CROP PROTECTION (1987) 6 (1), 28–32

Insecticide-induced changes in the levels of resistance of rice cultivars to the whitebacked planthopper *Sogatella furcifera* (Horváth) (Homoptera: Delphacidae)

M. SALIM AND E. A. HEINRICHS*

International Rice Research Institute, Box 933, Manila, Philippines

ABSTRACT. IR2035-117-3 (highly resistant), ARC 10239 (resistant), and TN1 (susceptible) rice plants received one application at 40 days after transplanting (DT) or three spray applications (20, 30, and 40 DT) of monocrotophos, diazinon or deltamethrin. When these plants were exposed to *S. furcifera* adults, either 24 hours after the single application, or 15 days after the third of the spray applications, the deltamethrin-treated plants were most preferred. The percentage of *S. furcifera* that alighted on the three varieties decreased correspondingly with an increase in the level of varietal resistance. Differences in *S. furcifera* population growth, nymphal survival, nymphal duration, growth index and feeding rate between IR2035-117-3 and TN1 were significant. Foliar application of deltamethrin caused a significant increase in population growth on IR2035-117-3, ARC 10239, and TN1 and an increase in the nymphal survival and growth index on TN1.

Introduction

The whitebacked planthopper, *Sogatella furcifera* (Horváth) was recorded as a pest of rice in Japan as early as 697 BC (Suenaga and Nakatsuka, 1958). It is widely distributed throughout South and South-East Asia, China, Japan, South Pacific Islands and northern Australia (Khan and Saxena, 1985). *S. furcifera* is now a serious pest of rice in many Asian countries where cultivars resistant to the brown planthopper, *Nilaparvata lugens* (Stål) are being grown (Heinrichs and Rapusas, 1983). Both the nymphs and adults feed on the leaves and leaf sheaths and remove plant sap, resulting in leaf yellowing, reduced tillering and plant height and increase in unfilled grains. Large populations of *S. furcifera* cause 'hopperburn', a complete drying of plants (Pathak, 1968).

The first attempt to screen rice cultivars for *S. furcifera* resistance was initiated in 1971 (IRRI, 1972). More than 40 000 cultivars from the IRRI germplasm collection have been evaluated for *S. furcifera* resistance and 300 resistant cultivars have been identified (Heinrichs and Rapusas, 1983). Genetic analysis of selected varieties has identified five genes for resistance: four of these are the dominant type and are designated *Wbph 1, Wbph 2, Wbph 3,* and *Wbph 5* and one is recessive, designated *wbph 4*. On resistant varieties, *S furcifera* lays few eggs, develops small populations, has a prolonged nymphal developmental period and its adults are small (Choi *et al.*, 1973).

Application of insecticides can cause resurgence of insects (Ripper, 1956; Chelliah and Heinrichs, 1980a), possibly because of improved nutritional quality and growth of host plants (McClure, 1977). Insecticide residues in host plants stimulate the reproduction and survival of insects, leading to pest resurgence (Dittrich, Streibert and Bathe, 1974). Deltamethrin produces a favourable environment for *N. lugens* to alight, feed, survive and reproduce (Chelliah and Heinrichs, 1980a).

In view of the importance of host plant resistance and insecticides as tactics in integrated control, studies were carried out to determine their effect on preference, population growth, nymphal survival, nymphal duration, and feeding rate of *S. furcifera.*

Materials and methods

Experiments were laid out in a split-plot design in the greenhouse at the International Rice Research Institute, Los Baños, Laguna, Philippines, and were conducted from November 1983 to April 1984. Three rice varieties—IR2035-117-3 (highly resistant to *S. furcifera*), ARC 10239 (resistant) and TN1 (suscep-

*Present address: Department of Entomology, 402 Life Sciences Bldg, Louisiana State University, Baton Rouge, LA 70803-1710, USA.

tible)—were sown in the main plots. Each main plot was divided into four subplots consisting of three insecticides applied as foliar sprays—deltamethrin (0·002%), diazinon (0·04%) and monocrotophos (0·075%)—and the untreated check (control). Experiments consisted of 12 treatments and each treatment was replicated four times. Foliar application of insecticides took place in a spray chamber with an atomizer. The quantity of spray fluid was calculated on the basis of field recommendations (500 l/ha). Four pots were placed an equal distance apart on an electrically operated revolving table for uniform distribution of insecticides. Check plants were sprayed with tap water.

