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Note

Development of Insecticide Resistance to Organophosphates and Carbamates in the White-Backed Planthopper, *Sogatella furcifera* Horváth, in Japan

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INTRODUCTION

The infestation of the white-backed planthopper (WBPH) in Japan, *Sogatella furcifera* Horváth, arises from the overseas immigration during the rainy season in the same way as with the brown planthopper (BPH), *Nilaparvata lugens* Stål. In contrast to the BPH, a large number of the WBPH arrive in paddy fields and multiply in the early summer season, then decrease drastically in late summer. Therefore, the damage to the rice crops by the WBPH up to now has not been as serious as the BPH. Moreover, since the WBPH has been relatively easy to control by conventional insecticides, the analysis of the evolution of its susceptibility to insecticides has been somewhat neglected.

Nagata *et al.*[1] reported that there was no significant change in the LD_{50} values for carbamates and organophosphates (OPs) of the populations collected in Kyushu in 1967 and 1976. However, Endo *et al.*[2,3] and Hosoda[4] reported recently that there has been a decrease in the insecticide susceptibility in the WBPH. In their reports in 1980, which recognized conclusively the resistance of the BPH to carbamates and OPs, they stated that the change of the WBPH susceptibility to insecticides was still not serious. The development of resistance probably started in the first half of the 1980's.

Since the WBPH and the BPH immigrate annually into Japan, it is of prime importance to monitor the pattern of change in their susceptibility to insecticides in order to devise adequate control measures. This paper reports the annual fluctuation of the insecticide susceptibility of the WBPH collected in Ono and other areas in Japan from 1984 to 1990.

MATERIALS AND METHODS

More than 100 female adults or 300–500 nymphs of the WBPH were collected annually in untreated paddy fields at Ono in Hyogo Prefecture from the middle of July to the middle of August. The National Kyushu Agricultural Experiment Station provided the Fukuoka population collected in 1986 and the National Tohoku Agricultural Experiment Station provided the Akita population collected in 1987. The other populations were collected in Nagasaki, Shizuoka and Fukushima during the first half of August from untreated fields.

Each collected population was reared on insecticide-free rice seedlings (Variety: Nihonbare) in rearing cages according to the method of Sugimoto.[5] Insects were kept in a rearing room at 25±2°C and under artificial light conditions of 16 hr daylight. Adult females of 1 to 6 days after emergence from F2–F5 generations were used for tests in this study. A 0.06 micro-liter droplet of acetone solution of the technical grade of insecticides was applied to the dorsal surface of the thorax of each female adult according to the micro-topical application technique of Fukuda and Nagata.[6] To facilitate handling the females were anesthetized with carbon dioxide in advance. The treated female adults were transferred to the untreated rice seedlings and kept in the laboratory under the same conditions as in the rearing. Each test was replicated twice with *ca.* 15 females for each replicate. Mortality was recorded 24 hr after treatment and the LD_{50} values were calculated by probit analysis combining data from 2–3 tests.

RESULTS

1. *Annual Change of Insecticide Susceptibility*

The annual change in the insecticide susceptibility of the WBPH collected in Ono during 7 years from 1984 to 1990 to several OPs and carbamates tested is shown in Table 1. High LD_{50} values of the Ono population for the carbamates tested were already observed in 1984. The LD_{50} values for MTMC, MIPC and carbaryl were *ca.* 4-fold higher than those of the Fukuoka population obtained in 1967 and they fluctuated slightly during the 7-year testing period. The LD_{50} values for BPMC and MTMC were practically similar in magnitude and fluctuation.

Table 1 Annual changes of insecticide susceptibility of the white-backed planthopper collected in Ono during 7 years.

