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Intra- and Inter-specific Effects of the Brown Planthopper and White Backed Planthopper on Their Population Performance

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Abstract Intra- and inters-specific effects of *Nilaparvata lugens* (Stål) and *Sogatella furcifera* (Horváth) (Homoptera: Delphacidae) on their population performances on *Indica* Zhe 852, *Japonica* XiuShui 11 and Hybrid XY 9308 were studied in the laboratory. Intra-specific crowding did not influence the performance of *N. lugens* except for emergence rate on Z 852, but adversely affected the nymphal development duration of *S. furcifera* on Xiushui 11 and XY 9308, and emergence rates, adult longevity and fecundity on Xiushui 11. The inter-specific interactions between the nymphs of *N. lugens* and *S. furcifera* provided positive effects for both the species, but more benefits to *S. furcifera*. The nymphal development duration, emergence rate and fecundity of *S. furcifera* raised in mixed cultures for all the three varieties were often significantly shorter or higher than those raised in pure cultures, but only the emergence rate and fecundity of *N. lugens* raised in mixed cultures on Zhe 852 and XY 9308 were higher than those raised in pure culture. Both species suffered little delayed negative intra-specific effects and gained dramatic delayed positive inter-specific effects from another species previously fed on the plants. The nymphal development duration, adult emergence rate, female longevity and fecundity of each species were positively affected when reared on the plants sucked by another species before. The change of distribution pattern of *S. furcifera* reared on the plants fed by BPH before revealed the positive effects from inter-specific interaction.

Key Words Brown planthopper, inter-specific interaction, intra-specific interaction

Introduction

Intra- and inter-specific effects of phytophagous insects are important ecological research focuses. These effects were scored as direct effects, indirect effects, or for each pair-wise interaction (Denno *et al.*, 1994). Direct effects either from tactile stimulation among individuals or from the production of chemicals that deter or attract other individuals. Indirect effects occur when individuals deprive or improve others of the benefits to be gained from those resources. Indirect effects may occur immediately and affect the performance of other co-occur individuals (immediate effects), or they may persist and alter the fitness of other individuals in subsequent generations or seasons (delayed effects). Most of the indirect effects are mediated through induced changes in the morphological character, physiological state, nutritional quality and secondary chemicals of host plants (Denno *et al.*, 1994; Lou and Cheng, 1997).

The Brown Planthopper (BPH), *Nilaparvata lugens* Stal and White Backed Planthopper (WBPH), *Sogotalla furcifera* Horvath are known as the most destructive pests of rice throughout Southeastern and Eastern Asia. Both species often co-occur on the same plant and feed on the phloem sap of rice. They share the same habitats throughout most of the rice-growing season (Zhao *et al.*, 1991). Each species has the traits of highly aggregated distribution and rapid population growth (Denno *et al.*, 1994). Consequently, intra- and inter-specific interactions between these two species are possible. Although there were studies on the consequences of the interactions of these two species (Qin *et al.*, 1992; Ma *et al.*, 1996; Wang *et al.*, 1997), the impacts of varieties on the interactions have not been elucidated. This paper reported the lab results for impacts of varieties on following aspects of intra- and inter-specific interactions between the two species: 1) Direct intra-specific effects; 2) Direct inter-specific effects; 3) Indirect intra- and inter-specific effects.

Materials and Methods

Insects

The lab populations of brown planthopper and white

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Table 1. Resistant level of Varieties used in the experiment

Variety	Type	Resistant level*		Reference
		BPH	WBPH	
Zhe 852	Indica	MR	S	Yu *et al.*, 1991
Xiu Shui 11	Japonica	S	MR	Tao *et al.*, 1992
XY 9308	Hybrid	MR	MR	Liu *et al.*, 1998

* S: Susceptibe; MR: Moderately susceptible

backed planthopper were established by collecting original planthoppers from paddy fields and rearing on 45-60 day seedlings of rice plants (TN1) for more than two generations.

