Resistance Performance to Whitebacked Planthopper in Different Phenotypes of Japonica / Indica Doubled Haploid Rice Lines

Kazushige SOGAWA [1,2], HU Jiang [2], ZENG Long-jun [2], QIAN Qian [2], ZENG Da-li [2]

([1]*Japan International Research Center for Agricultural Sciences, Tsukuba 305-8686, Japan*; [2]*State Key Laboratory of Rice Biology, China National Rice Research Institute, Hangzhou 310006, China*)

Abstract: Field performance of whitebacked planthopper (WBPH)-resistance of four phenotypes was evaluated in Chunjiang 06 (CJ-06) / TN1 DH rice lines, which were expressed by different combinations of sucking inhibitory and ovicidal traits inherited independently from CJ-06. WBPH established the highest populations in susceptible DH lines that had neither sucking inhibitory- nor ovicidal resistance. Both immigration and subsequent population levels were kept below the damage-causing density in the sucking inhibitory DH lines even under a WBPH outbreak. WBPH could not build up populations in the DH lines having both the sucking inhibitory and ovicidal resistance. Although WBPH immigrated preferentially to non-sucking inhibitory DH lines with ovicidal resistance, subsequent population buildup was significantly suppressed. It was concluded that the differential performance to WBPH-resistance in CJ-06 / TN1 DH lines was primarily due to the sucking inhibitory trait, and complementarily to the ovicidal trait.

Key words: *Sogatella furcifera*; rice; doubled haploid population; varietal resistance, sucking inhibitory resistance; ovicidal resistance

The whitebacked planthopper (WBPH), *Sogatella furcifera*, migrates from southern China to central China depending on the southwest monsoon in the rainy season. WBPH is, thus, an important economic insect pest of single-cropping japonica rice in central China, because the rice plant is usually transplanted in mid- to late June when WBPH immigrates most actively to it. We found that a Chinese japonica rice “Chunjiang 06” (CJ-06) had compound mechanisms of WBPH-resistance due to sucking inhibition and ovicidal response[2]. CJ-06 could be utilized to improve WBPH-resistance in japonica rice. To analyze the WBPH-resistance genes, we have established a new japonica / indica doubled haploid (DH) population from a cross between WBPH-resistant japonica CJ-06 and susceptible indica TN1 by anther culture method[4].

In the present experiments, we examined differential field performance of WBPH-resistance in the DH lines, which have different combinations of the two independent WBPH-resistance traits, under different conditions of WBPH infestations.

Received: 16 December 2004; **Accepted:** 2 March 2005

Corresponding author: Kazushige SOGAWA (ksogawa@jircas.affrc.go.jp)

MATERIALS AND METHODS

DH rice lines planted

A newly established CJ-06 / TN1 DH rice population was employed[4]. CJ-06 and TN1 were also used as resistant and susceptible check varieties, respectively. Twenty-five seedlings of 151 and 99 DH lines were transplanted in a square-meter plot on June 16 in 2003 and 2004, respectively. The DH lines were grown under the natural WBPH infestations without spraying any pesticides.

Monitoring of WBPH populations

Immigration and subsequent population development of WBPH were monitored by counting WBPH adults in 9 hills at the center of each DH line plot. Density of immigrants was recorded on July 2, 2003. In 2004, densities of macropterous and brachypterous females were separately recorded every week from June 25 to August 14. Relative densities of progeny were estimated by counting nymphs and adults that were tapped down from 2 hills in each DH line plot into a tray of 29 cm×41 cm×2.5 cm on July 22 in 2003, and on July 31 and August 20 in 2004.

Phenotype of WBPH-resistance

Sucking inhibitory resistance to WBPH in the DH lines was evaluated based mainly on density of WBPH immigrants. Honeydew data measured by the parafilm sachet method were also employed to confirm the sucking inhibitory property in DH lines. Honeydew excretion of less than 5 mg / (female · day) was phenotyped as sucking inhibitory resistance[4].

In 2003, the DH lines to which less than 2 and more than 5 WBPH females / hill immigrated were classified to be resistant and susceptible, respectively. The DH lines, where 2 to 5 females immigrated in each hill, were phenotyped based not only on immigrant density but also on honeydew measurement.

In 2004, because of very low WBPH immigration, the integrated number of macropterous females / hill for a period from June 25 to July 23 was employed to differentiate sucking inhibitory- and non-sucking inhibitory DH lines. The integral values below 12 indicated resistance, and those larger than 20 indicated susceptibility. The DH lines with integral values between 12 and 20 were phenotyped based on honeydew excretion as well as immigrant density.

Ovicidal resistance to WBPH was phenotyped by the ovicidal symptoms that were induced by WBPH oviposition[2]. Ovicidal DH lines were clearly distinct from non-ovicidal ones by conspicuous necrotic symptoms with watery lesions at oviposition sites in the leaf sheaths.

