NATURAL ENEMIES OF NILAPARVATA LUGENS AND OTHER LEAF- AND PLANT-HOPPERS IN TROPICAL AGROECOSYSTEMS AND THEIR IMPACT ON PEST POPULATIONS

D.J. GREATHEAD,

Commonwealth Institute of Biological Control, Silwood Park, Ascot, Berks., U.K.

ABSTRACT

There was little study on natural enemies of *Nilaparvata lugens* (Stål), *Sogatella furcifera* (Horvath) and *Nephotettix* spp. on rice in the tropics until outbreaks of the former began in the early 1970s following intensification of rice cultivation. Many records have since been published but little quantitative information allowing assessment of their impact is available. This information is reviewed. Most attention has been paid to predators. In the Philippines the importance of spiders has been demonstrated. Studies there on the mirid egg-predator *Cyrtorhinus lividipennis* Reuter suggest that it is ineffective except under outbreak conditions. The parasitoid complexes affecting rice planthoppers and leafhoppers (which comprise Mymaridae, Trichogrammatidae, Dryinidae, Pipunculidae and Strepsiptera) are similar except that *N. lugens* lacks an effective pipunculid parasitoid. Estimates of percentage mortality are difficult to interpret but it is considered that the impact of parasitoids on pest populations has been underestimated. Parasitic nematodes and fungal pathogens are also recorded, but their importance is unknown. Application of insecticides against other pests is believed to be the principal factor in inducing outbreaks while continuous irrigated rice culture is thought to favour regulation by natural enemies, but it is easily disrupted. Attempts are now being made to develop integrated pest control which will initially emphasise conservation of natural enemies. More research is required before augmentation programmes or introduction of additional or more effective natural enemies can be considered.

INTRODUCTION

Many species of leafhoppers and planthoppers are recorded feeding on rice; about ten cause serious injury directly through feeding and as vectors of virus diseases. Except in Japan, where outbreaks have been recorded for more than 1,000 years, they were regarded as minor pests and received little study until devastating outbreaks of the brown planthopper (*Nilaparvata lugens* (Stål)) became frequent in south and southeast Asia during the 1970s following the introduction of new high yielding rice varieties and intensification of cultivation. Now, there is concern about increased incidence of Tungro virus disease transmitted by green leafhoppers (*Nephotettix* spp.). These events have stimulated research upon leafhoppers and planthoppers, especially *N. lugens*, in tropical Asia. The rapidly accumulating information on natural enemies has been reviewed by Otake (1977), Chiu (1979) and Greathead (1979). Few investigators have made quantitative observations and only Kenmore (1980), working at the International Rice Research Institute (IRRI) in the Philippines, has attempted an evaluation of the impact of mortality factors on brown planthopper populations. Most authors only provide data on percentage parasitism or feeding rates of caged predators. Consequently, any generalisations must be largely speculative but will, it is hoped, stimulate research.

Most attention has been given to the arthropod predators which are easy to observe and count. Parasitoids and diseases which are less easily observed have been neglected and their importance is probably underestimated.

NATURAL ENEMIES

Predators

Numerous species of predatory arthropods have been recorded in rice fields - especially in Thailand where Yasumatsu *et al* (1981) made comprehensive inventories of species present and their numbers, chiefly from sweep net samples - but in most instances, there is no direct evidence that they actually feed on leafhoppers and planthoppers. Most of the predators recorded are generalists which tend to consume the most abundant easily captured prey, and so are only likely to have a significant impact on pest populations during outbreaks. They may assist in terminating them but are unlikely to influence low density populations. However, certain predators of *N. lugens* are consistently reported in large numbers in several countries and laboratory prey consumption rates have been estimated for several of them (Table 1).