Insecticide	LD_{50} values (μg/g)							
	1984	1985	1986	1987	1988	1989	1990	1967[a]
BPMC	5.9	11	4.6	5.7	6.2	7.5	7.7	—
MTMC	5.8	9.5	4.9	5.5	9.6	7.4	9.2	1.4
MIPC	3.8	3.2	5.2	—	—	—	—	0.89
Carbaryl	2.3	1.4	1.8	3.5	2.9	2.8	4.0	0.55
Diazinon	19	22	26	22	24	24	30	2.1
Malathion	68	55	80	39	69	—	89	1.9
Propaphos	4.9	5.6	3.7	—	5.1	5.3	7.7	—
Fenitrothion	—	—	—	22	45	39	55	0.72

[a] Data quoted from Fukuda and Nagata.[6]

Among the insecticides tested, malathion showed the highest LD_{50} values. In the first survey in 1984, malathion showed the high resistance ratio of *ca.* 36-fold relative to the Fukuoka-1967 data and thereafter its LD_{50} values fluctuated at the level of 21–47-fold. Fenitrothion was included in the survey only from 1987 onward and showed a difference of 31–79-fold. Diazinon increased from 9–14-fold. The susceptibility to propaphos was clearly higher than that of other OPs tested and fluctuated at the same level as the carbamates.

2. *Local Difference of Insecticide Susceptibility*

1985 and 1986: The LD_{50} values of the Shizuoka population collected from untreated fields in Haibara, Shizuoka Prefecture in 1985 and the Fukuoka population collected in Fukuoka Prefecture in 1986 were compared with those of the Ono population collected in the corresponding years. The results are shown in Table 2. The Shizuoka population showed extremely high LD_{50} values for malathion, its resistance ratio was 103-fold relative to the Fukuoka-1967 population and 3.5-fold relative to the Ono-1985 population. However, there was no apparent difference in the susceptibility to the other insecticides tested between the Shizuoka and Ono populations. The difference of susceptibility between the Fukuoka and Ono populations collected in 1986 was minimal (only 1–2-fold).

1987: The susceptibility of the 3 populations collected from untreated fields in Nagasaki, Fukushima and Akita Prefectures was investigated and compared with that of the Ono population collected in the same year. The results are shown in Table 3. The LD_{50} values for malathion and fenitrothion in the Nagasaki and Akita populations were higher than those of the Ono and Fukushima populations. The values for the diazinon were almost similar among 4 populations at *ca.* 16 to 26 μg/g of all populations tested, propaphos had the smallest LD_{50} values for all populations. Similarly, there was little difference in susceptibility of the 4 populations to the carbamates tested.

Table 2 LD_{50} values in μg/g of the white-backed planthopper collected in 1985 and 1986.

Insecticide	1985		1986	
	Shizuoka	Ono[a]	Fukuoka	Ono[a]
BPMC	6.9	11	6.3	4.6
MTMC	9.9	9.5	5.5	4.9
MIPC	6.4	3.2	2.2	5.3
Carbaryl	1.1	1.4	2.7	1.8
Diazinon	34	22	17	26
Malathion	190	55	76	80
Propaphos	8.5	5.6	3.5	3.7

[a] Data quoted from Table 1.

1989: The WBPH was collected in the beginning of August from untreated fields in Isahaya, Nagasaki Prefecture and its susceptibility was compared with that of Ono. The results are shown in Table 3. The LD_{50} values of the Nagasaki population for OPs and carbamates tested were similar to those of the Ono population.

DISCUSSION

In the first survey in 1984, the Ono population of the WBPH had already developed high resistance to diazinon and malathion at the level of 9 and 36-fold higher than those of the Fukuoka-1967 population. It also showed a resistance ratio of *ca.* 4-fold to carbamates such as

Table 3 LD_{50} values in $\mu g/g$ of the white-backed planthopper collected in 1987 and 1989.

Insecticide	1987				1989	
	Nagasaki	Fukushima	Akita	Ono[a]	Nagasaki	Ono[a]
BPMC	7.4	5.5	6.7	5.7	4.1	7.5
MTMC	7.4	5.3	6.6	5.5	5.1	7.4
Carbaryl	2.7	3.0	2.1	3.5	2.0	2.8
Carbofuran	1.1	0.81	0.89	0.91	0.73	1.2
Diazinon	26	16	21	22	17	24
Malathion	96	32	85	39	—	—
Propaphos	5.9	3.9	5.5	—	4.9	5.3
Fenitrothion	34	17	34	22	27	39

[a] Data quoted from Table 1.

