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Resurgence of *Nilaparvata lugens*[1] (Stål) Populations as Influenced by Method and Timing of Insecticide Applications in Lowland Rice[2]

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Abstract

Resurgence of *Nilaparvata lugens* (Stål) after insecticide application is a common phenomenon in rice in South and Southeast Asia. Among other insecticides inducing resurgence, carbofuran, decamethrin, and methyl parathion were selected for this study. Of the various methods of carbofuran application tested, foliar sprays were most active in inducing resurgence. Extent of resurgence was highly influenced by time of insecticide application. Sprays of methyl parathion and decamethrin applied 50 and 65 days after transplanting (DT) induced resurgence in the third generation of *N. lugens* at ca. 90 DT, whereas earlier applications had little effect. The cause(s) for resurgence was not definitely established, but stimulation of *N. lugens* reproduction appeared to be of more significance than destruction of natural enemies.

In the last decade, *Nilaparvata lugens* (Stål) has risen from the status of a minor pest to a position of major importance in tropical Asia. This pest feeds at the base of the rice plant near the water level, causing direct damage which results in "hopperburn" and the transmission of grassy, ragged (Ling et al. 1978), and wilted stunt viruses (Chen et al. 1978). From 1972 to 1974, major *N. lugens* outbreaks occurred throughout South and Southeast Asia. The economic threshold is about one *N. lugens* per tiller or 20 per hill (Dyck and Orlido 1977), but under severe infestations the population may reach 50 times the threshold level.

The cause of the sudden increase in prominence of *N. lugens* is not known, but changes in cultural practices which have accompanied the change from traditional to high-yielding varieties have been implicated. Traditional varieties are tall statured, produce few tillers, and have weak stems and lodge when high amounts of fertilizer are applied. The high-yielding varieties, however, are short statured, have a high tillering capacity, and respond to fertilizer applications by increased grain production rather than excess vegetative growth and subsequent lodging. It has been suggested that increased cropping intensity, increases in soil fertility, and the effect of high-tillering, closely spaced plants favor an increase of *N. lugens* (Dyck et al. 1979). However, high cropping intensity, where a susceptible rice variety is continuously cropped by weekly planting of small plots, has not resulted in an increase in the *N. lugens* population (Anonymous 1967–1979). In a study conducted in India (Pillai et al. 1979), only close plant spacings and high nitrogen rates, which were not recommended to farmers, caused moderate increases in the *N. lugens* population, but not to a level causing hopperburn.

Application of some insecticides to rice has resulted in economically crippling *N. lugens* infestations. Throughout Asia, most of the hopperburned fields reported or actually observed in India, Indonesia, Philippines, and Sri Lanka have had a history of insecticide applications before the occurrence of the outbreak.

Some insecticides applied to experimental fields at the International Rice Research Institute (IRRI) have frequently caused an unusual increase in the number of *N. lugens* (Anonymous 1967–1979). Here resurgence is defined as a statistically significant increase in the *N. lugens* population or *N. lugens* damage in insecticide-treated plots over that of untreated plots. Resurgence of *N. lugens* has also been reported in Bangladesh (Alam and Karim, unpublished data),[5] India (Anonymous 1978), Indonesia (Soekarna, unpublished data),[6] and the Solomon Islands (J. H. Stapely, personal communication). The extent to which insecticides have been responsible for the widespread outbreaks over thousands of hectares in Asia is not known, but they have been suggested as the major cause.

Insecticide-induced outbreaks of insect pests have been reported on the following: walnut (Bartlett and Ewart 1951), cotton (Bottrell and Rummel 1978), hemlock (McClure 1977), and soybeans (Shepard et al. 1977). Dittrich et al. (1974) discussed the effect of insecticides on mite resurgence and found that sublethal rates directly affected the oviposition rate of *Tetranychus urticae*. Sublethal doses of topically applied carbaryl and carbofuran increased the oviposition rate and longevity of western corn rootworm, *Diabrotica virgifera* (Ball and Su 1979). Mani and Jayaraj (1976) reported the resurgence of the leafhopper, *Zygina maculifrons* on rice in India after applications of monocrotophos and phosphamidon.

Laboratory studies were conducted at the IRRI to identify some of the possible factors leading to resurgence (Chelliah and Heinrichs 1980, Chelliah et al. 1980). Some insecticides applied at sublethal doses were shown to cause a decrease in the length of the life cycle of the insect, increased feeding activity, and an increase in the reproductive rate. Simultaneous with the conduction of the laboratory studies, field studies herein reported were conducted to determine the relationship between the degree of resurgence and: (1) method, (2) timing and number of insecticide applications, and (3) destruction of natural enemies of *N. lugens*.