Rice plants

Three varieties, Japonica rice XiuShui 11, *Indica* rice Zhe 852 and Hybrid rice XY 9308 were selected as host plants based on the levels of resistance to BPH and WBPH as shown in Table 1. Seeds were sown in a net-house and the seedlings were transplanted into plastic cups (ϕ 9 cm*10 cm), 4 seedlings in each cup. The plants at the maximum tillering stage (about 55 days after sowing) were used for the experiments after removing small tillers and yellow leaves. All the rice plants at any stages of the experiment were covered using plastic cages with the organdy gauze to avoid infestation of planthoppers and kept under natural temperature condition.

Direct intra-specific effects

Three levels of densities were set for each developing stage, 6, 12 and 24 per pot for nymphs and 2, 4 and 6 per pot for adults. Newly hatched 1st instar nymphs or newly emerged adults were transferred into the planted cups using an aspirator according to the density levels and covered with a cage (33 cm in length and 8 cm in diameter with two gauzing holes for air circulation at middle) as showed in Fig. 1. The rice plants were kept at 25±2°C until all the nymphs developed into adults (for nymphal stage) or all the adults died (for adult stage). All the treatments were replaced 5 times. The development durations for male and female nymphs, emergence rates, longevities of male and female adults and fecundity were recorded and calculated.

Inter-specific effects

Three or two levels of two species combined densities were set for nymph or adult stage, respectively. Two experimental designs were used to study the inter-specific effects between BPH and WBPH. The

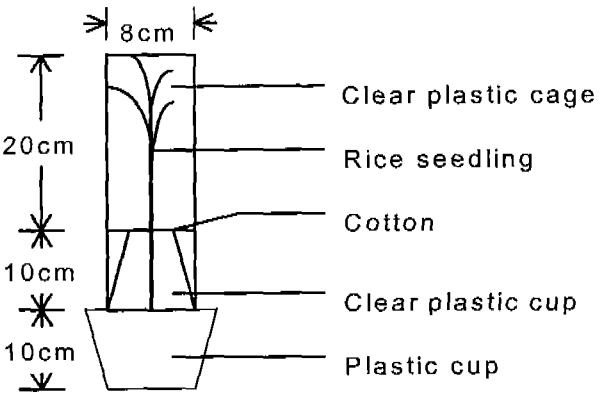

Fig. 1. Unit of indirect immediate effect of BPH to WBPH.

1st design is the total density (12 and 24 for nymphs, and 6 for adults) was same for all the treatments, but the density for each species is varied; the 2nd design is the densities for one species (6 for nymphs and 4 for adults) is same for all the experiments, but the densities of another species were varied. The procedures used for transferring and recording were same as the procedures mentioned above. All the treatments were replaced 5 times and carried out in the laboratory at 25±2°C.

Indirect intra-and inter-specific effects

Six first instar nymphs of BPH or WBPH were reared on the rice plants sucked by 18 old instar nymphs of the same or another species for 5 days prior to the experiment, using the healthy rice plants without any feeding by planthoppers as control. The planthoppers were allowed to develop into adults, which were transferred to the same treated plants with the density of 3 females and 3 males per pot. The plants were replaced using the plants from the same treatments in every 5 days to gain the consecutive effects. The vertical distribution, nymphal development duration and emergence rate, adult longevity and fecundity were recorded. Each treatment was replaced 6 times and all the treatment cages were randomly arranged in an incubator at 27.0±0.5°C and L12 : D12 h photoperiod.

