ABUNDANCE OF NATURAL ENEMIES OF RICE INSECT PESTS IN THAILAND

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Abstract

In this report, evidence is presented on the abundance of natural enemies of rice insect pests in Thailand, describing their seasonal occurrence throughout the year, their relative abundance, the high frequency of the joint activity of several species of egg parasites, and the results of continuous observations on the activity of some natural enemies during one crop season of rice in paddy fields.

Introduction

Studies of natural enemies of rice insece pests of major economic importance in Thailand have been performed for the past eight years through the financial assistance of the Department of Agriculture and the Department of Technical and Economic Cooperation of the Government of Thailand, the Food and Agriculture Organization of the United Nations and the Japan International Cooperation Agency. In this report we present a part of our studies on the abundance of natural enemies of rice insect pests of major economic importance in Thailand.

Materials and methods

Almost all the specimens of natural enemies were collected by the sweep-net method, using an ordinary insect-collecting net 3.5 cm in diameter. Specimens of natural enemies captured were placed in a wide-mouthed cyanide jar together with the other insects. When the materials in the jar were dead, they were brought to the laboratory or temporarily preserved in the vial with 70% alcohol and examined under a binocular microscope, and the number of each species was recorded. In some cases, the eggs and larvae of the pest insects were taken and brought back to the laboratory for future emergence of parasites.

Our research trips covered almost all the prefectures of Thailand. For the sake of convenience and importance we have classified the major rice insect pests as follows:

Defoliators: - *Cnaphalocrocis medinalis, Nymphula depunctalis, Pelopidas mathias, Methimna separata,* etc.

Stem borers: - *Chilo polychrysus, Scirpophaga nivella, S. gilviberbis, Tryporyza incertulas, Sesamia inferens,* etc.

Hoppers: - *Nephotettix* spp., *Nilaparvata lugens, Sogatella furcifera,* etc.

Gall midge. - *Orseolia oryzae.*

Revised list of natural enemies of the major rice insect pests in Thailand

Defoliators

Egg parasites:

Trichogramma japonicum (Trichogrammatidae)

Trichogramma spp. (Trichogrammatidae)

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Larval parasites:
Argyrophylax nigritibialis Baranov (Tachinidae) (Host: *Pelopidas mathias*)
Dolichocolon vicinum Mesnil (Tachinidae) (Host: *Mythimna separata*)
Eocarcalia illota Curran (Tachinidae) (Host: *Mythimna separata*)
Exorista xanthaspis Wiedeman (Tachinidae) (Host: *Mythimna separata*)
Halidaya luteipennis Walker (Tachinidae) (Host: *Pelopidas mathias*)
Charops bicolor (Szépligeti) (Tachinidae) (Host: *Pelopidas mathias*)
Apanteles baoris Wilkinson (Braconidae) (Hosts: *Parnara guttata, Pelopidas mathias*)
Brachymeria lasus (Walker) (Chalcididae) (Host: *Pelopidas mathias*)
Brachymeria excarinata Gahan (Chalcididae) (Host: *Cnaphalocrocis medinalis*)
Brachymeria spp. (Chalcididae)
Anthrocephalus spp. (Chalcididae)
Dirhinus spp. (Chalcididae)
Elasmus spp. (Elasmidae)
Tentatively identified as: *Elasmus hyblaeae, E. brevicornis, E. luteus, E. claripennis, E. zehntneri.*
Litomastix sp. (Encyrtidae) (Hosts: Noctuid larvae)
Parsierola sp. (Bethylidae)
Platyscelio abnormis Crawford (Scelionidae)

The following Tachinids have been recorded as parasites of *Mythimna separata* but further confirmation is needed: *Carcelia kockiana* Townsend, *Dolichocolon paradoxum* B.B., *Eutachina civiloidea* Baranoff, *Alsomyia anomala* Villeneuve, *Pseudogonia jacobsoni* (Townsend) (Tachinidae).

Egg predators:
Conocephalus longipennis (de Haan) (Tettigoniidae)
Conocephalus maculatus (Le Guillou) (Tettigoniidae)
Conocephalus sp. (Tettigoniidae)
Euscyrtus sp. (Encopteridae)
Anaxipha sp. (Trigoniidae)
Metioche vittaticolis Stal (Trigoniidae)
Ants
Larval or pupal predators:
Zicrona caerulea Linne (Pentatomidae)
Geocoris ochropetrus (Fieber) (Lygaeidae)
Reduviids (Reduviidae)
Nabis capsiformis Germar (Nabidae)
Orius tantilus (Motschulsky) (Anthocoridae)
Micraspis discolor (Fabricius) (Coccinellidae)
Micraspis vincta (Gorham) (Coccinellidae)
Harmonia octomaculata (Fabricius) (Coccinellidae)
Ophionea indica (Thunberg) (Carabidae)
Ophionea ishiii Mabu (Carabidae)
Paederus fuscipes Curtis (Staphylinidae)
Formicomus braminus braminus La Ferté-Senectère (Anthicidae)
Haplochrus rufofasciata Pic (Malachiidae)
Ropalidia fasciata (Fabricius) (Vespidae)
Ropalidia marginata sundaica van der Vecht (Vespidae)
Ants, spiders
Adult predators:
Damselflies, spiders, birds, bats