Materials and Methods

All experiments were conducted in irrigated lowland (5 to 15 cm of standing water) rice fields on the IRRI experimental farm in Los Baños, Laguna, Philippines. An insect-susceptible, high-yielding rice variety IR22, having a growth duration (seed sowing to harvest) of 115 days, was transplanted at 21 days after sowing at a hill spacing of 25 by 25 cm. Three to four seedlings transplanted in one spot made up a hill. Fertilizer was soil incorporated as a basal application before transplanting at a rate of 30 kg each of N, P_2O_5, and K_2O per ha. At panicle initiation, an additional 30 kg of N/ha was broadcast. A randomized complete block design with four replicates was used in all experiments. Plot size varied from 30 to 45 m^2 in the various experiments.

In previous field studies where insecticides were routinely evaluated for biological efficacy at IRRI, carbofuran, decamethrin, diazinon, and methyl parathion were observed to cause a resurgence of the *N. lugens* population and were thus selected for this study. Decamethrin and methyl parathion were used as foliar sprays in experiments on timing and number of applications. Decamethrin, diazinon, and methyl parathion sprays were used to determine the effect of insecticides on extent of *N. lugens* egg parasitization. Because carbofuran is a systemic insecticide which can be applied in several ways, it was used in the experiments to determine the effects of insecticide management on *N. lugens* resurgence.

Timing and Number of Applications

Two tests were conducted in 1978, one in the dry season (December through May) and another in the wet season (June through November) to determine the effect of time, in days after transplanting (DT) at which insecticide applications were made, and the number of insecticide applications on the degree of *N. lugens* resurgence. Insecticides were applied as foliar sprays with a knapsack sprayer. In test 1, conducted during the dry season, methyl parathion was applied at 0.75 kg of AI/ha. In test 2 (wet season), decamethrin was applied at 0.025 kg of AI/ha. In both tests, treatments consisted of sprays applied at the following DT: 20, 35, 50; 20 and 35; 35 and 50; 50 and 65; 20, 35, and 50; 20, 35, 50, and 65; and an untreated check. In the second test, an additional treatment of only one application of insecticide at 65 DT was added. Volume of spray solution in both tests was 300 liters/ha.

In test 1, only the *N. lugens* population was determined. The hoppers were visually estimated by tapping 10 hills per plot and counting the number of *N. lugens* that fell on the water surface. Counts were made weekly.

In test 2, populations of *N. lugens* and *N. lugens* predators, spiders (primarily *Lycosa pseudoannulata*) and *Cyrtorhinus lividipennis*, were collected weekly with a D-Vac suction machine by sampling 40 hills per plot. Spiders feed on *N. lugens* nymphs and adults, and *C. lividipennis* preys on *N. lugens* eggs and young nymphs. These are considered to be two of the major predators regulating *N. lugens* populations as based on their feeding capacity (Anonymous 1967–1979). *N. lugens* egg numbers were also recorded by removing 10 hills from each plot and counting the eggs per hill in the laboratory. To facilitate counting, hills were divided in half. Leaf sheaths were dissected, and eggs were counted with the aid of a stereomicroscope.

N. lugens *Egg Parasitism*

The effect of foliar spray applications of decamethrin, diazinon, methyl parathion, and ethylan on *N. lugens* egg parasites was studied. Decamethrin, diazinon, and methyl parathion are resurgence-inducing insecticides, whereas ethylan provides excellent *N. lugens* control (Chelliah and Heinrichs 1980). All insecticides were applied to 30-m^2 field plots at the rate of 0.75 kg of AI/ha, except for decamethrin, which was applied at 0.012 kg of AI/ha. Extent of egg parasitism was assessed by using the technique of Otake (1967), in which potted plants were infested with *N. lugens* eggs in the laboratory and exposed to egg parasites in the field. Seedlings of an *N. lugens*–susceptible variety, Taichung native 1, were transplanted into soil in 15-cm-diameter clay pots at the rate of four seedlings per pot and grown in the greenhouse. When plants were 30 to 40 days old, a Mylar film cage was placed over the seedlings in each pot, and 20 gravid *N. lugens* were released into the cage and allowed to oviposit for 24 h. The potted plants with *N. lugens* eggs were then placed at random in field plots at three pots per plot just before spraying at 18, 39, and 61 DT and 3 days after each spray application at 21, 42, and 64 DT. The *N. lugens* eggs were exposed to parasitism in the field for 1 day at 18 and 21 DT and 3 days at 39, 42, 61, and 64 DT.

After field exposure, the potted plants were returned to the laboratory. From each pot, three tillers including roots were removed, roots were washed, and tillers were transferred to glass tubes (2.5 by 20 cm) with 2.5 cm water and plugged with cotton. The number of *N. lugens* hatching was recorded daily, and the nymphs were removed. After *N. lugens* hatching was completed (7 to 10 days) and parasite emergence ceased, parasites were counted and plants dissected to determine the number of nonparasitized but unhatched eggs. Based on the total number of *N. lugens* eggs oviposited in the plants and the number of parasites counted, percent parasitization was determined.

