2-1982

Effects of Insecticides on *Nilaparvata lugens* and Its Predators: Spiders, *Microvelia atrolineata*, and *Cyrtorhinus lividipennis*

W. H. Reissig
International Rice Research Institute

E. A. Heinrichs
International Rice Research Institute, eheinrichs2@unl.edu

S. L. Valencia
International Rice Research Institute

Reissig, W. H.; Heinrichs, E. A.; and Valencia, S. L., "Effects of Insecticides on *Nilaparvata lugens* and Its Predators: Spiders, *Microvelia atrolineata*, and *Cyrtorhinus lividipennis*" (1982). *Faculty Publications: Department of Entomology*. 838.
https://digitalcommons.unl.edu/entomologyfacpub/838

Published in *Environmental Entomology* 11:1 (February 1982), pp. 193–199; doi: 10.1093/ee/11.1.193

Submitted December 12, 1980; published February 1, 1982.

Effects of Insecticides on *Nilaparvata lugens*[1] and Its Predators: Spiders,[2] *Microvelia atrolineata*,[3] and *Cyrtorhinus lividipennis*[4]

W. H. Reissig,[5] E. A. Heinrichs, and S. L. Valencia

International Rice Research Institute, Manila, Philippines

Abstract

Thirty-five insecticides used on rice in Asia were tested in the field against *Nilaparvata lugens*. The most important predators of the pest, *Cyrtorhinus lividipennis*, *Microvelia atrolineata*, and predacious spiders, *Lycosa pseudoannulata*, *Tetragnatha*, and *Araneus* species, were also monitored in the test plots. Ten insecticides significantly reduced numbers of *N. lugens*, but propoxur and ethylan gave the most consistent and effective control. Most insecticides did not significantly reduce populations of spiders and *M. atrolineata* compared with untreated checks, but they did reduce numbers of *C. lividipennis*. Fifteen treatments caused resurgence of *N. lugens*, resulting in significantly higher numbers in the treated plots than in untreated checks. Resurgence was apparently not caused by the toxicity of the materials against predators. Eleven of the insecticides had no effect on *N. lugens*.

Nilaparvata lugens (Stål) has become a serious pest of lowland rice in South and Southeast Asia during the last decade (Dyck and Thomas 1979). This pest damages the plant by direct feeding, called "hopperburn," and also transmits the viruses grassy stunt, ragged stunt (Ling et al. 1978), and wilted stunt (Chen et al. 1978). Chemical control of *N. lugens* on nonresistant rice varieties is difficult, and some ineffective insecticides may cause resurgence, a significant population increase in treated compared with untreated fields (Anonymous 1977–1979). The causes of insecticide-induced resurgence are not completely known. Sublethal dosages of some insecticides increased the longevity, feeding activity, and fecundity of *N. lugens* in the laboratory (Chelliah and Heinrichs 1980; Chelliah et al., unpublished data[6]). Subsequent field tests also demonstrated increased oviposition in plots treated with an insecticide associated with an increase in resurgence and indicated that the amount of population increase is influenced by the method and timing of applications (Heinrichs et al., in press). In addition to directly affecting the insects' physiology, insecticides may also destroy natural enemies that help regulate pest populations in the field (Chiu 1979, Kenmore 1980).

Most of the insecticides commonly used on rice in Asia were evaluated in the field during this study to test their effectiveness in controlling *N. lugens* and to identify those ineffective materials causing resurgence. Populations of important predators were also monitored in the test plots to compare the response of the different species to insecticides and to determine if resurgence was caused by the destruction of these natural enemies.

Materials and Methods

Tests were conducted on the International Rice Research Institute experiment farm in Los Baños, Philippines. A high-yielding dwarf rice variety, IR29, susceptible to the dominant *N. lugens* biotype of the IRRI farm and with a maturity of 115 days, was transplanted at 21 days after sowing at a spacing 25 by 25 cm. Fertilizer was incorporated into the soil just before transplanting ([19 kg of N + 14 kg of P + 14 kg of K]/ha). Additional nitrogen was broadcast 25 to 30 days after transplanting (DT) (16.5 kg/ha) and at panicle initiation (26 kg/ha). The plots (5 by 9 m) were arranged in a randomized complete block design with four replications. Plots were separated by levees and irrigated individually.