Preference tests

One insecticidal application. Seed of the three test varieties were sown in a wooden seedbox and 7-day-old seedlings were transferred to clay pots (14 cm diameter). Potted plants were placed on a galvanized iron tray filled with water. At 40 days after transplanting (DT) potted plants were placed on a revolving table and sprayed with the insecticides. Twelve potted plants, each representing one of the treatments, were then arranged in a circle on the iron tray and covered with a Mylar film cage (90 × 108 cm) which had a nylon mesh top with a hole in the middle. Each cage represented one replication. One hundred and eight *S. furcifera* adults (brachypterous females) were released, by means of a mouth aspirator, through the hole into the centre of each cage. The number of insects that alighted on plants of each treatment was determined at 0·5, 2, 4, 8 and 24 hours after release. Subsequent observations were recorded daily and continued for 10 days. After each observation any dead insects were replaced.

Three insecticidal applications. Foliar sprays were applied at 20, 30 and 40 DT. After each spray the potted plants were arranged in a circle. Fifteen days after the third insecticide application, the number of tillers, number of leaves and plant height were recorded. Plants were then covered with a Mylar film cage (90 × 108 cm) and 108 *S. furcifera* adults were released. Insects on the plants were counted as described for the previous test.

Population growth studies

Fifteen days after the third of three sprays applied at 20, 30, and 40 DT, three pairs (male and female) of *S. furcifera* adults were released per Mylar cage (11 × 108 cm). The progeny were counted 26 days after infestation.

Nymphal duration, nymphal survival and growth index

Fifteen days after the third spray application, 10 first-instar nymphs of *S. furcifera* were released into each Mylar cage (11 × 108 cm) by means of a mouth aspirator. After emergence of adults, the nymphal survival and growth index were computed as follows

$$\%\text{ Nymphal survival} = \frac{\text{No. of nymphs becoming adults}}{\text{No. of nymphs released}} \times 100$$

$$\text{Growth index} = \frac{\%\text{ Nymphs becoming adults}}{\bar{X}\text{ growth period (days)}}$$

Feeding rate

Seven days after the third insecticidal application the plants were transferred to small clay pots (5 cm diameter). One week subsequently the plants were prepared for the installation of a feeding chamber by cutting all except one of the tillers. A feeding chamber such as described by Paguia, Pathak and Heinrichs (1980) was used to estimate honeydew excretion. The feeding chamber consisted of an inverted plastic cup over bromocresol-green-treated filter paper resting on a Petri dish (Pathak and Heinrichs, 1982). The feeding chamber was fixed on a leaf sheath at the proper height and position with the help of pot labels and masking tape. Three 3- to 4-day-old brachypterous female adults, which had been starved but water satiated for 3 hours, were introduced into the chamber. Sixteen hours after insect release, filter papers were collected and the spots produced by the reaction of honeydew with bromocresol green were traced on paper. The area of spots was determined by counting the number of squares over millimetre squared graph paper and the feeding rate was expressed as the area of honeydew spots (Pathak and Heinrichs, 1982).

Results and discussion

Preference tests

One insecticidal application. Within 2 hours (0·08 day) after release of *S. furcifera* adults, the percentage that alighted on each of the three varieties differed significantly (Table 1), with 56% on TN1, 24·4% on ARC 10239 and 19·6% on IR2035-117-3. In the subsequent observations the number of *S. furcifera*

TABLE 1. Effect of resistant rice cultivars sprayed with insecticides on the orientational and settling response of *S. furcifera*. IRRI greenhouse, 1984

Days/hours after infestation	*S. furcifera* adults alighted (%)*		
	IR2035-117-3	ARC 10239	TN1
0·02 (0·5 h)	31·1 a (ab)	30·0 a (b)	38·9 e (a)
0·08 (2·0 h)	19·6 b (c)	24·4 ab (b)	56·0 d (a)
0·17 (4·0 h)	13·6 c (c)	22·4 bc (b)	64·0 cd (a)
0·33 (8·0 h)	8·4 d (c)	20·8 bcd (b)	70·8 bc (a)
1·00 (24 h)	4·8 ef (c)	20·4 bcd (b)	74·8 ab (a)
10·00	2·8 f (c)	14·0 e (b)	83·2 a (a)

* Insects were released in the centre of the cage by means of a mouth aspirator 24 h after insecticide application. The percentage of adult insects alighted for each treatment was calculated on the basis of the number on plants. Analysis is based on values transferred to $\sqrt{x+0\cdot5}$. Average of four replications. In a column, and in a row (in parentheses), means followed by a common letter are not significantly different at the 5% level by Duncan's multiple range test.

adults further increased on the susceptible and decreased on resistant cultivars. On the tenth day, 83·2% of the *S. furcifera* were on TN1, 14% on ARC 10239 and only 2·8% on IR2035-117-3.