Insecticide Management and Resurgence

Two tests were conducted in which three methods of carbofuran application were compared: (1) application of the flowable formulation into the rice root zone; (2) paddy water broadcast of granules; and (3) foliar spray. In test 1, the root zone application was made once at 5 DT by applying carbofuran (1 kg of AI/ha) in a band about 5 cm on one side of each row of plants and at a soil depth of about 4 cm. Broadcast application at 1 kg of AI/ha and foliar sprays at 0.5 kg of AI/ha were made four times at 5, 25, 45, and 65 DT. Insect counts were made by sampling 10 linear meters of row per plot (40 hills) with a D-Vac suction machine at 61 DT.

In test 2, insecticide applications were made at the rate of 0.75 kg of AI/ha at 25, 45, and 72 DT. The root zone application was made by injecting a solution of carbofuran into the soil near the plant at a depth of about 5 cm. Sampling for *N. lugens* and its predators, *Cyrtorhinus lividipennis*, *Microvelia atrolineata* (predators of young nymphs), and spiders was conducted 1 day before and 3 days after each application. An additional sample was taken 12 days after the last application. Thirty hills per plot were sampled by using a suction machine consisting of an auto vacuum sweeper powered by a 12-V battery (Cariño et al. 1979).

Results

Timing and Number of Applications

Timing and number of insecticide applications were factors in determining the ultimate degree of *N. lugens* resurgence (see Figs. 1–3). In test 1, with methyl parathion sprays (Fig. 1) the treatments receiving only one application at 20, 35, or 50 (not shown in Fig. 1) or the treatment receiving two applications at 20 and 35 DT (Fig. lA) were not significantly different from the check. However, the two applications at 35 and 50 DT (Fig. lB) significantly (0.05 level) increased in the second generation of *N. lugens* nymphs above that of the check at 60 DT, though the population again decreased in the third generation. Shifting the two applications to 50 and 65 DT (Fig. lC) caused a significant increase in the number of third-generation nymphs at 87 DT. Three applications at 35, 50, and 65 DT (Fig. 1D) or four applications at 20, 35, 50, and 65 DT (Fig. lE) gave results similar to the two applications at 50 and 65 DT.

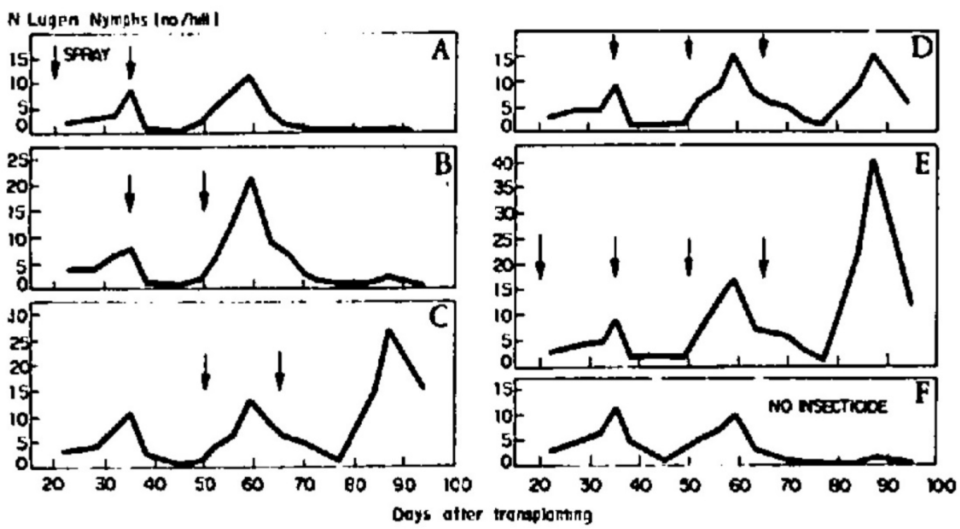

Figure 1. Number of *N. lugens* nymphs in field plots of rice receiving different numbers and timingof methyl parathion (0.075 kg of AI/ha) sprays. Population in plots receiving one application at 20, 35, or 50 DT are not shown because they were similar to the treatment with no insecticide. Arrows refer to insecticideapplication dates. Insect counts were estimated by tapping 10 hills per plot and counting the nymphs which fell on the water surface. Variety IR22, dry season, 1978.

In test 2, with decamethrin (0.025 kg of AI/ha) sprays, the *N. lugens* population reached extremely high numbers, the treatment with four applications having 1,900 nymphs per hill at 81 DT (Fig. 2E). However, those treatments receiving only one application at 20, 35, 50, or 65 DT (not shown in Fig. 2) had a low and insignificant population, similar to the check (Fig. 2F). As in the first test, any treatment receiving applications at 50 and 65 DT (Fig. 2C–E) again had a significantly higher population of the third generation than the check (Fig. 2F) resulting in hopperburn (Fig. 2G).