Kenmore (1980) analysed population changes in six unsprayed rice crops during 1977-79 at IRRI. In no instance was there an outbreak of *N. lugens* and maximum adult density did not exceed 50 adults per hill. Analysis of samples showed that there was a strong correlation between spider density (chiefly *Lycosa* spp.) and peak prey density ($r = 0.929$) and that spiders exhibited a density-dependent numerical response ($r = 0.812 - 0.969$). Numbers of other abundant predators, Veliidae, did not follow host population trends, possibly because they are only attracted to prey struggling on the water surface and not to prey on the rice plants. Insecticide check experiments and predator exclusion experiments substantiated these conclusions.

Unlike generalists, the mirids, *Cyrtorhinus* spp. and *Tytthus* spp., are specialist predators on homopteran eggs inserted into plant tissue, although they prey to some extent on young nymphs. *Cyrtorhinus lividipennis* Reuter is the most abundant and frequently encountered species in rice fields. It has been extensively studied in several

TABLE 1.

Important arthropod predators of *Nilaparvata lugens*

Predator	Countries recorded*	Source
VELIIDAE		
Microvelia atrolineata Bergroth	Philippines	IRRI (1978)
M. douglasi Scot	Japan	
CARABIDAE		
Casnoidea interstitialis Schmidt	Indonesia, Malaysia, Sri Lanka	
STAPHYLINIDAE		
Paederus fuscipes Curtis	Japan, Malaysia, Philippines, Thailand, Taiwan	Manley (1977)
P. tamulus Er.	Indonesia	
COCCINELLIDAE		
Coccinella arcuata F.	Australia, Fiji, India, Indonesia, Malaysia, Philippines, Solomon Islands	Abraham & Matthew (1976) IRRI (1978)
LYCOSIDAE		
Lycosa pseudoannulata (Bösenberg & Strand)	Japan, Philippines, Taiwan	Dyck & Orlido (1977)

*For references see Greathead (1979)

TABLE 2.

Parasitoid complex of ricefield leaf and planthoppers

Genus	Host: N. lugens	S. furcifera	N. cincticeps	N. nigropicta / N. virescens	Distribution
MYMARIDAE					
Anagrus	●	●	+	●	Japan, Fiji, Korea, Malaysia, Philippines, Sri Lanka, Thailan Taiwan, Vietnam
Gonatocerus			●	●	Korea, Philippines, Taiwan, Tha
Ooctonus			●		Japan
TRICHOGRAMMATIDAE					
Oligosita	●	●	●	●	Fiji, India, Korea, Malaysia, Philippines, Solomon Is., Sri L Taiwan, Thailand
Paracentrobia	●		●		Japan, Taiwan
DRYINIDAE					
Echrodelphax	●	●	●	●	India, Japan, Korea, Philippine Taiwan
Haplogonatopus	●	●		+	Fiji, India, Japan, Korea, Philippines
Pseudogonatopus	●	●	+	+	Japan, Philippines, Taiwan
STREPSIPTERA					
Elenchus	●	●		+	Fiji, India, Indonesia, Japan, Philippines, Solomon Is., Sri La Thailand
Halictophagus	+		●	●	India, Japan, Philippines, Saraw
PIPUNCULIDAE					
Pipunculus	+		●	●	Sri Lanka, Taiwan
Eudorylas			●	●	Japan, Philippines, Taiwan
Tomasvaryella	?		●	●	Japan, Philippines, Taiwan
undetermined	+				Sarawak, Sri Lanka

● major importance
+ minor importance

countries and is highly regarded by observers in India. Experiments at IRRI have shown that eggs of Nephotettix virescens (Dist.) are preferred to those of Nilaparvata lugens and in cage tests, the predator population increases more slowly than that of the prey which, with his field observations in irrigated rice, led Kenmore (1980) to conclude that it is an opportunistic predator which exploits outbreak populations only after other regulators have failed, though it may be more effective in upland rice. On the other hand, Stapley (1975, 1976) credits it with preventing outbreaks in irrigated rice in the Solomon Islands.

Parasitoids

The parasitoids of Delphacidae and Cicadellidae are a diverse assemblage but each host species is parasitised by a similar complex (Table 2). In rice fields, the same parasitoid genera tend to attack both host families and the species are so similar that there has been confusion over how many are involved. In consequence, their distributions and host ranges cannot be accurately determined at present.

