few dermapteran predators also observed in vegetative stage of crop. Mirid bug *Cyrtorhinus lividipennis* (Reuter), the most important predator was noticed in the rice crop just before panicle initiation with its population having peaked at 70 DAT but the population of dragonfly, damselfly, coccinellid and rove beetle appeared from transplanting to harvesting of crop (Figure 3). Although number of predacious bugs were recorded of which *Cleptocoris atromaculatus* (Satal) and *Andrallus spinidens* (Fabricius) were most predominant in vegetative and reproductive stages of the rice crop respectively. Among the Coleopteran predators *Ophionea nigrofasciata* (Scht-Gobel) and *Paederus fuscipes* (Curtis) are usually found from 15 days after transplanting to till the crop is harvested. The coccinellid predators *Coccinella transversalis* (Fabricius) reached early in panicle initiation stage whereas *Micraspis discolor* (Fabricius) dominated the other species in flowering stages of the crop. The water of the rice field is drained out as soon as maturity of grain is covered and huge number of ants are found in the rice field of which *Diacomma vaganas* (Smith), (*Camponotus compressus* (Fab.) and *Solenopsis geminata* (Fb.) were recorded during flowering and reproductive stages of crop respectively (Satpathi et al., 2000, Mandal et al., 2016).

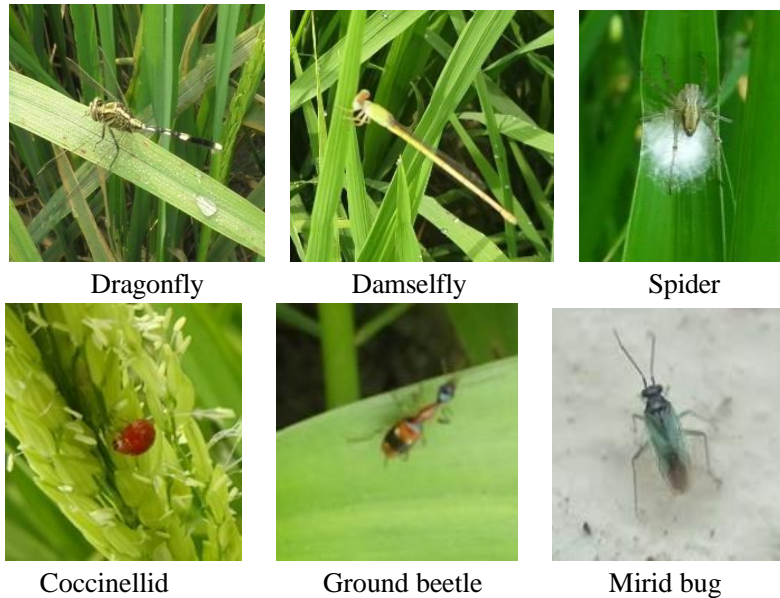


Figure 3. Some important predators of rice insect pests

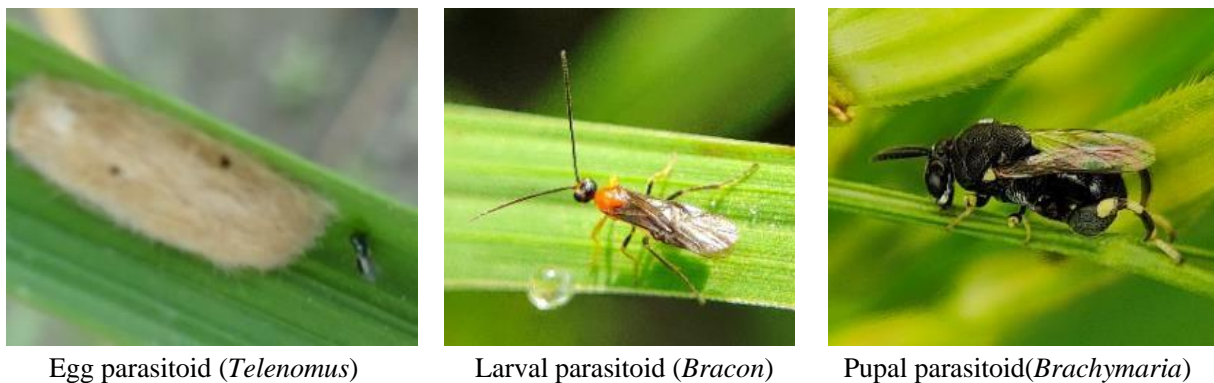


Figure 4. Some important parasitoids of rice insect pest

Insect parasitoids: Among the different parasitoids *Telenomus rowani*, *Tetrastichus schoenobii* Ferriere, *Cotesia angustibasis* Gahan and *Macrocentrus philippinensis* (Ashmead.), *Bracon* sp, *Brachymeria excarinata* Gahan is predominant (Figure 4) in dry and laterite zone of West Bengal (Pasalu et al., 2004).