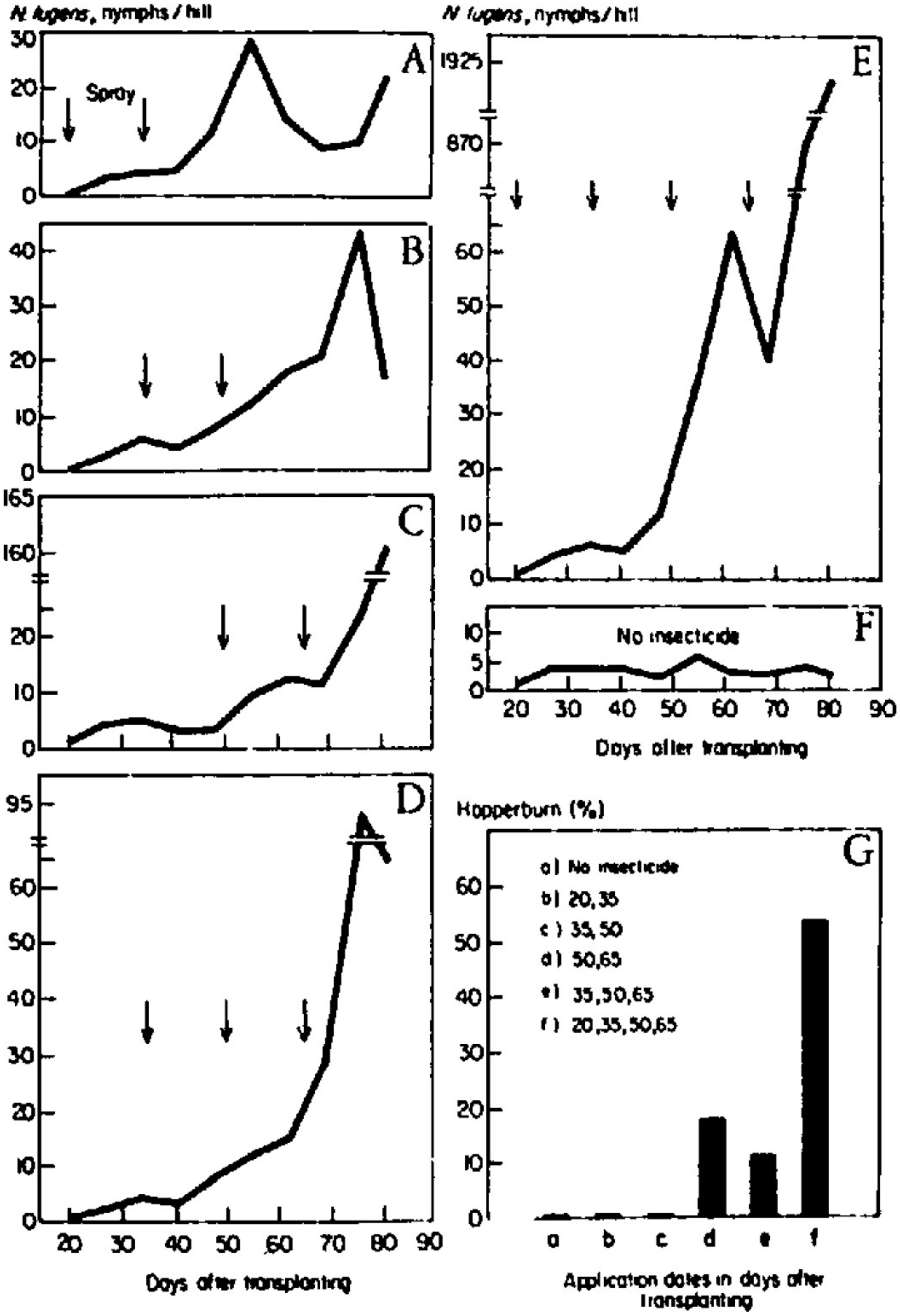

Figure 2. Number of *N. lugens* nymphs (A–F) and percent hopperburned hills (G) in field plots of rice receiving different numbers and timing of decamethrin (0.025 kg of AI/ha) sprays. Arrows refer to insecticide application dates. Insect counts were made by sampling 40 hills per plot with a D-vac suction machine. Variety IR22, wet season, 1978.

The high number of *N. lugens* nymphs in the treatment with applications at 50 and 65 DT was at least partially the result of a large number of eggs laid by *N. lugens* adults and not the survival of eggs and nymphs alone. Egg numbers reached 340 per hill at 78 DT in the treatment with sprays at 20, 35, 50, and 65 DT and 10 per hill in the check (Fig. 3B). Although the ratio of eggs in the treated per check plots at 78 DT was 34:1, the ratio of adults was only 5:1 (Fig. 3A).

