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Development of Insecticide Resistance in the Brown Planthopper, *Nilaparvata lugens* STÅL (Hemiptera: Delphacidae)

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The long-term change of the susceptibility of the brown planthopper to 8 widely used insecticides were estimated by micro-topical application technique. The LD_{50} values obtained in 1975–1976 were compared with the values obtained in 1967 to determine if insecticide resistance developed during these 9 years making reference to the change of susceptibilities of the white backed planthopper and the small brown planthopper during the corresponding period.

The results revealed development of resistance in the brown planthopper to organophosphates, especially to malathion by ca. 10 times of increase of LD_{50} over the last 9 years and susceptibility to the carbamates also decreased slightly. However, the white backed planthopper showed virtually no change in LD_{50} during the period.

The small brown planthopper increased susceptibility to BHC and developed remarkable resistance to malathion and fenitrothion. They also developed slight resistance to the carbamates.

INTRODUCTION

Development of insecticide resistance in the rice insects is not uncommon in Japan. Among the rice pests of major importance, the green rice leafhopper, *Nephotettix cincticeps* UHLER has already developed drastic degree of resistance to the organophosphates and the carbamates within a short period after the beginning of use. The small brown planthopper, *Laodelphax striatellus* FALLÉN also developed obvious resistance to the several kinds of insecticides which had been applied extensively.

Although, at the present time, the brown planthopper and the white backed planthopper have not so far developed such a striking resistance despite intensive exposure to insecticides in the rice paddy fields of Japan.

However, control failure in the fields have been reported to be increasing recently suggesting development of resistance. Lack of confirmatory toxicological data in Kyushu districts made it difficult to analyze this information. This study was initiated to determine the change of insecticide susceptibility in the brown planthopper by micro-topical application. We report here the yearly change of insecticide susceptibility from 1967–1976 and inter-generation change of LD_{50} between the immigrant generation and the autumn generations estimated in several locations of Kyushu districts which suffer chronic occurrence of the brown planthopper. For the reason of frequent usage, "BPH" will be used for "brown planthopper".

MATERIALS AND METHODS

An average of more than 50 female planthoppers were collected from each collecting site.

Each population of the planthoppers were reared on 25 g of rice seedlings (Variety:Reiho) in a cubic glass vessel ($11\times11\times19$ cm). The culture and the test samples were held at $25\pm1°C$ with 16 hour of continuous light provided in each 24 hour period. The adult females before 4 days after emergence were used for bioassay. The hoppers were anaesthetized with carbon dioxide. The individual insects were treated topically with 0.05 micro liter of acetone solution of the active ingredient of technical grade insecticides. Treatment was applied to the dorsal thoracic surface with a micro-applicator fitted with 50 micro liter syringe (Jintan®) for gaschromatography analysis. The treated hoppers were kept with food plants.

The LD_{50} values and regression equations were obtained by statistical analysis with probit technique from the mortality data taken 24 hours after treatment. Duplicate groups of 15–20 adults were assayed at each concentration.

All the tests were performed on F_3-F_6 generations after collection. The planthoppers were collected from Kagoshima pref., Nagasaki pref. and Fukuoka pref. located in the southest, west and northest end of Kyushu island respectively. All these prefectures would possibly suffer heavy damage of BPH every year if effective control was not achieved.

The immigrant generation of BPH was captured in July, 3rd generation in August, 4th generation in September and 5th generation in October respectively. The white backed planthopper and the small brown planthopper were collected in July.

RESULTS

1975: A 1975 survey showed apparent increase of LD_{50} values (ca. 5-fold) to malathion as compared with the data for 1967. A slight increase of LD_{50} was also observed with diazinon and MTMC while no change occurred with BHC over 8 years. A general decrease of the slope of regression lines was observed indicating that the populations became more heterogeneous in terms of insecticide susceptibility. There was no significant difference of susceptibility among the 3 generations examined (Table 1).

1976: The results were basically the same as those observed in 1975.

