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## Recent Trends of Insecticide Susceptibility in the Brown Planthopper, *Nilaparvata lugens* STÅL (Hemiptera: Delphacidae), in Japan

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The brown planthopper, *Nilaparvata lugens* STÅL, is known to immigrate annually into Japan from overseas, primarily from mainland China. The susceptibility to insecticides of the brown planthopper in the Ono area, Hyogo Prefecture, was monitored annually for 8 years, from 1980 to 1987, by the micro topical application technique. The susceptibility to 8 insecticides tested fluctuated greatly at levels which indicated some degree of resistance. The brown planthopper collected in 1984 and 1985 showed extremely high LD<sub>50</sub> values to both carbamates and organophosphates. Data for other prefectures showed similar fluctuations. The LD<sub>50</sub> values for 1984 and 1985 were also high.

*Key words:* *Nilaparvata lugens*, resistance monitoring

### INTRODUCTION

The brown planthopper (BPH), *Nilaparvata lugens* STÅL, migrates from abroad into Japan every rainy season (KISHIMOTO, 1981). The insecticide susceptibility of the BPH has gradually decreased since the middle of the 1970s (NAGATA et al., 1979; KILIN et al., 1981; OZAKI and KASSAI, 1982; HOSODA, 1983; ENDO et al., 1988) and reached a minimum in 1984 and 1985 (HOSODA, 1986). From 1986 to the present (ENDO, 1989), a recovering tendency became evident.

Assuming that the populations of the BPH have been renewed yearly in the Japanese paddy fields through immigration from abroad during the rainy season, it is quite possible that their susceptibility to insecticides would differ for each population in each migration year, or in each immigration wave of the same year. Therefore, it is important to monitor the insecticide susceptibility of the BPH collected yearly in the paddy fields in Japan in order to evaluate the efficacy of testing compounds. This study was conducted from 1980 to 1987.

I report here on the yearly trends in insecticide susceptibility of the BPH obtained in Ono and in other districts of Japan.

### MATERIALS AND METHODS

An average of over 100 female adults or 300–500 nymphs of the BPH were collected annually in paddy fields untreated by any pesticides, at Ono in Hyogo Prefecture, between the middle of August and the end of September. Other populations of the

BPH were collected in several districts in Kyushu and Honshu between September and October of every year from 1983 to 1987. The collection sites are shown in Fig. 1.

Each collected population was reared on rice seedlings (variety: Nihonbare) in cages according to the method of SUGIMOTO (1969, 1981). Insects were not subjected to insecticide treatment and were kept in a rearing room at a temperature of  $25^{\circ}\pm 2^{\circ}\text{C}$  and under artificial light conditions of 16L-8D. The experiments were conducted on  $F_1$ - $F_6$  generations depending on quantities available, with female adults aged 1 to 6 days being used in the tests.

The bioassay followed the micro topical application technique of FUKUDA and NAGATA (1969). A 0.06 micro-liter droplet of acetone solution of insecticides (prepared from technical grades) was applied topically to the dorsal surface of the thorax of each female adult which had been anesthetized with carbon dioxide. The treated female adults were transferred to the untreated rice seedlings and kept in the laboratory under the same conditions as in the rearing period. Each test was replicated twice with 15 female BPH each. Mortality was recorded 24 h after treatment, and  $LD_{50}$  values were calculated by probit analysis by combining data from 2-3 tests.