Stem borers

Egg parasites of *Tryporyza* spp.:
- *Telenomus rowani* (Gahan) (Scelionidae)
- *Telenomus* sp. (Scelionidae)
- *Tetrastichus schoenobii* Ferriere (Eulophidae)
- *Trichogramma japonicum* Ashmead (Trichogrammatidae)
- *Trichogramma chilonis* Ishii (Trichogrammatidae)

Egg parasites of *Chilo* spp.:
- *Telenomus dignus* (Gahan) (Scelionidae)
- *Trichogramma japonicum* Ashmead (Trichogrammatidae)
- *Trichogramma chilonis* Ishii (Trichogrammatidae)
- *Trichogramma chilotraeae* Nagaraja et Nagarkatti (Trichogrammatidae)

Larval or pupal parasites of *Tryporyza* spp.:
- *Temelucha stangli* (Ashmead) (Ichneumonidae)
- *Temelucha philippinensis* (Ashmead) (Ichneumonidae)
- *Amauromorpha accepta schoenobii* (Viereck) (Ichneumonidae)
- *Ischnojoppa luteator* (Fabricius) (Ichneumonidae)
- *Bracon chinensis* Szepligeti (Braconidae)
- *Tropobracon schoenobii* (Viereck) (Braconidae)

Larval or pupal parasites of *Chilo* spp.:
- *Apanteles flavipes* (Cameron) (Braconidae)
- *Bracon chinensis* Szepligeti (Braconidae)
- *Tetrastichus ayyari* Rowher (Eulophidae)

Larval or pupal parasites of *Sesamia inferens:*
- *Apanteles flavipes* (Cameron) (Braconidae)
- *Bracon chinensis* Szepligeti (Braconidae)
- *Tetrastichus ayyari* Rowher (Eulophidae)

Egg predators:
- *Conocephalus longipennis* (de Haan)(Tettigoniidae)
- *Conocephalus maculatus* (Le Guillou) (Tettigoniidae)
- *Conocephalus* sp. (Tettigoniidae)
- *Euscyrtus* sp. (Encopteridae)
- *Anaxipha* sp (Trigoniidae)
- *Metioche vittaticolis* Stal (Trigoniidae)
- *Micraspis discolor* (Fabricius) (Coccinelidae)
- *Micraspis vincta* (Gorham) (Coccinellidae)
- *Harmonia octomaculata* (Fabricius) (Coccinellidae)
- *Formicomus braminus braminus* La Ferté-Senectère (Anthicidae)
- *Ophionea indica* (Thunberg) (Carabidae)
- *Ophionea ishiii ishiii* Habu (Carabidae)
- *Paederus fuscipes* Curtis (Staphylinidae)
- *Hapalochrus rufofasciatus* Pic (Malachiidae)
- *Orius tantilus* (Motschulsky) (Anthocoridae)
- Ants

Larval predators:
- *Anatrichus pygmaeus* Lamb (Chloropidae)
- *Poecilotraphera taeniata* (Macquart) (Platysomatidae)
- *Orius tantilus* (Motschulsky) (Anthocoridae)

Adult predators:
- Damselflies, spiders, ants, birds, bats

Plant- and leafhoppers

Egg parasites:

Paracentrobia garuda Subba Rao (Trichogrammatidae) (Host: *Nilaparvata lugens)*
Paracentrobia yasumatsui Subba Rao (Trichogrammatidae) (Host: *Nilaparvata lugens)*
Oligosita brevicauda Girault (Trichogrammatidae)
Oligosita yasumatsui Viggiani et Subba Rao (Trichogrammatidae) (Hosts: *Nilaparvata lugens, Sogatella furcifera)*
Oligosita sp. (collina Walker group) (Trichogrammatidae)
Anagrus optabilis (Perkins) (Mymaridae) (Hosts: *Nilaparvata lugens, Nephotettix* spp.)
Anagrus spp. (Mymaridae)
Gonatocerus spp. (Mymaridae) (Host: *Nilaparvata lugens*)
Mymar taprobanicum Ward (Mymaridae) (Hosts: *Nilaparvata lugens, Sogatella furcifera)*
Polynema sp. *(Mymaridae)*
Tetrastichus formosanus (Timberlake) (Eulophidae) (Host: *Nilaparvata lugens*)

Nymphal or nymph-adult parasites:

Elenchus yasumatsui Kifune et Hirashima (Elenchidae) (Hosts: *Nilaparvata lugens, Sogatella furcifera*)
Pipunculus mutillatus Loew (Pipunculidae) (Hosts:*Nephotettix nigropictus, Nephotettix virescens*)
Tomosvaryella oryzaetora Koizumi (Pipunculidae) (Hosts: *Nephotettix nigropictus, Nephotettix virescens*)
Tomosvaryella subvirescens (Loew) (Pipunculidae) (Hosts: *Nephotettix nigropictus, Nephotettix virescens*)
Dryinids ca. 3 species
Nematods

Egg and first instar nymphal predators:

Cyrtorhinus lividipennis Reuter (Miridae)

Nymphal or adult predators:

