Chapter 11
Principles and Methods of Rice Lepidopteroid Pest and its Enemy Management (PEM) Program in North Vietnam

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Abstract The principle technological scheme of lepidopteroid rice pest and its natural enemy management (PEM) on an ecosystem basis is elucidated. The elaborated algorithm of rice agro-ecosystem management includes; (a) well grounded economic thresholds (ET) both for rice leaffolder and yellow stem-borer; (b) monitoring of number dynamics of lepidopteroid pests and their natural enemies; (c) decision making with employment of the standard survey forms; (d) registration of quantitative index – the zoophage efficiency level as an indicator of ecological resistance of paddy agro-ecosystem on rice pest injury, and its usage for lepidopteriod pest ET correction; (e) environment friendly tool set and tactics of lepidopteroid pest population management.The tactics of PEM program implementation allows to control of lepidopteroid pest populations (and secondary pests) and cutting down of the quantity of chemical insecticide treatments six times under the condition of the Red River Delta.

Keywords Lepidopteroid rice pest · economic threshold · paddy agro-ecosystem · generalist predator · monitoring · decision making

11.1 Introduction

At the end of 20th century a dependency of rice production on pesticide application in South-East Asia was one of the main factors which, side by side with population growth, degradation of soil fertility and water resources, created constant tension in food security and pesticide pollution of the environment (Bull, 1982; Kenmore, 1991; Lampe, 1994). Pesticides are significant inputs to rice production: in 1988 alone, insecticides costing US$ 910 000000 were used in rice world wide, more than for any other crop (Lampe, 1994). At the same time it is a known fact that an overuse of pesticides has negative impact on natural enemies of rice pests which is the cause of outbreaks of some secondary pests, for example, brown planthopper

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(*Nilaparvata lugens*). Brown planthopper was a minor pest of tropical rice in the past but increased dramatically in the early 1970s when pesticides used against lepidopteroid rice pests eliminated its natural enemies. It is obvious that development of environment-friendly rice pest and its enemy management is essential for sustainable productivity of rice.

In 1993, the Russian-Vietnamese Tropical Centre, Hanoi, Vietnam, began ecological studies on lepidopteroid pest and its enemy management (PEM) program in the Red River Delta which produced 20 per cent of the country's rice. The study was carried out at of Hanoi Agriculture University, Hanoi and in the Quoc Oai District, Ha Tay Province, during six rice seasons.

IPM principles and methods used in the Philippines (Reissig et al., 1986) and Indonesia (Kenmore, 1991) provided the basis for development and implementation of rice IPM in some areas of South-East Asia. However, the peculiarity of approach in Vietnam was the specific environment, pest and beneficial arthropod fauna, and local traditions on rice growing which helped to best address PEM tools and methods.

The choice of rice lepidopteroid pests as target species was conditioned by the potential hazard of its injury activity, and the visibility of plant damage which was used by farmers as a signal for insecticide treatment early in the season. This practice abolished natural enemies and disturbed the natural control of the pest, which resulted in resurgence of some secondary pests such as brown planthopper. The key rice pests in North Vietnam are: the leaf folder, *Cnaphalocrocis medinalis* (LF), the yellow stem-borer, *Scirpophaga incertulas* (YSB) (Pyralidae). Vu Quang Con (1992) brought out data on these species and other lepidopteroid rice pests and their parasites in Vietnam.

The feature of our approach was an elaboration of pest and its enemy management strategy assuming conservation of biodiversity at different trophic levels (zoophages mainly) in the rice agro-ecosystem and strengthening of an ecological stability in this ecosystem in order to turn events in the life of the rice arthropod community into a desirable direction. Hence, the main objectives were: a) Development of well-grounded economic threshold (ET) for main lepidopteroid pest species with obligatory consideration of associated circumstances; b) Rice plant ability to compensate for pest damage at different stages of plant growth; c) Pest population dynamics pattern during the spring and summer rice seasons; d) Share of natural enemies activity in the formation of resistance of the rice agro-ecosystem to pest injurious activity; e) Analysis of the pattern of pest population dispersion and elaborations of the method of monitoring of pest and its enemy populations for improvement of decision making; f) Use of bacteria compounds as the most environment-friendly insecticides; and g) Elaboration of the principle technological scheme (program) of PEM under the condition of the Red River Delta.