Insecticides were compared in five consecutive trials conducted from 1979 through 1980. The transplanting dates of tests 1 through 5 were, respectively: 7 November 1979; 28 November 1979; 24 December 1979; 9 January 1980; and 28 February 1980. Each insecticide was applied three times during crop growth at 30 to 35 DT, 45 to 50 DT, and 60 to 65 DT. Sprays and granules were applied at Philippine recommended rates of 0.75 and 1.0 kg of AI/ha, respectively. Granules were hand broadcast into the paddy water, and sprays were applied with a knapsack sprayer calibrated to deliver 300 liters of water per ha.

Ten randomly selected hills were sampled in the center of each plot with a FARMCOP suction device (Carino et al. 1979) 1 day before and 2 days after each insecticide treatment. A final sample was taken 70 to 80 DT. Both *N. lugens* adults and nymphs, as well as the predators *Microvelia atrolineata* (Bergoth), *Cyrotorhinus lividipennis* Reuter, *Lycosa pseudoannulata* Boes et Str., *Tetragnatha* sp., and *Araneus* sp., were counted. These predacious species were sampled because they are the most common in Asian rice fields and are considered to be most important in regulating populations of *N. lugens* (Heinrichs et al. 1979, Chiu 1979). The percentage of "hopperburned" hills in each plot was recorded several times during the later stages of each test.

Number of *N. Lugens*, average number of prey per predator (number of *N. lugens* adults and nymphs per number of predators), and percent hopperburn were subjected to an analysis of variance, and means were separated by Duncan's multiple range test ($P < 0.05$). Predator counts were tested for normality[7] and transformed if necessary (log x + 1), and means were separated by the Waller and Duncan BSD procedure ($P < 0.05$).

Results

Populations of *N. lugens* built up to levels sufficient to cause varying amounts of hopperburn in all experiments except test 1 (Table 1). Even in this test, the pest populations exceeded the proposed economic threshold of 20 per hill (Heinrichs et al. 1979) in the untreated check during the later crop growth stages. Despite the severe hopperburn that occurred in some insecticide-treated plots, very little damage was observed in the untreated checks. The checks in tests 1, 2, and 3 had no hopperburn, whereas those in tests 4 and 5 had, respectively, 10 and 13% damaged hills.

Sixteen of the insecticide treatments were considered to have caused resurgence of *N. lugens* because populations in these treatments significantly exceeded the check in one or more samples after the first treatment. These materials are marked with an asterisk in Table 1. This group included carbamate, synthetic pyrethroid, and organophosphate insecticides. Usually, *N. lugens* populations in the resurgence plots did not become significantly larger than those in the checks until later in the season, after the second insecticide application. The amount of population increase compared with the check varied considerably among the different tests and with different compounds, ranging from ca. 3-fold for fenvalerate and Penncap-M (microencopulated methyl parathion) to ca. 35- and 37-fold, respectively, for carbofuran and isazophos granules. The percentage of hopperburn occurring in plots treated with resurgence-promoting insecticides was significantly greater than that in the untreated checks, except for monocrotophos plots in test 3, and materials in test 1 in which no hopperburned plants occurred in any treatments.

Insecticides marked with a plus sign in Table 1 significantly reduced populations of *N. lugens* below that of the check in one or more samples taken 2 days after application. Ethylan was the most effective material and gave more consistent control during the season than other materials. Propoxur also consistently reduced numbers of *N. lugens* during crop growth and significantly reduced hopperburn compared with the check in test 5. All of the other materials providing control were inconsistent after the various applications. Carbofuran sprays in test 1 controlled *N. lugens*, but the granular formulation caused resurgence in the subsequent test 4. The reasons for this difference in effectiveness of the two carbofuran formulations are not known.