Results

Direct intra-specific effects

The intra-specific effects did not affect the developmental duration of BPH nymphs reared on all the

Table 2. Impacts of direct intra-specific interaction on nymphal development durations and emergence rates of BPH and WBPH

Species	Varity	Density	Development duration (Days)		Emergence rate (%)
			Female	Male	
BPH	Zhe 852	6B*	13.54±0.22 a	13.35±0.36 a	75.00±5.20 aA
		12B	13.78±0.09 a	13.63±0.18 a	66.67±0.00 abA
		24B	14.15±0.22 a	13.61±0.12 a	38.89±6.31 bA
	XiuShui 11	6B	13.87±0.08 a	13.08±0.25 a	91.67±3.40 a
		12B	13.79±0.07 a	13.06±0.16 a	85.42±1.81 a
		24B	13.59±0.03 a	13.25±0.00 a	87.50±2.95 a
	XY 9308	6B	13.58±0.22 a	13.29±0.18 a	79.44±7.67 a
		12B	14.03±0.05 a	13.20±0.08 a	78.33±5.58 a
		24B	13.63±0.47 a	13.10±0.22 a	68.00±5.73 a
WBPH	Zhe 852	6W**	12.48±0.74 a	11.82±0.26 a	68.33±7.40 a
		12W	13.50±0.77 a	12.56±0.48 a	79.17±11.22 a
		24W	12.88±0.16 a	12.43±0.13 a	83.59±4.87 a
	XiuShui 11	6W	13.81±0.17 bA	13.10±0.26 bA	83.17±0.68 aA
		12W	14.16±0.36 abA	13.68±0.26 abA	73.49±7.05 abA
		24W	14.83±0.12 aA	14.06±0.18 aA	60.98±5.38 bA
	XY 9308	6W	12.75±0.30 a	12.16±0.22 bB	66.67±9.43 a
		12W	13.24±0.36 a	12.49±0.21 bAB	61.56±11.93 a
		24W	13.92±0.59 a	13.64±0.47 aA	47.92±13.26 a

* B: BPH **W: WBPH

Table 3. Impacts of Intra-specific interaction on adult longevity and fecundity of BPH and WBPH

Species	Varity	Density	Longevity (days)		Fecundity (Eggs/day)
			Female	Male	
BPH	Zhe 852	2B*	27.60±4.84 a	18.60±2.11 a	20.28±1.64 a
		4B	25.86±2.05 a	15.33±0.83 a	16.64±1.30 a
		6B	22.65±1.08 a	17.02±2.12 a	15.80±1.17 a
	XiuShui 11	2B	24.55±2.22 a	19.90±2.44 a	24.56±1.27 a
		4B	22.43±1.52 a	21.90±2.96 a	23.34±1.69 a
		6B	22.17±2.22 a	15.70±1.43 a	23.68±0.76 a
	XY 9308	2B	28.83±3.39 a	14.70±2.89 a	19.60±2.69 a
		4B	26.48±2.26 a	20.9±2.53 a	20.86±1.36 a
		6B	23.27±3.40 a	18.67±2.24 a	18.72±1.17 a
WBPH	Zhe 852	2W**	24.20±5.58 a	14.50±2.05 a	13.88±1.79 a
		4W	20.68±3.25 a	17.30±3.88 a	11.36±1.54 a
		6W	18.80±1.99 a	14.37±2.03 a	10.47±0.62 a
	XiuShui 11	2W	27.25±2.87 a	29.55±2.96 aA	10.21±0.62 aA
		4W	23.50±1.30 a	18.1±2.29 bA	8.76±0.58 abAB
		6W	20.02±3.51 a	20.17±1.12 bA	6.88±0.42 bB
	XY 9308	2W	26.70±3.27 a	19.40±1.25 a	7.49±1.26 a
		4W	19.03±1.85 a	17.85±1.58 a	4.40±1.01 a
		6W	21.20±2.22 a	14.13±0.84 a	3.90±0.81 a

* B: BPH **W: WBPH

three rice varieties, but affected emergence rates of BPH reared on the *Indica* variety Zhe 852. The emergence rate of BPH declined as the increase of the density only on this variety. In comparison with BPH, intra-specific effects affected both development duration and emergence rate of WBPH, especially for the Japonica variety Xiushui 11. The development duration at lower densities for Xiushui 11 and XY 9308 were significantly shorter than those at higher densities. The fecundity at lower density for Xiusui 11 was significantly higher than those at higher density (Table 2).