RESULTS

WBPH population trends

In 2003, WBPH immigrated massively in late June. Density of macropterous females peaked on June 30. Their densities in susceptible TN1 and resistant CJ-06 were 5.6 females per hill and 0.3 females per hill on July 2, respectively. The populations established by the immigrants caused serious damages including hopperburn in TN1 and other susceptible lines in late July, while no population was built up in CJ-06. Almost all progenies emerged to macropterous adults, and emigrated out by the end of July. Thus, WBPH reproduced only one generation in 2003.

In 2004, WBPH started to immigrate in late June. However, immigrant density was much lower than that in 2003. Density of macropterous females peaked in July 9–15. The average density was 1.2–1.4 females per hill in TN1, while only 0–0.2 females per hill in CJ-06. The first-generation nymphs occurred in mid- to late July. A portion of nymphs emerged to brachypterous females due to a low-density effect in late July to early August, which reproduced second-generation nymphs in mid August. The WBPH populations disappeared after second-generation nymphs emerged to macropterous adults. Thus, WBPH reproduced two consecutive generations with declining density as generation progressed in 2004. No visible damages were recognized in any DH lines.

WBPH-resistance performance in different phenotypes

Of 151 DH lines used in 2003, 79 and 72 lines were identified as sucking inhibitory and non-sucking inhibitory lines, respectively. They were also divided into 77 ovicidal and 74 non-ovicidal DH lines. They were eventually classified into four phenotypes with different combinations of sucking inhibitory and ovicidal resistance; namely 36 sucking inhibitory / ovicidal (R/R), 43 sucking inhibitory / non-ovicidal (R/S), 41 non-sucking inhibitory / ovicidal (S/R), and 31 non-sucking inhibitory / non-ovicidal (S/S, susceptible) lines.

There were highly significant differences in immigrant density between sucking inhibitory and non-sucking inhibitory DH lines (Table 1). Population density of subsequent progeny reproduced by the immigrants was significantly lower in sucking inhibitory DH lines than that in non-sucking inhibitory lines. There was also a significant difference in density of progeny between ovicidal and non-ovicidal lines within non-sucking inhibitory DH lines, although WBPH immigrated equally to both the DH line groups. Population density in ovicidal lines was about a half of that in non-ovicidal ones. Population buildup was most strongly suppressed in sucking inhibitory DH

Table 1. Relative densities of immigrant and progeny in DH lines with different phenotypes of WBPH-resistance in 2003.

Phenotype[a]	No. of lines	Mean±sd(d) [b]	
		Immigrant	Progeny
R / R	36	1.2±0.7 a	66±87 a
R / S	43	1.1±0.1 a	126±55 a
S / R	41	6.5±0.3 b	408±45 b
S / S	31	6.7±0.4 b	827±95 c
CJ-06		0.3	7
TN1		5.6	681

[a]R / R, Sucking inhibitory / Ovicidal; R / S, Sucking inhibitory / Non-ovicidal; S / R, Non-sucking inhibitory / Ovicidal; S / S, Non-sucking inhibitory / Non-ovicidal.

[b]Densities of macropterous females (immigrants) per hill on 2 July, and first-generation progeny per sample on July 31 in 2003. Means of immigrant and progeny followed by the same letter are not significantly different in Kruskal-Wallis test.

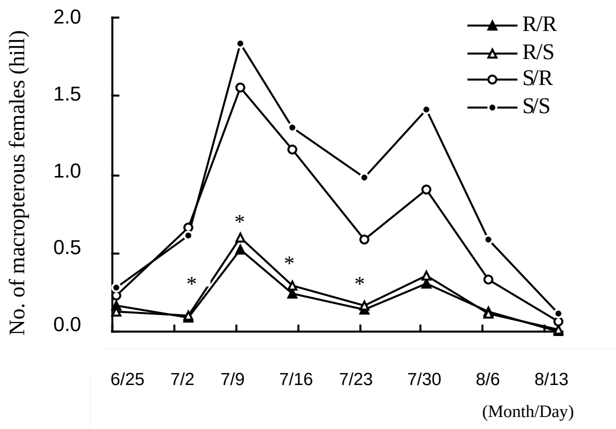

Fig. 1. Density fluctuation of macropterous females of WBPH in DH lines with different WBPH-resistance phenotypes.

* There are significant differences in the densities between sucking inhibitory and non-sucking inhibitory DH lines in Kruskal-Wallis test.

lines with ovicidal resistance, where relative population density was only about one-twelfth of that in susceptible DH lines in 2003 (Table 1).

Of 99 DH lines tested in 2004, 61 and 38 lines were sucking inhibitory and non-sucking inhibitory ones, respectively. Also, 37 and 62 DH lines were ovicidal and non-ovicidal, respectively. They were sub-divided into 19 sucking inhibitory / ovicidal (R/R), 42 sucking inhibitory / non-ovicidal (R/S), 18 non-sucking inhibitory / ovicidal (S/R), and 20 non-sucking inhibitory / non-ovicidal (S/S, susceptible) lines (Table 2).

