Chemical Control of the Brown Planthopper in Japan

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The brown planthopper, *Nilaparvata lugens*, (BPH), which is raging throughout rice growing areas of Asia, is a stubborn rice insect of primary importance also in the southern half of Japan. This species is considered to migrate from abroad together with the white-backed planthopper, *Sogatella furcifera*, during the rainy season in June and July and multiply with high reproduction potential to give devastating damage in the autumn. Massive use of insecticides has been adopted since we have no effective non-chemical control methods such as resistant varieties of rice used in Southeast Asia. Discovery of various organic insecticides after the 1940's has made steady suppression of this insect possible by taking place of the traditional sole protective measure, paddy water application of various oils. Nowadays a remarkable portion of the total insecticide production is consumed for BPH control.

History of insecticide use for BPH control

BHC was first evaluated against BPH as 0.5% dust in 1948 and turned out to be highly effective, so that a large-scale production of this dust was started in 1949. BHC was used extensively for the control of the hoppers. Meanwhile, BHC 3% dust proved to be effective as well for the control of the rice stem borer, *Chilo suppressalis*, the rice insect of primary importance at that time. As a result, the use of BHC in paddies was further expanded. Later on paddy water application of BHC 6% granules was developed for rice stem borer control in 1960. BHC was not used solely after the 1960's but used as mixtures with carbamates, especially carbaryl. However, BHC was generally banned in 1971 in spite of its cheap price and wide-spectrumed insecticidal efficacy because it was blamed for contaminating the environment as a considerable amount of BHC was detected in cow milk which was presumably taken up through the rice straw used as forage.

Some of organophosphorus insecticides used primarily for the control of the rice stem borer and the green rice leafhopper, *Nephotettix cincticeps*, (GLH), gave concurrent effects against BPH. Parathion gave supreme effects against the rice stem borer; its use started in 1952 and continued until 1969. Malathion was used primarily aiming at the control of GLH since 1954. Diazinon, fenthion and some other safe organophosphates were used after 1955 taking place of the human hazardous parathion and TEPP. The most potent group of insecticides used against BPH was carbamate, which was developed after 1960 to overcome organophosphorus resistant GLH. Carbaryl was the first of them and synthesis of many analogues followed, i.e., MPMC, BPMC, MTMC, CPMC, propoxur, XMC. The carbamates were much superior to the organophosphates against BPH as well as GLH. Later the carbamates were replaced by mixtures of carbamate with organophosphate. These mixtures were used predominantly to kill carbamate resistant GLH by utilizing the joint action which appears in a special combination of two pesticides. Thus choice of insecticide for BPH control has been made not simply for BPH control but rather for controlling other rice insects, primarily

GLH with developed insecticide resistance.

Formulation of insecticides used for BPH control

A feature characteristic to our rice insect control is the use of formulations adapted to the socioeconomic conditions of our farmers. Foliar application was once most popular in our country as presently it is in most part of Asian countries but labor shortage caused by our rapid industrialization changed foliar application into labor-saving dust application despite the increase in pest control cost. Dusting by the two-man operated labor-saving engine duster is an outstandingly popular manner of insecticide application in our paddies at present. Dusts are discharged from a delivery tube of 20–30 m long having many nozzle holes on it. In addition, a special formulation of dust, driftless dust (DL-dust), is being used in considerable amount in order to reduce public hazard to living areas located close to the paddy areas in Japan. These types of improved formulations fulfil the requirement for BPH control such as effective penetration through plant canopy to the basal part of rice hills where BPH is present.

Table 1 shows the production of insecticides used for BPH control in our country. These insecticides are not commercialized exclusively for BPH control. They are usually supplied as mixed formulations of several pesticide ingredients aiming at concurrent control of several rice pests. The largest production are carbamate dusts and mixtures of carbamate with organophosphates or fungicide. Broadcasting of granulars is conducted in smaller acreage under limited conditions because it is easy to handle by one man with a simple distributor or without any application equipments.

Table 1. Production of insecticide dust used for BPH control in Japan (1982)

Formulations	Production (ton)
Insecticides	
BPMC	6, 149
Malathion : BPMC	5, 903
Cartap : BPMC	3, 856
Fenthion : BPMC	2, 666
Diazinon : carbaryl	2, 645
MTMC	2, 644
Mixtures of insecticide and fungicides	
Fenthion : BPMC : ediphenphos	5, 833
Fenthion : XMC : ediphenphos	5, 633
Fenitrothion : BPMC : rabcide : Kasugamycin	2, 577
BPMC : ediphenphos	2, 115

Source: Japan Plant Protection Association "Noyaku-Yoran-1982"

Timing of application and persistent period of insecticides

Prevalence patterns of BPH is rather simple in Japan, because overlapping of generations is not so remarkable as in the tropics since the period of immigrant invasion is limited only within one month from June to July in Japan. The optimum timing of insecticide application can be rather easily determined. The eggs of BPH are the most difficult stage to kill with insecticides, followed by old nymph, adult, and young nymph in this order. The eggs layed inside plant tissues can escape the effects of insecticides. However, a proper kind of insecticides applied in a proper manner could kill the insects of all the stages except eggs without difficulty.