MTMC, MIPC and carbaryl. Thereafter, no further noticeable increase of insecticide resistance has been observed. Although the LD_{50} values fluctuated slightly during the testing period, the level of resistance remained practically at the same level until 1990. In the case of the BPH, the Ono populations collected in 1984 and 1985[7] showed extremely high resistance to the OPs and carbamates tested quite different from those of other years. Despite of lack of data for the WBPH between 1981 and 1983, the subsequent trend from 1984 to 1990 suggested that 1984 and 1985 were no special years for the WBPH in contrast to the BPH.

According to Nagata *et al.*,[1] the 2 populations of the WBPH collected in 1976 in Kyushu district showed no significant resistance to OPs and carbamates when compared with data obtained in 1967. Similarly, Endo *et al.*[2] did not observe any resistance development of the WBPH collected on the East China Sea in 1980. In contrast with the above results, Hosoda[4] concluded from his tests on 7 populations collected in Hiroshima during 1985 and 1987, that the susceptibility of the WBPH decreased significantly during 1981 and 1985. Endo *et al.*[2] also confirmed the resistance development of the WBPH to OPs and carbamates from the LD_{50} values of 2 populations collected in Kyushu district in 1987.

In 1984, one year prior to Hosoda's results in 1985, the WBPH had already developed a resistance to OPs at a level which would lead to control failure. Resistance to carbamates was also high (*ca.* 4-fold higher than the LD_{50} values obtained in 1967). The LD_{50} values obtained by Endo *et al.*[2] in 1980 were not beyond the level which suggests a resistance development, but they exhibited the onset of the resistance development which was reflected in and after 1984. Therefore, it may safely be said that the WBPH had developed resistance to both the OPs and carbamates in their native habitats in the first half of the 1980's as Hosoda[4] noted. The WBPH has been rather slow in developing resistance to insecticide than the BPH. The LD_{50} values of the WBPH for the OPs tested except propaphos since 1984 to the present have been more than 10 $\mu g/g$ and when compared with the data obtained in 1967, they showed a high resistance ratio of 8–103-fold. On the other hand, the carbamates and propaphos which had LD_{50}'s less than 10 $\mu g/g$ despite of the resistance ratio of *ca.* 4–7-fold could still be effective for the control of the WBPH at present. Hosoda[4] actually had confirmed that the efficacy of the OPs was clearly inferior to that of carbamates in his field trials, malathion and fenitrothion being unsatisfactory while BPMC was still good.

Malathion aside, there was no significant regional difference in the susceptibility of the populations of the WBPH from Shizuoka and Ono in 1985, Fukuoka and Ono in 1986, and Nagasaki, Ono, Fukushima and Akita in 1987 for all the insecticides tested. This makes the WBPH a relatively easy pest to control with conventional insecticides whose LD_{50}'s remain below 10 $\mu g/g$.[8] Although the monitoring of susceptibility is needed, the WBPH does not yet require urgent measure.

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要　約

有機リン剤とカーバメイト剤に対するセジロウンカの殺虫剤抵抗性の発達

平井勝義

兵庫県小野市で採集したセジロウンカの殺虫剤感受性を微量局所施用法で1984年から7年間検定した．1967年の結果と比較して有機リン剤に対して明らかな抵抗性の発達が観察された．とくにマラソンとフェニトロチオンで高い抵抗性比を示した．またカーバメイト剤に対して約4倍の抵抗性の発達が観察された．調査期間を通して，LD_{50}値はほぼ安定していて，その後の抵抗性の発達は観察されなかった．

感受性の地域差について1985, 1986, 1987, 1989年に行なった比較では，採集した個体群間では全く差異が見られなかった．