Resistance Gene of Rice Cultivar, Taichung Native 1 to Philippine Races of Bacterial Blight Pathogens

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In the inoculation tests on rice cultivars using Philippine races of bacterial blight (BB) caused by *Xanthomonas campestris* pv. *oryzae*, we found that Taichung Native 1 (TN1) was resistant only to race 5 (PXO112) and susceptible to races 1, 2, 3, 4, and 6. This kind of reaction pattern to BB pathogens has not been found in any other rice cultivar resistant to BB in Japan and at the International Rice Research Institute in the Philippines. Therefore, it was suggested that TN1 has a new gene for resistance to BB. The mode of inheritance of resistance in TN1 to race 5 was studied. The analysis of the F\(_1\) plants, the F\(_2\) populations, and the backcross progeny from the crosses between TN1 and susceptible cultivars revealed that the resistance of TN1 was controlled by a single dominant gene. Thus this new resistance gene was designated as *Xa-14*.

KEY WORDS: Oryza sativa, Xanthomonas campestris pv. oryzae, resistance gene, disease resistance.

**Introduction**

Genetic studies on resistance to bacterial blight (BB) caused by *Xanthomonas campestris* pv. *oryzae* were conducted mainly in Japan and at the International Rice Research Institute (IRRI) in the Philippines. Four resistance genes, *Xa-1*, *Xa-2*, *Xa-3*, and *Xa-11*, were identified using Japanese BB races in Japan (Sakaguchi 1967, Ezuka et al. 1975, Ogawa and Yamamoto 1986). On the other hand, *Xa-4*, *xa-5*, *Xa-7*, *xa-8*, *Xa-10*, and *xa-13* were identified using Philippine BB races at IRRI (Petris et al. 1977, Sidhu et al. 1978, Yoshimura et al. 1983, Ogawa et al. 1987). Moreover, *Xa-12* was identified using an Indonesian race in Japan (Ogawa et al. 1978).

During the inoculation tests using Philippine BB races, we found that Taichung Native 1 (TN1) is resistant only to race 5 (PXO112) but is very susceptible to races 1, 2, 3, 4, and 6. Thus we compared the reaction of TN1 with those of the other rice cultivars carrying known resistance genes to six Philippine races, and then analyzed the mode of inheritance for resistance of TN1 to race 5.

This study was carried out under a collaborative research between IRRI and the Japanese Ministry of Agriculture, Forestry, and Fisheries.

**Materials and Methods**

To compare the disease reaction to the BB pathogens, TN1 and resistant cultivars

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carrying known resistance genes were inoculated with Philippine BB races. The cultivars and their resistance genes used for the inoculation test are shown in Table 1. Isolates used were PXO61 for race 1, PXO86 for race 2, PXO79 for race 3, PXO71 for race 4, PXO112 for race 5, and PXO99 for race 6.

TN1 was crossed with susceptible cultivars, Milyang 23 and Toyonishiki, and with a Japanese differential cultivar, Te-tep, which shows similar reaction as TN1 to Japanese races (Ogawa and Yamamoto 1987a, Ogawa and Yamamoto 1987b). The F1 plants and the F2 populations from the crosses were tested for BB reaction to races 1, 2, 4, and 5. In addition, the backcross progeny of IR24/TN1/IR24 was also tested.

Resistant cultivars, the F1 plants, and the F2 populations were grown under standard management in a screenhouse covered with fine net. Before inoculation, tillers of each individual plant were divided into the required numbers of bacterial races with different colored vinyl ties, one color for each race.

Each BB race was transferred to semi-synthetic agar media (Wakimoto 1954) whenever inoculum was needed for inoculation and incubated at 28°C for 48 hours. The inoculum was diluted with distilled water. Using a spectrophotometer, the absorbance of the inoculum was adjusted to A = 0.05 (620 nm). This value corresponds to a concentration of about 10⁶ cells/ml. Inoculation was done during booting to flowering stage. The fully extended top leaves of two or three tillers were cut off following the clipping inoculation method developed by Kauffman et al. (1973). The lesion length caused by each race was measured in three leaves of each plant at 18 days after inoculation. Mean lesion length of the three leaves was used to determine the reaction of each plant. Disease reaction was evaluated based on lesion length and symptom of the lesion. In this study, a lesion length below 5 cm and/or aborted lesion development was evaluated as resistant, 5 to 10 cm as moderately resistant, 10 to 15 cm as moderately susceptible, and above 15 cm as susceptible.