The intra-specific effects at adult stage seem to be less important compared with that at nymphal stage. The results showed that the density, 6 per pot, did not affect adult longevity and fecundity of BPH. However, the intra-specific effect did affect longevity of male adults and fecundity of WBPH reared on Xiushui 11, the longevity and fecundity declined as the increase of density as showed in Table 3.

Table 4. Impacts of inter-specific interaction under same total den-sity condition on nymphal development durations and emergence rates of BPH

Varity	Density	Development duration (days)		Emergence rate (%)
		Female	Male	
Zhe 852	6B6W	13.63±0.11 a	13.56±0.20 a	95.83±3.61 aA
	12B*	13.78±0.09 a	13.63±0.18 a	66.67±0.00 bB
	6B18W**	13.46±0.31 a	13.46±0.20 a	95.83±3.61 aA
	18B6W	13.80±0.17 a	13.46±0.07 a	85.55±5.11 aA
	24B	14.15±0.22 a	13.61±0.12 a	38.89±6.31 bB
Xiushui 11	6B6W	13.83±0.07 a	13.13±0.22 a	90.00±5.96 a
	12B	13.79±0.07 a	13.06±0.16 a	85.42±1.81 a
	6B18W	13.98±0.30 a	13.60±0.26 a	89.00±5.58 a
	18B6W	13.71±0.05 a	13.25±0.04 a	88.89±6.93 a
	24B	13.59±0.03 a	13.25±0.00 a	87.50±2.95 a
XY 9308	6B6W	13.68±0.18 a	13.25±0.23 a	100.00±0.00 aA
	12B	14.03±0.05 a	13.20±0.08 a	78.33±5.58 bB
	6B18W	13.48±0.40 a	13.25±0.31 a	100.00±0.00 aA
	18B6W	13.56±0.21 a	13.17±0.07 a	65.05±7.47 bB
	24B	13.63±0.47 a	13.10±0.22 a	68.00±5.73 bB

* B: BPH **W: WBPH

Table 5. Impacts of inter-specific interaction under same total density condition on nymphal development duration and emergence race of WBPH

Varity	Density	Development duration (days)		Emergence Rate (%)
		Female	Male	
Zhe 852	6W6B*	12.00±0.00 a	12.08±0.07 a	93.33±5.96 a
	12W**	13.50±0.77 a	12.56±0.48 a	79.17±11.22 a
	6W18B	12.10±0.09 bA	12.07±0.20 a	96.67±2.98 aA
	18W6B	12.67±0.22 aA	12.17±0.24 a	83.33±1.96 bA
	24W	12.88±0.16 aA	12.43±0.13 a	83.59±4.87 bA
Xiushui 11	6W6B	13.60±0.28 a	13.20±0.13 a	96.00±3.58 aA
	12W	14.16±0.36 a	13.68±0.26 a	73.49±7.05 bA
	6W18B	13.44±0.28 bB	13.16±0.20 bB	91.67±4.17 aA
	18W6B	13.95±0.20 bAB	13.19±0.14 bB	91.11±3.37 aA
	24W	14.83±0.12 aA	14.06±0.18 aA	60.98±5.38 bB
XY 9308	6W6B	12.31±0.16 bA	12.41±0.23 a	87.50±3.61 a
	12W	13.24±0.36 aA	12.49±0.21 a	61.56±11.93 a
	6W18B	12.17±0.14 bA	12.00±0.00 bA	94.44±4.54 aA
	18W6B	13.27±0.24 abA	12.91±0.37 abA	82.68±8.32 aA
	24W	13.92±0.59 aA	13.64±0.47 aA	47.92±13.26 bB

* B: BPH **W: WBPH

Direct inter-specific effects

Same total density at nymphal stage

The levels of density were set at 12 and 24 per pot in total and the number of each species was varied to match the levels as showed in Table 4 and 5. The results indicated that the inter-specific effects at the experimental density range did not affect the nymphal development duration of BPH, but did affect WBPH. The developmental durations of WBPH reared in mixed culture with BPH were significantly shorter than those reared in pure culture with WBPH only, especially for the higher density (24) treatments. However, the inter-specific effects affected the emergence rates of both of the species, except for BPH reared on Xiushui 11. The emergence rates of planthoppers reared with another species were significantly higher than those reared with the same species only, and inter-specific effects were more obvious at higher density treatments (Table 4 and 5).