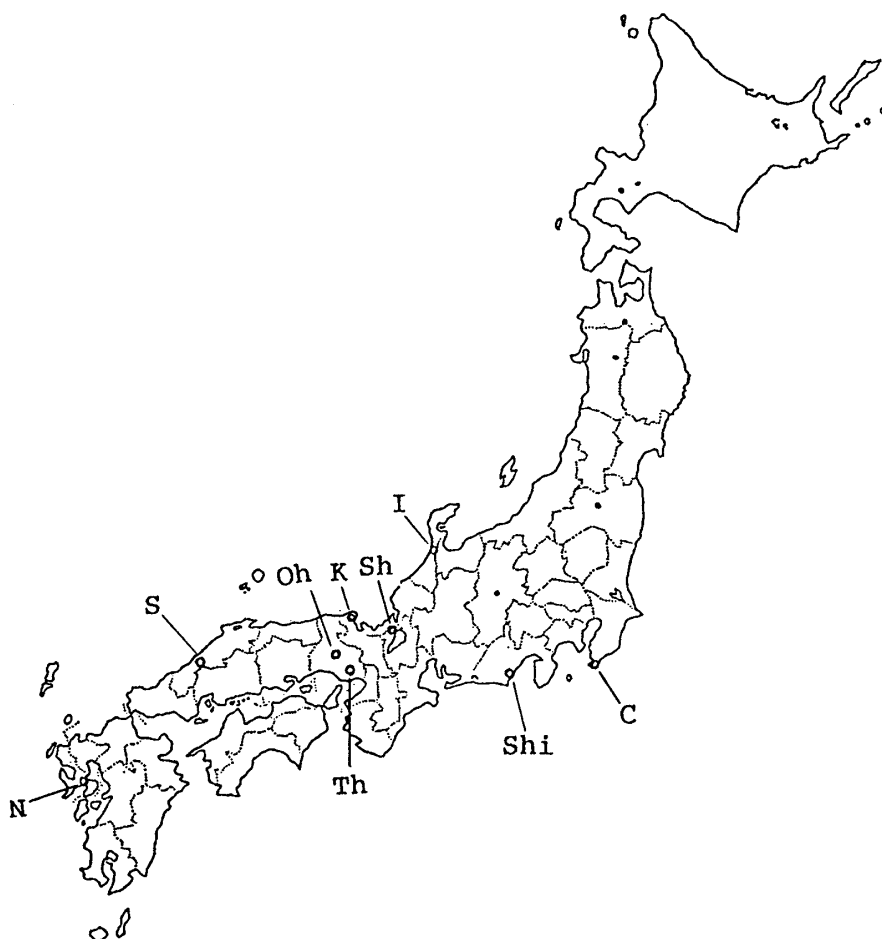


Fig. 1. Map of collection sites. N: Nagasaki, S: Shimane, Oh: Ono/Hyogo, Th: Takarazuka/Hyogo, K: Kyoto, Sh: Shiga, I: Ishikawa, Shi: Shizuoka, C: Chiba.

## RESULTS

*Annual fluctuation of insecticide susceptibility*

The annual fluctuation of the insecticide susceptibility of the BPH collected in Ono from 1980 to 1987 to carbamates and OPs is shown in Table 1.

The annual LD<sub>50</sub> values of the insecticides tested, except BPMC and diazinon, increased gradually until 1982. There was a general decrease in 1983, but in 1984 and 1985 the LD<sub>50</sub> values increased again to levels higher than in any of the previous years. In 1986 and 1987 all values reverted to low levels again, similar to those obtained in the early 1980s.

When compared with data obtained in 1967 by FUKUDA and NAGATA (1969), carbaryl showed a resistance ratio of 4.1 in 1980 (lowest) and 17.4 in 1984 (highest). It fell again to 5 in 1987. The insecticide susceptibility of the Ono population to other carbamates, such as BPMC, MTMC and MIPC, was almost at the level of carbaryl and fluctuated similarly. The LD<sub>50</sub>s for carbofuran, which has never been used in Japan owing to its high mammalian toxicity, decreased gradually from 1984 to 1987.

The Ono population showed the highest LD<sub>50</sub> values to malathion, one of the OPs tested, but the annual trend fluctuated in the same manner as with the other insecticides. In 1984 malathion showed the highest resistance ratio: 198.7 times greater than that obtained in 1967 by FUKUDA and NAGATA (1969). The LD<sub>50</sub> values for diazinon were the next highest of the OPs (ca. 10 times the values of the carbamates). Propaphos, on the other hand, had levels and fluctuations similar to those of the carbamates.

*Local differences of insecticide susceptibility*

1983: The susceptibility to insecticides of the BPH collected in Haibara (Shizuoka Prefecture), where hopperburns had occurred at the end of September, was investigated. The data were compared with those obtained for the Ono population collected in the same year. The results are shown in Table 2. The Shizuoka population showed relatively high LD<sub>50</sub> values for the 7 insecticides tested. They were 2–3 times higher for carbamates and 2 times higher for OPs as compared with those of the Ono population collected in the middle of September.

1984: The insecticide susceptibility of the BPH collected in Masuda, Shimane

Table 1. Annual changes of insecticide susceptibility of the brown planthopper collected in Ono during 8 years

Insecticide	LD <sub>50</sub> values ( $\mu\text{g/g}$ )								
	1980	1981	1982	1983	1984	1985	1986	1987	1967 <sup>a</sup>
BPMC	4.5	3.7	9.1	6.5	21.5	30.2	5.8	8.1	
MTMC	5.2	8.0	10.0	7.3	11.3	17.0	7.3	6.7	1.8
MIPC			6.7	5.0	22.7	18.0	4.8	6.1	1.1
Carbaryl	2.9	3.9	8.5	4.8	12.2	11.2	5.6	3.5	0.7
Carbofuran					4.1	2.3	0.6	0.7	
Diazinon	52.5	36.6	71.7	40.6	108.3	87.8	24.9	36.0	7.3
Malathion	62.9	71.3	167.4	165.7	1371.1	232.0	75.3	78.6	6.9
Propaphos	6.6	10.2	14.8	9.7	23.7	17.1	8.1	7.4	

<sup>a</sup> Data were quoted from FUKUDA and NAGATA (1969).