11.2 Paddy Agro-Ecosystem

The basic feature of the paddy agro-ecosystem is a combination of two life environments – aquatic and terrestrial ones that determine trophical relations of organisms connected with both kinds of environments (Settle, 1991). The detritophages and screeners build up the first level of substance and energy circulation which is not reserved because of many detritophagous arthropods and screeners are prey of generalist predators, e.g. spider-wolf, *Pardosa pseudoannulata*, during 20 days after transplanting (DAT) of rice sprouts particulary in the beginning of rice season (Table 11.1).

Thus, in a paddy agro-ecosystem, long before rice plant begins to play an important role in the environment formation in a given paddy field, significant stock of natural enemy populations are formed that will later determine an ecological situation in paddy agro-ecosystem. Overall, more than 220 species of predators and parasites are regular for the paddy agro-ecosystem in south China (Pu Zhelong and Zhou Changqing, 1986). During our investigation about 20 species of predators and parasitic Hymenoptera were most visible and important in natural biological control of rice pests (Table 11.2) (Sugonyaev et al., 1995).

The natural enemies are very convenient for identification from practical point of view as indicative zoophagous species the farmers recognize most of them in a field easily (after some training). It is believed that the number of indicative zoophagous species counted in a given paddy field reflects a general species diversity of zoophages. Besides there are four species of microhymenopteroid egg parasites of LF – *Trichogramma chilonis*, and YSB – *T. japonicum, Tetrastichus schoenobii* (Chalcidoidea) and *Telenomus dignus* (Scelionidae).

In general, an increase of zoophage numbers in paddy field without the use of insecticide treatment displays some correlation with rice growth. Although the

Table 11.1 Main functional groups of the paddy agro-ecosystem (sweep samplings with standard entomological net, 50 beats) in rice summer season

Date	DAT	Functional groups (%)		
		Zoophage	Phytophage	Detritophage and Screener
1993				
5.07	9	3.8	0.61	95.6
22.07	15	15.2	5.1	79.7
05.08	29	20.7	5.3	74.0
12.08	35	50.9	14.4	34.7
19.08	42	41.1	12.08	46.9
24.08	48	30.7	16.0	52.5
31.08	54	51.1	23.2	25.7
09.09	63	32.5	7.3	60.1
16.09	70	38.4	12.1	49.5
21.09	75	43.8	10.7	46.7
1994				
25.07	14	10.7	0.0	89.3
01.08	21	12.0	0.0	88.0
08.08	28	8.2	1.4	90.4
15.08	35	12.0	1.0	87.0
24.08	44	37.3	22.6	31.1
12.09	65	19.6	25.0	55.4
19.09	72	12.6	12.5	58.9

Table 11.2 The main zoophagous species in the paddy arthropod community

Type of zoophage, species and species group	Prey, host			
	LF	YSB	Other moth-species	Plant hopper
1	2	3	4	5
Predator				
Aranei				
Pardosa pseudoannulata	+	+	+	+
Oxyopes javanus	+	+	+	
Tetragnatha maxillosa	+		+	
Araneus spp.	+		+	+
Clubionia japonicola	+		+	+
Phidippus sp.				+
Coleoptera				
Micraspis spp.	+		+	+
Ophionea nigrofasciata	+		+	
Pederus fuscipes	+		+	+
Carabidae, gen., sp.	+		+	+
Odonata				
Agriocnemis spp.				+
Heteroptera				
Microvelia sp.				+
Cyrtorhinus lividipennis Reut.				+
Tettigoniidae				
Conocephalus spp.		+		
Parasitic Hymenoptera				
Cardiochiles philippinensis	+			
Temilucha philippinensis	+	+		
Xanthopimpla flavilineata		+		
Apanteles ruficrus, inc. coccon group			+	
A. cypris, inc. single coccon	+			
Charops bicolor, inc.coccon suspended at leaf			+	