Same total density at adult stage

The level of total density was set at 6 adults and the densities for other species were 0, 2 and 4 per pot. The results revealed that there were no significantly different on adult longevity for both BPH and WBPH, but there were significantly different on adult longevity of WBPH among these treatments. The fecundities of WBPH reared with BPH were significantly higher than those reared with the same spec-

Table 6. Impacts of Inter-specific interaction at adult stage under same total density condition on adult longevity and fecundity of BPH and WBPH

Species	Varity	Density	Longevity (days)		Fecundity (Eggs/day)
			Female	Male	
BPH	Zhe 852	2B4W	22.00±1.97 a	19.00±0.47 a	18.79±1.59 a
		4B2W	23.56±1.33 a	18.18±1.92 a	20.16±1.13 a
		6B*	22.65±1.08 a	17.02±2.12 a	15.80±1.17 a
	XiuShui 11	2B4W**	23.60±1.04 a	21.90±2.96 a	22.15±0.22 a
		4B2W	28.38±1.84 a	27.13±2.46 a	23.13±0.86 a
		6B	22.17±2.22 a	15.70±1.43 a	23.68±0.76 a
	XY 9308	2B4W	27.93±5.18 a	18.90±1.19 a	18.21±0.86 a
		4B2W	22.75±1.72 a	18.00±2.32 a	19.12±1.18 a
		6B	23.27±3.40 a	18.67±2.24 a	18.72±1.17 a
WBPH	Zhe 852	2W4B	22.83±0.98 a	18.90±2.17 a	21.69±1.76 aA
		4W2B	18.67±1.21 a	15.08±1.29 a	16.08±0.45 bB
		6W	18.80±1.99 a	14.37±2.03 a	10.47±0.62 cC
	XiuShui 11	2W4B	24.33±4.60 a	23.63±0.50 a	17.81±1.06 aA
		4W2B	24.60±2.37 a	20.70±1.05 a	15.09±1.00 aA
		6W	20.02±3.51 a	20.17±1.12 a	6.88±0.42 bB
	XY 9308	2W4B	20.50±1.22 a	22.45±2.51 a	8.87±0.91 aA
		4W2B	24.50±3.02 a	16.50±1.87 a	8.68±1.21 aA
		6W	21.20±2.22 a	14.13±0.84 a	3.90±0.81 bA

* B: BPH **W: WBPH

Table 7. Impacts of inter-specific interaction under same density for one species at nymph stage on nymphal development duration and emergence rate of BPH and WBPH

Species	Varity	Density	Development duration (Days)		Emergence rate (%)
			Female	Male	
BPH	Zhe 852	6B*	13.54±0.22 a	13.35±0.36 a	75.00±5.20 bA
		6B6W**	13.63±0.11 a	13.56±0.20 a	95.83±3.61 aA
		6B18W	13.46±0.31 a	13.46±0.20 a	95.83±3.61 aA
	XiuShui 11	6B	13.87±0.08 a	13.08±0.25 a	91.67±3.40 a
		6B6W	13.83±0.07 a	13.13±0.22 a	90.00±5.96 a
		6B18W	13.98±0.30 a	13.60±0.26 a	89.00±5.58 a
	XY 9308	6B	13.58±0.22 a	13.29±0.18 a	79.44±7.67 bA
		6B6W	13.68±0.18 a	13.25±0.23 a	100.00±0.00 aA
		6B18W	13.48±0.40 a	13.25±0.31 a	100.00±0.00 aA
WBPH	Zhe 852	6W	12.48±0.74 a	11.82±0.26 a	68.33±7.40 bB
		6W6B	12.00±0.00 a	12.08±0.07 a	93.33±5.96 aAB
		6W18B	12.10±0.09 a	12.07±0.20 a	96.67±2.98 aA
	XiuShui 11	6W	13.81±0.17 a	13.10±0.26 a	83.17±0.68 bA
		6W6B	13.60±0.28 a	13.20±0.13 a	96.00±3.58 aA
		6W18B	13.44±0.28 a	13.16±0.20 a	91.67±4.17 abA
	XY 9308	6W	12.75±0.30 a	12.06±0.22 a	66.67±9.43 bA
		6W6B	12.31±0.16 a	12.41±0.23 a	87.50±3.61 abA
		6W18B	12.17±0.14 a	12.00±0.00 a	94.44±4.54 aA