Hence, the insecticide applied when the number of eggs is minimum in the field will give the maximum effects to suppress population growth of BPH. This time was determined to be the period when the brachypterous* females of the first generation begin to emerge, falling on the end of July or beginning of August.[5] It was calculated to be ca. 28–30 days after main migration peak of the year since it is a labor-consuming task to find thinly populated brachypterous adults at this time by field observations. Corrections based on temperature-sum rules can be made

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* 1st generation BPH starting from the eggs layed by the immigrants totally grow into brachypterous form in Japan and macropterous form appears after 2nd generation.

according to the climatic conditions of respective areas. For instance was corrected to 22–25 days after the migration peak in Kagoshima districts, the southern extremity of Kyushu island.4)

If one application could give the persistent period longer than the egg period under natural conditions (ca. 10 days), there will be no problem of population recovery by the nymphs hatched from survived eggs after the application. The persistent period of conventional insecticides in various formulation types can be determined by the interval from the application to the first appearance of hatched nymphs.5) The persistent period of a carbamate dust (MTMC dust) was shorter than 3 days. Foliar spray of diazinon or BPMC E.C. was persistent up to 4–7 days. MIPC granules (4%) were found to be persistent up to 4–7 days when applied at a rate of 40 kg/ha. Thus two successive applications with the interval slightly longer than the egg period are a minimum prerequisite to exterminate BPH because any types of insecticides can not give a persistent period longer than the egg period at present.

A second best timing was also found at the corresponding stage of 2nd generation when macropterous adults of 2nd generation begin to emerge. However, deteriorating damage often appears before this period in the year of severe outbreaks. Remarkably rapid population build-up occurs with the insecticide application off these optimum timing.

Insecticide resistance and resurgence

The initial insecticide, BHC, had been used without any serious problem of resistance for nearly 20 years until its use was banned in 1971. Slow developing rate of insecticide resistance in this insect is considered to be due to extinction of our BPH population during winter and their yearly replacement with the new immigrants from some migration origins abroad. However, overall gradual decline of field efficacy of insecticides to BPH has become noticeable. A long-term comparison of insecticide resistance in the immigrant BPH revealed obvious development of resistance to the organophosphates and the carbamates though developing rates were much slower compared with GLH (Fig. 1). In comparison

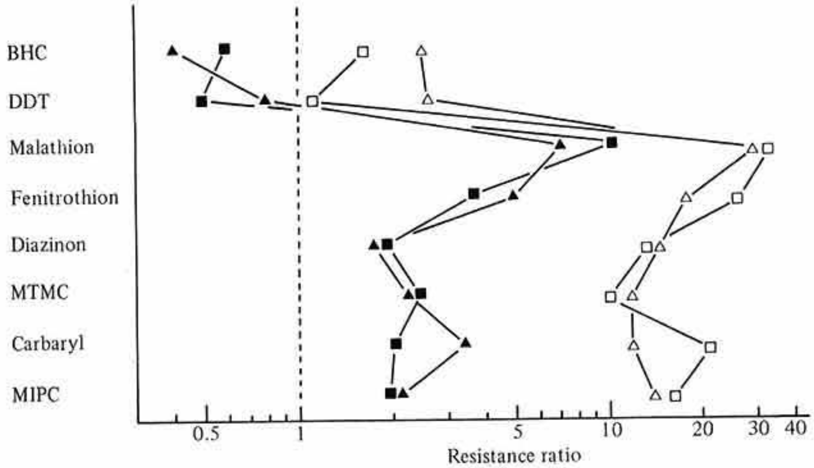

Fig. 1. Development of insecticide resistance in immigrant BPH
Note: The resistance is expressed by resistance ratio calculated as follows:
▲ : Kagoshima 1976, ■ : Nagasaki 1976,
△ : Kagoshima 1979, □ : Nagasaki 1979, tropical
LD_{50} in 1976 and 1979 divided by that in 1967.

with the 1967 data, an obvious increase of resistance was observed in 1976 for the organophosphates,5) and carbamate resistance was first verified in the 1979 survey.3) These trends were also supported by many other workers' data including results of autumn generation.2,6) At present we do not rely upon the organophosphates for BPH control any more. Although carbamates are still practically effective despite resistance development, their field efficacy has become apparently reduced and unstable and active ingredients of some carbamate dusts were increased up to 3% in order to strengthen the effects in recent years. Carbamate resistance in GLH has been overcome by using mixtures of two insecticides or mixtures of insecticide with fungicide. Synergism of mixtures to carbamate-resistant BPH is not so remarkable at present levels of resistance. i.e., topical LD_{50} values of the mixtures such as propaphos + carbaryl, fenitrothion + BPMC or phenthoate + propoxur were not smaller than those of mixing materials.2) However, some degree of synergism was observed with the mixtures such as IBP + malathion or IBP + phenthoate.7)

Fortunately after 1979 up to the present, no further remarkable increase of insecticide resistance has been observed, resistance levels remaining almost constant with slight yearly fluctuation. The recent increase of resistance seems attributable to the increase in pesticide use in the origins of migration. Though exact migration origins have not been fully clarified, southern part of China mainland is the most probable origin of migration to Japan where outbreaks of BPH have become conspicuous after the 1970's and a considerable amount of insecticide, especially BHC and parathion, is likely to have been used in the paddies since no effective resistant cultivars of rice were available there.