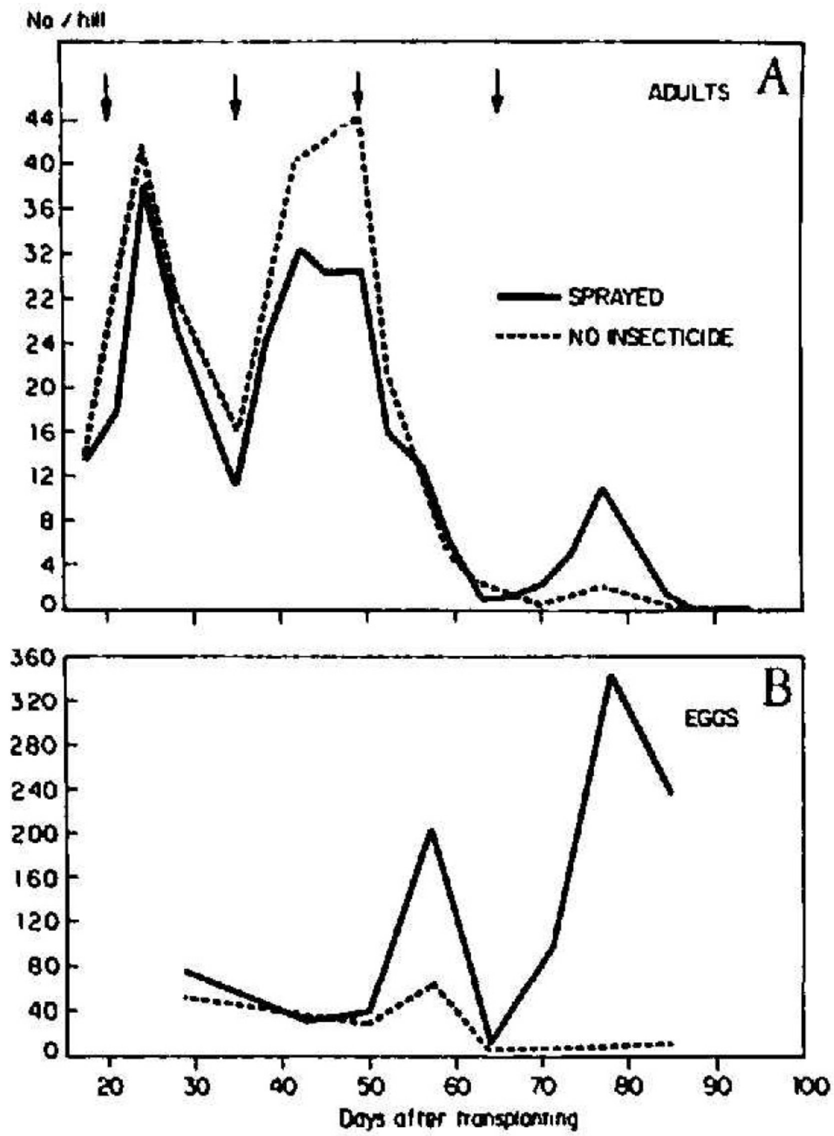

Figure 3. Population of *N. lugens* adults (A) and eggs (B) in field plots of rice receiving no insecticide and applications of decamethrin (0.025 kg of AI/ha) at 20, 35, 50, and 65 DT. Adults were collected by sampling 40 hills per plot with a D-Vac suction machine. The egg population was determined by removing 10 hills per plot and counting the eggs in the laboratory. Variety IR22, wet season, 1978.

Effect of Timing and Number of Applications on C. lividipennis *and Spiders*

The *N. lugens* population as recorded at 81 DT was extremely high in treatments receiving decamethrin sprays at 20, 35, and 50, and 20, 35, 50, and 65 DT (Fig. 4). There were no *C. lividipennis* in the check plots, and there was no statistically significant difference between the check and treatments receiving only one application of insecticide at 20, 35, or 65 DT. However, highest numbers of *C. lividipennis* occurred in the treatments with the highest *N. lugens* population. Spider populations responded differently from those of *C. lividipennis*. Although the spider population was less than one per hill in all treatments, the population in the check was the highest, being significantly greater than all treatments, except for the 20 or 20 and 35 DT treatments. No spiders were collected in the treatments receiving insecticide applications at 35 and 50 DT, 50 and 65 DT, 35, 50, and 65 DT, or 20, 35, 50, and 65 DT. The data suggest association between increased insecticide application and a subsequent decrease in the spider population.