The eggs are parasitised by a complex of Mymaridae and Trichogrammatidae. Species in these families are especially difficult to characterise and many more are believed to exist than are named in reports so that specific names are best avoided for the time being. In each area, each host species is parasitised by at least one parasitoid species in each family. The dominant genus of Mymaridae in rice fields is Anagrus and one or more species are major parasites of Nilaparvata lugens and Sogatella furcifera (Horv.), where new studies have been made. In Japan (Otake, 1977) and Taiwan (Lin, 1974), Nephotettix cincticeps (Uhler) is seldom attacked, but in the Philippines (Chandra 1980a), parasitism of Nephotettix spp. is substantial but Gonatocerus spp. are usually the more abundant egg parasitoids of this genus.

A species of Oligosita (Trichogrammatidae) is present in all areas of SE Asia and where quantitative data are presented is shown to be of equal importance to the major mymarid parasitoid, although it dominates in instances of multiparasitism (IRRI, 1978) and is at times more abundant. Paracentrobia androi (Ishii) replaces Oligosita spp. in Japan and Taiwan. It is not clear from most accounts whether the same species attack both Delphacidae and Cicadellidae but in Thailand, Miura et al (1979) have shown that there is an Oligosita sp. which is only reared from Nephotettix spp..

The impact of egg parasitoids is difficult to assess from field samples as they cannot easily be detected until they have reached an advanced stage of development, remain longer in the egg than the host and because hatched eggs in plant tissue are virtually impossible to count. Consequently, Otake (1977) developed a standardised "trapping" method using artificially infested potted rice plants containing eggs of known age which are exposed in the field. This technique gives comparative data on parasitoid activity but does not give a true measure of rates of mortality. Using the trapping method, rates of parasitism of up to 80% are obtained (Table 3). In Kenmore's (1980) study, positive correlation between percentage egg parasitism and time was obtained, suggesting that there is a density-dependent response.

Less quantitative information is available on parasitism of nymphs and adults and it is hard to interpret as much of it is based on external signs of parasitism and in most instances nymphs and adults are treated together. Overall, their combined percentage mortality (Table 4) appears to be less than for egg parasitoids. In each region, there is a complex of Dryinidae, Strepsiptera and Pipunculidae (Table 2). Identification is less uncertain, although often available to genus only, and identifications to species still need to be regarded with caution.

Several genera of Dryinidae are present in each area; the species do not seem to be host specific but they do show preference for particular hosts. Some develop as hyperparasites on other Dryinidae. Chandra (1980b), working at IRRI, has made the most complete study. There, five species are present of which four attack *N. lugens*. *Pseudogonatopus nudus* Perkins is dominant on this host, achieving up to 18% parasitism but it is 30-50% hyperparasitised by a ceraphronid and a pteromalid. Perhaps hyperparasites account for the low mean levels of parasitism, usually under 10%,

TABLE 3.

Summarised data on egg-parasitism from "trapping"

Country/Year	Host & parasitism (mean)			Source
	N. lugens	*S. furcifera*	*Nephotettix* spp.	
Philippines 1977	10-50(19)	10-40(20)	0-70(22)	IRRI 1977
Thailand 1977	9	41	69	Muira *et al* 1977
Sri Lanka 1976/7	78	48	-	Fujimura & Somasunderam (1978)
Taiwan 1970	5	-	19	Lin 1974

TABLE 4.