The interaction between varieties and insecticides for the attraction of *S. furcifera* adults was significant (F=2·65; d.f.=27; P=5%). On ARC10239 and TN1 the percentage of *S. furcifera* adults which alighted was significantly higher for deltamethrin than for the check (Table 2). On IR2035-117-3 the difference between insecticide-treated plants and the check was non-significant.

Three insecticidal applications. The numbers of *S. furcifera* adults which alighted had decreased significantly on IR2035-117-3 and ARC10239 plants but had increased considerably on TN1, 24 hours after release (Table 3). During all observations, TN1 attracted the most and IR2035-117-3 the least *S. furcifera* adults; ARC10239 was intermediate.

The interaction between varieties and insecticide applications was highly significant (F=7·1; d.f.=27; P=1%). Although the level of resistance was the major determinant of the degree of preference, insecticides also had a significant effect (Table 4). Foliar application of deltamethrin attracted a significantly higher percentage of *S. furcifera* than the check. These findings agree with those of Chelliah and Heinrichs (1980a,b and of Raman (1984), who recorded a significantly higher percentage of *N. lugens* adults on insecticide treated plants. Raman (1984) stated that foliar application of deltamethrin increased tillering and number of leaves. He attributed the increased percentage of *N. lugens* which alighted to an increase in the number of tillers and leaves rather than to an increase in plant height. In this study, the attraction of the *S. furcifera* adults tended to be towards those plants which had received foliar applications of insecticides, especially deltamethrin. There were no significant differences in the number of tillers and leaves which could be attributed to the application of insecticides. Chelliah and Heinrichs (1980a) found that, in a greenhouse test deltamethrin and diazinon did not differ from the check in improving plant growth. Similarly, in a field test insecticides (including diazinon and monocrotophos had no effect on plant height and number of tillers (IRRI, 1983). In this study, the increase in the orientational and settling response of *S. furcifera* after certain insecticide treatments may have been due to chemical changes in the rice plant rather than to an effect on plant growth.

TABLE 2. Effect of one foliar application of insecticides on the orientational and settling response of *S. furcifera* on rice cultivars with different levels of resistance. IRRI greenhouse, 1984

Insecticide	*S. furcifera* adults alighted (%)* IR2035-117-3	ARC 10239	TN1
Monocrotophos	1·8 a (c)	5·1 ab (b)	16·6 b (a)
Diazinon	2·1 a (c)	4·6 b (b)	16·8 b (a)
Deltamethrin	2·7 a (c)	5·7 a (b)	21·7 a (a)
Check	1·8 a (c)	4·5 b (b)	16·6 b (a)

* As Table 1. Average of four replications and 14 observations.

TABLE 3. Effect of insecticides based on the level of resistance in three rice cultivars on the orientational and settling response of *S. furcifera*. IRRI greenhouse, 1984

Days/hours after infestation	*S. furcifera* adults alighted (%)* IR2035-117-3	ARC 10239	TN1
0·02 (0·5 h)	26·3 a (c)	32·7 a (b)	41·0 d (a)
0·08 (2·0 h)	10·6 b (c)	25·4 b (b)	64·0 c (a)
0·17 (4·0 h)	7·6 bc (c)	22·4 b (b)	70·0 bc (a)
0·33 (8·0 h)	5·6 cd (c)	21·1 b (b)	73·2 b (a)
1·00 (24·0 h)	3·8 de (c)	8·9 cd (b)	87·3 a (a)
10·00	2·8 e (c)	7·6 d (b)	89·6 a (a)

* As Table 1, but insects released 15 days after third insecticidal application.

TABLE 4. Effect of levels of host plant resistance and insecticides on the orientational and settling response of *S. furcifera*. IRRI greenhouse, 1984

Insecticide	*S. furcifera* adults alighted (%)* IR2035-117-3	ARC 10239	TN1
Monocrotophos	1·3 ab (c)	3·4 b (b)	20·7 b (a)
Diazinon	1·3 ab (c)	4·0 a (b)	18·4 c (a)
Deltamethrin	1·8 a (c)	4·5 a (b)	22·[illegible] a (a)
Check	1·0 b (c)	2·6 c (b)	18·1 c (a)

* As Table 3. Average of 4 replications and 14 observations.

