

Original Article

Effect of Buprofezin on Oviposition of Brown Planthopper, *Nilaparvata lugens*, at Sub-lethal Dose

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Effects of buprofezin (Applaud®) on the oviposition and the life span of *Nilaparvata lugens* were examined at sub-lethal doses. The reference compound, deltamethrin, enhanced the number of ovarioles, eggs laid and the life span of female adults, when insects were exposed to sub-lethal doses (0.4-0.00064 ppm) of the chemical from 5th instar stage. On the other hand, buprofezin hardly increased or somewhat decreased the oviposition and the life span of female adults at sub-lethal doses (below 0.4 ppm) in the same exposure-treatment as above. These properties of buprofezin probably play important roles in the prevention of the resurgence of *N. lugens* along with a little adverse effects on the natural enemies and non-target species.

INTRODUCTION

In Southeast Asia, brown planthopper (BPH) is one of the most serious pests in paddy field, because of the developing resistance to many kinds of insecticides, the appearance of biotypes overcoming some BPH-resistant rice varieties and outbreaks due to application of insecticides. Among these problems, the last one is called resurgence and it is pointed out to be caused by the increase of oviposition of survival pests treated with insecticides at sub-lethal doses¹⁻¹²⁾ as well as by the adverse effect of insecticides on natural enemies.

Buprofezin (Applaud®, Nihon Nohyaku Co., Ltd.) is a highly selective insect growth regulator (IGR), which controls planthoppers and leafhoppers in paddy rice field^{13,14)} and no resurgence has been observed since registered. Heinrichs *et al.* and Kanaoka *et al.* reported that buprofezin had little adverse effect on the natural enemies and non-target arthropod species and such property is considered to be one of factors for the fact that buprofezin has never caused resurgence.^{15,16)} It was also shown that buprofezin decreased the number of oviposition or hatchability and shortened the life span of female adults of planthopper when the chemical was applied at the practical dose.¹⁷⁾ However, the effects are not examined at sub-lethal dose, which condition is directly related to resurgence problems in other conventional insecticides.

In the course of our work to make it clear why buprofezin causes no resurgence, we examined the effects of buprofezin on the oviposition and the life span at sub-lethal doses, compared with those of deltamethrin which was reported to cause resurgence.¹⁸⁻²¹⁾ The work reported in this paper represents the prominent properties of buprofezin to prevent resurgence of BPH.

MATERIALS AND METHODS

1. Chemicals

Buprofezin (25% wettable powder) and deltamethrin (1% emulsifiable concentrate), commercially available, were used. Both chemicals were diluted with distilled water to the desired concentrations and used for this study. The concentration of the test solution was expressed by the active ingredient.

2. Insects

The brown planthopper, *Nilaparvata lugens*, was collected in Wakayama Pref., Japan in 1983 and has been reared in our laboratory for many generations on rice seedlings (cv. Nihonbare) in an insectary (26±1°C, 70% R.H., 16L:8D). The last instar nymphs (5th instar) were used because buprofezin is not lethal to adults of BPH even at the practical dose.^{15,17)} All adults emerged were macropterous form.

3. Mortality, Oviposition and Hatchability

Test solution were sprayed on potted rice plants (cv. Nihonbare, 8-10 leaf stage growth) at the rate of 150 ml/

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plot (150 l/10 a). After air-dried, each pot was surrounded by a nylon mesh cylinder (40 cm in height × 13 cm in diameter), and 30 female 5th instar nymphs of *N. lugens* were released. The pots were placed in a greenhouse (25–30°C in the daytime, 20–25°C at night). Emerged adults were collected at 4 days after release and the corrected mortality of the 5th instar nymphs was calculated. The experiment was carried out with 2 or 4 replications.

Then each of the survived female adult was individually reared on the other potted rice plants pretreated with the test solution at the same concentration. Three untreated male adults were released to each pot for mating. Seven days after release, the number of survived female adults were counted and the corrected mortality was calculated. The rice pots oviposited were divided into two clusters: one was available for counting the number of eggs laid in rice plants and the other for the examination of hatchability in 15 days. The number of female adults used in this experiment varied from 4 to 22.

4. Effect on Ovaries

Female 5th instar nymphs of *N. lugens* were released to the potted rice plants sprayed with 150 ml of the test solution. Twenty female adults emerged were collected at random on the 4th day and transferred to the other rice plants pretreated. Twenty untreated male adults were released to each pot for mating. After 7 days, survived female adults were collected and the number of mature

eggs and ovarioles in ovaries were histologically examined. The number of females used in this experiment varied 4 to 15.

5. Life Span of Female Adults and Oviposition until Dead

Female adults treated with the test solution were prepared in the similar procedure to the above experiment. Twenty female adults and twenty untreated male adults were released on the potted rice plants pretreated. After 3 or 4 days, survived female and male adults were collected and the number of eggs laid in rice plants were counted. The collected adults were transferred on the other potted rice plants pretreated with the test solution. These procedures were repeated every 3 or 4 days until all female adults died.