Summarised data on parasitism of nymphs and adults

Country/Year	Host & parasitism (mean) Dryinidae	Strepsiptera	Pipunculidae	Nematodes	Source
Philippines 1977					
N. lugens	7.5	3.5	0	-	IRRI 1977
S. furcifera	4.9	2.1	0	-	
Nephotettix spp.	0.2	0.8	20	-	
Thailand 1976/7					
N. lugens	2.1(0)*	1.4(0)*	-	-	Muira *et al* 1977
S. furcifera	4.7(11.4)	1.1(4.7)	-	-	
Nephotettix spp.	0.1(0.2)	0.1(0.4)	-	-	
Sri Lanka 1973/4					
N. lugens & *S. furcifera*	(8.17)		5(1)	11(0)**	Otake *et al* (1976)
India 1978					
N. lugens	7.8	17.4	-	-	Manjunath (1979)

*Figures for nymphs with figures for adults in parentheses
**Figures for whole plant samples with figures for net & aspirator samples in parentheses

in Table 4. However, the females are predatory and do not oviposit in hosts killed for food so that the overall host mortality is higher than is indicated by the rate of parasitism. The females of many species are parthenogenetic and wingless, although males exist, which limits their powers of dispersal. They oviposit on nymphs and the larva develops in a sac protruding between the tergites which aids detection without recourse to dissection.

Detailed assessment of the potential of P. flavifemur Esaki & Hashimoto has been made at IRRI (Chua & Dyck, in press). This species shows a preference for N. lugens over S. furcifera and Nephotettix spp.. In cage experiments, a sigmoid functional response and a positive aggregative response were demonstrated and in small scale field trials (3-m^2 plots) augmentative release of about 260 parasitoids per plot over 24 days significantly raised parasitism and considerably reduced damage.

Adults and nymphs are parasitised by Strepsiptera. In all areas, there are records of Elenchus spp. from planthoppers. Kathirithamby (personal communication) believes that all are E. yasumatsui Kifune & Hirashima which is morphologically identical with E. tenuicornis (Kirby), a polyphagous species from the north temperate region, yet E. yasumatsui is reliably recorded from N. lugens and S. furcifera only. Species of Halictophagus are reported from N. lugens and Nephotettix spp. but the work of Chandra (1980a) and the taxonomic studies of Hirashima & Kifune (1978) on material from Sarawak suggest that this genus is essentially parasitic on leafhoppers.

Strepsiptera affect reproduction through suppression of the gonads and secondary reproductive organs, so that parasitised hosts are effectively sterile and remain so even when they survive parasitism. All stages, except the triungulin and male, remain inside the host which limits dispersal to very short distances, but parasitised hosts are able to fly and may be frequent in light trap catches (Kathirithamby, 1980). Reported rates of parasitism in rice fields (Table 5) are low but may be higher in grassland (Anon, 1977). However, Strepsiptera are easily overlooked without dissection.

TABLE 5.

Parasitism of Nephotettix spp. in Sarawak

	Wild grass	Wet padi	Light trap
Nephotettix virescens	9.8	0	0.7
N. nigropictus	28.1	7.1	0.9

The majority of records of Pipunculidae concern leafhoppers and more precise studies (e.g. Chandra, 1980a) suggest that most published records from rice planthoppers are erroneous and do not accord with the pattern of host relations established by Coe (1966). Consequently, reliable records of parasitism of planthoppers by unidentified Pipunculidae in Sri Lanka (Otake et al., 1976) and Sarawak (Anon, 1977) are of great interest and merit further investigation. Possibly this parasitism is due to a Pipunculus (Cephalops) sp., a subgenus which parasitises Delphacidae and has so far not been recorded from rice planthoppers, although 37 species (out of a total of 154 Pipunculidae) have been recorded from the Oriental Region (Hardy, 1975). The species associated with rice-field Delphacidae and Cicadellidae have been keyed by Yano (1979).

Pipunculidae attack nymphs and adults, and the larvae feed inside the host which is killed when the larva emerges to pupate. Although the host abdomen becomes distended and discoloured as the larva develops inside, dissection is necessary for reliable detection of parasitised hosts. Substantial rates of parasitism, up to 60%, are found at IRRI (Chandra, 1980a). The life histories have not yet been studied because it has not proved possible to obtain oviposition in captivity.