Population growth

Population increase of *S. furcifera* is considered to be an important criterion for assessing the level of resistance in rice cultivars because it represents the combined effects of feeding rate, nutritional value of food, oviposition and survival rate (Heinrichs and Rapusas, 1983). The population of *S. furcifera* on IR2035-117-3 sprayed with deltamethrin was significantly higher than those on plants treated with diazinon or monocrotophos, or on the check (Table 5) Plants of ARC10239 and TN1 that had been treated with monocrotophos or deltamethrin had higher *S. furcifera* populations than diazinon-treated plants or the check. The corresponding decrease in the level of varietal resistance was greatest on TN1 (243–300) intermediate on ARC10239 (103–126) and least on IR2035-117-3 (49–66). The population of *S. furcifera* increased by 8·2–11·0 and 40·5–50·0 times on

TABLE 5. Effect of foliar applications of insecticides on the population growth of *S. furcifera* on rice cultivars with different levels of resistance IRRI greenhouse, 1984

Insecticide	Number of insects/cage* IR2035-117-3	ARC 10239	TN1
Monocrotophos	53 b (c)	121 a (b)	277 b (a)
Diazinon	55 b (c)	107 b (b)	246 c (a)
Deltamethrin	66 a (c)	126 a (b)	300 a (a)
Check	49 b (c)	103 b (b)	243 c (a)

* Three pairs of adults were released per cage. Counts of insects were made 26 days after infestation. Average of four replications. In a column and in a row (in parentheses), means followed by a common letter are not significantly different at the 5% level by Duncan's multiple range test. Analysis is based on values transformed to $\sqrt{x}$.

IR2035-117-3 and on TN1, respectively. Pablo (1977) recorded a 3–19 times population increase of *S. furcifera* on resistant rice cultivars and of 39 times on susceptible TN1.

Nymphal survival

Nymphal survival was about 60% on IR2035-117-3, 75% on ARC10239 and 90% on TN1. Insecticides had no significant effect on *S. furcifera* survival except that deltamethrin treatment increased survival on TN1 from 88% (check) to 95%. The low survival rate of *S. furcifera* on resistant cultivars indicated the presence of an antibiosis factor.

Nymphal duration

Foliar applications of insecticides did not have a significant effect on the nymphal duration of *S. furcifera*. These results differ from those of Chelliah and Heinrichs (1980a) for *N. lugens*, where nymphal duration was significantly shorter on plants sprayed with deltamethrin. Nymphal duration of *S. furcifera* was longer on IR2035-117-3 (17 days), intermediate on ARC10239 (15 days) and shortest on TN1 (13 days), the differences between cultivars being significant.

Growth index

The higher the growth index, the more suitable is the cultivar for *S. furcifera* development. The growth indices of *S. furcifera* were about 3·7, 4·8 and 6·7 for IR 2035-117-3, ARC10239 and TN1, respectively and these differences were statistically significant (Table 6). The decrease in the growth index of *S. furcifera* due to resistance was attributable to a decrease in the nymphal survival and an increase in the nymphal duration. Foliar applications of deltamethrin on TN1 caused a significant increase in the growth index of *S. furcifera* compared with the check, but insecticides had no significant effect on the other cultivars, IR2035-117-3 and ARC10239.

Feeding rate

There was a significant difference in the amount of honeydew excreted by *S. furcifera* on the three cultivars (Table 7), with 12 times as much excreted on TN1 as on IR2035-117-3. With an increase in the level of resistance, there was a corresponding decrease in the feeding rate. Using an electronic device for monitoring *S. furcifera* feeding (Khan and Saxena, 1985) and using a technique for staining honeydew (Heinrichs and Rapusas, 1983) it has been shown that *S. furcifera* feeding is significantly reduced on resistant, compared with susceptible, plants. The increase in the feeding rate of *S. furcifera* after the foliar application of deltamethrin was statistically significant only on IR2035-117-3. On the basis of the insecticide means, deltamethrin significantly increased the feeding rate over that observed on the check plants.

TABLE 6. Impact of foliar applications of insecticides and resistance on the growth index of *S. furcifera*. IRRI greenhouse, 1984

Insecticide	Growth index on*		
	IR2035-117-3	ARC10239	TN1
Monocrotophos	3·51 a (c)	5·05 a (b)	7·13 ab (a)
Diazinon	3·65 a (c)	5·00 a (b)	6·95 ab (a)
Deltamethrin	3·83 a (c)	5·35 a (b)	7·43 a (a)
Check	3·65 a (c)	4·84 a (b)	6·68 b (a)

* In a column and in a row (in parentheses), means followed by a common letter are not significantly different at the 5% level by Duncan's multiple range test. Average of four replications. Analysis is based on actual values.

