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ORIGINAL ARTICLE/CONTROL

Effects of Root Zone Applications of Some Systemic Insecticides for Control of the Brown Planthopper, *Nilaparvata lugens* (Stål) (Homoptera: Delphacidae)

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Abstract

Laboratory and greenhouse experiments were conducted to evaluate the effect of root zone application of some systemic insecticides for control of the brown planthopper (BPH), *Nilaparvata lugens*, as one of the management option to minimize the adverse effects and maximize the efficacy of insecticide application. Five systemic insecticides, namely, carbofuran, carbosulfan, diazinon, ethoprophos and imidacloprid, as granular formulation were placed in the root zone and measured the mortality, fecundity, and nymphal survivorship of the planthopper. Diazinon and ethoprophos did not show the significant mortality of the BPH. When the BPH were inoculated at the day of carbofuran treatment, adult mortality was shown almost 100% at seven days after treatment and BPH nymphs were remained very few on rice at 25 days after treatment. When carbofuran were placed 10 days before the BPH inoculation, it showed almost 100% adult mortality after one day, and no nymphs were found until 25 day after inoculation. Efficacy of carbofuran on BPH when applied in 10 day-old rice was higher than in 30 day-old rice. These results indicated that the root zone application of carbofuran can control N. lugens effectively with less adverse effect to the natural enemies inhabited on rice plants.

Key words brown planthopper, insecticide, carbofuran, mortality, root zone application

Introduction

The brown planthopper (BPH), *Nilaparvata lugens* Stål, is one of the most serious pests of rice, causing economic damage directly by feeding and producing symptoms commonly referred to as 'hopper burn' (Bae and Pathak, 1970; Shepard *et al*., 1991; Qiu *et al*., 2004). The history of *N. lugens* as a pest of the green revolution of Asian rice production has been well documented (Heinrichs and Mochida, 1984). *N. lugens*, once a minor pest in tropical Asia, became one of the most important constrains to rice production following the introduction of high-yielding varieties and chemical insecticides in the 1960s. In some areas, *N. lugens* populations adapted to the new varieties in as little as two years. It was eventually determined that the massive outbreaks of *N. lugens* were being caused by insecticides overuse, which devastated natural enemy population and in some cases, stimulated *N. lugens* reproduction at sublethal doses (Cuong *et al*., 1997). The overuse and misuse of insecticides have caused target pest resurgence, secondary pest outbreaks, and environmental contamination. Nevertheless, it is difficult to foresee how insect pests can be controlled effectively without chemical intervention (Bruce, 1996).

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When insecticides are wrongly applied to the non-target organisms, the insecticides will kill natural enemies that profitable for the control of pest population afterward. Sometimes, the resurgence of *N. lugens* has been explained by the mortality of natural enemies in rice field caused by insecticide applications (Reissig *et al.*, 1982; Heinrichs *et al.*, 1982). The level of resurgence depends on numerous factors such as the chemical structure of insecticides, its application rate and formulation, its toxicity to both planthoppers and their natural enemies, and the level of host plant resistance to the planthoppers (Heinrichs, 1994). Foliar application cause not only reducing natural enemies in the rice field but also changing nutrient in rice plant, and induce the increase of *N. lugens* population. Reproductive stimulation is attributed to insect exposure to sublethal doses of insecticides and changes in nutrient substances of plants suitable to insect fecundity caused by insecticides (Wu *et al.*, 2001, 2003).

Although insecticides cause environmental contamination, but in fact when the pests occur in big population, the first choice of the farmers is using insecticide. Especially in developing countries such as Vietnam, the farmers had sprayed insecticides 7-8 times for one rice crops against *N. lugens* outbreak in 2005 and 2006. Reduction of the control efficacy of imidacloprid to *N. lugens* and the use of synthetic pyrethroid inseciticides to control rice leaf folder, *Cnaphalocrocis medinalis* Guenee, resulted in a serious resurgence of *N. lugens* during 2005-2006 in southern China (Yin, 2008).