Parasites

Unidentified parasitic nematodes have been recorded causing substantial mortality (*S. furcifera* up to 70%; *N. lugens* up to 43%) in Japan (Esaki & Hashimoto, 1930); 20% in Sri Lanka (Otake *et al.*, 1976) and a *Hexamermis* sp. is reported as common, especially in brachypterous *N. lugens* in India (Manjunath, 1978) but nematode parasitism is low in the Philippines (Chandra, 1978). It is reasonable to expect that nematodes are important parasites of rice hoppers since their humid moist environment is ideal for nematode transmission so that the paucity of records may reflect failure to observe rather than scarcity.

Pathogens

Similarly, there are few records of pathogens from rice hoppers, all of which refer to fungal diseases. Severe infestation of *Nephotettix virescens* by *Beauveria bassiana* (Bals.) Vuill. has been reported in India (Rao, 1975) but this ubiquitous insect pathogen has not been detected elsewhere. Heavy infection of *Nilaparvata lugens* by a *Hirsutella* sp. has been recorded at IRRI, but it is usually rare (Chandra, 1978). However, most records refer to species of *Entomophthora*, but do not suggest that they cause heavy mortality. Dyck & Orlido (1977) carried out field trials with *E. coronata* (Cost.) Kevork. but its performance was poor.

DISCUSSION

The relative unimportance of rice hoppers in tropical rice fields until the "green revolution" suggests that under low intensity production systems, the numbers of these insects must be regulated. The changes that have taken place in areas where outbreaks have become frequent and which it has been suggested are responsible for brown planthopper outbreaks include: (i) increased nutrient levels in the new varieties enhanced by application of fertilisers; (ii) more favourable microclimate in densely planted fields of short-stemmed rice grown under irrigation; (iii) staggered planting and multiple cropping allowing more or less continuous breeding at a single site; (iv) development of large-scale irrigation schemes leading to large areas under rice monoculture; (v) increased use of insecticides which stimulate reproduction at sub-lethal doses and are presumably more toxic to natural enemies than to pests. These factors all tend to increase fecundity and/or survival rates to which natural enemies may not be able to respond. Unfortunately, there is insufficient information to test this hypothesis as no studies on population dynamics were made before the planthopper problem developed. Kenmore (1980) concludes from his evaluation that there is no experimental confirmation of the role of modern varieties or nitrogen fertiliser in causing outbreaks in farmers' fields, but that there is a correlation between insecticide usage and outbreaks both in Japan and tropical Asia, also that outbreaks tend to occur in irrigated areas where the number of crops per year has been increased. He also notes that the conditions created by irrigation, allowing continuous rice growing, favour biotic population regulation which is in turn highly susceptible to upset from insecticides.

Continuous breeding at the same locality favours the establishment of population regulation by biotic agents and conversely closed seasons are known to break synchronisation between natural enemies and their hosts which is only re-established by the end of the crop. In rice, there is some evidence that continuous cultivation in Malaysia has reduced levels of infestation by lepidopterous stalk borers (Balasubramanian & Ooi, 1977) and at IRRI, the "rice garden" experiment in which rice was continuously planted and harvested on the same plot did not result in raised levels of pest damage (Kenmore, 1980).

In a survey summarised by Litsinger (1979) on the status of insect pests of rainfed wetland rice, as reported by government entomologists, brown planthopper is rated as a "major" pest (annual yield loss of at least 5% in at least one major rice growing region) in India, Indonesia and Sri Lanka, a "minor" pest in Malaysia and Thailand, and is not listed for Bangladesh, Burma and the Philippines. Some preliminary results from Sarawak where rice culture is not yet intensified suggest rates of parasitism may be higher in green leafhoppers in dry wild grass than in flooded rice. However, in another experiment there was no significant difference in parasitism between leafhoppers from flooded and dry rice plots, or between plots with and without food plants for adult parasitoids (Anon., 1977).