Results and Discussion

The results of the inoculation tests using six Philippine races of BB are given in Table 1. The susceptible cultivars, IR24 and Milyang 23, showed long lesions in reaction to the six Philippine BB races, about double time lesion lengths that developed in Toyonishiki. As expected, TN1 was resistant only to race 5, but susceptible to races 1, 2, 3, 4, and 6. Kinmaze, a susceptible check cultivar in Japan, was susceptible to the Philippine BB races.

The Japanese differential cultivars, Te-tep, Chugoku 45, Java 14, and Kogyoku have a combination of Xa-1, Xa-2, Xa-3, and Xa-11 resistance genes. Te-tep, which has Xa-1 and Xa-2 (Sakaguchi 1967), and TN1 showed similar reaction patterns to Japanese BB races (Ogawa and Yamamoto 1987b), but Te-tep is susceptible to the six Philippine BB races, Chugoku 45, which has Xa-3 (Ogawa et al. 1986), is moderately susceptible to race 6 but resistant to races 1 to 5. Its reaction was different from that of TN1. Java 14, which has Xa-1, Xa-3, and Xa-12 (Ogawa et al. 1978), showed a reaction pattern similar to that of Chugoku 45. According to Horino et al. (1980), Kogyoku, a Japanese differential cultivar, which has Xa-1 and Xa-12 (Ogawa et al. 1978), is susceptible to Philippine BB races. These data suggested that Xa-1, Xa-2, and Xa-12 do not convey resistance to Philippine BB races.
Therefore, the resistance genes of Japanese differential cultivars were different from that of TN1.

Table 1. The reaction of rice cultivars and F₁ plants to the Philippine races of bacterial blight pathogens at booting stage

