Studies on the Resistance of Green Rice Leafhopper (*Nephotettix cincticeps* Uhler) to Four Commonly Used Insecticides in Central Taiwan[1]

Chia-Pao Chang and Min-Nan Fang[2]

ABSTRACT

The green rice leafhopper (Nephotettix cincticeps Uhler) distributes throughout the temperate, subtropical and tropical areas in the world and is regarded as one of the most serious insect pests on rice in Taiwan. This species is prevalent in central Taiwan, occurring 8-10 generations annually and is more abundant in the first rice crop.

Among the seven areas surveyed, green rice leafhopper of PY strain was found resistant to monocrotophos, TC strain was also resistant to malathion, while strain HsHs was highly tolerant to monocrotophos. Continuous use of these insecticides may result in the entire population becoming resistant over a period of time. The green rice leafhopper strains from PY was found to be highly tolerant to vamidothion and carbaryl. Hereagain, the continuous use of these three insecticides may lead to the development of resistance. Strains examined from other areas remained relatively susceptible to these four insecticides. The small correlation among the resistance levels of these four commonly used insecticides in the field populations of green rice leafhopper in central Taiwan implies that they may have multiresistance to all four insecticides. It has also been found that the toxicity of insecticides and the occurrence of green rice leafhopper may be related to temperature which may influence the appearance of resistance. There are some positive correlations between toxicity of insecticide and temperature.

Vertical polyacrylamide slab gel electrophoresis was used in the study of the esterase activity of the strains collected from yarious locations. There was positive correlation between the esterase activity and the resistance level of green rice leafhopper to these four insectivides. The esterase activity is considered to be an important factor in the appearance of esistance.

---

1. Contribution No.0031 from Taichung DAIS. and presented at the 28th Annual Meeting of the Plant Protection Society of the Republic of China, Taichung, Taiwan, Republic of China, on Dec. 12-13, 1982.

2. Assistant and assistant Entomologist of Taichung DAIS respectively, and the first author received award from National Science Council under the Executive Yuan, Republic of China, in 1983.

INTRODUCTION

The green rice leafhopper (Nephotettix cincticeps Uhler) destributes throughout the temperate, subtropical and tropical areas in the world and is regarded as one of the most serious insect pests on rice in Taiwan. This species is prevalent in central Taiwan, occurring 8-10 generations annually and is more abundant in the first rice crop. The "green revolution" is said to have been interrupted by green rice leafhopper, brown planthopper and rice blast[27]. Green rice leafhopper is the most serious obstacle to the production of the first rice crop in Taichung area, because it damages rice not only by directly sucking the plant sap at tillering and heading stages of rice but also by indirectly transmitting virus diseases such as yellow dwarf and transitory yellowing[3,4,5].

Control of insect pests has been done exclusively by insecticidal application in Taiwan. Extensive use of insecticides causes air pollution, water pollution and other contaminations in paddy fields.

It is also a matter of great concern that insectides lose effectiveness because of the insect's development of resistance. As a result, the green rice leafhopper has become one of the most difficult species to control among rice insect pests, especially during the past two decades in Taiwan and other countries in Asia. Over 50 insecticides have been recommended by the government in 1982, which include organophosphorates carba-mates, synthetic pyrethroids and others[32] for the control of green rice leafhopper. Monocrotophos, vamidothion, carbaryl and malathion were commonly applied to protect rice against green rice leafhopper in central Taiwan, but effectiveness is gradually becoming lower. Ku *et al*[24] recently reported that the LC_{50} values of green rice leafhopper to organophosphorates and carbamates were much higher than those given by F A O. It sometimes showed several times higher. Plapp (1976) attributed the cause of resistance to the use of a single or the same kind of insecticide for a long period which might induce heavier selection pressure and produce resistant strains. However, failure of chemical control in the field is not necessarily caused by the resistance in the insect. The differences in susceptibility of green rice leafhopper to these four insecticides from various areas might reflect the differences in kinds of insecticides used, the number of applications, the occurrence environmental conditions and insecticidal quality. Therefore, we started to investigate whether the resistance to insecticide in green rice leafhopper had developed.