To avoid these problems, there are some suggestions of the researcher such as reduced pesticide use not only for decreasing selection pressure on pest insects but preserving natural enemies and other non-target species (Bruce, 1996). The control of BPH in the field by using neem is aimed at nymphs early in their development (Sengottayan, 2006).

In this study, we have done a method that is root zone application by using some kind of systemic insecticides. The systemic insecticides can control *N. lugens* effectively without adverse effects to the natural enemies which inhabit on rice plants.

Material and Methods

Experimental location

These experiments were carried out in two places, namely in Jinju province, Korea and in Long An province, Vietnam.

Rice culture and Insects

In Jinju, Korea, rice *Oryza sativa,* was grown in plastic pots (20 dia. x 25 cm ht.) in a greenhouse under natural light and was used rice from 40 to 50 days after seeding. Each plastic pot was grown two rice seedlings. *N. lugens* was taken from stock colonies reared successively on rice seedlings in our laboratory under a 16:8 h (L: D) photoperiod, 25±2°C, and 60±5% RH. In all experiments, 1 to 3 day-old adult macropterous females and males were used. After insecticides applied in the root zone of rice, we inoculated each five females and five males of *N. lugens* adults per rice pot covered by transparent plastic cage. The number of *N. lugens* adults were counted 1, 3, 5, 7 and 9 days after inoculation and emerging nymphs were counted 15, 20 and 25 days after the adults inoculation. Every treatment was replicated three times.

In Long an, Vietnam, rice seedlings were transplanted in batches of cement tanks (50 ht. x 100 length x 100 cm width). Each cement tank were transplanted with five seedlings for five times replication, planting distance was about 25cm. Insecticides were applied on the 10 day- old and 30 day-old the rice. After insecticides application we inoculated 20 *N. lugens* (including adult and nymph in 4th, 5th instar) per rice plant. Rice plants were also covered by transparent plastic cage. The *N. lugens* were counted 3, 6, 9, 12, and 15 days after inoculation. After checking the number of *N. lugens* each treatment, we changed new *N. lugens*. The *N. lugens* for experiments were collected in rice field, maintained in greenhouse from 3 to 5 days for adaptation, and inoculated to rice plant.

Pesticides and application

Five insecticides (Table 1) and two methods of insecticide

Table 1. Chemical name and formulation of insecticides used in the experiments

Insecticide	Chemical name	Formulation
Carbofuran	2,3-dihydro-2,2-dimethyl-7-benzofuranyl methycarbamate	3% GR
Carbosulfan	2,3-dihydro-2,2-dimethyl-7-benzofuranyl [(dibutylamino)thio]methylcarbamate	3% GR
Diazinon	*O,O*-diethyl-*O*-[6-methyl-2-(1-methylethyl)-4-pyrimidinyl]phosphorothioate	3% GR
Ethoprophos	*O*-ethyl *S,S*-dipropyl phosphorodithioate	5% GR
Imidacloprid	1-[(6-chloro-3-pyridinyl)methyl]-*N*-nitro-2-imidazolidinimine	10% WP

treatment, root zone application and irrigation into stumps of rice, were used for experiments. In root zone application method, the five test insecticides, namely, carbofuran, carbosulfan, diazinon, ethoprophos and imidacloprid, were encapsulated and located in the root zone of rice at the various rates and times. The root zone application was done by placing the encapsulated insecticide into the soil at about 5 cm depth. In method of irrigation into stumps of rice, at first carbofuran was dissolved in the water, and then irrigated into the stumps of rice. Root zone treatments were expected to provide valuable information for understanding the effect of insecticides on *N. lugens* mortality and the best timing to insecticides application.

These experiments were carried out under a greenhouse with a randomized complete block design under natural photoperiod and temperature conditions.