Eleven of the tested materials had no effect on *N. lugens* because populations in plots treated with these insecticides were not significantly different than the check after the first application (Table 1). Usually the percentage of hopperburn in these treatments was not significantly different from the check. However, in test 5, plots treated with dimethoate suffered more hopperburn than the check, and those treated with acephate had less damage than the check, even though the populations of *N. lugens* were similar during the season in all three treatments.

Table 1. Effects of insecticides on the brown plantbopper (BPH), *N. lugens*; Los Baños, Philippines, 1979–1980

			Avg. no. of BPH/hill[b]							
			First treatment		Second treatment		Third treatment			
Test no.	Insecticide[a]	Formulation	Before	After	Before	After	Before	After	Last sampling	% Hopper-burn
1	*Azinphos-ethyl	40% EC	1.4ab	2.6a	2.9ab	4.9a	21.5ab	77.2a	209.2a	0a
	*Quinalphos	25% EC	1.9ab	1.7ab	5.2ab	3.7bc	21.0ab	64.5a	241.5a	0a
	Chlorfenvinphos	20% EC	2.0ab	1.7ab	4.2ab	5.5ab	13.lab	39.1a	99.9ab	0a
	+ Carbofuran	12% F	1.8ab	0.3c	3.7ab	1.6d	6.9b	5.1b	29.4c	0a
	Diazinon	20% EC	1.1ab	1.1abc	4.2ab	4.8abc	28.4ab	41.7a	88.9ab	0a
	*Phenthoate	50% EC	1.5ab	1.2ab	6.2a	8.8a	30.4a	51.2a	273.7a	0a
	Fenthion	50%EC	2.3a	1.1abc	4.4ab	4.4abc	15.6ab	38.1a	138.8ab	0a
	+FMC 35001	20% EC	1.0ab	0.3c	2.3b	4.6cd	14.9ab	5.6b	133.7bc	0a
	*Methomyl	19.8% EC	1.1ab	2.4a	5.8ab	9.9ab	26.0ab	87.8a	418.9a	0a
	+Ethylan	45% EC	0.4b	0.4bc	2.9ab	1.5d	7.9b	2.2b	12.4d	0a
	Control		1.0ab	3.5a	4.4ab	5.5abc	15.8ab	95.1a	45.3bc	0a
2	Cartap	4% G	6.9a	6.6bc	179.3ab	65.7b	18.5b	19.6c	112.4b	0a
	* Diazinon	5% G	9.1a	15.3a	309.4ab	256.1a	54.0ab	358.6a	2544.8a	100b
	*Isazophos	3% G	6.2a	4.6c	308.5a	255.8a	58.0ab	861.6a	2814.0a	100b
	Carbaryl + BHC	4/4% G	8.5a	13.1ab	74.8b	66.4b	28.4ab	9.4c	45.2b	5a
	*Carbofuran	3% G	10.4a	8.0ab	262.2a	141.9a	54.2a	77.2b	2695.4a	80b
	Control		9.0a	11.4ab	215.7a	40.0b	36.2ab	14.8bc	76.6b	0a
3	*Tetrachlovinphos	75% WP	19.1a	75.4ab	43.6ab	45.1a	722.5a	1244.9a	361.4b	12d
	+BHC	20% EC	23.8a	6.3c	8.4c	14.0b	130.8bc	30.4ef	40.7c	0f
	*Methyl parathion	50% EC	30.0a	93.9a	43.3ab	33.3a	419.9ab	1110.7ab	814.8ab	65b
	*Monocrotophos	16.8% EC	27.8a	43.6ab	25.9b	18.5ab	399.3ab	422.6bcd	55.8c	2ef
	*Pyridaphenthion	75% WP	32.2a	51.4ab	35.9ab	31.5ab	955.2a	1012.3ab	363.5b	29c
	*Cyanofenphos	40% EC	21.3a	79.5ab	59.3a	39.7a	967.8a	1244.3ab	1787.5a	91a
	Carbaryl	80% EC	16.6a	31.3b	21.2b	12.3ab	225.0bc	353.6bc	61.3c	0f
	+Ethylan	45% EC	20.4a	0.9d	4.0d	1.6c	30.6d	11.0f	25.1c	0f
	Control		20.3a	82.0ab	8.0cd	12.3ab	76.0cd	69.7de	25.0c	0f