The metabolic resistance is probably one of the most important roles in detoxifying insecticide[33]. The change of quality and quantity on esterases possibly has the intimate relationship with the susceptibility of insect to insecticides. Thus, the second objective is to utilize vertical polyacrylamide slab gel electrophoresis to analyze esterase activity of each strain collected in central Taiwan.

MATERIALS AND METHODS

1.Insects:

The green rice leafhoppers used in the experiment were collected from paddy fields in Taichung city (T C), HuaTen (H T), Ta Chia (T Ch), Tung, Shih (T S) Pu Yen (P Y), Hsen His(Hs Hs) and Chu Teng (C T). They were reared with rice seedlings in the laboratory of Taichung District Agricultural Improvement Station. The susceptible strain (Sus) has been used as a standard. In all experiments, females 4 to 9 days after emergence were used.

2. Insecticides:

1)Monocrotophos

Produced by Shell Co. and Ciba Co. 70% Technical Grade.

2)Vamidothion

Produced by Rhone Poulenc Co. 40% Technical grade

3)Carbaryl

Produced by Union Carbide Co. 99% Technical grade

4)Malathion

Produced by American Cyanamid Co. 91% Technical grade

3. Toxicity test:

Topical application was used to perform the test of insecticides. Series of various concentration of test solu. Were prepared by dissolving technical grade insecticide in acetone 0.5 ul of the solution was applied on the ventral surface of the abdomen of the female adult anesthetized with carbon dioxide. The treated insects were placed in a glass bottle containing the rice seedlings supplied as food plants with their roots folded in cotton and moistened with water. The bottles were kept in a chamber of temperature at 25±1℃ for 24 hrs and the mortality recorded. Finney's method was used to calculate the LD_{50} values.

4. The analysis of electrophoresis on the esterases of green rice leafhopper:

The female adult was ground with50μl of base solution and 20μl of ground solution was autopipetted for electrophoresis. The vertical polyacryamide slab gel electro-phoresis was adopted in this experiment. The method described by Maurer[26] was used with some modifications. The specimens were placed in a refrigerator having a voltage of 300 volts and current of 30-60 amperes for 2-3 hrs. It was then removed into α-naphthyl acetate (in phosphate buffer) solution. After 15 mins, the specimens were stained with fast blue B salt solution for 15 mins, and then fixed in acetic acid-alcohol solution. Glycerin was added to make the gel solid and treated with formalin to prevent the gel from molding. Degee of staining was judged according to Su[31]. Based on the intensity of staining, the specimens were classified into "ex. dark", "dark" , "light" and "ex. light" which represented scores of 4, 3, 2 and 1, respectively. This classifica tion was used to analyze the relationship between the intensity of esterases zymogram band and resistance.

RESULTS and DISCUSSION

A. Toxicity test in each area:

1. Toxicity test for Monocrotophos

LD_{50} values were presented in Table 1.

Resistance levels for each strain, arrange descendingly were as follow:

PY>HsHs>TC>HT>CT>TS>TCh.

Table 1 The susceptibility, regression equation and parameter of 8 strains of green rice leafhopper treated with Monocrotophos

Field collected	LD_{50} 95% Confidence limit		LD_{50} (ug/female)	LD_{50}* Ratio	Regression eguaton y = a + bx	Sb	(ug/female)
	upper	lower					
TC	0.017	0.010	0.014	3.86	y = 2.66 + 1.64x	0.43	0.081
TS	0.009	0.007	0.008	2.29	y = 2.30 + 2.26x	0.44	0.029
TCh	0.006	0.004	0.005	1.29	y = 4.01 + 1.03x	0.34	0.079
HT	0.013	0.012	0.013	3.57	y = 2.01 + 2.08x	0.24	0.051
PY	0.020	0.018	0.019	5.29	y = 0.82 + 2.92x	0.50	0.051
HsHs	0.015	0.014	0.014	4.00	y = 0.81 + 2.89x	0.46	0.039
CT	0.013	0.011	0.012	3.43	y = 1.84 + 2.29x	0.44	0.043
Sus	0.005	0.003	0.004	1.00	y = 3.30 + 2.01x	0.35	0.015

*LD_{50} Ratio=LD_{50} of field strain/LD_{50} of Sus strain.