Conocephalus longipennis (de Haan) (Tettigoniidae)
Conocephalus maculatus (Le Guillou) (Tettigoniidae)
Conocephalus sp. (Tettigoniidae)
Orius tantilus (Motschulsky) (Anthocoridae)
Geocoris ochropterus (Fieber) (Lygaeidae)
Nabis capsiformis Germar (Nabidae)
Microvelia douglasi Scott (Veriidae)
Gerris adelaidis Dohn (Gerridae)
Limnogonus parvulus (Stal) (Gerridae)
Ephydrid sp. (Ephydridae)
Empids ca. 2 species (Empidae)
Paederus fuscipes Curtis (Staphylinidae)
Micraspis discolor (Fabricius) (Coccinellidae)
Micraspis vincta (Gorham) (Coccinellidae)
Harmonia octomaculata (Fabricius) (Coccinellidae)
Ophionea indica (Thunberg) (Carabidae)
Ophionea ishiii ishiii Habu (Carabidae)
Hapalochrus rufofasciatus Pic (Malachiidae)
Bembicinus sp. (Sphecidae)
Psen sp. (Sphecidae)
Ants, damselflies, spiders, fishes, birds, bats

Gall midge

Egg-larval parasites:
Platygaster oryzae Cameron (Platygasteridae) (Primary egg-larval parasite)
Platygaster foersteri (Gahan) (Platygasteridae) (Primary egg-larval parasite)
Larval parasites:
Obtusiclava oryzae Subba Rao (Pteromalidae) (Mainly secondary, rarely primary parasite)
Eurytoma sp. (Eurytomidae)
Pupal parasites:
Neanastatus oryzae Ferriere (Eupelmidae) (Sometimes primary, sometimes secondary parasite)
Neanastatus cinctiventris Girault (Eupelmidae) (Primary parasite, sometimes secondary parasite)
Egg predators:
Amblyseius imbricatus Corpuz et Rimando (Phytoseiidae)
Ants
Larval or pupal predators:
Ophionea indica (Thunberg) (Carabidae)
Ophionea ishiii ishii Habu (Carabidae)
Adult predators: Ephydrid sp. (Ephydridae)
Empid 2 species (Empidae)
Damselflies, spiders, fishes

Occurrence of natural enemies of rice insect pests throughout the year

The results of our analysis of data on the occurrence of some important parasites and predators of rice insect pests are summarized in Tables 1-3.

Table 1 Seasonal occurrence of some important parasites of rice pests as observed from 1972 to 1979 in Thailand

Parasites \ Months	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Trichogramma spp.	●	●	●	●	●	●	●	●	●	●	●	
Paracentrobia spp.	●	●	●	●	●	●	●	●	●	●	●	
Oligosita spp.	●	●	●	●	●	●	●	●	●	●	●	
Anagrus spp.	●	●	●	●	●	●	●	●	●	●	●	
Gonatocerus spp.	●	●	●	●	●	●	●	●	●	●	●	
Mymar taprobanicum	●	●	●	●	●			●	●	●	●	
Telenomus spp.	●	●	●	●	●	●	●	●	●	●	●	
Tetrastichus schoenobii	●	●	●	●	●	●	●	●	●	●	●	
Tetrastichus formosanus	●	●	●	●	●	●	●	●	●	●	●	
Platygaster spp.		●	●	●	●	●	●	●	●	●	●	
Neanastatus spp.	●	●	●	●	●	●	●	●	●	●	●	
Obtusiclava oryzae		●	●	●	●	●	●	●	●	●		
Predacious Ceratopogonids		●	●	●	●	●		●	●	●	●	
Elasmus spp.	●	●	●	●	●	●	●	●	●	●	●	●
Apanteles spp.	●	●	●		●	●	●	●	●	●	●	●
Tropobracon schoenobii	●	●	●	●		●		●	●		●	●
Elenchus yasumatsui		●	●	●	●			●	●	●	●	
Pipunculids	●	●	●		●	●		●	●	●	●	

Table 2 Seasonal occurrence of some important predators of rice pests as observed from 1972 to 1979 in Thailand

Predators \ Month	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Amblyseius imbricatus	●	●	●	●	●	●	●	●	●	●	●	
Conocephalus spp.	●	●	●	●	●	●	●	●	●	●	●	●
Damselflies	●	●	●	●	●	●	●	●	●	●	●	●
Spiders	●	●	●	●	●	●	●	●	●	●	●	●
Geocoris ochropterus		●	●		●	●			●	●	●	
Nabis spp.		●	●		●				●		●	●
Orius tantilus	●	●	●	●	●	●	●	●	●	●	●	●
Cyrtorhinus lividipennis				●	●	●	●	●	●	●	●	●
Micraspis spp.	●	●	●	●	●	●	●	●	●	●	●	●
Harmonia octomaculata	●	●	●	●	●	●	●	●	●	●	●	●
Ophionea spp.	●	●	●	●	●	●	●	●	●		●	
Paederus fuscipes				●	●							
Formicomus braminus	●	●	●	●	●	●	●	●	●	●	●	●
Ropalidia spp.	●	●			●	●	●	●	●	●	●	●
Anatrichus pygmaeus	●	●	●	●	●	●	●	●	●		●	●
Poecilotraphera taeniata		●	●	●	●	●	●	●	●	●	●	●