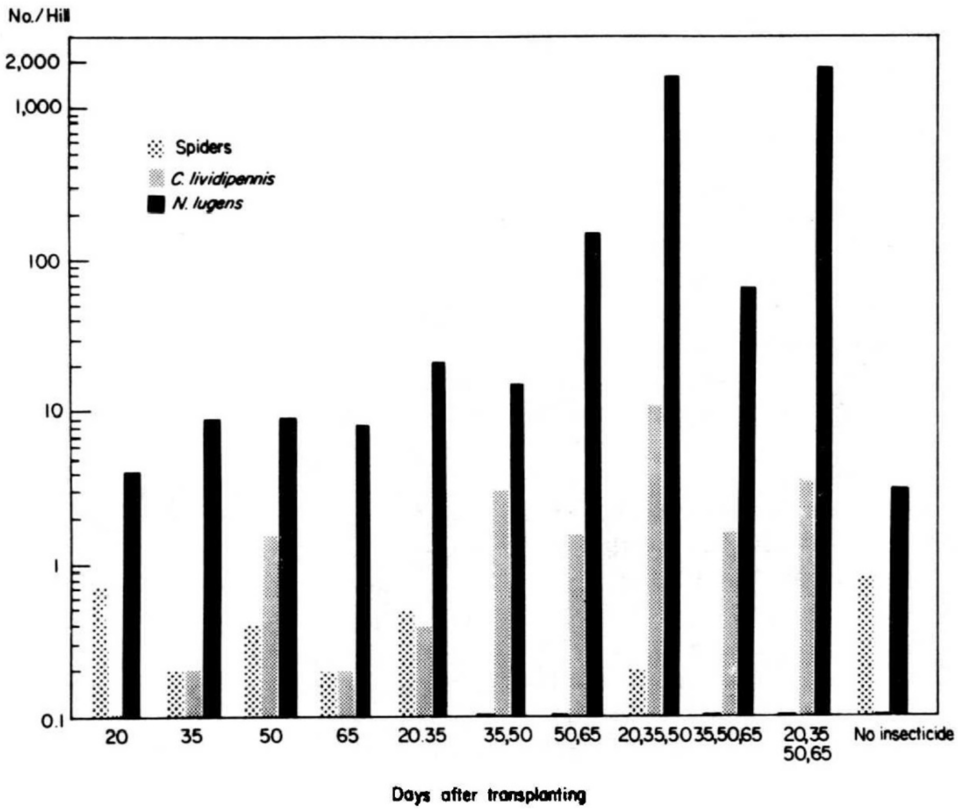

Figure 4. Populations of *N. lugens* and its predators, spiders, and *C. lividipennis* at 81 DT in field plots of rice receiving different numbers and timing of application of decamethrin (0.025 kg of AI/ha). Insect counts were made by samplIng 40 hills per plot with a D-Vac suction machine. Variety IR22, wet season, 1978.

Effect of Foliar Sprays of Insecticides on N. lugens *Egg Parasitism*

Two species, *Anagrus* sp. and *Oligosita* sp., parasitized *N. lugens* eggs. Parasitization by *Anagrus* reached 65% at 64 DT, whereas that by *Oligosita* reached a peak of 22% at 42 DT. Parasitism increased in all treatments at 42 DT and remained high at 61 and 64 DT (Fig. 5). None of the insecticides, regardless of their resurgence-inducing capability, adversely affected the extent of egg parasitism.

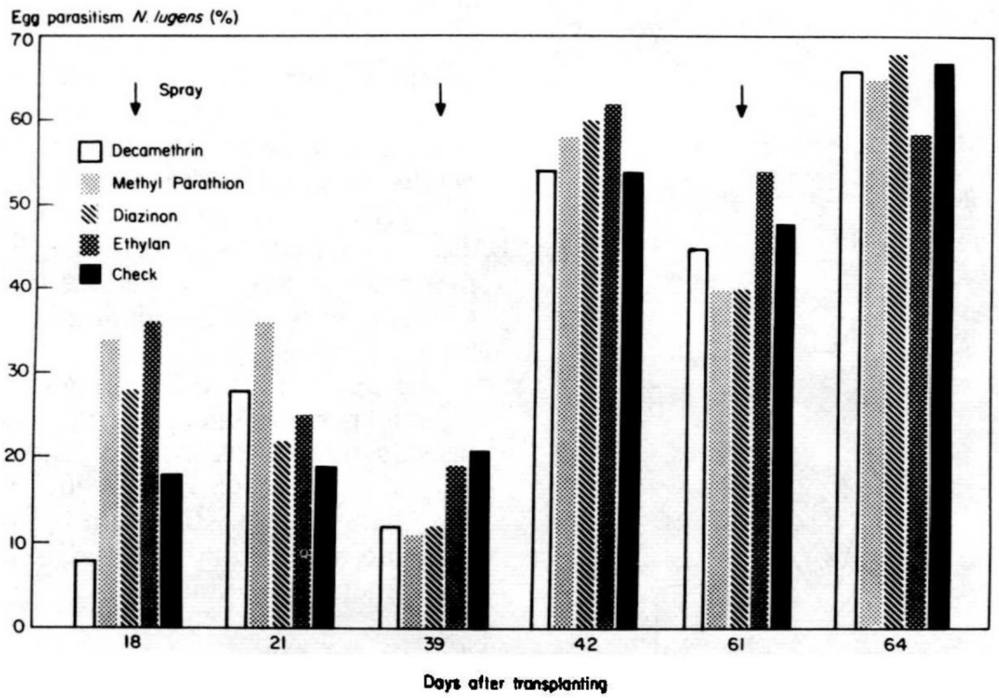

Figure 5. Effect of insecticides on parasitism of *N. lugens* eggs at various DT. Sum of *Anagrus* sp. and *Oligosita* sp. parasitism. Decamethrin was applied as a 0.002% foliar spray and others as 0.04% foliar sprays at 18, 39, and 61 DT. Arrows indicate spray dates. Variety IR22, dry season, 1979.