Table 2. LD<sub>50</sub> values of the brown planthopper collected in 1983

Insecticide	LD <sub>50</sub> values ( $\mu\text{g/g}$ )	
	Shizuoka	Ono
BPMC	19.4	6.5
MTMC	12.8	7.3
MIPC	11.9	5.0
Carbaryl	8.1	4.8
Diazinon	83.6	40.6
Malathion	307.4	165.7
Propaphos	18.6	9.7

Table 3. LD<sub>50</sub> values of the brown planthopper collected in 1984

Insecticide	LD <sub>50</sub> values ( $\mu\text{g/g}$ )		
	Shimane	Kyoto	Ono
BPMC	43.4	43.0	21.5
MTMC	24.3	32.8	11.3
MIPC	39.6	32.0	22.7
Carbaryl	27.3	19.1	12.2
Carbofuran	4.7	3.6	4.1
Diazinon	116.1	99.4	108.3
Malathion	1133.9	2001.9	1371.1
Propaphos	23.4	29.0	23.7

Table 4. LD<sub>50</sub> values of the brown planthopper collected in 1985

Insecticide	LD <sub>50</sub> values ( $\mu\text{g/g}$ )						
	Shimane	Kyoto	Ishikawa	Hyogo <sup>a</sup>	Shizuoka	Chiba	Ono
BPMC	40.6	30.4	33.2	23.4	31.1	29.1	30.2
MTMC	26.9	21.3	22.8	21.9	17.8	18.9	17.0
MIPC	35.8	29.1	35.4	20.5	25.1	31.5	18.0
Carbaryl	34.9	22.8	20.4	16.1	14.7	15.2	11.2
Carbofuran	3.4	4.6	4.5	1.6	3.7	3.4	2.3
Diazinon	84.8	97.2	95.8	86.2	70.0	99.7	87.8
Malathion	573.3	1411.2	552.9	427.6	301.6	595.8	232.0
Propaphos	27.0	18.3	20.4	19.8	17.9	20.9	17.0

<sup>a</sup> Collected in Takarazuka in Hyogo Prefecture.

Prefecture, and in Amino, Kyoto Prefecture, at the end of September was investigated. The results are shown in Table 3. There was no significant difference in susceptibility between the Shimane and Kyoto populations to the insecticides tested, and both populations showed extremely high LD<sub>50</sub> values for carbamates (except carbofuran) and OPs, especially. The resistance level to malathion was remarkably high for all populations.

1985: The insecticide susceptibility of the BPH collected from 6 districts between

Table 5. LD<sub>50</sub> values of the brown planthopper collected in 1986

Insecticide	LD <sub>50</sub> values ( $\mu\text{g/g}$ )		
	Shiga	Shizuoka	Ono
BPMC	6.3	12.1	5.8
MTMC	7.2	9.7	7.3
MIPC	5.6	9.4	4.8
Carbaryl	3.9	8.0	5.6
Carbofuran	0.3	0.9	0.6
Diazinon	35.3	39.5	24.9
Malathion	96.9	177.4	75.3
Propaphos	9.1	7.9	8.1

Table 6. LD<sub>50</sub> values of the brown planthopper collected in 1987

Insecticide	LD <sub>50</sub> values ( $\mu\text{g/g}$ )			
	Nagasaki	Shimane	Ishikawa	Ono
BPMC	4.5	6.2	6.8	8.1
MTMC	6.1	6.5	7.3	6.7
MIPC	5.1	6.8	4.4	6.1
Carbaryl	2.9	5.4	5.7	3.5
Carbofuran	0.4	0.4	0.7	0.7
Diazinon	32.5	31.9	41.1	36.0
Malathion	68.9	76.5	81.3	78.6
Propaphos	6.9	6.6	7.6	7.4

the beginning of September and the beginning of October was investigated and compared with that of the Ono population collected in the same year. The results are shown in Table 4. All tested populations showed a very high resistance, which was similar to that of the populations collected in 1984, to the 8 insecticides tested. Especially the Kyoto population had extremely high LD<sub>50</sub> values for malathion. There was no significant difference in susceptibility between the 7 populations tested (including Ono).

1986: The study was done on the BPH collected in Haibara, Shizuoka Prefecture, and in Adogawa, Shiga Prefecture, in 1986. The results are shown in Table 5. Both populations showed low LD<sub>50</sub> values which were basically the same as those obtained in 1983. The LD<sub>50</sub> values of both populations were almost equal to those of Ono.