Results and Discussion

Efficacy of root zone application of insecticides in Jinju, Korea

Insecticides application is the first choice of many farmers when rice planthopper outbreaks in the rice field. Spraying insecticides were not only decreasing spider density but also inducing *N. lugens* resurgence in the rice field. Under such circumstance, we still need to consider how to control BPH effectively without adverse effects of insecticides such as resurgence. We have also tried to find out the way to deliver the insecticides effectively to the feeding location of *N. lugens*, such as the activity can be displayed only on *N. lugens* and no adverse effects to the natural enemies. We had chosen the root zone application as delivery way of target insecticides and tried to screen effective chemicals and determined dosages by that method for increasing management options.

We used four systemic insecticides of granular form and placed them in the root zone of rice with different timing and dosages. When insecticide application and inoculation *N. lugens* were at the same day individually, carbofuran showed high efficacy to *N. lugens*. Percent mortality of planthopper adults was reached 100% in 7-day after treatment, while other insecticides were lower than control (Fig. 1). There were very few nymphs occurred in the carbofuran treated pots at 20 and 25-day after inoculation. Number of nymph occurred in the diazinon treated pots were higher than control at 15-day after inoculation. This may be one of the evidences of proving that diazinon is one of the resurgence producing agents. Wu *et al.* (2001, 2003) said that reproductive stimulation is attributed to insect exposure to sublethal doses of insecticides and changes in nutrient substances of plants suitable to insect fecundity caused by insecticides.

When the insecticides were applied 10-day before the *N. lugens* inoculation, carbofuran treated pots displayed 100% of adult mortality in just one day after inoculation and no nymphs were occurred afterward. Diazinon did not show any effect on *N. lugens*, only stimulate increase of their density. This is the same tendency as showed in Fig. 1. Carbosulfan was also the next effective insecticide. We had also experimented various timings and dosages to find out the best chemical, dosage and timing of application. Carbofuran was the most effective in all experiments and the second was carbosulfan. Diazinon and ethoprophos did not show the significant mortality of planthoppers when treated in the root zone. These two insecticides were not registered in Korea as *N. lugens* control agents (Korea Plant Protection Association, 2007). Carbofuran root zone application ten days prior to