When the LD_{50} obtained from the 2nd generation, the immigrant generation, of BPH was compared, very little difference was found between the 2 districts collected, Kagoshima and Nagasaki, with respect to the 8 insecticides tested.

However, those immigrant generations from both collection sites collected in 1976 showed resistance to malathion at a level higher than 7-times as compared with the past values obtained in series of micro-topical application tests conducted for the first time on BPH (Fukuda and Nagata, 1969).

The highest resistance ratio was obtained with malathion in agreement with the 1975 data. The 2 populations collected in 1976 showed similar trend towards

Table 1. CHANGES IN THE TOPICAL LD_{50} OF THE BPH DURING 1967—1975, FUKUOKA PREF.

Insecticides	1975[a]						1967[b]	
	3rd generation		4th generation		5th generation		3rd generation	
	LD_{50}[c]	b[d]	LD_{50}	b	LD_{50}	b	LD_{50}	b
BHC	— —	—	0.074(29.6)	1.6	— —	—	0.061(24.4)	2.1
Malathion	0.082(32.8)	1.3	0.082(32.8)	1.7	0.097(38.8)	1.8	0.017(6.8)	2.8
Diazinon	0.053(21.2)	3.3	0.047(18.8)	3.8	0.052(20.8)	2.3	0.018(7.2)	2.7
MTMC	0.010(4.0)	2.7	0.009(3.6)	3·8	0.008(3.2)	3.0	0.005(2.0)	5.6

[a] Insecticide was not applied to the paddy fields of collection sites.
[b] Data were quoted from FUKUDA and NAGATA (1969).
[c] μg/female (μg/g)
[d] Slope of regression line.

Table 2. CHANGES IN THE TOPICAL LD_{50} OF THE BPH DURING 1967—1976. KYUSHU DISTRICT

Insecticides	1976						1967[c]	
	Nagasaki[b]			Kagoshima[b]			Fukuoka	
	LD_{50}	b	Ratio[a]	LD_{50}	b	Ratio	LD_{50}	b
BHC	0.034(13.6)	1.7	0.6	0.022(8.8)	1.8	0.4	0.061(24.4)	2.2
DDT	0.021(8.4)	1.7	0.5	0.034(13.6)	2.3	0.8	0.042(16.8)	2.2
Malathion	0.18 (72.0)	2.7	10.6	0.12 (48.0)	2.8	7.1	0.017(6.8)	2.8
Fenitrothion	0.09 (36.0)	2.7	3.8	0.12 (48.0)	2.3	5.0	0.024(9.6)	3.4
Diazinon	0.034(13.6)	3.7	1.9	0.032(12.8)	3.8	1.8	0.018(7.2)	2.7
MTMC	0.012(4.8)	5.0	2.4	0.011(4.4)	4.7	2.4	0.005(2.0)	5.6
Carbaryl	0.005(2.0)	2.0	2.0	0.007(2.8)	3.0	3.5	0.002(0.8)	4.1
MIPC	0.006(2.4)	3.3	2.0	0.006(2.4)	6.6	2.0	0.003(1.2)	4.8

[a] Resistance ratio : LD_{50}(1976)/LD_{50}(1967).
[b] 2nd generation (immigrant generation).
[c] 3rd generation, See footnote b in Table 1.

Table 3. LD_{50} VALUES DETERMINED BY THE 5TH GENERATION OF THE BPH, 1976

Insecticides	Nagasaki[a]			Kagoshima[b]		
	LD_{50}	b	Ratio[c]	LD_{50}	b	Ratio
BHC	0.066(26.4)	1.7	1.9	0.044(17.6)	1.8	2.0
DDT	0.031(12.4)	3.0	2.1	0.042(16.8)	1.7	1.2
Malathion	0.21 (84.0)	3.8	1.2	0.29(116.0)	3.7	2.4
Fenitrothion	0.10 (40.0)	2.0	1.1	0.17 (68.0)	4.2	1.4
Diazinon	0.030(12.0)	5.0	0.9	0.034(13.6)	5.0	1.1
MTMC	0.009(3.6)	9.0	0.8	0.008(3.2)	5.0	0.7
Carbaryl	0.004(1.6)	3.3	0.8	0.004(1.6)	3.3	0.6
MIPC	0.002(0.8)	4.0	0.3	0.003(1.2)	9.6	0.5