General approaches to insect pests management of rice

Among the different approaches for insect pest management of rice include cultural practices, varietal resistance, bio intensive management, use of semiochemical and chemical control.

Cultural practices

It is a common practice maintaining the tradition or custom of the farmers of a particular locality where rice crop is intensively grown. The effect of different cultural practices on yellow stem borer (YSB) and hopper population are incorporated herewith as follows:

Effect on rice YSB population as influenced by dates of transplanting and chemical protection during boro (summer) season in West Bengal: The mean percentages of damage on the plant receiving the chemical treatment regardless of the dates of transplanting were significant. Here, there was significant difference in damage at 45, 60 and 75 DAT and it indicated that late planting crop was liable to infestation by YSB from active tillering to yellowing stage second degree of interaction i.e. dates of transplanting x treatment was not significant.

Effect of dates of transplanting on incidence of yellow stem borer (YSB) population in rice crop: The rice crops are cultivated between first week February to second week of March during summer season but if the date deferred to first week of April the crop is liable to maximum damage and even more than 75% crop loss occurred in West Bengal.

Incidence of white backed planthopper (WBPH) population as influenced by spacing and fertilizer: Rice crop become luxurious and bushy with application of high dose of nitrogenous fertilizer (80:40:40 kg/ha of NPK) and close spacing 20cm x 10cm (L x B) spacing which favors to build up maximum population of WBPH from the month of November till the crop is harvested in West Bengal (Satpathi 2012).

Silicon (Si) and Nitrogen amendment in soil impairs population buildup of hopper pests: Rice is an important crop which can utilize both nitrogen(N) and silicon (Si) for its growth and development. Additionally both the elements have contrasting characters with respect to the resistance to hopper pests infesting in rice crop.

Here the amorphous Si is usually deposited in plant tissue causes physical barrier to the hopper pest which also reduce the digestibility of the insect. Although excessive use of nitrogen favors to build up the hopper population but there is a strong interaction between Si and N accumulation were the activity of Si declined with high doses (100kg/ha) of nitrogen in rice crop (Satpathi 2024).

Varietal effect on yellow stem borer (YSB) population in rice crop: The cultivation of early (IET4786), medium (MTU 7029) and late variety (Ranjit) are common practice depending upon the topography of land but no significant difference was recorded with the maturity of crop. Consequently, the aromatic rice varieties are susceptible to yellow stem borer attack in entire rice growing areas of West Bengal.

Biological control

Biological control is comparatively better approach with respect to the long-term productivity of the crop. The predatory insects and mites, parasitoids, nematode, entomopathogenic fungi, bacteria, and viruses are used globally (Satpathi et al, 2022).

Some important natural enemies of insect pests of rice crops in West Bengal

Spider: Among the other bioagents the eleven species of spider viz *Lycosa pseudoannulata* (Boes and Strand), *Phidippus indicus* Tikader, *Oxyopes lineatipes* C.L. Koch, *Argiope pulchella* Thorell, *Zygoballus narmadaensis* Tikader, *Neoscona mukherjei* Tikader, *Leucauge celebasiana* walk, *Nephila maculata* (Fab), *Tetragnatha bengalensis* W. *Clubiona japonicola* Boes. and Strand and *Atypena formosana* Oi. were predominant in rice crop in West Bengal (Satpathi 2004).

Hemipteran predator: Mirid bug *Cyrtorhinus lividipennis* Reuter is a very common hemipteran predator of hopper pest. The incidence of this predator increases with either BPH or WBPH population during the month of September to November in rice crop in West Bengal (Satpathi et al., 2000, Satpathi 2001).