1987: The insecticide susceptibility of the BPH collected in Isahaya in Nagasaki Prefecture, Izumo in Shimane Prefecture and Kanazawa in Ishikawa Prefecture was investigated. The results are shown in Table 6. The LD<sub>50</sub> values were almost equal to those obtained in 1986. There was no significant difference in susceptibility between the 4 populations (including Ono) to the 8 insecticides tested.

#### DISCUSSION

During 8 years of monitoring, from 1980 to 1987, the insecticide susceptibility of the Ono population of the BPH to carbamates and OPs fluctuated greatly, at levels

which indicated the appearance of a certain degree of resistance. In general, the resistance level for overwintering insect pests in Japan would increase steadily in proportion to the frequency of insecticide usage in the field. In contrast, a zig-zag fluctuation in susceptibility of the BPH collected in Ono during the study period seems to support the immigration theory wherein the fluctuation of susceptibility is concurrent with the yearly fluctuation of infestation.

The LD<sub>50</sub> values of the populations surveyed in 1984 and 1985 were remarkably different from those of other years. They showed high resistance to carbamates and OPs and extremely high resistance to malathion. Possibly, the populations of both years may have immigrated from habitats different from those of other years. Most likely, the BPH which immigrates to Japan every year already had a different level of insecticide susceptibility or resistance to carbamates and OPs.

The LD<sub>50</sub> values of the Shizuoka population of the BPH collected in 1983 were 2–3 times higher for carbamates and 2 times higher for OPs than those of the Ono population collected in the same year. The Shizuoka population was collected from several spots of hopperburn in the end of September in the paddy fields which were treated twice with Hino-baycid dust 2+2.5% (fenthion+edifenphos). The difference in LD<sub>50</sub> values between the 2 populations may be caused by the difference in susceptibility in the immigrant generation and/or different exposure intensity to insecticide after immigration.

In the years 1984 and 1985 there was a remarkably high resistance of the BPH to carbamates and OPs in the whole country, and in 1986 and 1987 the susceptibility seemed to recover as the LD<sub>50</sub> values fell to the 1980/1981 levels. However, there was no significant difference in the susceptibility of the populations collected in each area in each year for this study.

Since the BPH cannot hibernate in Japan and their populations arise each year from migration from abroad during the rainy season, the insecticide susceptibility detected in Japan would be a reflection of the chemical selection pressure in the area where they have originated. According to recent studies on the migration of the BPH, one of the most probable sources of migration to Japan is the southern part of mainland China. However, since the BPH can inhabit only an extremely limited part of Southern China for the entire year, most populations are presumed to arise from migration from Southeast Asia in the spring. The populations which have been subjected to chemical selection pressure in Southern China migrate again to the central-northern parts at harvest time for the first rice crop, which corresponds to the rainy season in Japan. It is known that long-distance migration of the BPH is effected through weather fronts, and direct migration from Southeast Asia to Japan, although unconfirmed cannot be excluded. The frequency of insecticide application, and thus the selection pressures in Southeast Asia, varies with different countries and different districts. Therefore, even in southern parts of mainland China, it is possible that the insecticide susceptibility of the BPH varies with years and localities independently of the insecticide usage in those different localities. This is still a matter of conjecture, but it is quite possible that the BPH populations, which already have different levels of susceptibility in Southern China, have arrived in different migration waves in Japan.

With regard to the relation between the susceptibility and the efficacy of insecticidal application in the field, IWATA and HAMA (1973) thought that the LD<sub>50</sub> of 10 µg/g was a critical level for the resistance of the green rice leafhopper. According to his

results from field trials, FUKAMACHI (1985) thought that this LD<sub>50</sub> level of 10 µg/g would enable acceptable control of the BPH. Hosoda (1983) also confirmed that existing compounds which have LD<sub>50</sub> values of less than 10 µg/g showed a good controlling effect against the BPH population. Based on the above assumption, the results obtained in the present survey show that malathion and diazinon cannot be used for the control of the BPH. Although the LD<sub>50</sub> values suggest that the BPH had already developed resistance to carbamates, most of the carbamates and propaphos could still provide satisfactory control, except in 1984 and 1985.

In recent years carbamates have been used extensively on rice in southern Asia which is one of the highly probable sources of immigration of the BPH to Japan. Their continuous and exclusive use will undoubtedly lead to the development of significant resistance. Therefore, it is quite possible that the BPH populations with high resistance to carbamates and OPs similar to those of 1984 and 1985 could again immigrate into Japan in the future. Thus, it is very important that the insecticide susceptibility of the BPH is monitored regularly as a means of early warning in order to devise an effective and cheap method of control.

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