TABLE 7. Effect of insecticidal applications on the feeding rate of *S. furcifera* on rice cultivars with different levels of resistance. IRRI, 1984

Insecticide	Area of honeydew (mm^2)*			Insecticide mean
	IR2035-117-3	ARC 10239	TN1	
Monocrotophos	17 ab (c)	61 a (b)	252 a (a)	110 b
Diazinon	18 ab (c)	54 a (b)	259 a (a)	110 b
Deltamethrin	21 a (c)	65 a (b)	269 a (a)	118 a
Check	16 b (c)	53 a (b)	226 a (a)	98 bc

* Average of four replications. In a column and in a row (in parentheses), means followed by a common letter are not significantly different at the 5% level by Duncan's multiple range test. Analysis is based on values transformed to log (X), base 10.

Conclusion

This study indicated that foliar applications of insecticides, especially of deltamethrin, attracted more adults and increased nymphal survival, growth index, and population development of *S. furcifera*: these may be some of the factors leading to insecticide-induced resurgence of *S. furcifera* in the field. The effect of the insecticides, in altering susceptibility of plants to *S. furcifera*, occurred in both susceptible and resistant cultivars.

References

CHELLIAH, S. AND HEINRICHS, E. A. (1980a). Factors affecting insecticide-induced resurgence of the brown planthopper, *Nilaparvata lugens* on rice. *Environmental Entomology* **9**, 773–777.

CHELLIAH, S. AND HEINRICHS, E. A. (1980b). Influence of insecticide sprays on brown planthopper resurgence. *International Rice Research Newsletter* **5**(2), 10–11.

CHOI, S. Y., SONG, Y. H., LEE, J. O. AND PARK, J. S. (1973). Studies on the varietal resistance of rice to the whitebacked planthopper, *Sogatella furcifera*. *Korean Journal of Plant Protection* **125**, 139–142 (Korean with English summary).

DITTRICH, V., STREIBERT, P. AND BATHE, P. A. (1974). An old case reopened: mite stimulation by insecticide residues. *Environmental Entomology* **3**, 534–540.

HEINRICHS, E. A. AND RAPUSAS, H. R. (1983). Levels of resistance to the whitebacked planthopper, *Sogatella furcifera* (Homoptera: Delphacidae) in rice varieties with different resistance genes. *Environmental Entomology* **12**, 1793–1797.

IRRI (1972). *International Rice Research Institute Annual Report for 1971*. Los Baños, Laguna, Philippines. 238 pp.

IRRI (1983). *Insecticide Evaluation for 1982*. Los Baños, Laguna, Philippines: Entomology Department, IRRI. 121 pp.

KHAN, Z. R. AND SAXENA, R. C. (1985). A selected bibliography of the whitebacked planthopper, *Sogatella furcifera* (Horváth) (Homoptera: Delphacidae). *Insect Science Applications* **6,** in press.

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

PABLO, S. J. (1977). *Resistance to Whitebacked Planthopper*, Sogatella furcifera (*Horváth*) *in Rice Varieties.* PhD thesis, Indian Agricultural Research Institute, New Delhi, India. 143 pp.

PAGUIA, P., PATHAK, M. D. AND HEINRICHS, E. A. (1980). Honeydew excretion techniques for determining differential feeding activity of biotypes of *Nilaparvata lugens* on rice varieties. *Journal of Economic Entomology* **73,** 35–40.

PATHAK, M. D. (1968). Ecology of common insect pests of rice. *Annual Review of Entomology* **13,** 257–294.

PATHAK, P. K. AND HEINRICHS, E. A. (1982). Bromocresol green indicator for measuring feeding activity of *Nilaparvata lugens* on rice varieties. *Philippine Entomologist* **5,** 209–212.

RAMAN, K. (1984). Effect of insecticide applications on rice growth. *International Rice Research Newslaetter* **9**(2), 20.

RIPPER, W. E. (1956). Effect of pesticides on balance of arthropod populations. *Annual Review of Entomology* **1,** 403–438.

SUENAGA, H. AND NAKATSUKA, K. (1958). Critical review of forecasting the occurrence of planthoppers and leafhoppers on rice in Japan. *Byogaityu-Hasseiyosatu-Tokubetu-Hokoku* **1,** 1–453 (in Japanese).

Received 15 July 1985
Accepted 17 February 1986