In strains of PY and HsHs, resistance ratios were 5 and 4-5 respectively. Those between 3 and 4 included strains TC (3.86), HT (3.57) and CT (3.43). Others were less than 3. According to Decker and Bruce[7], resistance ratios higher than 5, would show ineffectiveness of insecticide in field. These lower than 5, however close to 5, thought as highly tolerant. Thus, PY is resistant to monocrotophos and HsHs, highly tolerant. Other strains were less significant when compare with the susceptible strain.

From the regression coefficient (b), i.e., the slope of the regression line, it can be seen that the order of the seven strains, from the highest to the lowest is : PY>HsHs>CT>TS>HT>TC>TCh; this series may indicate the ratio of heterogenous individuals in each population. The slopes of PY and HsHs were higher, suggesting that the dosage of the range of mortality from ten percent to ninety percent to kill green rice leafhopper was not significantly different. That is , the range was smaller, and the two strains are having the trend of the homogenous population of resis-tance[24]. The slope of TC was small; however, if the selection pressure continues, the LD_{50} ratio value may rise over the present value of 3.86. HT and CT may also be becoming resistant strains. The other population strains did not show resistance, but they had considerable variation among the individuals.

2. Toxicity test for Vamidothion

LD_{50} values were presented in Table 2.

Resistance levels for each strain, arranged descendingly were as follow:

PY>TCh>HT>CY>TC>TS>HsHs.

Table 2 The susceptibility, regression equation and parameter of 8 strains of green rice leafhopper treated with Vamidothion

Field collected	LD_{50} 95% Confidence limit		LD_{50} (ug/female)	LD_{50}* Ratio	Regression equaton y = a + bx	Sb	LD_{90} (ug/female)
	upper	lower					
TC	0.093	0.079	0.086	2.49	y = 1.78 + 2.61x	0.53	0.267
TS	0.082	0.072	0.077	2.23	y = 0.48 + 2.80x	0.35	0.167
TCh	0.119	0.103	0.109	3.16	y = 1.54 + 2.58x	0.32	0.342
HT	0.111	0.096	0.103	3.13	y = 2.14 + 2.18x	0.41	0.397
PY	0.157	0.143	0.150	4.48	y = 0.90 + 2.78x	0.45	0.430
HsHs	0.045	0.043	0.044	1.28	y = 3.84 + 2.40x	0.58	0.150
CT	0.101	0.088	0.095	2.74	y = 1.27 + 2.92x	0.44	0.260
Sus	0.042	0.027	0.035	1.00	y = 3.67 + 1.59x	0.28	0.219

*LD_{50} Ratio=LD_{50} of field strain/LD_{50} of sus strain.

In comparison to the susceptible strain, none of the strains had susceptible ratio value over 5. PY was close to 5; with values above 3 were TCh (3.10) and HT (3.13), while the others were below 3. Therefore, PY has shown high tolerance, and would be considered to have resistance to vamidothion. Other strains were less significant, when compared with the susceptible strain.

In the regression line, the descending order of the seven strains was CT>TS>PY>TC>TCh> HsHs>HT, which indicates the ratio of heterogenous individuals in each population, The slope of each strain was very high, indicating that the dosage required for the mortality from ten per cent to ninety per cent of green rice leafhopper was not significantly different. If the range was smaller and the strains had higher LD_{50} values, it might predict the strains are having the trend of the homogenous population of resistance. The slope of HT was the smallest; however, if selection pressure continues, the LD_{50} ratio values might rise rapidly. This is also true for the other strains.

3. Toxicity test for Carbaryl:

LD_{50} values were presented in Table 3.

Resistance levels for each strain, arranged descendingly were as follow:

Table 3 The susceptibility, regression equation and parameter of 8 strains of green rice leafhopper treated with Carbaryl

Field collected	LD_{50} 95% Confidence limit		LD_{50} (ug/female)	LD_{50}* Ratio	Regression equaton y = a + bx	Sb	LD_{90} (ug/female)
	upper	lower					
TC	0.095	0.065	0.08	1.60	y = 1.33 + 2.07x	0.35	0.545
TS	0.085	0.055	0.07	1.40	y = 0.33 + 2.17x	0.38	0.355
TCh	0.120	0.105	0.12	2.30	y = 1.28 + 2.75x	0.47	0.325
HT	0.135	0.115	0.13	2.50	y = 1.38 + 2.10x	0.43	0.605
PY	0.265	0.215	0.24	4.80	y = 0.22 + 3.11x	0.55	1.025
HsHs	0.170	0.140	0.16	3.10	y = 1.38 + 2.43x	0.40	0.515
CT	0.125	0.105	0.12	2.30	y = 0.88 + 3.04x	0.38	0.295
Sus	0.060	0.040	0.05	1.00	y = 3.52 + 1.47x	0.24	0.365

*LD_{50} Ratio=LD_{50} of field strain/LD_{50} of Sus strain.