<table>
<thead>
<tr>
<th>Cultivar¹ and cross</th>
<th>Race 1</th>
<th>Race 2</th>
<th>Race 3</th>
<th>Race 4</th>
<th>Race 5</th>
<th>Race 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>IR24 (none)</td>
<td>25.7 S</td>
<td>35.6 S</td>
<td>32.5 S</td>
<td>31.6 S</td>
<td>22.7 S</td>
<td>36.0 S</td>
</tr>
<tr>
<td>Milyang 23 (none)</td>
<td>15.3 S</td>
<td>26.5 S</td>
<td>28.5 S</td>
<td>31.3 S</td>
<td>24.9 S</td>
<td>43.5 S</td>
</tr>
<tr>
<td>Toyonishiki (none)</td>
<td>8.3 MR</td>
<td>17.0 S</td>
<td>16.2 S</td>
<td>11.6 MS</td>
<td>12.9 MS</td>
<td>21.2 S</td>
</tr>
<tr>
<td>Taichung Native 1</td>
<td>19.6 S</td>
<td>35.2 S</td>
<td>37.4 S</td>
<td>31.5 S</td>
<td>4.9 R</td>
<td>30.7 S</td>
</tr>
<tr>
<td>Kinmaze (none)</td>
<td>15.2 S</td>
<td>18.0 S</td>
<td>21.0 S</td>
<td>21.7 S</td>
<td>17.1 S</td>
<td>20.4 S</td>
</tr>
<tr>
<td>Te-tep (Xa-1, Xa-2)</td>
<td>14.5 MS</td>
<td>30.7 S</td>
<td>29.1 S</td>
<td>26.5 S</td>
<td>17.0 S</td>
<td>33.1 S</td>
</tr>
<tr>
<td>Chugoku 45 (Xa-3)</td>
<td>0.4 R</td>
<td>1.9 R</td>
<td>2.2 R</td>
<td>1.3 R</td>
<td>3.5 R</td>
<td>11.5 MS</td>
</tr>
<tr>
<td>Java 14 (Xa-1, Xa-3, Xa-12)</td>
<td>0.6 R</td>
<td>2.3 R</td>
<td>1.4 R</td>
<td>2.9 R</td>
<td>6.9 MR</td>
<td>24.4 S</td>
</tr>
<tr>
<td>IR8 (Xa-11)</td>
<td>17.0 S</td>
<td>25.6 S</td>
<td>28.7 S</td>
<td>14.9 MS</td>
<td>13.6 MS</td>
<td>19.5 S</td>
</tr>
<tr>
<td>IR20 (Xa-4)</td>
<td>6.9 MR</td>
<td>22.5 S</td>
<td>24.5 S</td>
<td>9.7 MR</td>
<td>3.9 R</td>
<td>18.3 S</td>
</tr>
<tr>
<td>IR1545-339 (xa-5)</td>
<td>1.2 R</td>
<td>2.6 R</td>
<td>1.1 R</td>
<td>17.9 S</td>
<td>4.4 R</td>
<td>30.3 S</td>
</tr>
<tr>
<td>DV85 (xa-5, Xa-7)</td>
<td>0.4 R</td>
<td>0.4 R</td>
<td>0.5 R</td>
<td>6.0 MR</td>
<td>2.0 R</td>
<td>6.5 MR</td>
</tr>
<tr>
<td>Cas 209 (Xa-10)</td>
<td>24.2 S</td>
<td>3.5 R</td>
<td>45.3 S</td>
<td>40.0 S</td>
<td>1.7 R</td>
<td>50.4 S</td>
</tr>
<tr>
<td>BJ1 (xa-5, xa-13)</td>
<td>0.6 R</td>
<td>3.8 R</td>
<td>2.8 R</td>
<td>4.7 R</td>
<td>0.6 R</td>
<td>3.7 R</td>
</tr>
<tr>
<td>PI231129 (xa-8)</td>
<td>3.5 R</td>
<td>8.0 MR</td>
<td>6.5 MR</td>
<td>12.2 MS</td>
<td>5.5 MR</td>
<td>4.5 R</td>
</tr>
<tr>
<td>Milyang 23/TN1</td>
<td>16.9 S</td>
<td>32.9 S</td>
<td>—— ⁴</td>
<td>29.5 S</td>
<td>2.7 R</td>
<td>—— ⁴</td>
</tr>
<tr>
<td>TN1/Te-tep</td>
<td>12.1 MS</td>
<td>25.2 S</td>
<td>—— ⁴</td>
<td>29.2 S</td>
<td>1.0 R</td>
<td>—— ⁴</td>
</tr>
<tr>
<td>Toyonishiki/TN1</td>
<td>15.3 S</td>
<td>30.0 S</td>
<td>—— ⁴</td>
<td>25.5 S</td>
<td>3.3 R</td>
<td>—— ⁴</td>
</tr>
</tbody>
</table>

¹ Genes for resistance are in parentheses
² The mean of lesion length from 15 inoculated leaves (3 leaves from 5 plants) at 18 days after inoculation
³ R = resistant; MR = moderately resistant; MS = moderately susceptible; and S = susceptible
⁴ —— = not tested.

The resistance genes of IR8, IR20, IR1545-339, Cas 209, and PI231129 are Xa-11, Xa-4, xa-5, Xa-10, and xa-8, respectively (Ogawa and Yamamoto 1986, Petpjisit et al. 1977, Yoshimura et al. 1983, Sidhu et al. 1978). The reaction patterns of the five cultivars, due to the resistance genes Xa-11, Xa-4, xa-5, Xa-10, and xa-8, were different from that of TN1. DV 85 has a recessive gene xa-5 and a dominant resistance gene Xa-7. Sidhu et al. (1978) reported that the F₁ plants from the cross of TN1/DV85 were resistant to race 1 (PXO61) at flowering stage. It indicates that the dominant resistance gene Xa-7 is resistant to race 1. Therefore, the reaction of resistance gene Xa-7 was different from that of resistance gene of TN1.