numbers of any single species of entomophage may change. Nevertheless, their mean number is relatively high and constant during the season, forming a so called biological barrier. Which put together are hundreds of specimens indicative zoophagous species registered during 30 minutes of walk through the plot, in the peak for the mid-season (40–60 DAT) (Sugonyaev and Monastyrskii, 1997, 2008). In the first half of both rice seasons spider-wolf, *P. pseudoannulata*, is the main dominating species – the curve of its numbers correlates best with that of the total numbers of all registered predators. In the spring rice season small beetles (Staphylinidae, Carabidae) also reach significant numbers in the middle of cropping season whereas lady beetles, *Micraspis* spp., reach the most numbers in the middle – end of the season. In the middle of the summer rice season spiders (*Oxyopes javanus, Araneus* spp., etc), dragon-fly (*Agriocnemis* spp.) and predaceous grasshopper (*Conocephalus* sp.) have significant contribution to the total number of predators. Thus, the probable importance of zoophages rises until the numbers of detritophages and screeners decline while pest populations grow uniformly. The change of the zoophagous species numbers is almost similar, both in optimal and late-planted paddy fields in contrast to cotton, for instance (Sugonyaev, 1994).

11.2.1 Economic Threshold (ET)

For solution of ET issues, data of experimental research in laboratory and field surveys was critically analyzed. The main variety of rice was CR203, and in special cases other varieties were also used. Concept of ET accepted fixed quantity of both 5 per cent and 7 per cent yield loss admissible levels (YLAL) which form the economic basis of ET.

11.2.1.1 ET of Leaf Folder (LF)

From the studies, it was found that if the average rate of leaffolder damaged leaves increased by 1% then the loss of grain increased by 0.3% approximately. Since plant ability for damage compensation decreases with growth of a plant, the equations have been developed for both vegetative (1) and reproductive (2) periods of the plant cycle (Monastyrskii and Sugonyaev, 1995; Sugonyaev and Monastyrskii, 1997, 2008).

$$a(\%) = \left[\frac{(0.088 + 0.844N) \times e^{(0.204-0.0085N)T}}{-53.95 + 30.021\ln(t_0 + T)}\right] \times 100 \qquad (11.1)$$

where: a (%) – level of damage leaves in %;

N – density of pest population;
T – duration of pest activity;
t_0 – days after transplanting (DAT);
e – basis of natural logarithm.

$$a(\%) = \left[\frac{(0.088 + 0.844N) \times e^{(0.204-0.0085N)T}}{485 - 106.91\ln(t_0 + T)}\right] \times 100 \qquad (11.2)$$

The equations allow calculating ET of leaf folder at any time during the crop growing season. But as a guide, some data would be useful. For instance, for plant aged 20–30 DAT the ET is 20 (lower level) – 25 (upper level) per cent of damaged leafs; for 50–70 DAT – 6–8 per cent of damaged leafs. Of course, the information will be more useful if lower and upper levels of larvae number are also used. Thus, till 25 DAT, the ET is 1.5–2 larvae per hill, for 70 DAT – 0.15–0.25 larvae per hill (Sugonyaev and Monastyrskii, 1997, 2008).

11.2.1.2 ET of Yellow Stem-Borer (YSB)

"White head" damage appears because of yellow stem borer activity during the reproductive period, i.e. 50–80 DAT, and it has provocative effect on the farmer to treat his paddy field with chemical insecticide. Of course, knowledge of the real YSB, ET is urgently needed (Monastyrskii and Sugonyaev, 2001).

There is a negative correlation between pest damage activity and quantity of stems per hill, a count of stem average for at least 20 hills need to be done. For example, the mean number of stems per hill is 7.0. If the unit is a hill, make use of the counted diagram (Fig. 11.1). The equation for calculation is:

$$D^{st}(\%) = \left(\frac{n}{N \times x}\right) \times 100 \tag{11.3}$$

where: n – quantity of damaged hills;

N – quantity of hills in the sample;
x – a mean of stems per hill.