Table 3 Seasonal occurrence of four species of damselflies as observed from 1972 to 1979 in Thailand

Damselflies \ Month	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Ischnura senegalensis		●	●	●	●	●	●	●	●	●	●	●
Ischnura aurora		●	●	●	●	●	●	●	●	●	●	●
Agriocnemis femina		●	●	●	●	●	●	●	●	●	●	●
Agriocnemis pygmaea	●	●	●	●	●	●	●	●	●	●	●	●

These tables indicate that many of the important parasites and predators occur throughout the year if the environment is suitable for their survival. The growing season of the first crop of rice usually starts in June and ends in October up to November during the wet season followed by a long fallowing period during the dry season. Farmers of Thailand have been producing rice without using any insecticides in many of the rain-fed paddies since the beginning of rice cultivation. This is the main reason why the populations of natural enemies are very high, maintaining the rice pest populations under the economic injury level. After harvest many of the natural enemies may be forced to migrate from the paddies to other favorable areas where they can survive during the fallow period. In Thailand, the favorable areas are scattered in the paddies. There are areas of ever-green vegetation with adequate moisture where wild rice or other leguminaceous plants grow even in the dry season. There are corn or sugarcane fields nearby the paddies in the dry season. There are several common insect pests between rice and corn or sugarcane. Thus, such areas are refuge areas for natural

enemies of rice insect pests, and may contribute greatly to their conservation. Recently, with the development of irrigation system, the area of paddies for the second crop of rice has been increasing. Our survey revealed that the population of natural enemies is as high as that in the first crop of rice.

Relative abundance of natural enemies

During our field research trips we collected a number of specimens of natural enemies of rice insect pests. Table 4 indicates the relative abundance of several important species.

Table 4 Number of collected specimens of natural enemies of rice insect pests (1976 – 1979)

Natural enemy	Parasite or Predator	Number collected
Amblyseius imbricatus	Predator	15970
Spiders	Predator	11605
Oligosita spp.	Parasite	11015
Anagrus spp.	Parasite	4143
Trichogramma spp.	Parasite	2027
Damselflies	Predator	1849
Telenomus spp.	Parasite	1434
Coccinellids	Predator	1432
Platygaster spp.	Parasite	1184
Conocephalus spp.	Predator	1042
Anatrichus pygmaeus	Predator	1041
Gonatocerus spp.	Parasite	938
Orius tantilus	Predator	672
Paracentrobia spp.	Parasite	598
Elenchus yasumatsui	Parasite	562
Tetrastichus formosanus	Parasite	497
Dryinids	Parasite	402
Tetrastichus schoenobii	Parasite	394
Sepedon spp.	Host of Parasite	375
Cyrtorhinus lividipennis	Predator	365
Tachinids	Parasite	322
Pipunculids	Parasite	170
Poecilotraphera taeniata	Predator	167
Neanastatus spp.	Parasite	140
Ophionea spp.	Predator	131
Gryon nixoni	Parasite	125
Eurytoma sp.	Parasite	93
Mymar taprobanicum	Parasite	64

Obviously, the figures showing the relative abundance of natural enemies may vary from year to year, from locality to locality, or from season to season. But, we can evaluate the dominance among the natural enemies, though their high number is not always associated with the effectiveness of the species in the regulation of rice insect pest populations.

Co-existence of several species of egg parasites against one egg mass of rice insect pests

Co-existence of several species of egg parasites against one egg mass of rice insect pests is a rather common phenomenon. We investigated this co-existence in the egg masses of *Tryporyza incertulas, Nilaparvata lugens* and *Sogatella furcifera*. The results are shown in Tables 5 and 6.

Table 5 Examples of 183 rice paddies where eggs of *Tryporyza incertulas* were parasitized in various districts of Thailand (1972 – 1979)

Parasites	No. of cases	Frequency (%)
Case of a single genus and species		
Trichogramma sp.	12	6.55
Telenomus sp.	12	6.55
Tetrastichus schoenobii	19	10.38
Case of co-existence of different genera and species		
Telenomus sp. and *Tetrastichus schoenobii*	35	19.12
Trichogramma sp. and *Tetrastichus schoenobii*	25	13.66
Trichogramma sp. and *Telenomus* sp.	16	8.74
Trichogramma sp., *Telenomus* sp. and *Tetrastichus schoenobii*	64	34.97

As seen from Tables 5 and 6, egg masses of three species of rice insect pests are usually attacked by more than one species of egg parasites at the same time in the same paddies. On the contrary the emergence of one species of parasite from one egg mass is very rare. Each species of egg parasite may have its specific life-cycle, behavior and adaptability to its environmental conditions. Although interspecific competition between the species of egg parasites seems to occur, more advantage would be expected in the percentage of egg parasitism if the fauna of egg parasites were richer and if more abundant egg parasite complexes were found in the paddies. In addition to the egg parasite complex, there are many predacious natural enemy complexes against the eggs of rice insect pests.

Continuous observations on the activity of natural enemies of rice insect pests during one rice crop season in the paddies

In 1973, we made experiments to observe the activity of natural enemies of rice insect pests at the Rice Experiment Stations of Khlong Luang in the central plain, and San Pa Tong in the north. The schedule is shown below.