* B: BPH **W: WBPH

ies only (Table 6).

Same density for one species at nymphal stage

The density of one species was set to 6 per pot, but 0, 6 or 18 nymphs of other species were added to each pot to create various density levels. The inter-specific effects under these levels did not affect the nymphal development duration for the two species, but affected the emergence rates. All the emergence rates of WBPH reared on the three varieties with BPH were higher than those reared with the same species only. However, this phenomenon only appeared in Zhe 852 and XY 9308 for BPH (Table 7).

Table 8. Impacts of inter-specific interaction under the same density for one species at adult stage on longevity and fecundity of BPH and WBPH

Species	Varity	Density	Longevity (days)		Fecundity (Eggs/day)
			Female	Male	
BPH	Zhe 852	4B*	25.86±2.05 a	15.33±0.83 a	16.64±1.30 a
		4B2W**	23.56±1.33 a	18.18±1.92 a	20.16±1.13 a
	XiuShui 11	4B	22.43±1.52 a	21.90±2.96 a	23.34±1.69 a
		4B2W	28.38±1.84 a	27.13±2.46 a	23.13±0.86 a
	XY 9308	4B	26.48±2.26 a	20.9±2.53 a	20.86±1.36 a
		4B2W	22.75±1.72 a	18.00±2.32 a	19.12±1.18 a
WBPH	Zhe 852	4W	20.68±3.25 a	17.30±3.88 a	11.36±1.54 bA
		4W2B	18.67±1.21 a	15.08±1.29 a	16.08±0.45 aA
	XiuShui 11	4W	23.50±1.30 a	18.1±2.29 a	8.76±0.58 bB
		4W2B	24.60±2.37 a	20.70±1.05 a	15.09±1.00 aA
	XY 9308	4W	19.03±1.85 a	17.85±1.58 a	4.40±1.01 bA
		4W2B	24.50±3.02 a	16.50±1.87 a	8.68±1.21 aA

* B: BPH **W: WBPH

Table 9. Impacts of indirect inter-specific interaction on population biological parameters of BPH and WBPH

Species	Treatment	Nymphal development duration (days)		Emergence rate (%)	Female longevity (days)	Fecundity (Eggs/Female)
		Female	Male			
BPH	Sucked by WBPH	12.42±0.17bA	11.95±0.23a	83.33±4.71a	30.25±1.24aA	958.00±48.89aA
	Sucked by BPH	12.68±0.16abA	12.57±0.45a	73.33±8.94a	22.75±0.96bA	587.42±13.84bB
	Control	13.08±0.07aA	12.20±0.11a	70.00±6.56a	25.33±3.29abA	772.11±76.11bAB
WBPH	Sucked by WBPH	12.47±0.20aA	11.78±0.46a	72.22±3.93abAB	21.17±0.95bA	353.00±17.00bB
	Sucked by BPH	11.21±0.11bB	10.90±0.26a	91.67±4.17aA	25.56±0.72aA	550.44±6.40aA
	Control	12.22±0.14aA	11.72±0.32a	58.33±9.43bB	21.50±1.27bA	394.38±36.89bB

Same density for one species at adult stage

The density level of one species was set to 4 per pot, but 0 or 2 adults of other species were added to each pot. The results showed that the inter-specific effect at the experimental density range did not affect the adult longevity and fecundity of BPH, but affected the fecundity of WBPH. The fecundities of WBPH reared with BPH together were significantly higher than those reared with WBPH only, even though the total density in the mixture culture was higher than that in pure culture (Table 8).