Effect of Insecticide Management on Resurgence

Foliar sprays were the most active in promoting *N. lugens* resurgence. In test 1 only the plots receiving the foliar spray applications had significantly higher *N. lugens* populations and percent hopperburned hills than the check (Table 1). Number of *N. lugens* in the plots receiving four foliar sprays was 749 per hill at 61 DT, whereas the population in the treatment receiving four broadcast applications was 44 per hill.

Table 1. Influence of method of carbofuran application on population[a] of *N. lugens* and degree of hopperburn; IRRI, 1977, 1980

	Test 1[c]		Test 2[d]	
Treatment[b]	*N. lugens*/hill	Hopperburned hills (%)	*N. lugens*/hill	Hopperburned hills (%)
Root zone	87b	14b	1,196ab	19a
Broadcast	44b	4b	541bc	16a
Foliar spray	749a	97a	2,456a	25a
Check	120b	8b	123d	18a

a. Means followed by a common letter are not significanlty different at the 5% level by Duncan's multiple range test.

b. In test 1, root zone application was made once with a basal application at 5 DT at 1 kg of AI/ha; broadcast applications made at 1.0 kg of AI/ha, and foliar sprays at 0.5 kg of AI/ha, both at 5, 25, 45, and 72 DT. In test 2, all applications made at 0.75 kg of AI/ha at 25, 45, and 72 DT.

c. *N lugens* counts taken at 78 DT, and hopperburn recorded at 92 DT.

d. *N. lugens* counts taken at 71 DT, and hopperburn recorded at 84 DT.

In test 2, *N. lugens* numbers were higher than the check in all treatments receiving insecticide (Table 1). Degree of resurgence was highest in the foliar spray treatment, followed by the root zone and broadcast treatments. There was a 20-fold increase in the foliar spray treatment over that of the check and a 4-fold increase in the broadcast treatment. There was an unexplained rapid decrease in the *N. lugens* population in all plots at about 80 DT and, as a result, there were no differences in percentage of hopperburned hills among treatments. Only the foliar spray treatment had an adverse effect on the *C. lividipennis* and spider population after application (Table 2).

Table 2.—Influence of method of carbofuran application on the population[a] of natural enemies; IRRI, 1980

	C. lividipennis/hill[c]							Spiders/hill[c]							*M. atrolineata*/hill[c]						
	First application		Second application		Third application		Last sample	First application		Second application		Third application		Last sample	First application		Second application		Third application		Last sample
Treatment[b]	Before	After	Before	After	Before	After		Before	After	Before	After	Before	After		Before	After	Before	After	Before	After	
Root zone	7a	21a	50a	28a	75a	50a	15b	3a	4ab	9a	10a	26a	14a	14ab	20a	339a	60a	342a	42a	47a	29a
Broadcast	7a	10a	39a	25a	44a	19b	9bc	3a	6a	8a	12a	21a	12a	19a	16a	95a	67a	104a	48a	26a	8a
Foliar spray	10a	12a	62a	3b	33a	7b	127a	3a	2b	9a	3b	4b	7a	12b	17a	197a	66a	194a	47a	50a	68a
Control	4a	18a	75a	35a	27a	22ab	9b	4a	8a	12a	8ab	18a	13a	18a	42a	71a	78a	145a	32a	18a	10a

[a] Means followed by a common letter are not significantly different at the 5% level by Duncan's multiple range test.

[b] Insecticides applied at 25, 45, and 72 DT at the rate of 0.75 kg of AI/ha per application.

[c] Counts based on sample of 30 hills per plot taken 1 day before and 3 days after each application. Last sample taken 12 days after third application at 84 DT.

Discussion

Evidence is presented that some insecticides can cause extremely high increases in the *N. lugens* population. Degree of resurgence was dependent on time, number, and method of insecticide application. Foliar sprays applied at 50 and 65 DT resulted in a high *N. lugens* egg and subsequent nymphal population, reaching a peak at about 80 DT. Stimulation of reproduction as indicated by the high *N. lugens* egg population in the insecticide-treated plots was the most important factor causing resurgence. Natural enemy destruction was a minor factor, as indicated by the effect of resurgence-inducing insecticides on *N. lugens* egg parasites and predators. A similar conclusion was reported by Soekarna.[7] Insecticides can indirectly increase reproduction by affecting the nutritional status of the plant (Rudd 1964) and by direct contact (Chelliah et al. 1980). The latter was shown to be dosage dependent in the case of the western corn rootworm, *Diabrotica virgifera* (Ball and Su 1979). The difference in degree of *N. lugens* resurgence as affected by method of carbofuran application may have been due to the differences in amount of insecticide which made contact with the insect directly or through feeding on the treated plants.