Size of one replication plot:	100 m²
Three replications	
Spacing between hills:	25 x 25 cm
One row with 20 hills	
Weed control by hand	
Fertilizer:	N : P : K 16 : 20 : 0, 60 kg/rai, two applications after transplanting, after 20 days and 40 days.
Rice varieties used:	
Resistant varieties:	Glutinous variety RD4 and non-glutinous variety BKN 6809. 74-4.
Susceptible varieties:	Glutinous variety RD2 and non-glutinous variety TN1.
Insect pests chiefly concerned:	Defoliators, stem borers, hoppers and gall midge.
Their natural enemies including predators and parasites	

Table 6 Examples of 177 rice paddies where eggs of *Nilaparvata lugens* and *Sogatella furcifera* were parasitized in various districts of Thailand (1973 – 1979)

Parasites	No. of cases	Frequency (%)
Case of a single genus and species		
Oligosita sp. (Dominant sp.: *yasumatsui*)	2	1.12
Anagrus sp. (Dominant sp.: *optabilis*)	2	1.12
Gonatocerus sp.	3	1.69
Mymarid sp. (Dominant sp.: *Mymar taprobanicum*)	1	0.56
Tetrastichus formosanus	4	2.25
Case of co-existence of different genera and species		
P, O, A, G, M, T	1	0.56
P, O, A, G, M	1	0.56
P, O, A, G, T	32	18.07
P, O, A, G	29	16.38
P, O, A, M	1	0.56
P, O, A, T	8	4.51
P, O, G, T	8	4.51
P, O, A	8	4.51
P, O, G	2	1.12
P, O, T	4	2.25
P, O	3	1.69
P, A, G, M, T	2	1.12
P, A, G, T	2	1.12
P, A, G	1	0.56
P, G, T	1	0.56
P, A	1	0.56
P, G	1	0.56
O, A, G, M	3	1.69
O, A, M, T	1	0.56
O, A, G, T	9	5.08
O, A, G	10	5.64
O, A, M	1	0.56
O, A, T	8	4.51
O, A	10	5.64
O, G, M	1	0.56
O, G. T	1	0.56
O, M, T	1	0.56
O, G	4	2.25
O, M	1	0.56
O, T	4	2.25
A, G, T	1	0.56
A, G	1	0.56
G, T	3	1.69

Period and frequency of surveys: Eight surveys, from transplanting to harvesting.
Method to determine the degree of infestation: See Nishida (1967), Nishida *et al.* (1970).

Remarks:
Yield of grains in San Pa Tong area is much higher than that in Khlong Luang area owing to the fertility of the soil. So far as the injury caused by rice insect pests remained under 5 percent, no insecticidal treatment was applied.

According to the specialists in spider studies, the number of species collected by the sweep-net method amounts to 40 to 50 percent of the whole population of spiders on rice plants. Therefore, the actual number of spiders per hill or per unit area may be about twice the figures indicated in the Tables. The percentage of leaf- and planthoppers collected by the same method shows the same tendency as that for the spiders.

With damselflies, comparison was made between the number of individuals carefully observed and counted in a unit area and those captured by sweep-net method. As indicated in Table 7, the number of damselflies observed was far superior to that of those collected.

Table 7 Number of damselflies observed per unit area in the rice paddies at Khlong Luang Rice Experiment Station. Figures in brackets indicate the number of damselflies captured by sweep-net method

Date of observation	Experimental plot			
	RD2	RD4	TN1	BKN
August 22, 1973	82	20	40	69
September 3	31	34	41	43
September 13	760	796	776	1056
	(272)	(560)	(432)	(412)
	2.7*	1.4*	1.8*	2.3*
September 27	456	320	424	272
	(52)	(22)	(44)	(72)
	8.8*	19.0*	9.0*	3.8*
October 11	276	240	96	156
	(20)	(44)	(28)	(72)
	13.8*	5.4*	3.1*	2.1*
October 24	120	108	92	52
	(0)	(8)	(4)	(0)
		13.5*	23.0*	
November 1	48	60		60
	(4)	(20)		(22)
	12.0*	3.0*		2.7*
November 12	108	96		
	(0)	(0)		

* indicates the rate of the observed number of damselflies to that of those captured by sweeping method.

In the following tables (Tables 8 to 23) we give a part of our results which should help emphasize the abundance of natural enemies of rice insect pests in the undisturbed paddies of Thailand.

Table 8 **Estimated number of damselflies per unit area in experimental plot in rice paddies at Khlong Luang Rice Experiment Station. Figures in brackets indicate the estimated number of damselflies per acre**

Date of observation	Experimental plot				Average
	RD2	RD4	TN1	BKN	
August 22	82	20	40	67	
	(1093.3)	(266.6)	(533.3)	(893.3)	(696.6)
September 3	31	34	41	43	
	(413.3)	(453.3)	(546.3)	(573.3)	(496.6)
September 13	760	796	776	1056	
	(10146.6)	(10613.3)	(10346.6)	(14080.0)	(11296.6)
September 27	456	320	424	272	
	(6080.0)	(4266.6)	(5653.3)	(3626.6)	(4906.6)
October 11	276	240	96	156	
	(3680.0)	(3200.0)	(1280.0)	(2080.0)	(2560.0)
October 24	120	108	92	56	
	(1613.3)	(1440.0)	(1226.6)	(746.6)	(1256.6)
November 1	48	60		60	
	(640.0)	(800.0)		(700.0)	(746.6)
November 12	108	96			
	(1440.0)	(1280.0)			(1360.0)