Odonata: Both dragonfly and damselflies belonged to the order Odonata are considered as natural predator of rice insect pest. Although 75 species of dragonfly fauna associated with rice ecosystems in Eastern India of which, 15 species were regular and rest were sporadic (Satpathi 2017). Among the different species of dragonflies *Brachythemis contaminata* (Fab.), *Orthetrum sabina sabina* (Drury), *Crocothemis survillia survillia* (Drury), *Diplacodes trivialis* (Rambur), *Pantala flavescens* Fab were found as frequent visitor in rice field whereas the present damselfly species particularly *Agriocnis famina famina* Brauer, *Agriocnis pygmaea pygmaea* (Rambur), *Ceriagrion* sp., *Ishnura aurora aurora* Brauer, *Ishnura senegalensis* (Rambur) were very common in low land areas of most of the rice growing areas (Satpathi and Sarkar 2009, 2009, 2010) in Eastern India (Satpathi 2010). The dragonfly usually lay their eggs in soil under the water after final land preparation whereas damselfly inserted their eggs into the slits made by ovipositor on the rice stem surface under the water. The nymphs of both the Odonata species are first predatory stage under the water whereas adults catch terrestrial aerial prey particularly adult stages of borer, leaf folder, gall midge and hopper pests of rice crop. However, their population declined with application of high doses of neem cake over the soil surface (Satpathi 2010, Satpathi and Sarkar 2010). Due to global warming the lifecycle of *Orthetrum sabina sabina* (Drury) becoming shorter from year 2011 than the previous years (Satpathi 2011).

Entomopathogenic fungus: The common pathogenic fungus *Hirsutella* sp. attached on the adult GLH to cause stop feeding within 2 to 3 days after infection. Fungal mycelium grew out as long as filament, which are dirty white at first and later turn grey. The spores produced from these elongated mycelia dispersed by air, which led the control 80 to 90 % of the hopper population during the month of October to first week of November in West Bengal (Satpathi 2000). Some natural fungi are also responsible for control of rice brown plant hopper where *Aspergillus flavus* Linkk. caused maximum mortality (20 to 30%) followed by *Aspergillus niger* (Teig.) (15 to 20%), *Rhizopus* sp. (10-20%) and *Fusarium* sp. (5-20%) in Eastern India (Satpathi et al., 2016).

Entomopathogenic nematodes against insect pests of rice: Among the different entomopathogenic nematodes the incidence of *Hexameris* sp. is predominant as endoparasite of both brown planthopper (BPH) & whitebacked planthopper (WBPH) in rice crop in West Bengal (Figure 5). This nematode is appeared with very low population in September but about 25% parasitization occurred in the month of October and disappeared with the onset of winter in November (Satpathi 1999, Satpathi et al. 2008, Satpathi et al. 2010, Acharjee et al. (2020).



Figure 5. *Hexameris* sp. emerged out from nymph and adult of BPH

Here both male and female BPH are attacked by this nematode. The female BPH are ochraceous brown dorsally and brown vertically whereas males are dark black with white dome shaped indentations (Satpathi 2009).

Effect of pheromone

The pest management practices of rice could be eco-friendly and sustainable approach by using synthetic pheromones and allelochemicals (Datta and Satpathi 2023). Pheromone trap is used for trapping the male moth whereas ExosexYSBTab is used only for sexual confusion to the male moth. In this process the antennae of male moth saturated with powder and pheromone [mixture of (Z)-11 hexadecinal and (Z)-9 hexadecinal at 3: 1 ratio] and they preventing them from locating the female. It acts as false female lure and enhance the mating disruption effect. The use of ExosexYSBTab @ 1600 mg/ha reduce the egg mass and number of male / traps in rice field as compare to normal trapping (Figure 6) in farmers field where two to three round pesticides are used (Satpathi 2011, Satpathi et al., 2017, Raut and Satpathi 2013, Raut et al. 2017). Beside mass trapping Pheromone trap is used to alter sex ratio of yellow stemborer, *Scirpophaga incertulas* (Walk.) in rice field (Raut & Satpathi 2017, Mondal et al., 2023).