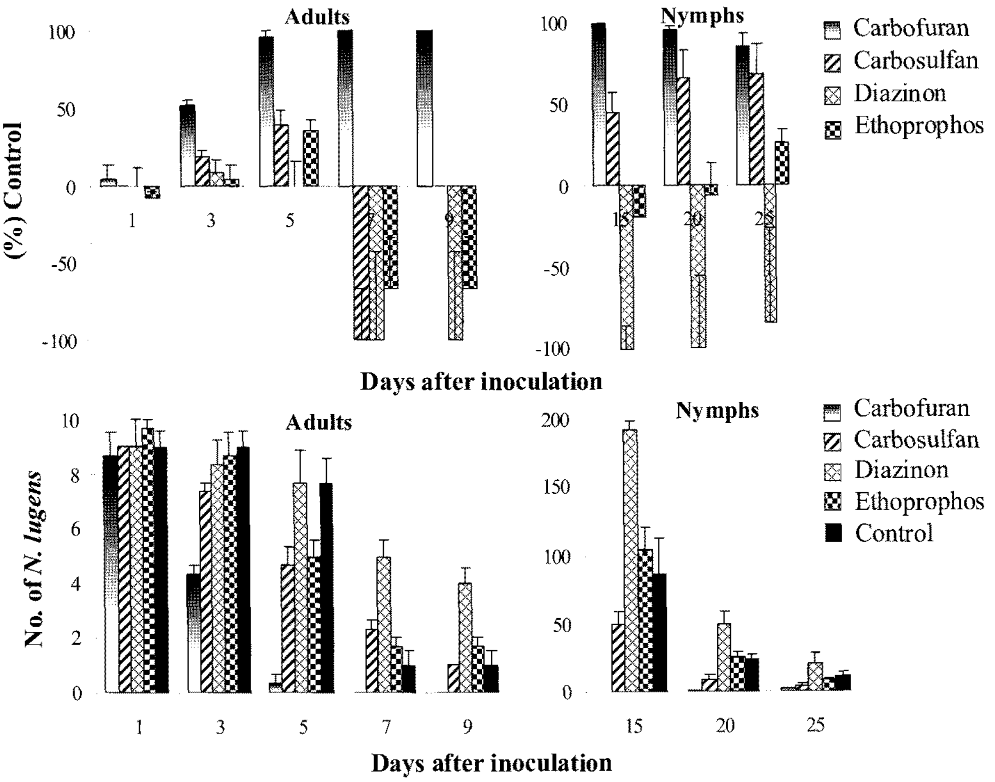

Fig. 1. Percent corrected mortality and number of *N. lugens* adults and nymphs after the root zone application of carbofuran, carbosulfan, diazinon and ethoprophos. All pesticides were applied at the same day *N. lugens* inoculation.

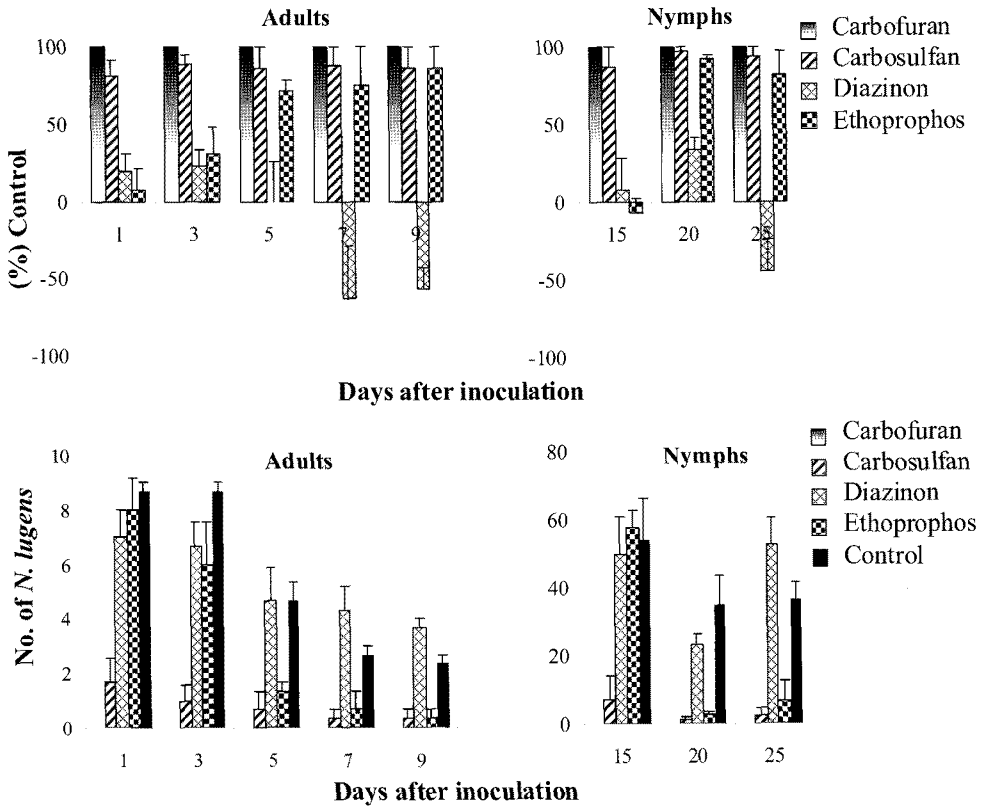

Fig. 2. Percent corrected mortality and number of *N. lugens* adults and nymphs after the root zone application of carbofuran, carbosulfan, diazinon and ethoprophos. All pesticides were applied in 10 days before *N. lugens* inoculation.

planthopper inoculation was the best timing and displayed 100% adult and nymphal mortality even one day after inoculation (Fig. 2).