RESULTS

1. Lethal Effect

Table 1 shows the mortality of female 5th instar nymphs and emerged female adults of *N. lugens* on the potted rice plants treated with the chemicals. Buprofezin provided 100, 89 and 0% mortality on 5th instar female nymphs at 50, 10 and 2 ppm, respectively. Fifty-seven percent of emerged female adults was killed at 10 ppm and 69% at 2 ppm just after final ecdysis. At the concentrations below 0.4 ppm, buprofezin almost lost molting-inhibition activity. Deltamethrin showed 100 and 40% mortality to 5th instar female nymphs at 50 and

Table 1 Effect of buprofezin on 5th instar female of *Nilaparvata lugens*.

Chemical	Concn. (ppm)	No. of nymphs used	Corrected mortality (%)		
			5th instar female	Female adults	Cumulative
Buprofezin	50	60	100		100
	10	120	89	57	95
	2	60	0	69	69
	0.4	60	7	13	19
	0.08	60	0	9	9
	0.016	60	0	3	3
	0.0032	60	0	0	0
	0.00064	60	0	0	0
	0.000128	60	0	11	11
	0.0000256	60	0	0	0
Deltamethrin	50	60	100		100
	10	60	40	0	40
	2	60	4	0	4
	0.4	60	9	0	9
	0.08	60	2	0	2
	0.016	60	0	9	9
	0.0032	60	0	0	0
	0.00064	60	0	4	4
	0.000128	60	0	0	0
	0.0000256	60	0	4	4
Control		60	(75)	(94)	(70)

Values in parentheses represent percent of survived.

10 ppm, respectively. The nymphicidal effect was practically not observed at the concentrations below 2 ppm, and most of emerged adults survived for 7 days. From these results, sub-lethal doses of buprofezin and deltamethrin were estimated to be below 0.4 and 2 ppm, respectively.

2. Effect on Oviposition and Hatchability

Table 2 shows the average values of the number of eggs laid for 7 days and their hatchabilities. Buprofezin-treated-female laid few eggs at the concentration of 10 and 2 ppm. The inhibitory effect of the chemical was completely lost at sub-lethal concentrations below 0.4 ppm (mentioned above) and the number of eggs laid was almost equal to that of the control, though the tendency of the slight increase was observed in treated plots

without statistical significance. Hatchability was only inhibited in eggs treated with 2 ppm of buprofezin and was equal to the control at sub-lethal concentrations.

On the other hand, deltamethrin at lethal concentration (above 10 ppm) was not effective on the oviposition, but it drastically enhanced the oviposition at sub-lethal concentrations (below 0.4 ppm), with the highest enhancement of 150% of the control plot at 0.016 ppm. The enhancement effect appeared to be dose dependent in sub-lethal doses agreeing with the results obtained by Chelliah *et al.* using *N. lugens*.⁹⁾ Deltamethrin showed no effect on the hatchability at any dose tested.

3. Effect on Ovaries

Table 3 shows that buprofezin was not effective on the development of eggs and ovarioles in the ovaries below

Table 2 Effect of buprofezin on oviposition and hatchability of *Nilaparvata lugens*.

Chemical	Concn. (ppm)	No. of female adults survived	No. of eggs laid/Female alive for 7 days	Hatchability (%)
Buprofezin	10	4	0 (0) a	
	2	6	39 (36) b	74
	0.4	7	108 (99) c	97
	0.08	8	121 (111) c-f	98
	0.016	8	120 (110) c-f	96
	0.0032	5	125 (115) c-f	—
	0.00064	5	116 (106) c-e	—
	0.000128	5	127 (117) c-f	—
	0.0000256	6	106 (97) c	—
Deltamethrin	10	7	110 (101) cd	98
	2	22	119 (109) c-f	92
	0.4	18	143 (131) e-g	94
	0.08	19	122 (112) c-f	98
	0.016	17	164 (150) g	98
	0.0032	11	148 (136) fg	—
	0.00064	9	139 (128) d-g	—
	0.000128	10	114 (105) c-e	—
	0.0000256	9	117 (107) c-e	—
Control		16	109 (100) c	96

Values in parentheses represent percent of control. Means followed by a common letter are not significantly different at the 5% level (Duncan's multiple range test). —: Assays were not examined.

Table 3 Effect of buprofezin on ovaries of *Nilaparvata lugens*.

Chemical	Concn. (ppm)	No. of female adults used	No. of mature eggs	No. of ovarioles
Buprofezin	0.4	6	32.8 (100) a	30.2 (107) a
	0.016	6	34.7 (106) a	29.8 (106) a
	0.00064	4	32.0 (98) a	29.0 (103) a
Deltamethrin	0.4	15	37.0 (113) a	32.3 (114) a
	0.016	7	42.9 (131) b	37.4 (133) b
	0.00064	10	35.9 (110) a	28.8 (102) a
Control		9	32.7 (100) a	28.2 (100) a

Values in parentheses represent percent of control. Means followed by a common letter are not significantly different at the 5% level (Duncan's multiple range test).

Table 4 Effect of buprofezin on life span of female adults and oviposition of *Nilaparvata lugens*.