Table 9 **Estimated number of damselflies per unit area in experimental plot in rice paddies at San Pa Tong Rice Experiment Station. Figures in brackets indicate the estimated number of damselflies per acre**

Date of observation	Experimental plot				Average
	RD2	RD4	TN1	BKN	
September 5	17	20	31	37	
	(200.6)	(266.6)	(413.3)	(493.3)	(343.4)
September 14	42	37	98	112	
	(560.0)	(493.3)	(1306.6)	(1493.3)	(963.3)
September 25	248	269	247	206	
	(3306.6)	(3586.6)	(3270.0)	(2746.6)	(3227.4)
October 6	180	160	192	180	
	(2400.0)	(2133.3)	(2560.0)	(2400.0)	(2373.3)
October 15	256	368	304	384	
	(3413.3)	(4906.6)	(4053.3)	(5120.0)	(4373.3)
October 25	16	224	80	80	
	(213.3)	(2986.6)	(1066.6)	(1066.6)	(1333.2)
November 5	60	38			
	(800.0)	(506.6)			(653.3)
November 15	32	46			
	(426.6)	(613.3)			(519.9)

Table 10 Estimated number of damselflies per hills in rice paddies at Khlong Luang Rice Experiment Station

Date of observation	Estimated number of individuals per unit area in experimental plot	Area covering the number of hills where one damselfly is found
August 22	52.2	91.9
September 3	37.2	129.0
September 13	846.5	5.7
September 27	368.0	13.0
October 11	167.0	29.0
October 24	94.0	51.0
November 1	56.0	35.7
November 12	102.0	47.0

Table 11 Estimated number of damselflies per hills in rice paddies at San Pa Tong Rice Experiment Station

Date of observation	Estimated number of individuals per unit area in experimental plot	Area covering the number of hills where one damselfly is found
September 5	28.2	148.0
September 14	72.2	66.4
September 25	242.5	19.7
October 6	178.0	26.9
October 15	328.0	14.6
October 25	100.0	48.0
November 5	49.0	97.9
November 15	39.0	123.0

Table 12 Estimated number of spiders per unit area in experimental plot in rice paddies at Khlong Luang Rice Experiment Station

Date of observation	Experimental plot				Average
	RD2	RD4	TN1	BKN	
August 22	29	30	22	27	27.0
September 3	26	22	18	26	23.0
September 13	248	476	292	392	352.0
September 27	300	384	382	340	351.5
October 11	256	352	612	292	378.0
October 24	68	88	252	144	138.0
November 1	536	276	480		428.5
November 12	16	28			22.0

Table 13 Estimated number of spiders per unit area in experimental plot in rice paddies at San Pa Tong Rice Experiment Station

Date of observation	Experimental plot				Average
	RD2	RD4	TN1	BKN	
September 5	94	81	87	155	104.2
September 14	163	213	117	189	170.5
September 25	218	183	247	360	252.0
October 6	472	384	432	744	508.0
October 15	328	324	100	488	310.0
October 25	172	200	300	325	249.2
November 5	288	352			320.0

Table 14 Estimated number of spiders per hills in rice paddies at Khlong Luang Rice Experiment Station

Date of observation	Estimated number of individuals per unit area in experimental plot	Number of hills harboring one spider
August 22	27.0	177.7
September 3	23.0	208.6
September 13	352.0	13.6
September 27	337.5	15.2
October 11	378.0	12.7
October 24	138.0	35.1
November 1	430.6	1.0
November 12	22.0	24.4

Table 15 Estimated number of spiders per hills in rice paddies at San Pa Tong Rice Experiment Station

Date of observation	Estimated number of individuals per unit area in experimental plot	Number of hills with one spider
September 5	104.2	46.1
September 14	170.5	28.1
September 25	252.0	19.0
October 6	508.0	9.4
October 15	310.0	15.4
October 25	249.0	19.2
November 5	320.0	15.0

Table 16 Estimated number of *Conocephalus* spp. per unit area in experimental plot in rice paddies at Khlong Luang Rice Experiment Station. Figures in brackets indicate the number of rice stem borer eggs observed

Date of observation	Experimental plot			
	RD2	RD4	TN1	BKN
September 13	8	8	0	4
	(16)	(6)	(7)	(3)
September 27	20	0	24	12
	(236)	(1)	(1)	(0)
October 11	4	4	36	4
	(112)	(0)	(32)	(32)
October 24	16	4	44	8
	(16)	(0)	(32)	(0)
November 1	20	4		
	(0)	(0)		
November 12	4	4		
	(0)	(0)		

Table 17 Estimated number of *Conocephalus* species per unit area in experimental plot in rice paddies at San Pa Tong Rice Experiment Station. Figures in brackets indicate the number of rice stem borer eggs observed