Carbofuran application in the root zone of rice seemed to be one of the promising options in the circumstance of insecticide application for preventing the *N. lugens* outbreaks in Korea rice fields. The actual implementation methods of this option remain in question and need to be done further research. We also need to examine the possible adverse effects of the root zone application on the aquatic community of rice paddy before implementation.

Efficacy of root zone application of insecticides in greenhouse Long An, Vietnam

The results in Fig. 1 and Fig. 2 indicated that diazinon and ethoprophos did not effect on *N. lugens*; they even increased number of nymphs compared to control, so imidacloprid was chosen to test in Long An, Vietnam. Although experiment conditions in Vietnam is rice-rice double cropping system in one year and using short time varieties that was different from Korea, these results indicated that carbofuran was the most effective on *N. lugens*, followed by imidacloprid and carbosulfan.

When the insecticides were applied to the 10 day-old rice, carbofuran root zone application and carbofuran broadcasting treated pots displayed 100% mortality of *N. lugens* in 6 days and efficacy extend to 12 days after insecticide application. In 15 days after application effect of all insecticides were reduced to about 80% (Fig. 3).

When insecticides were applied to the 30 day-old rice, the efficacy of all insecticides were lower than application in 10 day-old rice. In this treatment, the efficacy of carbofuran on *N. lugens* was about 80% in 12 days after application. These results were different from those got by applying to 10 day-old rice. Imidacloprid treatment displayed 70% control efficacy, which was higher than carbofuran broadcasting treatment (Fig. 4). In tropical countries using the short time varieties like Vietnam, the efficacy was much better when insecticides were applied to younger rice plants than when applied to older rice plants for controlling of *N. lugens*. The best applying time of insecticides is about 10 days before *N. lugens* immigration to rice field.

In all experiments, carbofuran root zone application was the most effective to control *N. lugens*. Several insecticides in various groups have been reported to be effective against the BPH. Carbofuran, quinalphos, phosphamidon and chlorpryriphos (Rao and Rao, 1979) were effective in BPH control. Carbosulfan gave maximum control of BPH both in greenhouse and field tests in Malaysia (Riddell, 1982). In India, the field tests conducted at Kerala revealed that carbosulfan showed quick knock down effect on BPH (Pillai *et al.*, 1983). Granular insecticides such as carbofuran, phorate and isofenphos yielded a high degree of BPH control (Koshaiya *et al.*, 1981). Patnaik *et al.* (1986) reported that the granular formulations of fenobucarb and carbofuran consistently gave high control of BPH. Root zone application of carbofuran at 1.5 kg ai/ha controlled effectively green leafhopper and BPH (Chiu *et al.*, 1980). Many researchers

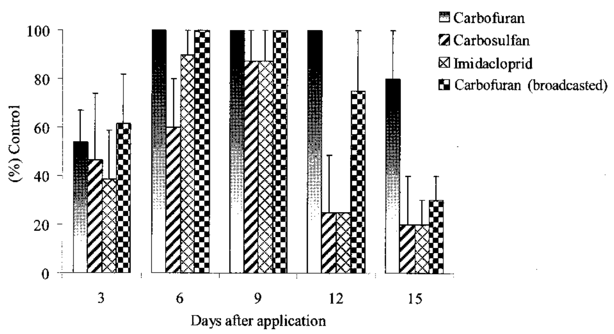

Fig. 3. Percent corrected mortality of *N. lugens* after root zone application of carbofuran, carbosulfan, imidacloprid and carbofuran broadcasting. All insecticides were applied to 10 day-old rice plants.