For example, there are 100 damaged hills in the sample out of 500 total hills while the mean number of stems per hill is 7.0.

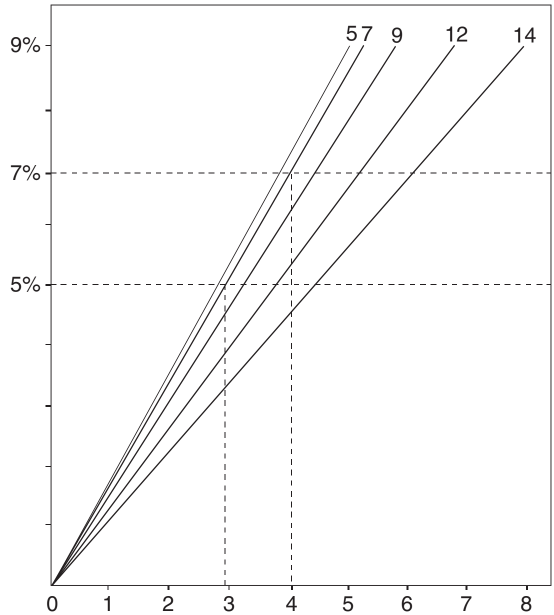

Fig. 11.1 The diagram showing on dependence of grain loss as a result of damaged stems by yellow stem-borer, *Scirpophaga incertulas*, into hills with different quantity of stems per 1 hill – 5, 7, 9, 12 and 14 ones. On ordinate axis – grain loss in %; on absciss axis – stem in %

Table 11.3 The probable threshold meanings of YSB damages for 5 and 7% YLAL

Plant age, DAT	YLAL	Maximal quantity of damaged stems per hill
20–35	5%	0,9
	7%	1,7
36–55	5%	0,4
	7%	0,8
56–75	5%	0,7
	7%	1,1

$$D^{st}(\%) = \left(\frac{100}{500 \times 7.0}\right) \times 100 = 2.86\%$$

In order to know the weight of this value use diagram (Fig. 11.1), and draw the perpendicular from the found point 2.86% to the intersection with the inclined line giving the mean of stems per hill. In our case, the point of the intersection will be on the horizontal line giving 5% YLAL, i.e. no serious injury. Next 7% YLAL would be about 4% of damaged stems.

The relation between the growth stage of plant, the quantity of damaged stems and YLAL for preliminary decision making can be determined by Table 11.3.

The recommended ET is characterized by two levels – a lower and upper one. In other words, ET is not one fixed line but a sort of strip. The notion of ET levels is useful for improving decision making because it allows in evaluating a change in pest population density not only at one moment of time but over a period of time also. Really, if ET is just a line then any crossing of the line will mean a need for immediate managing action – often treatment with insecticide. However, if two-leveled ET is used then the process of population density change can be watched because the crossing of the lower level by pest number curve does not mean a need of immediate managing action. In fact, the curve perhaps will not reach the upper level of the ET, and consequently no measure is required. Thus, two-leveled ET informs and improves the decision making process. In terms of this concept, the lower and upper levels of ET are threatening and operative ones, respectively.

11.2.2 Zoophage Efficiency Level (ZEL)

Zoophage Efficiency Level is a definite summed up population density of indicative zoophagous species, which is typical for field study state in ecological science, and used for cotton field monitoring (Sugonyaev, 1994). From our studies of several years it is clear that the higher the indicative zoophagous species number, the lower the number of leaves damaged by LF, (Sugonyaev and Monastyrskii, 1997).

A pattern of indicative zoophagous species appearance during the season shows that its number reaches the peak mostly during the mid-season. Based on empirical data we consider that the zoophage numbers in the range of 70–100 specimens per survey in mid-season (about 50 DAT) is the minimal zoophage efficiency level (ZEL). It shows a probable steady type of a given paddy agro-ecosystem which is most resistant to lepidopteroid pest injury. On the contrary, a number of 30–50 specimens of indicative zoophagous species imply an unsteady type of paddy agro-ecosystem that is more prone to lepidopteroid pest problems. The advantage of this method is an opportunity to estimate both a probable injury level of pest and an ecological situation in paddy that is important for decision making process.