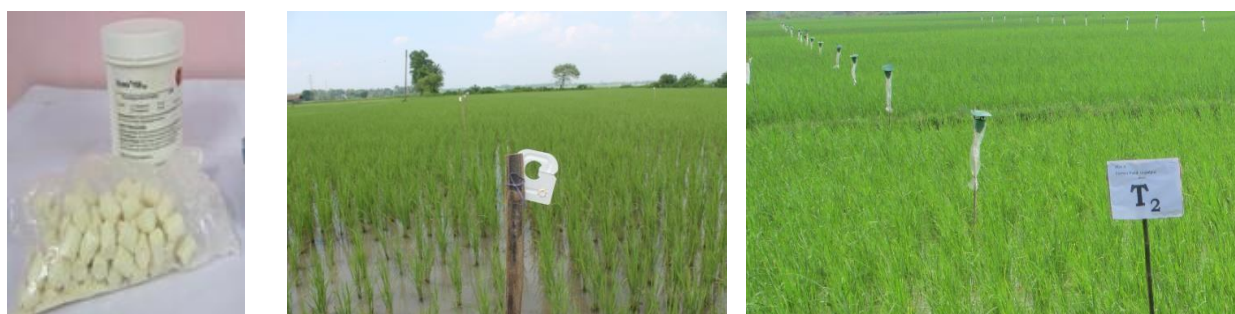


Figure 6. Installation of ExosexYSBTab, and funnel trap in rice field (Collaborating work of BCKV with Exosect Pvt. Ltd. United Kingdom)

Effect of different agrochemicals on biodiversity of predators

The adverse effect different agrochemical changes the biodiversity of rice ecosystem as the most abundant species of predator constitute only 17.9% whereas it was 24.25 in untreated plot (Satpathi 2023).

Effect of insecticides on rice yellow stem borer and its natural enemies: The application of both granular and spray formulations of chlorantraniliprole significantly reduced the damage caused by yellow stem borer. The next level of 2 other insecticides were in order to effectiveness, cartap hydrochloride 4%G, cartap hydrochloride 50%SP, chlorpyrifos 20%EC and chlorpyrifos 10%G. The bio insecticide azadirachtin 0.15%G had the lowest toxicity while the chlorpyrifos 20%EC had the highest toxicity to natural enemies in the present investigation. Considering the low efficacy but relatively good effects on natural enemies azadirachtin 0.15%G is preferred over the other insecticides in controlling yellow stem borer. However, the relative less effective as compare to chemical pesticides is a barrier to the farmers. Thus the insecticides chlorantraniliprole either granules or spray formulation could also be advised to manage YSB for better efficacy against yellow stem borer and cost effectiveness (Satpathi 2024).



Figure 7. Field demonstration of chlorantraniliprole 5% tablet and cyclaniliprole 50%SL against rice yellow stem borer and leaf folder by Dr. C.R.Satpathi (Left side) at RRSS, Chakdaha, BCKV, WB, India.

Field demonstration of the manual placement of 1500 tablets of chlorantraniliprole 5% per hectare at 21 and 42 days after transplanting can effectively control both rice stem borer and leaf folder together. Consequently, the tablets have no toxic effect on aquatic animal other natural enemies prevailing in rice ecosystem of West Bengal. Among the other new molecules Cyclaniliprole 50SL@ 50 g a.i/ ha or formulation 500ml/ ha reduced substantial level of stem borer and leaf folder population and even the chemical is safe to natural enemies (Figure 7).

Effect of insecticide on hopper pest complexes and its natural enemies: Bio efficacy of a new formulation of chlorpyrifos 20% CS for the control of brown planthopper, green leaf hopper and white backed planthopper on paddy crops indicated that chlorpyrifos 20% CS @500g a.i/ ha offered better crop protection against all the three hopper pests and resulted in higher grain yield. Imidacloprid 17.8% SL @25 g a.i./ha and fipronil 5%Sc@75 g a.i/ ha were also found equally effective against all these pests. Beside controlling the hopper pests, all those treatments showed no adverse effect on the natural enemies particularly spiders (*Phidippus* sp., *Oxyopes javanus*, *O. lineatipes* and *Lycosa pseudoannulata*) and damselfly (*Agriocnemes femina femina*, *A. pigmaea pigmaea*, *Ceriagrion* sp., *Ischnura aurora aurora*, *I. senegalensis*) (Satpathi et al. 2016).

Effect of different groups of insecticide on predator diversity: The effect of twelve different groups of insecticides on diversity of major predators (insects and spiders) treatment and least in case of lambdacyhalothrin. Similar trend was observed for evenness index in the emamectin benzoate and lambda cyhalothrin. During boot leaf stage, Shannon index was maximum in during active tillering and boot leaf

stage of rice crop was evaluated in West Bengal. The results showed that spinosad, emamectin benzoate, sulfoxaflor and pymetrozine were highly safe while buprofezin, imidacloprid, indoxacarb and chlorantraniliprole were moderately so. The insecticides like lambda-cyhalothrin, fipronil and chlorpyrifos were found to be toxic. During active tillering stages the predator diversity was maximum in emamectin benzoate, sulfoxaflor and minimum in lambda-cyhalothrin. Overall, insecticidal treatments resulted in decrease in diversity of predators during both stages of rice crop (Satpathi 2023).

