

## Genetics of resistance of rice cultivar ARC 10550 to Bangladesh brown planthopper biotype

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**Abstract.** Resistance to brown planthopper in rice cultivar ARC 10550 was found to be governed by a single recessive gene which was designated *bph* 5. It conveys resistance to brown planthopper populations in South Asia but not to the populations in East and Southeast Asia. This gene segregated independently of four other known genes for brown planthopper resistance. It should be possible to combine this gene with any of the other four genes to develop rice cultivars with a broad spectrum of resistance.

**Keywords.** *Nilaparvata lugens* Stal; *Oryza sativa* L.; recessive gene; independent segregation.

### 1. Introduction

Natural populations of brown planthopper *Nilaparvata lugens* Stal. (BPH) in South Asia differ from those in East and Southeast Asia in virulence patterns. Cultivars of rice *Oryza sativa* L. with *Bph* 1 or *bph* 2 genes (Athwal *et al* 1971) are resistant to BPH populations in East and Southeast Asia but not in South Asia. Rice cultivars with *Bph* 3 and *bph* 4 (Lakshminarayana and Khush 1977) are resistant to BPH populations in all the regions of Asia (Khush 1977). However, some rice cultivars such as ARC 10550 are resistant to BPH populations in South Asia but not in East and Southeast Asia (Seshu and Kauffman 1980). The genetic basis of resistance of these cultivars has not been investigated.

On the basis of these differential reactions, BPH populations in different countries have been categorized into four biotypes. The original populations in East and Southeast Asia belonged to biotype 1. Biotype 2 originated in the Philippines, Indonesia and Vietnam in 1976–1977 after the introduction and widescale cultivation of cultivars with *Bph* 1 (Khush 1979), and is the dominant biotype in these countries. Biotype 3 was produced in the laboratory at the International Rice Research Institute (IRRI) by rearing the insect on ASD 7, a rice cultivar with *bph* 2 for resistance (Pathak and Khush 1979). The BPH populations in South Asia have been variously referred to as the South Asian biotype (Khush 1977) or biotype 4 (Khush 1984).

This study was undertaken to determine the genetic basis of resistance to biotype 4 (Bangladesh population) of BPH.

### 2. Materials and methods

Rice cultivars used in the study and their reactions to different biotypes are listed in table 1. A Northeast India cultivar ARC 10550, which is susceptible to biotypes 1, 2 and

**Table 1.** Rice cultivars used in the study, and their reactions to different biotypes of brown planthopper.

| Cultivar      | Accession No. | Gene possessed by the cultivar and reaction to biotypes |                       |   |   |   |
|---------------|---------------|---|-----------------------|---|---|---|
|               |               | Gene  | Reaction to biotypes* |   |   |   |
|               |               |   | 1                     | 2 | 3 | 4 |
| TN1           | 105           | None  | S                     | S | S | S |
| IR1539-823    | 32618         | <i>Bph 1</i>  | R                     | S | R | S |
| IR1154-243    | 19909         | <i>bph 2</i>  | R                     | R | S | S |
| Rathu Heenati | 11730         | <i>Bph 3</i>  | R                     | R | R | R |
| Babawee       | 8978          | <i>bph 4</i>  | R                     | R | R | R |
| ARC 10550     | 12507         |   | S                     | S | S | R |

\*R = resistant; S = susceptible.

3 but resistant to biotype 4, was crossed with TN1, which is susceptible to all the known biotypes of BPH. The F<sub>1</sub>, F<sub>2</sub>, and F<sub>3</sub> populations were tested for reactions to biotype 1 at IRRI, Los Banos, Philippines, and to biotype 4 at the Bangladesh Rice Research Institute (BRRI), Joydebpur, Bangladesh.

For allele tests, ARC 10550 was crossed with IR1539-823, IR1154-243, Rathu Heenati, and Babawee. F<sub>1</sub>, F<sub>2</sub>, and F<sub>3</sub> populations were tested for reaction to biotype 1 at IRRI and for reaction to biotype 4 at BRRI. The same set of F<sub>3</sub> lines of two crosses (IR1539-823/ARC10550 and IR1154-243/ARC10550) was tested for reaction to biotypes 1 and 4 to determine the independence of the two genes involved.

All the crosses were made at IRRI and F<sub>1</sub> and F<sub>2</sub> populations were also grown at IRRI. Part of the seed of F<sub>1</sub> and F<sub>2</sub> populations and each of the F<sub>3</sub> lines was used for tests against biotype 4 at IRRI and part was tested at BRRI.

Greenhouse reared populations of biotypes 1 and 4 were used. The bulk seedling test (Athwal *et al* 1971) was employed for evaluating the reaction of parents, F<sub>1</sub> hybrids, and segregating populations. F<sub>1</sub> populations and F<sub>3</sub> lines were scored on a row basis and were classified as resistant, susceptible, or segregating. Each seedling of the F<sub>2</sub> populations was classified as resistant or susceptible. Scoring was done when the seedlings of the susceptible control were killed.