The widespread planting of nitrogen-responsive, high-yielding rice varieties has created an ecosystem which is beneficial to *N. lugens*. The "green revolution" has been accompanied by the establishment of national production programs where farmers have been encouraged through loans and subsidies to increase their low level of insecticide applications. Because of the habit of feeding at the base of the plant where often only sublethal doses reach, the *N. lugens* population has often responded by increasing to outbreak levels. In attempts to curb the *N. lugens* outbreaks, levels of insecticide use have increased. In countries where *N. lugens*-resistant varieties have not been released, success of the green revolution is in jeopardy of being limited by insecticide-induced *N. lugens* outbreaks. To avoid catastrophe, it is essential to adopt a more sophisticated level of pesticide management as part of an integrated pest management approach. Before being recommended to farmers, insecticides must be thoroughly screened to determine their tendency to promote *N. lugens* resurgence. Insecticide application methods must be improved to increase the degree of *N. lugens* control. As Rudd (1964) has aptly stated, "sublethal effects will become increasingly obvious convincing, I hope, even doubting applied biologists that the responsibility for control methods does not stop with the initial recommendations." This statement is certainly applicable to the situation in rice insect control in tropical Asia today.

Notes

1. Homoptera: Delphacidae.
2. Received for publication 9 December 1990.
3. Present address: Tamil Nadu Agricultural University, Coimbatore, India.
4. Present address: New York Agricultural Experiment Station, Geneva, New York.
5. S. Alam and A. N. M. R. Karim. 1977. Brown planthopper—a probable threat to rice cultivation in Bangladesh. Paper presented at the 2nd Bangladesh Annual Science Conf., Bangladesh Agric. Univ., Mymensingh, Jan. 23–26.
6. D. Soekarna. 1979. Time of insecticide application against *N. lugens*, based on population density and the occurrence of resurgence. Proc. Kongres Entomologi, Jakarta, Indonesia, Jan. 9–11. Mimeo. 12 pp.
7. D. Soekarna. 1979. The side effect of EC and WP type pesticides to the predators of the brown planthopper, *N. lugens*. Proc. Kongres Entomologi, Jakarta, Indonesia, Jan. 9–11, Mimeo. 17 pp.

References Cited

Anonymous. 1967–1979. Annual reports for 1966, 1967, 1968, 1969, 1970, 1972, 1976, 1977, and 1978. International Rice Research Institute, Los Baños, Philippines.

Anonymous. 1978. All India Coordinated Rice Improvement Project. Prog. Rep., Kharif 1978. Indian Council of Agric. Res. New Delhi, India.

Ball, H. J., and P. P. Su. 1979. Effect of sublethal dosages of carbofuran and carbaryl on fecundity and longevity of the female western corn rootworm. J. Econ. Entomol. 72: 873–876.

Bartlett, B., and W. H. Ewart. 1951. Effect of parathion on parasites of *Coccus hesperidum*. Ibid. 45: 783–785.

Bottrell, D. G., and D. R. Rummel. 1978. Response of *Heliothis* populations to insecticides applied in an area-wide reproduction diapause boll weevil suppression program. J. Econ. Entomol. 71: 87–92.

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

Chelliah, S., L. Fabellar, and E. A. Heinrichs. 1980. Effect of sublethal doses of three insecticides on the reproductive rate of the brown planthopper, *Nilaparvata lugens* (Stål) on rice. Ibid. 9: 778–780.

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.

Dittrich, V. P., P. Streibert, and P. A. Bathe. 1974. An old case reopened: mite stimulation by insecticide residues. Environ. Entomol. 3: 534–540.

Dyck, V. A., B. C. Misra, S. Alam, C. N. Chen, C. Y. Hsieh, and R. S. Rejesus. 1979. Ecology of the brown planthopper in the tropics, pp. 61–98. *In* Brown planthopper: threat to rice production in Asia, International Rice Research Institute, Los Baños, Philippines. 369 pp.

Dyck, V. A., and G. L. Orlido. 1977. Control of the brown planthopper (*Nilaparvata lugens*) by natural enemies and timely application of narrow-spectrum insecticides. pp. 58–72. *In* The rice brown planthopper. Food and Fertilizer Technology Center for the Asian and Pacific Region, Taipei, Taiwan. 258 pp.

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

Mani, M., and S. Jayaraj. 1976. Biological investigations on the resurgence of the blue leafhopper, *Zygina maculifrons* (Motch.). Indian J. Exp. Biol. 14: 636–637.

McClure, M. S. 1977. Resurgence of the scale, *Fiorinia externa* (Homoptera: Diaspididae) on hemlock following insecticide application. Environ. Entomol. 6: 480–484.

Otake, A. 1967. Studies on the egg parasites of the smaller brown planthopper, *Laodelphax striatellus* (Fallen) (Hemiptera: Delphacidae). I. A device for assessing the parasitic activity and the results obtained in 1966. Bull. Shikoku Agric. Exp. Stn. 17: 91–103.

Pillai, K. Gopalakrishna, M. B. Kalode, and A. V. Rao. 1979. Effects of nitrogen levels, plant spacings, and row orientation on the incidence of the brown planthopper of rice. Indian J. Agric. Sci. 49: 125–129.

Rudd, R. L. 1964. Pesticides and the living landscape. Faber, London. 320 p.

Shepard, M., G. R. Carner, and S. G. Turnipseed. 1977. Colonization and resurgence of insect pests of soybean in response to insecticides and field isolation. Environ. Entomol. 6: 501–506.