Immigrant density was significantly lower in sucking inhibitory DH lines than that in non-sucking inhibitory ones during the period from July 2 to 23 (Fig. 1). The peak densities on July 9 were 0.6±0.4 and 1.8±0.7 females / hill in sucking inhibitory and non-sucking inhibitory lines, respectively. There was no significant difference in the immigrant densities between ovicidal and non-ovicidal ones within either sucking inhibitory or non-sucking inhibitory DH lines.

Population densities of the first-generation progeny were significantly lower in sucking inhibitory and/or ovicidal DH lines than those in susceptible lines (Table 2). On average, 0.2 and 0.7 brachypterous females per hill emerged from the first generation nymphs in sucking inhibitory and non-sucking inhibitory DH lines, respectively. In sucking inhibitory and/or ovicidal DH lines, the second-generation populations were again suppressed to 1/2–1/4 of the population in susceptible lines.

Table 2. Relative densities of WBPH populations in DH lines with different phenotypes of WBPH-resistance in 2004.

Phenotype	No. of lines	Immigrant	G1-progeny	B-female	G2-progeny
R / R	19	0.5±0.4 a	17±13 a	0.2±0.2 a	8±8 a
R / S	42	0.7±0.5 a	21±15 a	0.2±0.2 a	11±12 a
S / R	18	1.7±0.6 b	31±15 a	0.7±0.6 b	16±21 a
S / S	20	1.8±0.8 b	69±31 b	0.7±0.6 b	33±19 b
CJ-06		0.2	21	0.0	2
TN1		0.2	165	1.4	124

Immigrant, Density of macropterous females / hill on July 9; G1-progeny, Relative population density at the first-generation per sample on July 31; B-female, Density of brachypterous females / hill on August 6; G2-progeny, Relative population density at the second-generation per sample on August 20. The data were mean±sd.

In each column, means followed by the same letter are not significantly different in Kruskal-Wallis test.

DISCUSSION

CJ-06 / TN1 DH lines are divided into four different phenotypes with different combinations of sucking inhibitory and ovicidal resistance to WBPH, which are independently inherited from CJ-06 [3,4]. In the present experiments, we found distinct differences in WBPH-resistance performance among the phenotypes under different intensities of WBPH infestations.

Sucking inhibitory and non-sucking inhibitory DH lines were discriminated based on the relative densities of macropterous females of WBPH during an immigration period, because the sucking inhibitory property of rice plants against WBPH causes a distinct non-preference behavioral response of WBPH immigrants [2]. The present experiments demonstrated that WBPH immigration and subsequent population buildup were strongly suppressed below the damage-causing density in the sucking inhibitory DH lines even under a massive immigration of WBPH in 2003.

Ovicidal resistance also suppressed population development of WBPH. Performance of ovicidal resistance was, however, indistinct in the sucking inhibitory DH lines, because of very few ovipositions due to limited WBPH immigration. However, ovicidal performance was significant in non-sucking inhibitory DH lines, to which WBPH immigrated and laid eggs preferentially. WBPH population density significantly declined in the non-sucking inhibitory DH lines with ovicidal resistance even under an epidemic situation in 2003. In 2004, when WBPH reproduced continuously for two generations, densities of the first- and second-generation nymphs in the non-sucking inhibitory DH lines with ovicidal resistance was suppressed as low as those in the sucking inhibitory DH lines.

Based on the present results, we concluded that the differential expression of WBPH-resistance in CJ-06 / TN1 DH lines was attributed primarily to antixenosis due to the sucking inhibitory trait, and complementarily to antibiosis due to the ovicidal trait derived independently from CJ-06. The present conclusion reconfirmed our previous results obtained by employing different japonica rice varieties with sucking inhibitory and/or ovicidal resistance [4].

ACKNOWLEGEMENTS

JIRCAS International Collaborative Project Fund (B33102-331) and Grant Project of Zhejiang Province for International Collaboration (2002AA217111) supported this work.

REFERENCES

1 Sogawa K, Li Y H, Zhang J, Liu G J, Yao H G. Genealogical analysis of resistance to the whitebacked planthopper, *Sogatella furcifera* in Chinese japonica rice Chunjiang 06. *Chinese J Rice Sci*, 2003, **17**(suppl): 67-72.

2 Sogawa K, Liu G J, Teng K, Lin H F, Shen L L. Resistance to the whitebacked planthopper, *Sogatella furcifera* in Chinese japonica rice Chunjiang 06. *Chinese J Rice Sci*, 2003, **17**(suppl): 56-66.

3 Sogawa K, Liu G J, Zhu C G. Inheritance of whitebacked planthopper resistance in Chinese japonica rice Chunjiang 06. *Chinese J Rice Sci*, 2003, **17**(suppl): 73-76.

4 Sogawa K, Sun Z X, Qian Q, Zeng D L. Phenotypic expression of whitebacked planthopper resistance in the newly established japonica / indica doubled haploid rice population. *Rice Sci*, 2004, **11**: 155-160.