Japan is invaded each year by migrant brown planthoppers which do not overwinter. Elsewhere there is evidence of migration but its importance in brown planthopper outbreaks is not fully understood. However, dispersal must take place at least over short distances to allow infestation of fields. Natural enemies of mobile pests also require a mechanism synchronising with the availability of hosts. Polyphagous predators can overcome the problem by turning to alternative prey but more specialised species must become quiescent or move with the host population. The mirid egg-predators do migrate and *Cyrtorhinus lividipennis* and *Tytthus chinensis* (Stål) have been trapped in numbers over the East China Sea during planthopper migration (Kisimoto, 1979) and have also been taken in large numbers in light traps during dispersal of their hosts on a large scale irrigation scheme in Malaysia (Ooi, 1979). As noted, Strepsiptera and other parasitoids of adults are transported in parasitised hosts although (Table 5) in small numbers compared with their incidence in the source population. Here, the enormous fecundity of Strepsiptera enables rapid build-up once established at a new site.

Integrated control programmes being developed by FAO aim at reducing insecticide usage and enhancing natural enemy action by conservation of natural enemies. Augmentation of natural enemies from mass-rearing has appeal but should not be hastily begun as the numbers required and logistics of production can make this approach prohibitively expensive. For example, Chua & Dyck (in press) calculate that 22 female *Pseudogonatopus flavifemur* would be needed per 10 rice plants to achieve 50% parasitism of brown planthopper at a host density of 150 per plant. Increasing natural mortality by introduction of natural enemies to fill gaps in the natural enemy complex or replacing inefficient species with more efficient ones is not yet contemplated. Before it can be considered, much more research is required on the identity and distribution of natural enemies and their impact on pest populations. In a region of peninsulas and islands, the opportunities for exchange of species should be good. The most important gap in the brown planthopper natural enemy complex is a Pipunculid.

These measures alone are unlikely to solve the problem, but could well provide an important tool for the management of brown planthopper and other leaf and planthopper pests on rice.

REFERENCES

Anon. (1975) Entomology. pp. 231-245. In Annual Report of the Research Branch, Department of Agriculture for the year 1975, Ministry of Agriculture & Community Development, Sarawak.

Anon. (1977) Entomology. pp. 197-204. In Annual Report of the Research Branch, Department of Agriculture for the year 1977, Ministry of Agriculture & Community Development, Sarawak.

Balasubramanian, A. & Ooi, A.C.P. (1977) Status of rice stem-borers following double cropping in Krian, Malaysia. *Malaysian Agricultural Journal* 51, 54-61.

Chandra, G. (1978) Natural enemies of rice leafhoppers & planthoppers. *International Rice Research Newsletter*, 3(5), 20-21.

Chandra, G. (1980a) Taxonomy and biology of the insect parasites of rice leafhoppers and planthoppers in the Philippines and their importance in natural biological control. *Philippine Entomologist* 4, 119-139.

Chandra, G. (1980b) Dryinid parasitoids of rice leafhoppers and planthoppers in the Philippines 1. - Taxonomy and bionomics. *Acta Oecologica*, 1, 161-172.

Chiu, S-C. (1979) Biological control of the brown planthopper pp. 335-355. In brown planthopper: threat to rice production in Asia. International Rice Research Institute, Manila, Philippines.

Chua, T.H. & Dyck, V.A. (in press) Assessment of *Pseudogonatopus flavifemur* E. & H. (Dryinidae: Hymenoptera) as a biocontrol agent of rice brown planthopper. *Proceedings of the International Conference on Plant Protection in the Tropics, Kuala Lumpur, March 1982*.