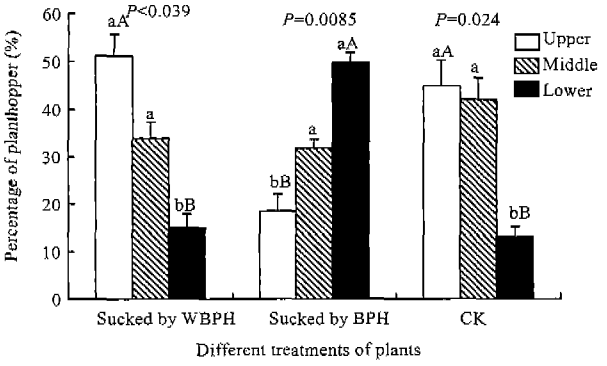

Fig. 2. Diversities of the vertical distribution of WBPH in differently treated plants**. Diversities among the percentage of WBPH in different sites of the same treated rice were compared by Friedman Rank Sums (FRS) (Danniel, 1983). Means in the same site of different treatments followed by the same small (capital) letter are not significantly different at $P = 0.05$ ($P = 0.01$) by Duncan's ultimate comparison.

Indirect intra- and inter-specific effects

On biological parameters at nymphal and adult stage

The rice plants after feeding for 5 days by old nymphs of one of the species were used to rear nymphs and adults, using healthy plants as control. The nymphal development duration, emergence rate, adult longevity and fecundity were measured and the results indicated that both of the two species got benefits from feeding the plants sucked by other species before. The development durations of female nymphs of both species feeding on the rice plants sucked by other species were significantly shorter; their longevities of adults were longer and emergence

rates and fecundities were higher than those feeding on the healthy plants or the plants sucked by the same species before (Table 9).

On distribution

The rice plants were divided into three parts, top (16 cm above), middle and low (below 8 cm from ground) part and the number of planthoppers in each part was recorded at 2 days after releasing. The results showed that more BPH stayed in the low parts of the plants sucked by WBPH before, but the change did not affect the distribution pattern of BPH. However, the common distribution pattern of WBPH was completely changed on the plants sucked by BPH before, more WBPH was moved to low part from top part as showed in figs. 2 and 3.

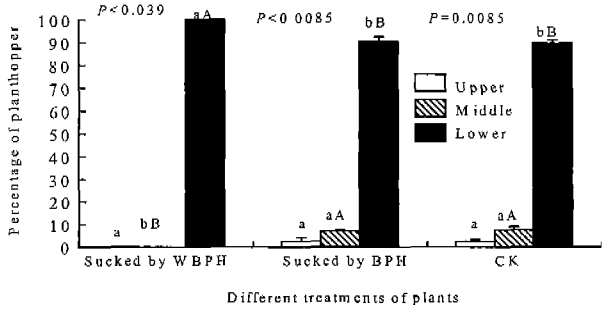

Fig. 3. Diversities of vertical distribution of BPH in differently treated plants. Diversities among the percetage of WBPH in different sites of the same treated rice were compared by Friedman Rank Sums (FRS) (Danniel, 1983). Means in the same site of different treatments followed by the same small (capital) letter are not significantly different at $P = 0.05$ ($P = 0.01$) by Duncan's ultimate comparison.