Table 1. *Continued*

			Avg. no. of BPH/hill[b]							% Hopper-burn
			First treatment		Second treatment		Third treatment		Last sampling	
Test no.	Insecticide[a]	Formulation	Before	After	Before	After	Before	After		
4	+BPMC	50% EC	109.4a	7.1a	382.8a	466.2bc	500.0cd	269.4abc	267.2cd	12cde
	MIPC	50%WP	69.0ab	16.3a	355.4a	1241.5abc	748.6abc	310.6abc	529.1abcd	25cd
	+ Carbophenothion	48% EC	55.9ab	11.0a	507.0a	612.9bc	623.3bcd	235.7abc	445.2abc	30c
	+MTMC	30% EC	39.6ab	7.4a	450.9a	396.1c	286.0d	117.2c	107.0d	2e
	Phosphamidon	50%EC	17.7ab	8.7a	231.2a	856.5abc	701.1abc	439.0ab	536.9abc	14cde
	+ Endosulfan	35% EC	29.4ab	12.8a	343.4a	517.4bc	640.5bcd	267.3bc	283.2bcd	1e
	*Triazophos	40% EC	64.7ab	12.8a	487.0a	1752.7ab	1578.6a	844.9a	1203.5a	78b
	*Decamethrin	31% EC	34.1ab	8.1a	342.4a	1452.2ab	1304.4ab	868.8a	1162.9a	100a
	Control		32.0ab	17.1a	326.6a	2502.2a	455.9cd	428.9abc	217.4bcd	10cde
5	Acephate	75% WP	81.2a	50.6a	471.6ab	1860.9abc	1023.5b	799.0ab	199.2bc	0e
	Azinphos-ethyl + MTMC	32% EC	51.0a	38.2a	803.3a	920.5de	391.1bcd	814.7ab	178.7bc	5cd
	BPMC + Chlorpyrifos	32% EC	30.4a	37.9a	443.3ab	1393.0bcd	98.9e	504.7ab	106.9c	3e
	Dimethoate	38% EC	51.5a	53.5a	1427.6a	2579.3ab	2293.3a	1094.3a	409.4ab	91b
	+Propoxur	20% EC	24.0a	39.7a	243.8b	577.7e	31.7c	42.6c	11.3d	0e
	+ Chlorpyrifos	40% EC	44.4a	37.1a	840.8ab	1146.1cd	200.7d	359.5b	93.2c	9cd
	*Penncap-M	25% EC	28.8a	62.0a	1031.8a	3155.4a	2747.9a	1139.la	499.0a	91b
	*Fenvalerate	38% EC	64.5a	28.4a	658.7ab	1143.8bcd	992.lbc	1024.6a	613.5a	99a
	Control		65.7a	53.0a	993.8ab	1891.9abcd	1301.5ab	1250.3a	216.9bc	13c

a. * Insecticides causing resurgence, a significantly larger population of *N. lugens* than in untreated check plots after insecticide applications; + Insecticides that significantly reduced *N. lugens* population below those in untreated checks in samples taken 2 days after one or more applications.

b. Means in a column followed by the same letters are nor significantly different by Duncan's multiple range test (DMRT) ($P < 0.05$).