PY>HsHs>HT>TCh=CT>TC>TS, and no strain had a susceptible ratio value of over 5. PY was in the range 4-5. The other strains had values less than 3 except HsHs, which had a ratio of 3.1. Therefore, PY has shown higher tolerance and this could be due to resistance to carbaryl.

Other strains were less significant in compa rison to the susceptible strains.

As shown in the regression line, the descending order of the seven strains is: PY>HT>TCh> HsHs>TS>CT>TC; this would indicate the ratio of heterogenous individuals in each population. The slope of each strain was very high, suggesting that the dosage required for the range of mortality from ten per cent to ninty per cent of green rice leafhopper was not significantly different, that is , the range was smaller. HsHs strain had higher LD_{50} and may have the trend of homogenous population of resistance. The slope of CT was the highest. If the selection pressure continues, the LD_{50} ratio value might rise, but it is small. The strain of TC and HT had the same reason. The other strains had no resistance to appear, but having variation among the individuals.

4. Toxicity test for Malathion:

Ld_{50} values were presented in Table 4.

Resistance levels for each strain, arranged descendingly were as follow:

Table 4 The susceptibility, regression equation and parameter of 8 strains of green rice leafhopper treated with Malathion

Field collected	LD_{50} 95% Confidence limit		LD_{50} (ug/female)	LD_{50}* Ratio	Regression equaton y = a + bx	Sb	LD_{90} (ug/female)
	upper	lower					
TC	0.480	0.950	0.30	5.55	y = 1.88 + 0.42x	0.42	1.460
TS	0.120	0.100	0.11	2.00	y = 2.31 + 1.76x	0.35	0.550
TCh	0.135	0.115	0.13	2.27	y = 1.74 + 0.51x	0.45	0.725
HT	0.205	0.090	0.14	2.45	y = 2.49 + 1.74x	0.41	0.740
PY	0.295	0.150	0.20	3.73	y = 1.09 + 2.41x	0.45	0.705
HsHs	0.225	0.130	0.17	3.09	y = 0.99 + 2.62x	0.41	0.170
CT	0.140	0.105	0.12	2.18	y = 0.46 + 3.10x	0.49	0.375
Sus	0.070	0.040	0.06	1.00	y = 3.53 + 1.41x	0.32	0.445

*LD_{50} Ratio=LD_{50} of field strain/LD_{50} of Sus strain.

TC>PY>HsHs>HT>TCh>CT>TS. The susceptible ratio value is over 5 for TC. Strains PY (3.73) and HsHs (3.09) are over 3, while the others are less than 3. Therefore, strain TC appears to have developed resistance to this insecticide. Other strains were less significant when compared with that of the susceptible strain.

From the regression coefficient (b) ,i. e., the slope of the regression line, it can be seen that the order of the seven strains, from the highest to the lowest is: CT>HsHs>PY>TS>HT>TCh>TC; this series may indicate the ratio of heterogenous individuals in each population. The slope of mortality from ten per cent to ninety per cent to kill green rice leafhopper was not significantly different, that is the range was smaller, and these three strains had higher LD_{50} values. we might predict that these three strains have the trend of the homogenous population of resistance. The

slope of TC was small; however, if the selection pressure continue, the LD_{50} ratio value may rise over the present value of 5.55. TCh strain also became a resistant strain. The other strains did not show resistance, but they had considerable variation among the individuals.