Coe, R.L. (1966) Diptera Pipunculidae - Handbooks for Identification of British Insects. 10(2c), 83 pp.
Dyck, V.A. & Orlido, G.C. (1977) Control of the brown planthopper (*Nilaparvata lugens*) by natural enemies and by timely application of narrow spectrum insecticides. pp. 58-72. In The rice brown planthopper. Food and Fertiliser Technology Center for the Asian and Pacific Region, Taipei.
Esaki, T. & Hashimoto, S. (1930) Report on the leafhoppers injurious to the rice plant and their natural enemies. Publications of the Kyushu Imperial University Entomology Laboratory, Fukuoka, No. 2, 29 pp. (in Japanese) (Review of Applied Entomology (A)19, 339).
Fujimura, T. & Somasunderam, P.M. (1978) Some studies on the ecology of paddy planthoppers in Sri Lanka. 60 pp. (multigraph).
Greathead, D.J. (1979) Critical review of natural enemies of insect pests of rice in south and south east Asia and their potential for biological control. Prepared for 9th session of the FAO/UNEP Panel of Experts on Integrated Pest Control, Wad Medani, Sudan, 9-13 December 1979. AGP:IPC/WP/ (multigraph).
Hardy, D.E. (1975) Pipunculidae pp. 296-306. In Delfinado, M.D. & Hardy, D.E. A Catalog of the Diptera of the Oriental Region. Vol. 2. University of Hawaii Press.
Hirashima, Y. & Kifune, T. (1978) Strepsipterous parasites of Homoptera injurious to the rice plant in Sarawak, Borneo, with description of a new species (Notulae Strepsipterologicae - II). Esakia, 11, 53-58.
IRRI, 1978. Biological control of insects pp. 215-219. Annual Report for 1977. International Rice Research Institute.
Kathirithamby, J. (1980) Studies of the *Nephotettix* spp. (Cicadellidae: Homoptera) in the Krian District, Peninsular Malaysia. Malaysian Agricultural Journal, 53, 273-279.
Kenmore, P.E. (1980) Ecology and outbreaks of a tropical insect pest of the green revolution, the rice brown planthopper, *Nilaparvata lugens* (Stål) Ph.D. Thesis, University of California, Berkeley.
Kisimoto, R. (1979) Brown planthopper migration. pp. 113-124. In Brown planthopper: threat to rice production in Asia. International Rice Research Institute, Manila.
Liu, K.S. (1974) Notes on some natural enemies of *Nephotettix cincticeps* (Uhler) and *Nilaparvata lugens* (Stål) in Taiwan. Journal of Taiwan Agricultural Research 23, 91-115 (in Chinese).
Litsinger, J.A. (1979) Major insect pests of rainfed wetland rice in tropical Asia. International Rice Research Newsletter, 4(2), 14.
Manjunath, T. (1978) Two nematode parasites of rice brown planthoppers in India. International Rice Research Newsletter, 3, 22.
Miura, T., Hirashima, Y. & Wongsiri, T. (1978) Egg and nymphal parasites of rice leafhoppers and planthoppers. A result of field studies in Thailand in 1977. Esakia, 13, 21-44.
Ooi, P.A.C. (1979) Flight activities of brown planthopper, white-backed planthopper and their predator *Cyrtorhinus lividipennis* in Malaysia. International Rice Research Newsletter, 4(6), 12.

Otake, A. (1977) Natural enemies of the brown planthopper. pp. 42-56. In The rice brown planthopper. Food and Fertiliser Technology Center for the Asian and Pacific Region, Taipei.

Otake, A., Somersunderam, P.H. & Abeykoon, M.B. (1976) Studies on populations of *Sogatella furcifera* Horvath and *Nilaparvata lugens* (Stål) (Hemiptera: Delphacidae) and their parasites in Sri Lanka. *Applied Entomology and Zoology*, 11, 284-294.

Rao, P.S. (1975) Widespread occurrence of *Beauveria bassiana* on rice pests. *Current Science*, 44, 441-442.

Stapley, J.H. (1975) The problem of the rice brown planthopper (*Nilaparvata lugens*) on rice in the Solomon Islands. *Rice Entomology Newsletter*, No. 2, 37.

Stapley, J.H. (1976) The brown planthopper and *Cyrtorhinus* spp. predators in the Solomon Islands. *Rice Entomology Newsletter*, No. 4, 37.

Yano, K. (1979) Faunal and biological studies on the insects of paddy-fields in Asia. Part II. Illustrated key to the Thai species of Pipunculidae (Diptera). *Esakia*, 13, 45-54.

Yasumatsu, K., Wongsiri, T., Tirawat, G., Wongsiri, N. & Lewanich, A. (1981). Contributions to the development of integrated rice pest control in Thailand. Japan International Cooperation Agency.