The next important point for decision making is to take into consideration the parasitization of egg masses of yellow stem borer by hymenopteroid parasitic species collected during examination of 100 hills. Each single egg mass is put into a separate small test tube for rearing, either yellow stem borer larvae or minute parasitic wasps, or the former and the latter together. If the parasitization of egg masses is about 70 per cent, then approximately 50 per cent of host eggs will be eliminated, i.e. probability of pest damage reduces by two times. The parasitization of egg masses by about 90 per cent indicates insignificant damage in the coming week.

11.3 Monitoring for Decision Making

Decision making based on the sequential method of sampling and analysis, and a weekly ZEL field survey is the operative ground of rice pest and its enemy management (PEM) program. Of course, a standardization of survey methods is a prerequisite of PEM implementation. Standard survey forms (SSF) for definite age period of rice plant based on biometrical interpretation of an insect dispersion pattern are offered. SSF are used for quick field survey and preliminary decision making by summing up of both pest infested and non infested rice hills till the drawn curve will cross either lower or upper inclined lines of the figure, meaning lower and upper levels of the ET. Accordingly, the lower intersection means there is no necessity for managing action while the higher intersection implies the need for such action.

Besides the SSF include definite predictable information because the size of the first, “harmless” zone lying under lower level gives objective guidance on the general susceptibility of paddy field to lepidopteroid pest problems. Actually, the declining of the 1st zone and an increase of the 2nd “harmful” zone show how a lepidopteroid pest problem probability grows from early to mid-season. The above described method is used directly for the counting of leaffolder larvae and stems damaged by yellow stem borer in rice hills (Sugonyaev and Monastyrskii, 1997, 2008; Sugonyaev et al. 1997; Monastyrskii and Sugonyaev, 2005).

In any case, the calculation of indicative zoophagous species needs thirty-minutes walking on ridge along the edges of the paddy fields. During final decision making there is a necessity to follow next directions. For example, the density of indicative zoophages reaches the ZEL, and at the same time the summed up curve of leaffolder number crosses the upper level of the ET after examination of at least 40 hills then a managing action is not needed. If the upper level of the ET is crossed after examination of less than 40 hills, for instance 20–30 hills, a managing action is needed. The density of 20–50 indicative zoophages in a given paddy field in any case shows a necessity of a managing action.

In case of yellow stem borer, counting of egg masses parasitization by parasite wasps is essential for taking any management action. This way of identification of ecological situation in a given paddy field seems complicated but there is a need to get improved information because every chemical insecticide application is undesirable from ecological point of view and it must be rejected even if there is some risk.

11.4 IPM Tools

11.4.1 Application of Bacteria Compound

From our studies, it was clear that one application of 1% solution of Bitoxibacillin$^{\text{TM}}$ (BTB-202) decreases a leaf folder population by about 60% within 5 days of treatment. In PEM program, such effectiveness is satisfactory because the remaining part of the pest population will be devoted by entomophages owing to a change of entomophage: pest ratio in favor of the former. On the other hand, BTB-202 made in Russia showed itself to be a effective compound under the tropical condition. But BTB-202 is not recommended for suppression of yellow stem borer population because of protective mode of life of the latter.

11.4.2 Manipulation of Transplanting Time

Time of rice transplanting largely determines the feature of a relationship between rice plant and pest. There is a link between plant growth studies and probability of yellow stem borer injury. The critical point is the time of panicle initiation: the rice crop with early panicle initiation is much less susceptible to the pest injury activity. So, the variety with the early panicle initiation (∼56 DAT) is not damaged by yellow stem borer or damage is upto 1–1.5% only. Yellow stem borer to the extent of 8–10% may damage v.v., variety with comparatively late panicle initiation (∼77 DAT) because in this case plant growth stage coincides with the peak of yellow stem borer moths flying stage (Sugonyaev and Monastyrskii, 2007).