### 3. Results

The F<sub>1</sub> and F<sub>2</sub> populations of the cross TN1/ARC 10550 were susceptible to biotype 1 as expected (table 2). The F<sub>1</sub> progenies of this cross were susceptible to biotype 4 but the F<sub>2</sub> population segregated in a ratio of 1 resistant to 3 susceptible and the F<sub>3</sub> families segregated in a ratio of 1 resistant:2 segregating:1 susceptible (table 2). These results show that resistance to biotype 4 in ARC 10550 is governed by a single recessive gene.

The F<sub>1</sub> progeny of the cross IR1539-823/ARC 10550 was resistant to biotype 1 and the F<sub>2</sub> population segregated in a ratio of 3 resistant to 1 susceptible. The F<sub>3</sub> families of this cross segregated in a ratio of 1 resistant:2 segregating:1 susceptible. These results indicated the segregation of *Bph 1* in this cross. The F<sub>1</sub> progeny of this

Table 2. Reaction<sup>a</sup> to brown planthopper biotypes 1 and 4 of F<sub>1</sub> and F<sub>2</sub> populations and F<sub>3</sub> lines from the crosses of ARC 10550 with various testers.

| Cross                   | Reaction to biotype 1 |     |                    |                               |     |    | Reaction to biotype 4     |    |     |                |   |                    |                               |                   |    |                           |    |                   |   |                      |   |
|-------------------------|-----------------------|-----|--------------------|-------------------------------|-----|----|---------------------------|----|-----|----------------|---|--------------------|-------------------------------|-------------------|----|---------------------------|----|-------------------|---|----------------------|---|
|                         | F <sub>1</sub>        |     |                    | F <sub>2</sub> (No seedlings) |     |    | F <sub>3</sub> (No lines) |    |     | F <sub>1</sub> |   |                    | F <sub>2</sub> (No seedlings) |                   |    | F <sub>3</sub> (No lines) |    |                   |   |                      |   |
|                         | R <sup>b</sup>        | S   | X <sup>2</sup> 1:3 | R                             | Seg | S  | X <sup>2</sup> 1:2:1      | S  | Seg | R              | S | X <sup>2</sup> 1:3 | R                             | Seg               | S  | X <sup>2</sup> 1:2:1      | R  | Seg               | S | X <sup>2</sup> 1:2:1 |   |
| TNI/ARC 10550           | S                     | 0   | 425                | —                             | —   | —  | —                         | —  | —   | —              | S | 57                 | 195                           | 0.76              | 28 | 65                        | 31 | 0.44              | — | —                    | — |
| IR1539-823/ARC 10550    | R                     | 458 | 173                | 1.96                          | 31  | 77 | 1.11                      | 38 | 77  | 31             | S | 92                 | 295                           | 0.31              | 35 | 77                        | 34 | 0.45              | — | —                    | — |
| IR1154-243/ARC 10550    | S                     | 181 | 540                | 0.004                         | 36  | 73 | 1.93                      | 27 | 73  | 36             | S | 96                 | 236                           | 2.71              | 33 | 68                        | 35 | 0.06              | — | —                    | — |
| Rathu Heenati/ARC 10550 | R                     | 322 | 96                 | 0.96                          | 37  | 79 | 0.55                      | 34 | 79  | 37             | R | 153                | 56                            | 8.87 <sup>c</sup> | 58 | 67                        | 13 | 2.37 <sup>d</sup> | — | —                    | — |
| Babawee/ARC 10550       | S                     | 201 | 523                | 2.95                          | 38  | 82 | 0.86                      | 34 | 82  | 38             | S | —                  | —                             | —                 | —  | —                         | —  | —                 | — | —                    | — |

<sup>a</sup>Reaction to biotype 1 was determined at IRRI, Philippines and reaction to biotype 4 was determined at BRRI, Bangladesh.

<sup>b</sup>R = resistant; Seg = segregating, S = susceptible; <sup>c</sup>X<sup>2</sup> for 13:3 ratio; <sup>d</sup>X<sup>2</sup> for 7:8:1 ratio.

Table 3. Two-way classification of  $F_3$  lines from the crosses of ARC 10550 with IR 1539-823 and IR 1154-243, for reaction to biotypes 1 and 4 of brown planthopper<sup>a</sup>.

| Reaction to biotype 1 | Reaction to biotype 4                              |     |    |       |                    |                    |  |     |    |       |                    |                    |
|-----------------------|--|-----|----|-------|--------------------|--------------------|--|-----|----|-------|--------------------|--------------------|
|                       | F <sub>3</sub> lines of IR1539-823/ARC 10550 (no.) |     |    |       |                    |                    | F <sub>3</sub> lines of IR1154-243/ARC 10550 (no.) |     |    |       |                    |                    |
|                       | R <sup>b</sup>                                     | Seg | S  | Total | X <sup>2c</sup>    | X <sup>2d</sup>    | R  | Seg | S  | Total | X <sup>2c</sup>    | X <sup>2d</sup>    |
| R                     | 7  | 17  | 7  | 31    |                    |                    | 5  | 20  | 11 | 36    |                    |                    |
| Seg                   | 21   | 42  | 14 | 77    | 3.97 <sup>ns</sup> | 5.44 <sup>ns</sup> | 18   | 37  | 18 | 73    | 4.60 <sup>ns</sup> | 7.45 <sup>ns</sup> |
| S                     | 7  | 18  | 13 | 38    |                    |                    | 10   | 11  | 6  | 27    |                    |                    |
| Total                 | 35   | 77  | 34 | 146   |                    |                    | 33   | 68  | 35 | 136   |                    |                    |