BJ1 has two recessive resistance genes xa-5 and xa-13, and shows resistance to six Philippine BB races (Ogawa et al. 1987). As resistance gene xa-5 in IR1545-339 shows susceptibility to race 6, resistance gene xa-13 conveys resistance to race 6. The reaction of xa-13 was also different from that of TN1.

From the above inoculation tests, the resistance of TN1 to Philippine race 5 appeared to
be controlled by an unknown gene(s).

The reaction of the F₁ plants from the crosses of Milyang 23/TN1, TN1/Te-tep, and Toyonishiki/TN1 to four Philippine BB races are shown in Table 1. They were resistant to race 5 and susceptible to races 1, 2, and 4, which is similar to the reaction of TN1. Therefore, it is concluded that resistance of TN1 to race 5 is controlled by a dominant gene(s).

The disease reaction of the F₂ populations from the three crosses of Milyang 23/TN1, TN1/Te-tep, and Toyonishiki/TN1 to Philippine BB races 1, 2, 4, and 5 are shown in Table 2. The F₂ populations from the crosses of Milyang 23/TN1 and TN1/Te-tep segregated into 200 SSSR: 70 SSSS and 208 SSSR: 57 SSSS plants, respectively (the combined capitals stand for the reaction to races 1, 2, 4, and 5, respectively; R = resistant, S = susceptible) and fitted the expected ratio of 3:1. This means that the resistance of TN1 to race 5 is due to a

<table>
<thead>
<tr>
<th>Cross</th>
<th>Reaction of F₁ plants</th>
<th>Reaction of F₂ populations</th>
<th>$\chi^2$</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milyang 23/TN1</td>
<td>SSSR</td>
<td>SSSR</td>
<td>0.12</td>
<td>0.70~0.80</td>
</tr>
<tr>
<td>TN1/Te-tep</td>
<td>SSSR</td>
<td>200</td>
<td>70</td>
<td>270</td>
</tr>
<tr>
<td>Toyonishiki/TN1</td>
<td>SSSR</td>
<td>185</td>
<td>84</td>
<td>269</td>
</tr>
</tbody>
</table>

1) R = resistant; S = susceptible, The combined capitals stand for the reaction to races 1, 2, 4, and 5, respectively.

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![Fig. 1. Frequency distribution for lesion length F₁ population from the cross of Toyonishiki (P₂)/TN1(P₁) to race 5 (PXO 112) of the bacterial blight pathogen.](image1)

![Fig. 2. Frequency distribution for lesion length of backcross progeny from the cross of IR24 (P₂)/TN1(P₁)//IR24 to race 5 (PXO 112) of the bacterial blight pathogen.](image2)
single dominant resistance gene. The F2 population from the cross of Toyonishiki/TN1 to Philippine BB races 1, 2, 4, and 5 segregated into 185 SSSR:84 SSSS plants, but this segregation was significantly different from the expected ratio of 3 SSSR:1 SSSS at 5% level. The number of resistant plants in F2 population was less than its expected value based on segregation of a single dominant gene. We considered that the segregation distortion was caused by cross combination between japonica and indica rice plants. In addition, poor growth of japonica rice plants under short-day condition in low latitude influenced the expression of resistance in some F2 plants.

The frequency distribution for lesion length of the F2 population from the cross of Toyonishiki/TN1 to race 5 is shown in Fig. 1. The group of F2 plants had less than 10 cm lesion length was considered resistant and while those F2 plants with over 10 cm lesion length was classified as susceptible. The frequency distribution for lesion length of the other two F2 populations to the races was also observed and similar results were obtained.

The backcross progeny of IR24/TN1/IR24 to races 1, 2, 4, and 5 segregated into 98 SSSR and 97 SSSS plants (Fig. 2). The segregation fitted a ratio of 1:1 ($x^2 = 0.005, 0.98 < P < 0.99$).