In general, under the condition of the Red River Delta, (a) In the spring rice season if the plant ripening stage in a given paddy begins in the middle of May then the crop will be less prone to lepidopteroid pest problems; (b) In case of summer rice season a ripening stage begins first, partly in second ten-day period of September then a given paddy will have more tolerance to lepidopteroid pest injury.

11.4.3 Monitoring and Decision Making

The SSF for revealing of lepidopteroid pest density and damage level are good ground for PEM program implementation. However, PEM will run the risk if principle of ET is used as a sort of a trigger for chemical insecticide application. That is why an incorporation of the ZEL and YSB egg masses parasitization (70%) in the decision making process is a necessity.

11.4.4 Application of Broad-Spectrum Chemical Insecticides

From the PEM strategic point of view, less is always better when it comes to insecticide application in rice. The regulation of insecticide application are: (a) when pest number curve crosses the upper level of the ET and when the density of indicative zoophages is low (20–50 specimens per survey); (b) unavailability of bacterial compounds and other biological means of control; (c) local use of insecticide at damaged plot or spot application only; (d) rejection of so called “prophylactic” application; (e) screening of most safe insecticides for zoophages, its dosage and application methods.

11.4.5 Tactics of the PEM Program Implementations

There is a definite pattern of population density dynamics of lepidopteroid pest in each rice growing season. In the spring (1st) season the increase of lepidopteroid pest abundance has a low rate, and as a rule it does not reach ET. On the contrary, the summer (2nd) season is characterized by fast increase in their population density, and a strong probability of crossing the upper (operative) level of ET (Vu Quang Con, 1992; Sugonyaev and Monastyrskii, 1997, 2007). Almost every year, the critical situation necessitating rice protection appears during rice flowering at the end of August and in the first ten days of September when the peak of 6th generation of leaf folder and 5th generation of yellow stem borer take place. Thus, perennial data allows us to distinguish the period of natural history for both leaf folder and yellow stem borer when their damage activity is high, and at the same time, the opportunity for suppression of pest populations is also good. During this period one treatment by bacterial compound, for instance BTB-202, will take care of lepidopteroid pest problem in rice and address two main tasks: a) rice protection and b) particularly conservation of paddy agro-ecosystem biodiversity and natural enemy populations. It is assumed that suppression of leaf folder population and preservation of zoophage number in a given paddy creates the ground for natural control of yellow stem borer, brown planthopper and other insect pests by maintaining their population below their economic thresholds (Sugonyaev and Monastyrskii, 1997, 2008).

11.5 Effectiveness of Rice Pest and Its Enemy Management Program

The principle technological scheme of rice pest management on ecological basis is the creation of the optimized ET for both leaf folder and yellow stem borer, ascertaining the ZEL, and formalization of survey through SSF for improveing to a great extent the decision making process and rice protection on the whole under the conditions of the Red River Delta.

The tactics of PEM program implementation allows six times decrease in the of quantity of chemical insecticide treatments which are conventionally in use here. As it has been discussed above, one per year and time fixed treatment with bacterial compounds would be more effective and cheaper than two-three treatments with chemical insecticides during the same period. Simultaneously, the former removes the problem of pest resurgence, for example, brown planthopper, the cost of which may be much higher. This feature of the paddy agro-ecosystem is the direct consequence of high activity of natural enemies there by maintaining most of the rice pest species below their economic threshold level. The similar conclusion has been drawn by our Vietnamese colleagues as a result of organization of farmers' IPM demonstration schools in the south and north parts of the country. Almost everywhere, both in rice crop treated with chemical insecticides and untreated ones, the rice harvests have been similar (Tran Quy Hung and Pham Thi Nhat, 1994).

The worth of the suggested PEM program is its relative simplicity for rice farmer after training, e.g. in farmer's school. The result of our research have proved that it is not necessary to spend about $1 billion (Lampe, 1994) on chemical pesticide treatments under the tropical condition in South-East Asia because a mobilization of natural control resources on an ecological basis, and the definite investment into production and distribution of bacteria compounds, e.g. Bitoxibacillin™, ensure success in productive rice growing, removal of the danger of both outbreaks of secondary rice pest and pesticide pollution of the environment.

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