Date of observation	Experimental plot			
	RD2	RD4	TN1	BKN
October 6	212	208	120	184
	(0)	(0)	(0)	(0)
October 15	44	46	8	56
	(0)	(0)	(0)	(0)
October 26	16	68	10	32
	(0)	(0)	(0)	(0)
November 5	16	32		
	(0)	(0)		

Table 18 **Estimated number of defoliators and their predators and parasites per unit area in experimental plot in rice paddies at Khlong Luang Rice Experiment Station. Figures in brackets indicate the number of predators and parasites**

Date of observation	Experimental plot			
	RD2	RD4	TN1	BKN
September 13	32	144	64	128
	(> 32)	(> 36)	(> 48	(> 32)
September 27	176	48	160	94
	(> 48)	(> 12)	(> 44)	(> 24)
October 11	160	32	0	32
	(> 16)	(> 16)	(> 24)	(> 16)
October 24	0	0	0	0
	(0)	(> 8)	(0)	(> 4)
November 1	0	0		0
	(> 8)	(> 16)	>	(> 4)

Table 19 **Estimated number of defoliators and their predators and parasites per unit area in experimental plot in rice paddies at San Pa Tong Rice Experiment Station. Figures in brackets indicate the number of predators and parasites**

Date of observation	Experimental plot			
	RD2	RD4	TN1	BKN
October 6	160	80	64	64
	(32)	(32)	(36)	(0)
October 15	0	0	0	0
	(24)	(20)	(8)	(16)
October 26	0	0	16	16
	(4)	(4)	(8)	(20)
November 5	0	0		
	(50)	(40)		

Table 20 **Estimated number of the egg-parasites (Mymaridae and Trichogrammatidae) per unit area in experimental plot in rice paddies at Khlong Luang Rice Expriment Station**

Date of observation	Experimental plot			
	RD2	RD4	TN1	BKN
September 13	108	280	156	280
September 27	148	108	88	236
October 11	56	52	72	68
October 24	24	8	24	12
November 1	24	4		20

Table 21 Estimated number of leaf- and planthoppers and their natural enemies per unit area in experimental plot in rice paddies at San Pa Tong Rice Experiment Station. Figures in brackets indicate the number of predators and female parasites

Date of observation	Experimental plot			
	RD2	RD4	TN1	BKN
October 6	162	984	1948	1352
	(478)	(1042)	(408)	(374)
October 15	144	232	156	380
	(76)	(50)	(30)	(36)
October 26	68	130	76	112
	(12)	(28)	(26)	(20)
November 5	244	520		
	(69)	(100)		

Table 22 Estimated number of *Sogatella furcifera* and the percentage of parasitism by *Elenchus yasumatsui*, per unit area in experimental plot in rice paddies at San Pa Tong Rice Experiment Station. Figures in brackets indicate the number of parasitized host insects

Date of observation		Experimental plot			
		RD2	RD4	TN1	BKN
October 6		367	1236	1224	2072
		(128)	(869)	(260)	(276)
	%	34.6	70.3	21.2	13.3
October 15		52	64	60	112
		(32)	(24)	(16)	(20)
	%	61.5	37.5	26.6	17.8
October 26		12	12	4	0
		(8)	(4)		
	%	66.5	33.3		
November 5		120	12		
		(0)	(4)		
	%	0.0	33.3		

Table 23 Estimated number of *Leptocorisa* sp. and its egg parasite, *Gryon nixoni*, per unit area in experimental plot in rice paddies at Khlong Luang Rice Experiment Station. Figures in brackets indicate the number of egg parasites

Date of observation	Experimental plot			
	RD2	RD4	TN1	BKN
September 13	0	0	0	0
September 27	0	0	4	0
October 11	0	28	8	56
				(20)
October 24	4	52	8	16
	(4)	(4)	(4)	
November 1	4	12	0	20
	(4)			

As efficient predators of the adult moths of both stem borers and defoliators and the nymphal and adult leaf- and planthoppers, the abundance of damselflies and spiders is of considerable importance. (Tables 7-15). Especially, damselflies catch not only the flying insects but also attack rice pests resting on the leaves and stems of the rice plant. When the population of damselflies become highest, an average of one damselfly per 14.6 hills can be found. As they fly, their movement is far more rapid than that of spiders and their effectiveness is therefore much greater.

At Khlong Luang, egg masses of stem borers were found from the start of the experiment, but the damage caused by stem borers was below the economic injury level. The activity of egg parasites was prominent in suppressing the population of stem borers while the scarcity of *Conocephalus* species was responsible for supplementing the death of stem borer egg masses. The average percentage of parasitism of egg masses by egg parasites was 45.1, and the maximum record reached 100 percent. Among the parasites, *Tetrastichus schoenobii* was prominent. Its advantage as an egg parasite is that the parasite larvae consume the whole egg mass. In Khlong Luang experimental plot, spiders and damselflies were also responsible for the scarcity of rice stem borers and other pests including hoppers (Table 16).