In our recent experiments BPH obtained

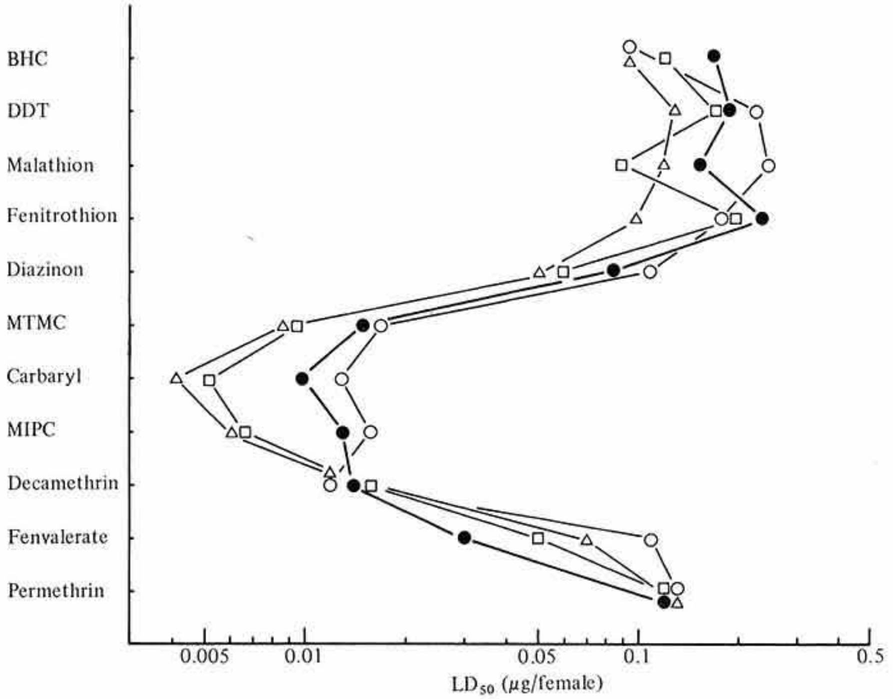

Fig. 2. Insecticide-resistance patterns of BPH collected from China mainland ○ : Shanghai (1981, autumn), △ : Hangchow (1981, autumn), □ : Kwangchow (1982, summer), ● : Immigrant (1982, summer: Kyushu, Japan).

from the East China Sea and several parts of China mainland showed resistance levels almost similar to those of immigrants collected in Japan in the same year (Fig. 2). However, when examined in details, considerable variations of insecticide susceptibilities have been occasionally found between migration waves and locations of collection.1) There remains much to be solved on the relation between insecticide resistance and migration of this species. Data obtained on insecticide susceptibilities of BPH collected from the tropics showed LD_{50} values smaller than those of Japanese BPH in general.5)

In order to predict future resistance development of this insect, it is necessary to keep close watch on insecticide susceptibilities of the immigrant BPH and to study the relationship between migration and resistance development in this species. In addition, we should be prepared for substitute chemicals for future uses when resistance levels of BPH reach a still higher degree, which is actually probable because it is caused by increased use of insecticides in migration origins. Several pyrethroids effective against BPH with low fish toxicity and high photostability are being developed in our country. Insect growth regulator is an another promising group of BPH control agents. A novel compound, buprofezine (2-tert-butylimino-3-isopropyl-5-phenylperhydro-1, 3, 5-triazine-4-one: Applaude®, NNI-750) has unique mode of action compared with the conventional insecticides, interferring nymphal moulting with strikingly long persistent period up to 20–30 days in the fields. One or two applications with pliable timing of application give complete control throughout the crop season. This chemical shows no cross resistance to the organophophorus or carbamate resistance in BPH, and toxicity to the predators in paddy fields is low.

Resurgence of BPH population has been studied in many Asian countries in the tropics but we have no marked problems of BPH resurgence in Japan. Although resurgence factors in common with those pointed out in the tropics seem to be involved also in our paddies, this difference is perhaps primarily due to relatively high frequency of insecticide application in Japan. Though we basically recommend 2 or 3 applications for BPH control during one crop season, application frequency of pesticides applied as mixtures containing active ingredients effective against BPH amounts to as many as 7 times in southern Kyushu areas, which barely suppress population build-up of BPH regardless of their resurgence potentials.

Conclusion

In Japan, integration of several control practices has been overlooked in the control of BPH in the past. This is mainly attributable to relatively cheap market price of our pesticides, which tempted farmers to use them abundantly without thinking much over economic injury levels of BPH. Therefore concept of integrated pest management should be stressed from now on and we should reconsider present control systems which are exclusively dependent on insecticide use from the viewpoint to reduce adverse effects caused by massive use of pesticides: actually BPH resistant varieties of Japonica rice possessing desirable agronomic qualities are in the process of being developed since 1966 in Japan and several promising varieties are coming forth.

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