Chemical	Concn. (ppm)	Life span of female adults (days)	No. of eggs laid/Female used until dead
Buprofezin	10	4.7 (28)	31 (5)
	0.4	13.0 (78)	483 (79)
	0.016	16.9 (101)	562 (92)
	0.00064	17.8 (106)	535 (88)
Deltamethrin	10	18.7 (112)	639 (105)
	0.4	20.9 (125)	755 (124)
	0.016	17.1 (102)	784 (128)
	0.00064	20.1 (120)	707 (116)
Control		16.7 (100)	610 (100)

Values in parentheses represent percent of control.

0.4 ppm. On the contrast deltamethrin gave an enhancement activity on the development of mature eggs and ovarioles. The activity maximized at 0.016 ppm.

4. Effect on Life Span and Oviposition

Table 4 summarizes the life span of female adults and oviposition until every female died. Buprofezin shortened the life span of BPH at the concentration of 10 ppm by about 10 days, compared to that of the control plot. The life span was slightly shortened at 0.4 ppm, and little effect was observed at the concentration below 0.016 ppm. The total number of eggs oviposited during the life span was decreased to 5% of the control plot by the treatment of buprofezin at 10 ppm, and was slightly decreased at sub-lethal concentrations (below 0.4 ppm). On the other hand, deltamethrin slightly prolonged the life span at sub-lethal concentrations. The degree was 125% of the control plot at the highest. The treatment of 0.4 and 0.016 ppm of deltamethrin enhanced the oviposition to about 130% of the control. The stimulative effect of the chemical observed in the previous experiment (7 days after emergence, Table 2) was confirmed in this system (from emergence to death), again.

DISCUSSION

Resurgence of arthropod pest is a well known phenomenon, and hypotheses have been put forward to explain it: (a) The reduction of the population of natural enemies and competitive species by the pesticide applied, (b) Stimulation of natality of pest by the pesticide, (c) Indirect influence of pesticides on arthropod pest through the host plant.²²⁾ The previous papers proved buprofezin did not reduce natural enemies of BPH.^{15, 16)} It was also shown that buprofezin decreased the number of eggs laid or hatchability of BPH at the practical dose.¹⁷⁾ And the results obtained in this paper make it clear that buprofezin hardly increases or somewhat decreases the number of nymphs of the next generation of *N. lugens*

even at the sub-lethal doses. Although mechanistic aspects of this phenomenon at the sub-lethal doses is not clear, it was probably due to the inhibition of the biosynthesis of prostaglandin E₂²³⁾ and/or ecdysteroids disorder²⁴⁾ which was observed in *N. lugens*.

On the other hand, the enhancement effect on the oviposition of BPH was observed at the sub-lethal doses of deltamethrin (Tables 2-4). Roan & Hopkins reported that the brain extracts of *Carausius morosus* and *Iphita limbata* were able to induce their oviduct movement or oviposition.²⁵⁾ It is likely that sub-lethal dose of deltamethrin stimulates the brain of *N. lugens* resulting in the development of ovarioles and consequent development of eggs, since previtelogenesis begins before emergence in homopterous insects.²⁶⁾

These results show the distinct difference between buprofezin and deltamethrin in the effect on oviposition at their sub-lethal doses. The stimulative effect on the oviposition at one's sub-lethal doses seems to be one of key factors to determine whether the chemical causes the resurgence or not. Moreover, Mochida *et al.* reported the results of the field trial on the efficacy of buprofezin carried out in Philippines in 1982. In this report buprofezin prevented 5 other insecticides, including deltamethrin, from causing resurgence of *N. lugens* in their combination and provided stable control efficacy.²¹⁾ This preventive effect of resurgence was probably due to the longer persistence of control effect of buprofezin on hoppers than those of adverse effects of the broad-spectrum insecticides on natural enemies, or maybe due to the cancelling effect of buprofezin on the stimulation of reproduction by other insecticides.²⁷⁾ In fact, combination of deltamethrin and buprofezin (Dadeci®) was widely used for controlling both target pests, rice stem borer and hoppers, without any resurgence in Southeast Asia. These properties of buprofezin probably play an important role in the prevention of the resurgence in the paddy field.

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要 約

ブプロフェジンのトビイロウンカの産卵に及ぼす低濃度での影響

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ブプロフェジン (アプロード®) は, トビイロウンカ♀成虫に対して実用濃度以上での寿命短縮, 産卵抑制または孵化抑制作用を示すことが知られているが, 今回さらに低濃度での影響について検討を行なった。対照のデルタメスリン 0.4~0.00064 ppm をトビイロウンカ 5 齢~成虫に継続処理した場合, 成虫発育後の卵巣小管数, 産卵数の増加および寿命延長が認められた。これに対しブプロフェジン処理区では, 5 齢に影響のなくなる 0.4 ppm 以下でも成虫脱皮後の産卵抑制および寿命短縮の傾向が認められた。致死量以下の薬量におけるこのような効果は, 天敵への影響が小さいこととあわせ, ブプロフェジンがリサージェンスをきわめて起こしにくい IGR であることを示唆した。