5. The relationship of resistance in these four insectides:

According to the results of toxicity tests in each strain of green rice leafhopper, the regression relationships are:

1) Monocrotophos and malathion y=0.09+9.93x, r=0.6700

2) Monocrotophos and carbaryl y=0.05+8.86x, r=0.7611*

3) Monocrotophos and vamidothion y=0.10+3.57x, r=0.4966

4) Carbaryl and malathion y=0.21+0.40x, r=0.3186

5) Carbaryl and vamidothion y=0.11+0.31x, r=0.5475

6) Vamidothion and malathion y=0.18+0.72x, r=0.3511

The LD_{50} values of all four insecticides are somewhat positively correlated to each other. Green rice leafhopper may have some multiresistance to these four insecticides. The correlation between monocrotophos and carbaryl is significantly different. The use of these four insecticides is widespread and often farmers spray them as mixtures which may be responsible for the development of multiple resistance.

The results of the experiment show that PY strain has attained resistance to monocrotophos and HsHs strain had resistant individuals and high tolerance to monocrotophos. If the application of this insecticide is continued, it might easily induce a resistant strain. Therefore, it is essential to adopt countermeasures of control early. TC strain was also resistant to malathion. The green rice leafhopper strains HsHs and PY were found to be highly tolerant to monocrotophos and vamidothion respectively; strain PY was resistant to carbaryl for the same reason. Continuous use of these three insecticides might lead to the entire population becoming resistant over a period of time. Strains surveyed from the rest of the areas remained relatively susceptible to these four insecticides. There were clear correlations among the resistance levels of these four commonly used insecticides, occurring in the field populations of green rice leafhopper in central Taiwan, which could be attributed to the existence of multiresistance to these insecticticides.

The meteorological data indicated that there were marked differences among the seven areas surveyed. There were differences between the plain and mountain areas. The toxicity of insecticide and the occurrence of green rice leafhopper may be affected by temperature(2), which in turn may affect the appearance of resistance.

According to the meteorological data, the regression relationships are:

1) Carbaryl ratio value and temperature, y= –9.37+0.52x r=0.5437

2) Monocrotophos ratio value and temperature, y= –13.61+0.74x, r=0.6846*

3) Malathion ratio value and temperature, y= –0.59+0.16x, r=0.1485

4) Vamidothion ratio value and temperature y= –7.76+0.46x, r=0.5539

The relationships clearly show there is some correlation between the resistance of the four insecticides and the temperature, specially, the correlation between the monocrotophos ratio value

and temperature is significantly different. The higher temperature at lower-elevation location HT could be attributed to the occurrence of greater numbers of generations than at the higher-altitude location in TS. According to Lin (1978). a positive correlation existed between temperature (15℃ –25℃) and toxicity of MIPC & MTMC to brown planthoppers. At high temperature, the suscep-tibility of brown planthoppers to these two chemicals was variable. Similar, observations were made by Harris & Kinoshita (1977) on phyllotreats crucifera. As a result, the green rice leafhopper in HT had more opportunity for selection by insecticide than that in TS. Therefore, the development of resistance of green rice leafhopper in HT to insecticide was rapid.

Excessive application of insecticide to the early crop induced stronger resistance in PY, whereas application of insecticides at insufficient rates caused weaker resistance in HsHs.

The time of application by farmers is always based on the incidence of green rice leafhopper attack. Generally, application is done once a week, but where the incidence so heavy, application may be once every two or these days.

Therefore, the different susceptibilities to these four insecticides of green rice leafhopper from various areas might reflect the difference in kinds of insecticides used, the number of application, the ocurrence of green rice leafhopper, the environmental conditions and insecticidal quality.

B. The electrophoresis of esterases and relationship between esterases and resistance in each green rice leafhopper strain:

1) The electrophoresis of esterases in green rice leafhopper strain:

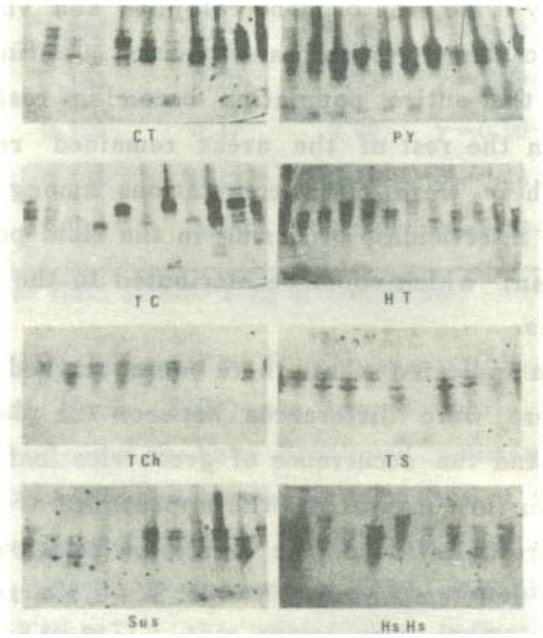


Fig. 1 The esterase zymogram of green rice leafhoppers tested

In Fig. 1, each esterase zymogram represents the activity of esterase to α-naphthyl acetate. Based on the degree of staining, the ratio value of intensity of esterase zymogram on each green rice leafhopper strain was obtained and the degree of staining from the highest to the lowest is: PY, TC, CY, HT, HsHs, TS, TCh, Sus, where PY was the darkest suggesting high activity, Sus was the lightest and others moderate.

2) The relationship between the analysis of electrophoresis in esterases and resistance.

The relationships between the analysis of electrophoresis in esterases and ratio values of resistance are:

1) Carbaryl, y= –0.52+1.10x, r=0.7143*

2) Monocrotophos, y= –1.25+1.64x, r=0.8711**

3) Malathion, y= –0.46+1.21x, r=0.6948

4) Vamidothion, y= –0.24+1.26x, r=0.7396*

Thus, the results strongly indicate a positive correlation between the activity of esterases and the ratio value of resistance. The higher the resistance, the greater the activity of esterases. Chung(1981) observed a correlation between the activity of esterases in brown planthopper and the ratio value of resistance to malathion. Citing the same reason, Chang (1982) also showed a correlation between the activity of esterases in brown planthopper and the ratio value of resistance to MIPC, MTMC, hokbal and monocrotophos. Carbamate resistance in the green rice leafhopper is mainly due to reduced sensitivity of esterase to inhibition by carbamate insecticide (Hama and Iwata, 1971, 1978; Iwata and Hama 1972), although a complementary resistance factor, an increased degradation of carbamates, is involved in it, (Kazano ***et al***, Hama ***et al*** 1979). Ozaki ***et al*** (1966) showed the occurrence of resistance of green rice leafhopper to malathion and smaller planthopper to fenitrothion and malathion; it was the activity of esterases, which might resolve these two insecticides into impoisonous material. Electrophoresis showed the esterases taking part in detoxification. Besides, Devonshire (1977) has shown the correlation between the esterases in ***Myzus persicae*** and the resistance to organophosphate. Similar, observations were made by Georghiou Pasteau(1980) on ***Culex quinquefasciatus***.

The results obtained from the present experiment are in agreement with the findings of others and the esterases activity is an important factor in the appearance of resistances.

ACKNOWLEDGEMENTS

The author wishes to express his sincere gratitude to Prof. C. N. Sun, National Chung Hsing University, Dr. T. C. Wang, Academia sinica and Dr. J. N. Daniel, Hawaii University, for their valuable suggestions, kind encouragement and revision of the manuscript.

LITERATURE CITED

1. Chang, C.P. 1982. Studies on the resistance of brown planthopper (***Nilaparvata lugens*** Stal) to four commonly used insecticides in central Taiwan. TDAIS Bull,(Taiwan, R. O. C.). 6:46-61 (in Chinese

with an English summary).