[a] Insecticides applied during the crop season: Ethyl thiometon, Pyridaphenthion, MTMC, Fenitrothion Carbaryl(2 times), BPMC(3 times), Fenitrothion(2 times) Cartap(4 times).
[b] Insecticides applied during the crop season: Ethyl thiometon, Cartap(2 times), MTMC(2 times), Propaphos, Chlordimeform(2 times).
[c] Ratio: LD_{50} of the 5th generation/LD_{50} of the immigrant generation.

Table 4. CHANGES IN THE TOPICAL LD_{50} OF THE WHITE BACKED PLANTHOPPER DURING 1967—1976, KYUSHU DISTRICT

Insecticides	1976[a]						1967[b]	
	Nagasaki			Kagoshima			Fukuoka	
	LD_{50}	b	Ratio[c]	LD_{50}	b	Ratio	LD_{50}	b
BHC	0.012(8.9)	2.7	0.6	0.005(3.7)	2.3	0.2	0.021(15.6)	1.5
DDT	0.016(11.9)	2.7	2.0	0.030(22.2)	4.0	3.8	0.008(5.9)	2.0
Malathion	0.005(3.7)	2.3	1.7	0.003(2.2)	3.0	1.0	0.003(2.2)	7.4
Fenitrothion	0.002(1.5)	2.0	2.0	0.002(1.5)	3.3	2.0	0.001(0.7)	5.3
Diazinon	0.003(2.2)	5.0	1.0	0.003(2.2)	3.0	1.0	0.003(2.2)	6.5
MTMC	0.003(2.2)	4.0	1.5	0.002(1.5)	5.0	1.0	0.002(1.5)	4.4
Carbaryl	0.001(0.7)	6.9	1.0	0.001(0.7)	7.3	1.0	0.001(0.7)	3.8
MIPC	0.001(0.7)	5.0	1.0	0.001(0.7)	8.6	1.0	0.001(0.7)	5.8

[a] Collected in July.
[b] See footnote b in Table 1.
[c] Resistance ratio : LD_{50}(1976)/LD_{50}(1967).

Table 5. CHANGES IN THE TOPICAL LD_{50} OF THE SMALL BROWN PLANTHOPPER DURING 1967—1976, FUKUOKA PREF.

Insecticides	1976[a]			1967[b]	
	LD_{50}	b	Ratio[c]	LD_{50}	b
BHC	0.007(5.7)	5.6	0.2	0.034(27.6)	1.7
DDT	0.007(5.7)	5.6	0.8	0.009(7.3)	3.3
Malathion	0.046(37.4)	3.3	23.0	0.002(1.6)	4.3
Fenitrothion	0.011(8.9)	3.3	11·0	0.001(0.8)	4.9
Diazinon	0.015(12.2)	3.3	7.5	0.002(1.6)	3.3
MTMC	0.010(8.1)	5.3	3.3	0.004(3.2)	4.8
Carbaryl	0.007(5.7)	5.6	3.5	0.002(1.6)	5.9
MIPC	0.011(8.9)	2.3	1.6	0.007(5.7)	5.0

[a] Collected in July.
[b] See footnote b in Table 1.
[c] Resistance ratio: LD_{50}(1976)/LD_{50}(1967).

higher resistance to fenitrothion over 9 years.

Low level of resistance was also found with the carbamate insecticides.

The LD_{50} obtained for the 3 carbamates in 1976 were ca. 3 times greater than 1967 data (Table 2).