Discussion

Our study demonstrated that BPH endured weak direct intra-specific effects. No components of fitness for BPH were affected as a result of intra-specific crowding in the experimental condition except for the emergence rate of BPH reared on Zhe 852. WBPH suffered adverse direct intra-specific effects and all the biological parameters tested in this experiment, including nymphal development duration, emergence rate, adult longevity and fecundity, were negatively affected by the density. These results indicated that BPH was more tolerant to crowding compared with WBPH. The results also revealed that intra-specific effects were closely related to the food condition (or resistant level), the lower the resistant level of variety, the less the intra-specific effects. Among the three varieties, Zhe 852 is more suitable for WBPH (relative shorter nymphal development duration and higher fecundity), relative less negative effects for WBPH were observed in the experiment.

However, the results from our experiment showed that inter-specific interactions between BPH and WBPH provided positive effects for the two species. The nymphal development duration, emergence rate, adult longevity and fecundity of the two species reared in mixed culture with other species were usually shorter or higher than those reared in pure culture. But the positive effects were also related to the species and the variety. WBPH received more positive effects under the mixed culture condition compared with BPH. Among the three varieties, Xiushiu 11 is more suitable for BPH, there were almost no positive effects for BPH reared on this variety under the experimental condition.

No components of fitness for BPH or WBPH were dramatically different between the population reared on un-sucked plants and the plants previously sucked by the same species on rice variety XiuShui 11, which indicated that the previous feeding at the experiment condition did not cause serious reduction of nutrition. But the nymphal development duration, adult emergence rate, female longevity and fecundity of the two species were positively affected by feeding plants sucked by another species before. It was concluded that the subsequent population of each species suffered feeble indirect delayed intra-specific effects transmitted by the host plants from the earlier population, but gained significant positive indirect delayed inter-specific effects from the earlier -population of another species previously fed on the plants. The vertical distributions of WBPH changed when rice plants were sucked by BPH and more WBPH moved to low part where BPH usually stay.

Host plant nitrogen has been called on to explain the host plant-insect interactions and population biology of planthoppers (Fukumorita and Chino, 1982; Cook and Denno, 1994). However, the Intra- and inter-specific effects of BPH and WBPH may be mediated primarily through induced changes in morphological character, physiological state, and second chemicals of rice plants (Seino *et al.*, 1996). Those induced changes may occur on the feeding sites only and do not or rarely transmit to other sites of plants, just as the ovicidal substance ?benzyl benzoate ?was produced exclusively in the watery oviposition lesion irrespective of the species of rice planthoppers (Seino *et al.*, 1996). On the other hand, saliva of the planthoppers was injected into the rice tissue during the precession of the feeding performance of planthoppers (Sogawa, 1982; Li *et al.*, 1996). The compositions of the saliva of different planthoppers may differ from each other (Sogawa, 1982; Li *et al.*, 1996). If the saliva were ingested by another species, they may directly affect the performance and devel-

opment of this species. The compositions of saliva may also take chemical reaction with the compositions of the phloem sap of rice. As the result, the compositions and contents of phloem sap of rice were changed. Inter-specific effects between WBPH and BPH may be achieved by these indirect ways. Furthermore, the protainase and other effective compositions of saliva may concentrated on the sites previously fed on by planthoppers, and only changed the microenvironment of nearby sites. This may explain why the inter-specific effects of BPH on WBPH were not systematic but partial and WBPH moved to the low part of rice plants where BPH stayed before. Further research in this area will be useful for understanding the mechanisms of these inter-specific effects.

Variety resistance is an effective means of controlling the brown planthopper and the white-back planthopper, but the resistant extent of rice varieties may change in the field. Many studies showed that induced insect resistance occurred in some plants or varieties after being fed on by phytophagous insects (Lou and Cheng, 1997). In contrast, the changes of plants or varieties induced by phytophagous insects might reduce the resistant extent of some plants or varieties (Kidd *et al.*, 1985; Lou and Cheng, 1997). Our laboratory experiments showed the development, survival, and fecundity of BPH and WPBH could be positively affected by the feeding performance of another species on rice variety. These results indicated that the BPH and WBPH resistant degrees were significantly reduced when the rice plants were previously fed on by another species. This revealed that the development of varieties with both internal and external resistance should be a new area for rice variety breeding.

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