Effect on ecological engineering on incidence of insect pests of rice

Cultivation of Napier grass, Fennel, Coriander, French bean, Cowpea, Soybean, Cosmos over the bunds around rice field reduce stem borer population whereas Marigold, Fennel, French bean, Coriander reduce specifically brown plant hopper population. This “bund cropping” techniques lead to modification of existing insect ecology interfering with their chemical communication. Field bund tree litters grasses and herbs can be used for maintenance of overwintering sites of lady bird beetles (Datta and Satpathi 2023).

Quantification of the role of Integrated Pest Management

Effect on borer complexes: Among the different borer pests yellow stem borer *Scirpophaga incertulas* (Walk.), Lepidoptera; Pyralidae, dark headed stem borer *Chilo polychrysus* (Meyrick), Lepidoptera; Pyralidae and pink stem borer *Sesamia inferens* (Walk.), Lepidoptera; Noctuidae are predominant in West Bengal (Figure 8). Morphologically they differed each other but damage symptoms could not be separated by naked eye.



Figure 8. Borer complexes (Yellow stem borer, dark headed striped caterpillar and pink borer) of rice (Curtsey: A. M. Raut & Chitta Ranjan Satpathi, 2017)

Considering the damage % *Scirpophaga incertulas* (Walk.) ranked first (10.64 to 12.42%) followed by *Chilo polychrysus* (Meyrick) (0.84 to 1.72%) and *Sesamia inferens* (Walk.) (0.84 to 1.12%) respectively. The proportion distribution of five different types of stem borers in West Bengal could be represented as 68.4% and 6% for *Scirpophaga incertulas* (Walk.), *Sesamia inferens* (Walk.) respectively (Raut et al 2014). Five different breeds of rice yellow stem borer *Scirpophaga incertulas* (Walk.) occurred in rice from Eastern India (Raut and Satpathi 2022). Effect of different pest management practices leads to change the aboveground aquatic arthropod diversity in irrigated rice *Oryza sativa* L production system (Satpathi et al 2011).

Effect on hopper pests : Cultivation of resistant variety viz., Chaityanya (MTU-2067), delaying planting time up to first week of August, application of fertilizer @ 60:40:40 (N:P:K) with spacing 20x15cm, alternate

wetting and drying the field at 80,87 and 94 DAT, and spraying of imidacloprid 17.8 SL @ 30 gm a.i. / ha at 75 and 90 DAT could maintain the BPH population below economic threshold level in upland rainfed rice growing areas of West Bengal (Satpathi & Acharjee 2007, Acharjee et al., 2020).

Effect on natural enemies of hopper pest: Among the different natural enemies of hopper pests the spider and mirid bugs are predominant in rice crop in West Bengal. The population of these natural enemies in IPM are relatively lower than natural biological control (NBC) but higher than schedule-based protection (SBP) adopted by the farmer (Satpathi et al., 2005).

Integrated pest management in rice crop

Select BPH tolerant variety Chaitanya (MTU-2067), release *Trichogramma japonicum* and *Trichogramma chilonis* @16000 adults/ hectare starting from 15DAT. Follow suitable cultural practices of which alternate wetting and drying at 7 days interval at 50 to 60DAT in rainfed lowland areas and single irrigation at 20DAT in rainfed upland against mealy bug and termite. Spray application of cartap hydrochloride 500g a.i/ ha at reproductive stage. The cost benefit ratio was higher in IPM treatment providing higher net return to the farmers. There was also high in natural enemy population in IPM treatment due to reduction in pesticide use. (Katti et al., 2006)

Conclusion

Among the IPM components, farmers are aware and have adapted the environment friendly components such as use of pheromone traps for monitoring yellow stem borer, use of tolerant varieties in case of gall midge and BPH, release of *Trichogramma* egg parasitoids against leaf folder, balanced application of fertilizers, formation of alley way and water management and need based pesticide application had a positive and convincing impact on farmers. The natural enemy population became significantly higher in IPM treatment due to reduction in pesticide use. The low amount of pesticide load in the IPM treatment also highlights the advantage in term of safety regarding human health (Pasalu et al., 2004). Similarly, EXOSEX YSB tab with 3.2mg with two application and single application of EXOSEX YSB tab 20mg were found to control YSB damage from active tillering to harvest of crop.

Competing interest

The author has declared that he has no conflict of interest.

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