2. Chen, C. C. 1969. Studies on the effect of different temperatures on egg stage and nymph stage of *Nephotettix cincticep* in Taiwan. Taiwan Agriculture quarterly. (Taiwan, R.O.C.). 5(2):1-7(in Chinese with an English summary).
3. Chen, C. C. 1980. Epidemiological studies on rice transitory yellowing with special reference to its transmission by the rice green leafhoppers. TDAIS Bull. (Taiwan, R.O.C.). 4:1-61. (in Chinese with on English summary).
4. Chiu, R. J., J. H. Jen and M. H. Chen. 1966. Transmission of yellow dwarf of rice by two leafhoppers in Taiwan. Plant Prot. Bull.(Taiwan, R.O.C.). 8:275-286.
5. Chiu, R. J., J. H. Jean, M. H. Chen and T. C. Lo. 1968. Transmission of transitory yellowing virus of rice by two leafhoppers. Phytopathology. 58:740-745.
6. Chung, T. C. 1981. Resistance to several organophosphorus and carbamate insec-ticides in brown planthopper, ***Nilaparvata lugens*** Stal (Homoptera; Delphacidae). MS Thesis, National Chung Hsing University, 50pp. (Taiwan, R.O.C.). (in Chinese with on English summary).
7. Decker, G. C. and W. N. Bruce. 1952. House fly resistance to chemicals. Amer. J. Trop. Med. and Hyg. 1(3):395-403.
8. Devonshire, A.L. 1977. The properties a carboxylesterase from the peach potato aphid, ***Myzus pericae*** (Sulz), and its role in conferring insecticide resistance. Biochem. J. 176:676-683.
9. FAO. 1969. General Principles. In "Recommended Methods for the Detection and Measurement of Resistance of Agricultural Pest to Pesticides." Chap. 1. FAO Port. Bull. 17:76-81.
10. Finney, D. J. 1962. Estimation of the median effective dose. IN:Probit analysis (D. J. Finney, 3rd edited). Cambridge University Press, 19-47pp.
11. Georghiou, G. P., N. Pasteur and M. K. Hawley. 1980. Linkage relationships between organophosphate resistance and a highly active esterase-B in ***Culex quin-quefasciatus*** from California. J.Econ. Entomol. 73(2):301-305.
12. Hama, H. 1975. Toxicity and antiacetylcholinesterase activity of propaphos, O, O-di-(n)-propyl-0-4-methylthiophenyl phosphate, against the resistant green rice leafhopper, ***Nephotettix cincticeps*** Uhler. Botyu-Kagaku 40:14-19 (in Japanese with an English summary).
13. Hama, H. 1976. Modified and normal cholinesterased in the respective strains of carbamate-resistant and susceptible green rice leafhoppers, ***Nephotettic cincticeps*** Uhler (Hemiptera: Cicadellidae). Appl. Ent. Zool. 11:239-247.
14. Hama, H. 1980. Mechanism of insecticide resistance in green rice leafhopper and small brown planthopper. Rev. Plant Prot. Res. 13:54-73.
15. Hama, H. and T. Iwata. 1971. Insensitivity of cholinesterase in ***Nephotettix cincticeps*** resistant to carbamate and organophosphorus insecticides. J. Econ. Entoml. 65(3):643-644.
16. Hama, H. and T. Iwata. 1971. insensitive cholinesterase in the Nakagawara strain of the green rice leafhopper, ***Nephotettix cincticeps*** Uhler (Hemiptera: Cicadellidae), as a cause of resistance to

carbamate insecticides. Appl. Ent. zool. 6:183-191.