In San Pa Tong, the damage caused by stem borers was very low—far below the economic injury level. It was almost impossible to find egg masses and dead heart. This may chiefly be ascribed to the activity and abundance of *Conocephalus* species predacious on egg masses. The estimated number of *Conocephalus* species was 2413.3 individuals per acre. The population of *Conocephalus* species was very high in the earlier growth stages of rice plants when the number of deposited egg masses of stem borers is usually very high and tends to decrease towards the heading stage. Therefore, many of the egg masses of stem borers were fed on by *Conocephalus* species during the earlier period of rice cultivation as shown in Table 17. Although no single egg mass of stem borers was found, it was possible to collect a small number of egg parasites, *Telenomus* sp., *Trichogramma* sp. and *Tetrastichus schoenobii* in the rice paddies.

In both experimental plots, the population of defoliators and leaf- and planthoppers remained very low, well under the economic injury level. The average proportion of defoliators to their natural enemies was 1070 : 388 in Khlong Luang and 360 : 294 in San Pa Tong; for *Nilaparvata lugens* and other hoppers, it was 2266 : 2470 at Khlong Luang and 6503 : 2749 at San Pa Tong. (Tables 18-21). *Oligosita yasumatsui* and *Anagrus optabilis* (egg parasites), *Cyrtorhinus lividipennis* and *Orius tantilus*, and other general predators such as damselflies and spiders were responsible for the scarcity of hoppers.

In San Pa Tong, many stylopitized *Sogatella furcifera* and *Nilaparvata lugens* were found (See Table 22 for *Sogatella furcifera*). Parasitism of the Strepsipteron, *Elenchus yasumatsui*, was 30 percent on an average and 90 percent in the maximum in the first crop of rice. Research indicated that this Strepsipteron was also found in the bodies of the same hoppers on the second crop of rice in the northern provinces. The discovery of this Strepsipteron both in the first and second crops may indicate the occurrence of at least two generations a year in the rice growing seasons.

In both experimental plots, it was proved that the varieties RD4 and BKN were extremely resistant to the attack of the gall midge, but more susceptible to *Leptocorisa* species than RD2 and TN1. An egg parasite of this bug was found and identified as *Gryon nixoni* previously recorded in the Philippines, Indonesia ad Malaysia. The proportion of population of the *Leptocorisa* bug to *Gryon nixoni* was 207 : 40 in Khlong Luang experimental plot. This figure may indicate that the number of egg parasites is sufficient to suppress the outbreak of *Leptocorisa* species because the egg parasites may lay more than 50 eggs. (Table 23).

The damage caused by rice stem borers in the experimental plots was 2% for RD2, less than 2% for RD4, almost none for TN1 and BKN in San Pa Tong; and less than 2.8% for RD2, about 4% for RD4, almost negligible for TN1 and under 3.5% for BKN in Khlong Luang. In both experimental plots, rice plants were cultivated without the use of insecticides or fungicides and with little weed control, as there was no sign of any outbreak of rice insect pests and the population of all major rice insect pests seemed to remain under the economic injury level.

Considerations

The importance, abundance and effective activity of many species of natural enemies of rice insect pests have not hitherto been thoroughly investigated since the start of rice cultivation in Thailand. Therefore, their importance as biological control agents is seldom recognized from the entomological and ecological viewpoints.

The research carried out for eight years revealed that each of the key insect pest species is attacked by a complex of many species of natural enemies, and they have a great repressive effect on populations of rice insect pests. Evidence is overwhelming that predation and parasitism of natural enemies are always regulating the outbreaks of rice insect pests and significantly contributing to preventing excessive increase of rice pest populations.

We were able to observe many under-estimated natural enemies such as damselflies that attack adult moths of stem borers and defoliators as well as adults and nymphs of leaf- and planthoppers, both in flight and rest, Tettigoniid grasshoppers, an Anthicid, and a Malachiid that eat egg masses of stem borers and sometimes adults and nymphs of leaf- and planthoppers, several species of Vespidae that catch larvae of defoliators, and a Strepsipteron that parasitizes nymphal or adult leaf- and planthoppers.

Our study indicates that biological control or natural control of rice insect pests by natural enemies is essential as the most important component of the integrated rice pest control program.

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Discussion

Chang, P.M. (Malaysia): 1) I would like to congratulate you, Dr. Yasumatsu and your group of workers for this major contribution to rice entomology as regards natural enemies. However I would like more specific information on host specificity. In your figures you only show the predators and parasites as being common to the groups of major pests, e.g. defoliators. 2) With regard to the Chironomid population, I believe that we should not completely eliminate the Chironomids, otherwise the predators would starve. We have to find out more about the desired population level of Chironomids.

Answer: 1) We shall send you this information later on. 2) This point is controversial. I think that the Chironomids should be left in the fields without being disturbed.

Yasumatsu, K. (Japan) **Comment**: The Chironomids which consist of about 30 species in Southeast Asia should not be eliminated in the paddy fields. It is true that when their population is high, the effectiveness of the predators on rice insects decreases as adult Chironomids are their first prey. However, Chironomids are an important source of food for the natural enemies when there is a shortage of the population of host insects in the rice fields.

It is interesting to note that the Chironomid population can be regulated by predators such as the Ceratopogonidae. Other non specific predators, the Tettigoniidae which are observed in the northern part of Thailand prey on egg masses of rice stem borers or hoppers. I would like to add that we plan to publish in the near future an illustrated booklet on "Natural Enemies of Rice Pests". Fifty to sixty species of major importance will be listed.