Table 2. Comparison of predator numbers and the average prey per predator in insecticide-treated and untreated plots[a]; Los Baños, Laguna, Philippines

			Spiders				*M. atrolineata*				*C. lividipennis*			
			Avg. no./hill		Avg. *N. lugens*/ spider		Avg. no./hill		Avg. *N. lugens*/ *M. atrolineata*		Avg. no./hill		Avg. *N. lugens*/ *C. lividipennis*	
Test no.	Insecticide	Formulations	After treatments[b]	Last sample	After treatments	Last sample	After treatments	Last sample	After treatments	Last sample	After treatments[b]	Last sample	After treatments	Last sample
1	Azinphos-ethyl	40% EC	0.9a	2.0b	33a	114a	0.7cde	6.2a	33a	63a	0.1a	0.6a	431a	963a
	Quinalphos	25% EC	1.0a	2.2b	23ab	105ab	2.3abc	23.7a	16b	20ab	< 0.1a	1.2a	844a	428ab
	Chlorfenvinphos	20% EC	1.0a	2.9ab	15ab	36cd	2.7ab	8.6a	5b	22ab	0.1a	0.3a	256a	150b
	Carbofuran	12% F	0.7a	2.7ab	4b	14d	1.4bcd	12.0a	2b	6b	< 0.1a	0.1a	53a	100b
	Diazinon	20% EC	1.1a	2.3ab	16ab	48cd	2.4ab	24.7a	8b	14b	< 0.1a	2.5a	509a	206b
	Phenthoate	50% EC	1.1a	4.8a	21ab	56bcd	1.5abc	30.2a	11b	26ab	0.1a	4.7a	500a	98b
	Fenthion	50% EC	1.0a	2.5ab	15ab	58bcd	3.7a	24.3a	9b	34ab	< 0.1a	1.4a	439a	58b
	FMC 35001	20% EC	0.7a	3.7ab	5b	27cd	0.4e	13.0a	8b	9b	< 0.1a	0.1a	163a	1572a
	Methomyl	19.8% EC	0.9a	4.4ab	36a	80abc	3.1ab	18.1a	13b	36ab	0.1a	1.9a	399a	173a
	Ethylan	45% EC	0.8a	2.5ab	2b	9d	0.5de	17.6a	2b	7b	< 0.1a	0.3a	19a	41b
	Control		1.2a	2.5ab	27a	17d	2.9ab	6.9a	12b	27ab	0.1a	1.5a	457a	149b
2	Cartap	4% G	1.9ab	1.8ab	15c	28b	0.1c	0.3b	232ab	197bc	2.1a	7.2ab	13b	7b
	Diazinon	5% G	2.3a	3.1a	65b	527a	1.9a	2.2ab	98b	682ab	2.3a	14.0a	80b	96b
	Isazophos	3% G	1.6b	2.4a	137a	630a	0.9b	2.5a	474a	701a	0.1b	9.9a	1611a	173b
	Carbaryl + BHC	4/4% G	1.9ab	1.3b	14c	24b	0.6b	0.3b	111b	61c	2.5a	3.4b	14b	15b
	Carbofuran	3% G	2.0ab	3.4a	31bc	472a	1.8a	4.0a	40b	358abc	0.3b	2.2b	428b	692a
	Control		1.5b	1.8ab	13c	21b	0.3b	0.4b	68b	82c	3.3a	4.8b	11b	8b
3	Tetrachlorvinphos	75% WP	1.5a	2.8a	293ab	140b	0.8bc	1.2ab	592a	318bc	1.0bc	0.5ab	729ab	762b
	BHC	20% EC	0.3d	0.8cd	87ab	55b	0.5c	1.9ab	44b	76c	1.5b	1.3a	12b	47b
	Methyl parathion	50% EC	1.3a	3.4ab	310ab	300b	2.6a	0.9ab	201b	1113a	0.3cd	0.8ab	2120ab	1158b
	Monocrotophos	16.8% EC	0.5cd	0.6d	535a	92b	3.8a	1.9ab	36b	134c	0.1d	0.1c	1982ab	362b
	Pyridaphention	75% WP	1.1ab	2.3ab	346ab	156b	3.8a	10.8a	135b	174c	0.2d	0.5bc	1646ab	2121b
	Cyanofenphos	40% EC	1.0bc	2.2ab	452ab	1040a	3.9a	2.7ab	141b	914ab	0.2d	0.3bc	3660a	5877a
	Carbaryl	80% WP	0.9b	1.6bcd	195ab	51b	2.2ab	3.0a	128ab	41c	0.2d	0.2bc	1010ab	259b
	Ethylan	45% EC	0.7bc	0.8cd	7b	35b	0.6c	1.2b	11b	44c	0.4cd	0.3bc	32b	90b
	Control		1.4a	1.7abc	45ab	16b	0.9bc	2.1a	71ab	24c	5.2a	1.2ab	11b	30b