17. Hama, H. and T. Iwata. 1978. Studies on the inheritance of carbamate-resistance in the green rice leafhopper, ***Nephotettix cincticeps*** Uhler (Hemiptera: Cicadellidae). Relationships between insensitivity of acetylcholinesterase and cross resistance to carbamate and organophosphate insecticides. Appl. Ent. Zool. 13:190-202.
18. Hama. H., T. Iwata and C. Tomizawa. 1979. Absorption and degradation of propoxur in susceptible and resistant green rice leafhoppers, ***Nephotettix cincticeps*** Uhler (Homoptera: Cicadellidae). Appl. Ent. Zool. 14:333-339.
19. Hama, H., T. lwata, T. Miyata and T. Saito.1980. Some properties of acetylcholinesterase partially purified from susceptible and resistant green rice leafhoppers, ***Nephotetttix cincticeps*** Uhler (Hemiptera: Deltocephalidae). Appl. Ent. Zool. 15:249-261.
20. Harris, C. R. and G. B. Kinoshita. 1972. Influence of posttreatment temperature on the toxicity of pyrethroid insecticides. J. Econ. Entomol. 70:215-218.
21. Iwata, T. and H. Hama. 1972. Insensitivity of cholinesterase in ***Nephotettix cincticeps*** resistant to carbamate and organophosphorus insecticides. J. Econ. Entomol. 65:643-644.
22. Iwata, T. and H. Hama. 1981. Selection of the multiple-resistant green rice leafhopper, ***Nephotettix cincticeps*** Uhler (Hemiptera: Deltocephalidae) with pro-pohos:reversio-of resistance to propoxur. Appl. Ent. Zool. 16(1):37-44.
23. Kazano H., M. Asakawa, T. Miyata and T. Saito. 1978 Ann. Meet., Jap. Soc. Appl. Ent. Zool., Sendai.
24. Ku, T. Y. and S. C. Wang. 1978. Further studies on the resistance of green rice leafhoppers to insecticides(Ⅱ). Plant Prot. Bull. (Taiwan, R.O.C.).(in Chinese with an English summary).
25. Lin, Y.H. 1978. Brown planthopper(***Nilaparvata lugens*** Stal) resistance to MIPC & MTMC in Taiwan. MS Thesis, National Chung Hsing University, 46pp. (Taiwan, R. O.C.)(in Chinese with an English summary).
26. Maurer, H. R 1971. Disc Electrophoresis and related Techniques of Polyacrylamide Gel Electrophoresis. Walter de Grnyter. Berlin. N.Y. 222pp.
27. Nagata, T. 1982. Insecticide resistance and chemical control of the brown plant-hopper, ***Nilaparvata lugens*** Stal (Homoptera: Delphacidae) Bull. Kyushu. Agr-Expt. Sta. 22:49-162.
28. Ozaki, K., Y. Kurosu and H. Koike. 1966. The relation between malathion resistance and esterase activity in the green rice leafhopper, ***Nephotettix cincticeps*** Uhler. SABCO, J.2:98-106.
29. Ozaki, K, Y. Kurosu and H. Koike. 1971. Cross resistance to insecticides in the malathion and fenithion resistant strains of the smaller planthopper, ***Laodelphax striatellus*** Fallen. Botyu-Kagaku. 36:111-116.
30. Plapp, F. W. Jr. 1979. Biochemical genetics of insecticides rsistance. Ann. Rev. Entomol. 21:179-197.
31. Su, W. Y. 1976. A study on the susceptibility of tropical house mosquitoes (***Culex Pipiens fatigans***

Wied) and yellow fever mosquitoes (***Aedes aegypti*** (L)) to several insecticides in Taiwan. MS Thesis, National Chung Hsing University, 61pp. (Taiwan, R.O.C.). (in Chinese with an English summary).
32. Taiwan provincial Government. 1982. Plant Protection Manual. 22-27 pp. (Taiwan, R.O.C.).
33. Wang, T.C. 1981. Biochemical genetics of insecticide resistance. Plant Prot. Bull.(Taiwan, R.O.C.) (in Chinese with an English summary).

臺灣中部地區黑尾浮塵子(Nephotettix cincticeps Uhler)對四種常用殺蟲劑抗藥性之研究[1]

章加寶　方敏男[2]

摘　要

黑尾浮塵子(Nephotettix cincticeps Uhler)爲本省水稻之主要害蟲，尤其在第一期稻作爲害最爲嚴重。調查之七個地區品系中，埔鹽品系對Monocrotophos已有抗藥性產生，臺中品系對Malathion亦有抗藥性產生，線西品系對Monocrotophos具高度之受性，若再繼續受此等藥劑之選汰壓力，亦可能成爲抗藥性品系。埔鹽品系對Vamidothion及Carbaryl亦由於相同之道理可能會成爲抗藥性品系。其他品系對此四種藥劑尚未產生明顯之抗藥性，但具相當之感受性。不同地區黑尾浮塵子品系對此四種藥劑感受性程度之差異，可能與用藥習慣、施藥次數、害蟲發生情形及環境狀況不同有關。

由相關迴歸分析顯示黑尾浮塵子品系對此四種藥劑可能具有多重抗藥性產生，而由相關迴歸分析，抗藥性之發生與溫度有些相關。電泳分析顯示，酯酶活性與黑尾浮塵子抗藥性具密切之相關性，活性較高者，其抗藥性可能較高；花壇、埔鹽品系之抗藥性比值較高，其酯酶活性亦較高，而東勢、大甲品系之抗藥性比值較小，其酯酶活性亦較低。故酯酶活性之增強，可能爲黑尾浮塵子對此類殺蟲劑產生抗藥性之一個重要因子。

---

[1]·臺中區農業改良場研究報告第0031號。
[2]·臺中區農業改良場助理及助理研究員兼股長，第一作者得72學年度國科會獎助。