In the experiment to compare the inter-generation difference of susceptibility, increase of LD_{50} in the autumn generation was not observed in both populations though intensive control was conducted in the collection sites as indicated in Table 3. None of the values differed by more than a factor of 2 between the 2 generations compared (Table 3).

The tests with the white backed planthopper showed that there was no significant change of LD_{50} during these 9 years except BHC in Kagoshima which showed considerable decrease of LD_{50} values (Table 4).

By contrast, the small brown planthopper showed the most remarkable change of LD_{50} during the corresponding period though 1967 data were in good agreement with those obtained in 1962 (MIYAHARA and FUKUDA, 1964).

Susceptibility to BHC have increased significantly but they showed 23-fold resistance to malathion, 11-fold to fenitrothion and 2–4-fold to the carbamates (Table 5).

DISCUSSION

Apparent but slow development of resistance for BPH to the organophosphates as compared with those values obtained in 1967 was confirmed in these tests.

Ozaki (1978) also reported general trend of decrease of insecticide susceptibility of BPH involving local variations and yearly fluctuations from his data obtained between 1967–1975 in Shikoku districts.

In comparison with other species of rice leaf- or planthoppers such as the green rice leafhopper which developed resistance to malathion in 1962 (KOJIMA et al, 1963) and subsequently acquired resistance to the carbamates with topical LD_{50} values about 100 times as large as that of susceptible population in 1970, ca. 8 years after the introduction of the carbamate insecticides (IWATA and HAMA, 1971) and the small brown planthopper which developed resistance to BHC in 1961 (KIMURA, 1973) and to malathion in 1964 (KIMURA, 1965), BPH seems very slow in developing resistance though it belongs to similar species, lives in nearly the same habitats and is likely to have been exposed to almost equal selection pressure by insecticides applied to the paddy fields. Furthermore, it seems possible that insecticidal application in the rice paddy have exerted the highest selection pressure on BPH because they are so extremely monophagous that non-rice host plants provide only a marginal habitat though a few alternate hosts have been noted in the literature. Other rice leaf- or planthopper generally breed on different host plants when the rice plants were not found in their habitats.

However, there is a striking contrast in the rapidity of development of insecticide resistance between the migratory group of the rice planthoppers, BPH or the white backed planthopper and the non-or less migratory group of the rice leaf-or planthoppers, the green rice leafhopper or the small brown planthopper.

According to recent studies, BPH and the white backed planthopper of Japan are believed to migrate northward depending on the movement of air mass from the breeding areas in the temperate or tropical regions, probably the southern part of the China mainland or some Southeast Asian regions. Usual period of migration begins about the middle of June and continues until the middle of July every year. Four generations are produced in the rice fields and create damaging population destructive to the rice plant in September or October and then perish in the winter because they are considered not to be able to overwinter at least abundantly in Japan due to the absence of suitable hosts and low temperature during that period. This hopper migration seems to offer reasonable grounds for the explanation of the slow development of resistance in the migratory group of the planthoppers.

A particular fluctuation of insecticide susceptibility of BPH to BHC which seemed to be related to the migration of the planthopper has been reported in Kyushu districts (NAGATA and MORIYA, 1974). That is, sharp increase of BHC susceptibility in every immigrant generation and decrease in autumn generations in insecticide-treated rice paddies which consequently made a zig-zag fluctuation curve. This restoration of BHC susceptibility in the immigrant BPH seemed to have retarded development of resistance to BHC which had been used in large amount for more than 20 years.

Although not conclusive, other evidence of immigration of BPH in relation to insecticide resistance lies in the fact that BPH did not regain susceptibility to BHC against expectation though 5 years have passed since the general prohibition of BHC use for rice in 1971.

In the tests to compare the insecticide susceptibility between generations, there was no definite difference between the immigrant generation and the autumn generation in both collection sites though heavy treatments were made as shown in Table 3. The reason is perhaps because the types of chemicals applied to the paddy has changed greatly and it appeared that the variety of insecticides in current use in Japan do not establish a resistant population rapidly even when applied intensively during one crop season.

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