Table 2. *Continued*

			Spiders				*M. atrolineata*				*C. lividipennis*			
			Avg. no./hill		Avg. *N. lugens*/ spider		Avg. no./hill		Avg. *N. lugens*/ *M. atrolineata*		Avg. no./hill		Avg. *N. lugens*/ *C. lividipennis*	
Test no.	Insecticide	Formulations	After treatments[b]	Last sample	After treatments	Last sample	After treatments	Last sample	After treatments	Last sample	After treatments[b]	Last sample	After treatments	Last sample
4	BPMC	50% EC	0.7ab	0.6ab	365b	337b	3.0ab	0.1a	101b	1695c	0.5bc	1.5a	770bc	165a
	MIPC	50%WP	0.7ab	0.6ab	779b	799b	2.2ab	< 0.1a	292b	9825a	0.5bc	1.6a	1130bc	290a
	Carbophenothion	48% EC	0.6ab	0.5ab	511b	1120b	1.5abc	< 0.1a	311b	7650b	0.3bc	2.0a	940bc	316a
	MTMC	30% EC	0.6ab	0.5ab	457b	194b	0.9bc	< 0.1a	358b	—	0.2bc	0.4a	904bc	257a
	Phosphamidon	50% EC	0.7ab	1.1a	642b	592b	5.1a	< 0.1a	128b	—	0.2bc	1.6a	8862ab	353a
	Endosulfan	35% EC	0.4abc	0.5ab	633b	440b	0.8abc	< 0.1a	324b	1322d	0.5bc	1.4a	770bc	356a
	Triazophos	40% EC	0.5ab	0.4ab	1904b	3711b	0.5c	< 0.1a	3356a	—	0.1c	31.1a	13052a	727a
	Decamethrin	31% EC	0.3c	0.2b	5632a	10433a	1.0bc	< 0.1a	1734ab	—	0.8b	2.2a	2094bc	571a
	Control		0.8a	0.8a	1131b	286b	1.4abc	< 0.1a	1070ab	—	4.4a	2.3a	273c	100a
5	Acephate	75%WP	1.4b	1.4ab	654ab	94bcd	12.6ab	3.5a	92ab	145a	1.9abc	1.3bc	681a	161b
	Azinphos-ethyl + MTMC	32% EC	1.0d	1.4ab	590abc	79bcd	3.2c	0.7a	253ab	260a	0.6c	2.2b	2165a	97b
	BPMC + Chlorpyrifos	32% EC	1.1bcd	1.5ab	613abc	40cd	7.3abc	2.3a	106ab	64a	0.6c	0.5cd	2026a	345b
	Dimethoate	38% EC	1.5bc	1.6ab	921a	209b	10.1abc	4.5a	397a	286a	0.8bc	1.2bc	1855a	601b
	Propoxur	20% EC	1.2bcd	1.1ab	182c	7d	10.3ab	4.7a	23b	4a	1.0c	0.1e	1990a	66b
	Chlorpyrifos	40% EC	1.4b	1.0b	358bc	95bcd	6.8abc	6.0a	86ab	19a	0.6c	0.3de	2680a	512b
	Penncap-M	25% EC	1.4b	2.3ab	1049a	168bc	24.1a	8.3a	178ab	469a	0.9c	0.4cde	3710a	1607a
	Fenvalerate	38% EC	1.0cd	1.3ab	798ab	349a	4.1bc	3.9a	216ab	458a	3.4ab	19.2a	250a	37b
	Control		1.7a	2.3a	612abc	74bcd	7.8abc	2.0a	205ab	129a	5.3a	9.7a	261a	74b

a. All treatments in a column followed by a common letter are not significantly different by Waller and Duncan's BSD ($P < 0.05$).

b. Average per hill after treatments = (no. after treatments 1 + 2 + 3/total no. of hills samples).

c. —, *M. atrolineata* were not sampled.