<sup>a</sup>Reaction to biotype 1 was determined at IRRI, Philippines and reaction to biotype 4 was determined at BRRI, Bangladesh;

<sup>b</sup>R = resistant; Seg = segregating; S = susceptible; <sup>c</sup>X<sup>2</sup> for independence of reaction to two biotypes;

<sup>d</sup>X<sup>2</sup> for 1:2:1:2:4:2:1:2:1 ratio; ns = nonsignificant at 5% level.

cross was susceptible to biotype 4 and the  $F_2$  population segregated in a ratio of 1 resistant:3 susceptible. The  $F_3$  families of this cross segregated in a ratio of 1 resistant:2 segregating:1 susceptible. The results indicated the segregation of the recessive resistance gene of ARC 10550 for biotype 4 in this cross.

The two-way classification of the  $F_3$  lines of this cross for their reaction to biotypes 1 and 4 (table 3) showed that the recessive resistance gene of ARC 10550 segregates independently of *Bph* 1.

The  $F_1$  progeny of the cross IR1554-243/ARC 10550 was susceptible to biotypes 1 and 4 and the  $F_2$  population segregated in a ratio of 1 resistant:3 susceptible. The  $F_3$  families segregated in a ratio of 1 resistant:2 segregating:1 susceptible for both biotypes. Resistance to biotype 1 was governed by *bph* 2 and the resistance to biotype 4 by the resistance gene of ARC 10550. The two-way classification of the  $F_3$  lines of this cross for their reaction to two biotypes (table 3) showed that the two recessive genes segregate independently of each other.

The  $F_1$  progeny of the cross Rathu Heenati/ARC 10550 was resistant to biotype 1 and the  $F_2$  population segregated in a ratio of 3 resistant:1 susceptible. The  $F_3$  families segregated in a ratio of 1 resistant:2 segregating:1 susceptible. These results indicated segregation of *Bph* 3 for resistance to biotype 1. The  $F_1$  progeny of this cross was resistant to biotype 4 and the  $F_2$  population segregated in a ratio of 13 resistant:3 susceptible. The  $X^2$  value for the 13:3 ratio was significant but its applicability was confirmed by segregation of  $F_3$  families in a ratio of 7 resistant:8 segregating:1 susceptible. These results indicated that the recessive resistance gene of ARC 10550 segregates independently of *Bph* 3.

The  $F_1$  hybrid Babawee/ARC 10550 was susceptible to biotypes 1 and 4. The  $F_2$  population and  $F_3$  families of this cross were evaluated for resistance to biotype 2 only.  $F_2$  segregated in a ratio of 1 resistant:3 susceptible and the  $F_3$  families in a ratio of 1:2:1.

#### 4. Discussion

The results show that ARC 10550 has a recessive gene for resistance to biotype 4 of BPH.

This gene does not convey resistance to biotypes 1, 2 and 3. However, it confers resistance to BPH populations in Bangladesh, India, and Sri Lanka, which are presently assumed to constitute biotype 4. This recessive gene is distinct from the other four known genes for resistance to BPH. Following the standard rules for gene nomenclature (IRC – International Rice Commission – 1959) this new gene is designated *bph* 5.

The data also show that *bph* 5 segregates independently of *Bph* 1, *bph* 2 and *Bph* 3. Since *Bph* 3 and *bph* 4 are tightly linked, it is assumed that *bph* 5 is independent of *bph* 4. It should be possible to combine *bph* 5 with either of the other genes in future rice varieties to gain a wider spectrum of resistance. This new gene should be particularly useful in developing resistant varieties for Bangladesh, India, and Sri Lanka. Numerous other varieties with resistance to biotype 4 have been identified. We are analyzing more varieties genetically to identify additional genes for resistance to biotype 4.

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#### References

- Athwal D S, Pathak M D, Bacalangco E H and Pura C D 1971 *Crop. Sci.* 11: 747–750  
IRC 1959 *IRC. Newsl.* 8: 1–6  
Khush G S 1977 *Adv. Agron.* 29: 265–341  
Khush G S 1979 in *Brown planthopper: Threat to rice production in Asia* (Manila: International Rice Research Institute) pp. 331–332  
Khush G S 1984 *Prot. Ecol.* 7: 147–165  
Lakshminarayana A and Khush G S 1977 *Crop Sci.* 17: 96–100  
Pathak M D and Khush G S 1979 in *Brown planthopper: Threat to rice production in Asia* (Manila: International Rice Research Institute) pp. 285–302  
Seshu D V and Kauffman H E 1980 *IRRI Res. Pap. Ser.* 52