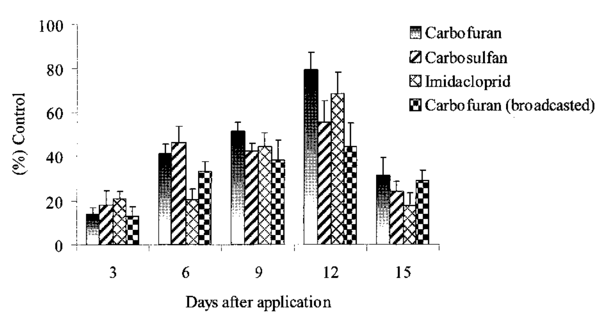

Fig. 4. Percent corrected mortality of *N. lugens* after root zone application of carbofuran, carbosulfan, imidacloprid and carbofuran broadcasting. All insecticides were applied to 30 day-old rice plants.

agree that carbofuran is the very effective control agent of BPH. But as experienced many times with insecticide resistance, BPH resistance to carbofuran will be the main obstacles to use carbofuran for BPH control in near future. So we must use carbofuran carefully and rationally for keeping the efficacy of carbofuran for long time. IPM program for BPH control including carbufuran will be the best way of living with BPHs. Highly resistant strains of the BPH were obtained after 30 generations of laboratory selection by carbofuran. Topical LD_{50} for carbofuran increased 51-68 times while the LD_{50} for diazinon increased only 6-7 times by the same selection (Yoo *et al.*, 2001). This result suggests that possibility of BPH getting resistance to carbofuran will be very high. This means that we have to take care of rice with great concern on their use for another pests control in rice paddy field.

This study also revealed that diazinon and ethoprophos did not show the significant mortality of the *N. lugens* when treated in the root zone of rice plant, only increased BPH density. Diazinon and ethoprophos must be the very good chemicals inducing resurgence of brown planthopper. It is supported by (Song, 1984; Rao and Rao, 1980). Song (1984) said that the population increases were due in part to the increase of fecundity of the hopper by decamithrin application and Rao and Rao (1980) reported that root zone application of carbofuran and fenobucarb had an inhibitory effect on hatching of BPH eggs.

The results of this study will be very helpful for tropical countries where BPH problem occur any time of the year. Especially BPHs damage rice seedlings. In case of Korea BPHs migrate from China and increase their density for 3 generations. They damage rice plant seriously after August. At that time systemic insecticides do not give very good control efficacy. We need much effort to elucidate the reason why carbofuran does not work well on late stage of rice plant growing.

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벼멸구에 대한 여러 가지 침투성 살충제의 근부처리 효과

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요 약 벼 천적에는 최소한의 영향을 주면서 벼멸구에는 최대한의 효과를 줄 수 있는 침투성 살충제의 근권처리 효과를 검정하기 위해 실험실과 온실내에서 실험을 수행하였다. 벼멸구의 사충률과 번식력, 약충의 생존율을 알아보기 위해서 입제형의 5가지 약제(carbofuran, carbosulfan, diazinon, ethoprophos, imidacloprid)를 근권에 처리한 결과 carbofura이 모든 실험에서 가장 효과가 있었으며, diazinon과 ethoprophos는 벼멸구의 사충률에 큰 영향을 주지 않았다. Carbofuran 처리 후 당일 벼멸구를 접종하였을때, 성충은 처리 7일 후에 거의 100% 사충률을 보였고, 처리 25일 후까지 약충은 1~2마리 발견되었다. Carbofuran 처리 10일후에 벼멸구를 접종하였을 때, 벼멸구 접종 1일 후 100%에 가까운 사충율을 보였고, 약충은 25일 후까지도 발생되지 않았다. Carbofuran은 벼멸구 접종 30일 전보다 10일 전에 처리하는 것이 효과가 높았다. 따라서 carbofuran의 근권처리는 천적에는 해를 입히지 않고 벼멸구을 효과적으로 관리할 수 있는 것으로 나타났다.

색인어 벼멸구, 살충제, Carbofuran, 사충율, 근권처리