In contrast to the large differences among treatments in numbers of *N. lugens*, predator populations were relatively low throughout crop development and quite uniform in both insecticide-treated and check plots (Table 2). Prey were generally abundant compared with the numbers of predators, particularly during mid- to late stages of crop development. BHC, monocrotophos, decamethrin, azinphos-methyl + MTMC, BPMC + clorpyrifos, and fenvalerate consistently reduced numbers of spiders below those in untreated checks, but the effects of the other insecticides were usually insignificant. The average number of prey per spider was significantly reduced compared with the check after some applications of some of the materials controlling *N. lugens*, such as FMC 35001, ethylan, MTMC, endosulfan, and propoxur, indicating that those materials were more toxic to prey than to the spiders. Also, most of the insecticides did not significantly affect populations of *M. atrolineata*. Methyl parathion, monocrotophos, pyridaphenthion, cyanofenphos, carbaryl sprays, isazophos, and carbofuran granules apparently were slightly more toxic to *M. atrolineata* than to *N. lugens*, since application of these materials usually caused a significant increase in the average number of prey per predator. *C. lividipennis* were generally more sensitive to insecticides than the other predator species. Most insecticides significantly reduced populations of *C. lividipennis*, and the prey-per-predator averages were usually larger than the check averages after application.

Discussion

A substantial number of insecticides commonly used on rice, including organophosphates, carbamates, and a synthetic pyrethroid, caused resurgence of *N. lugens*. The population increases observed in this study were probably not caused by the destruction of natural enemies, as suggested by other researchers (Chiu 1979, Kiritani 1979, Otake 1977). Numbers of spiders and *M. atrolineata* and the average numbers of *C. lividipennis* and *Microvelia* even in the untreated checks in this study were probably not sufficiently large to regulate *N. lugens*. In previous studies in the tropics in which these predators were reported effective against *N. lugens*, predator-prey ratios approached 1:1 during the mimddle stage of crop growth, and predator populations were often larger than prey numbers during late crop development (Hinckley 1963, Kenmore 1980, Murthy et al. 1976, Stapely 1976). Also, populations of spiders in the checks were much lower than those normally occurring in untreated fields in the Philippines (Anonymous 1977–1979, Dyck and Orlado 1977, Kenmore 1980). Therefore, this study supports previous work (Chelliah and Heinrichs 1980, Heinrichs et al., in press) demonstrating that insecticides can stimulate fecundity of *N. lugens* females, which causes populatioin increase in the fields.

Natural enemies in the tropics are apparently most important in regulating relatively low densities of *N. lugens* (Mochida and Dyck 1977). When conditions favor a rapid increase of *N. lugens* in the field, populations of the most important predators, such as spiders, *C. lividipennis*, and *M. atrolineata* cannot increase at a sufficient rate to suppress the pest (Anonymous 1977–1979, Hinckley 1963, Otake 1977). If resurgence-promoting insecticides which can stimulate the population growth of *N. lugens* are applied, natural enemies will become ineffective. Therefore, applications of resurgence-promoting insecticides are antagonistic to biological control because of their effect on the pest, regardless of their relative toxicity to natural enemies.

Previous studies also demonstrated that insecticides are generally more toxic to *C. lividipennis* than to spiders (Anonymous 1976, Chiu 1979). This work also showed that many insecticides are relatively nontoxic to *M. atrolineata*. One of the materials most effective in this study, propoxur, was apparently more toxic to *N. lugens* than to either spiders or *M. atrolineata*. In the future, field tests should be conducted with this material and other insecticides that controlled *N. lugens* to determine if selective dosages, modified formulations, different application techniques, or altered timing can be used to reduce pest populations and increase the effectiveness of important predators.

Notes

1. Homoptera: Delphacidae.
2. *Lycosa pseudoannulata* Boes et Str. (Araneae: Lycosidae). *Tetragnatha* species (Aranea: Tetragnathidae). *Araneus* species (Aranea: Argiopidae).
3. Hemiptera: Veliidae.
4. Hemiptera: Miridae.
5. Received for publication 12 December 1980. Present address: Dept. of Entomology, State Agric. Exp. Stn., Geneva, NY 14456.
6. S. Chelliah. 1979. Insecticide Application and Brown Planthopper *Nilaparvata lugens* (Stål). Resurgence in Rice. IRRI. Los Baños, Philippines.
7. T. A. Ryan and B. L. Joiner. Normal probability plots and tests for normality. Statistics Department. The Pennsylvania State University. University Park.

References Cited

Anonymous. 1977–1979. Annual reports for 1976, 1977, and 1978. International Rice Research Institute, Los Baños, Philippines.

Carino, F. O., P. E. Kenmore, and V. A. Dyck. 1979. The FARMCOP suction samples for hoppers and predators in flooded rice fields. Int. Rice Res. News 4: 21–22.

Chelliah, S., and E. A. Heinrichs. 1980. Factors affecting insecticide-induced resurgence of the brown planthopper, *Nilaparvata lugens* on Rice. Environ. Entomol. 9: 773–777.

Chen, C. C., W. H. Ku, and R. J. Chiu. 1978. Rice wilted stunt and its transmission by the brown planthopper, *Nilaparvata lugens* (Stål). Plant Prot. Bull. Taiwan 20: 376.

Chiu, S. 1979. Biological control of the brown plathopper. *In* Brown planthopper: threat to rice production in Asia. IRRI, Los Baños, Philippines. 369 pp.

Dyck, V. A., and G. C. Orlado. 1977. Control of the brown planthopper, *Nilaparvata lugens*, by natural enemies and timely applications of narrow spectrum insecticides. *In* The rice brown planthopper. Food and Fertilizer Technology Center for the Asian and Pacific Region, Taipei, Taiwan. 258 pp.

Dyck, V. A., and B. Thomas. 1979. The brown planthopper problem. *In* Brown planthopper: threat to rice production in Asia. IRRI, Los Baños, Philippines. 369 pp.

Heinrichs, E. A., R. C. Saxena, and S. Chelliah. 1979. Development and implementation of insect pest management systems for rice in tropical Asia. Food and Fertilizer Technology Center. Ext. Bull. No. 127. 38 pp.

Heinrichs, E. A., G. B. Aquino, and S. Chelliah. (in press) Resurgence of the brown planthopper, *Nilaparvata lugens*, as influenced by method and timing of insecticide applications in lowland rice. Environ. Entomol.

Hinckley, A. D. 1963. Ecology and control of rice planthoppers in Fiji. Bull. Entomol. Res. 54: 467–481.

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.

Kiritani, K. 1979. Pest management in rice. Annu. Rev. Entomol. 24: 279–312.

Ling, K. C., E. R. Tiongco, and V. M. Aguiero. 1978. Rice ragged stunt: a new virus disease. Plant Dis. Rep. 62: 701–705.

Mochida, O., and V. A. Dyck. 1977. Bionomics of the brown planthopper, *Nilaparvata lugens*. *In* The rice brown planthopper. Food and Fertilizer Technology Center for Asia and Pacific Region, Taipei, Taiwan. 258 pp.

Murthy, K. S. R. K., B. H. Krishnamurthy Rao, S. M. Zaheruddeen, and K. Laxminarayana. 1976. Seasonal abundance of the predator *Cyrtorhinus lividipennis* (Miridae: Hemiptera) on the brown planthopper in Andhra Pradesh, India. Rice Entomol. Newslett. 4: 19–20.

Otake, O. 1977. Natural enemies of the brown planthopper. *In* The rice brown planthopper. Food and Fertilizer Technology Center for the Asian and Pacific Region. Taipei, Taiwan. 258 pp.

Stapely, J. H. 1976. The brown planthopper and *Cyrtorhinus* spp. predators in the Solomon Islands. Rice Entomol. Newslett. 4: 15.