Thus, we concluded that the resistance of TN1 is governed by a single dominant gene, and we designated it as Xa-14 following the rule of the Rice Genetic Cooperative (Taura et al. 1987).

Acknowledgement

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Literature Cited


Petpitsit, V., G. S. Khush, and H. E. Kauffman 1977. Inheritance of resistance to bacterial blight in


台中在来１号のフィリピン産イネ白葉枯病菌に対する抵抗性遺伝子

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フィリピン産イネ白葉枯病菌を用いた接種の結果、台中在来１号（TN１）はレース５（PXO112）に対して抵抗性を、レース１、２、３、４および６に高い感受性を示した。これは今までは見られない特別な反応であった。

そこでTN１と既存の抵抗性遺伝子を有する抵抗性品種のイネ白葉枯病菌に対する反応を比較するため、これらの品種にフィリピン産菌系、レース１（PXO61）、レース２（PXO86）、レース３（PXO79）、レース４（PXO71）、レース５（PXO112）およびレース６（PXO99）の接種を試みた。結果はTable１に示した。日本の判別品種、金南風はフィリピン産６菌系に対して感受性を示した。抵抗性遺伝子Xa-１およびXa-２を有するTe-tepは日本産菌系に対してはTN１と同様な反応（OGAWA and YAMAMOTO 1987b）を示し、フィリピン産６菌糸に対して感受性を示した。Xa-３を有する中国45号はレース１～５に対して抵抗性を示し、レース６に中等度感受性を示した。Xa-１、Xa-３およびXa-１２を有するJaval14は中国45号と同様な反応を示した。HORINO et al.（1980）はXa-１およびXa-１２を有する黄玉がフィリピン産６菌糸に対して感受性であると報告していることから日本の判別品種が有するXa-１、Xa-３およびXa-１２はTN１の抵抗性と異なる。

抵抗性品種、IR8、IR20、IR1545-339、Cas209およびPI231129はXa-11、Xa-4、xa-5、Xa-10およびxa-8のそれぞれ1個の抵抗性遺伝子を有する、これらはTN１のフィリピン産菌系に対する反応と異なかった。よってXa-11、Xa-4、xa-5、Xa-10およびxa-8はTN１の抵抗性と異なる。

抵抗性品種DV85は劣性遺伝子xa-5と優性遺伝子Xa-7を有する。SUDH et al.（1978）はTN１／DY85のF₁
植株はレース１に抵抗性を示すと報告していることからXa-7の抵抗性反応はTN１の反応と異なる。BJ１は2個の劣性遺伝子xa-5およびxa-13を有する。Ogawa et al.（1987）はxa-13がフィリピン産レース6に抵抗性を示すと報告していることからxa-13の抵抗性反応はTN１の反応と異なる。

フィリピン産6菌系の接種試験の結果、既存の抵抗性遺伝子Xa-１、Xa-２、Xa-３、Xa-４、xa-５、Xa-７、xa-８、Xa-10、Xa-11、Xa-１２およびxa-13の反応はTN１の抵抗性反応と異なるものであり、TN１のフィリピン産レース5に対する反応は未知の抵抗性遺伝子によるものである。

TN１の有する抵抗性遺伝子の遺伝様式を調べるため、TN１を感受性品種南密23号、トヨシキおよび日本産菌糸に対してTN１と同様な反応を示すTe-tepと交配した、それぞれのF₁植物にフィリピン産レース１、２、４および５を接種した結果、すべてのF₁植物はTN１の反応と同様な反応を示した（Table１）。これはTN１の有する抵抗性が優性の遺伝子であることを見出した。

この3組の組合せから得たF₂集団のフィリピン産レース１、２、４および５に対する反応を調べた、南密23号／TN１およびTN１／Te-tepのF₂集団はレース５に対する1個の優性遺伝子による分離比3：1に適合した。トヨシキ／TN１のF₂集団は分離比3：1に適合しなかったが他のF₂集団に同様な病斑数の頻度分布を示した（Table２、Fig.１）。さらに、IR24／TN１／IR24の組交配のF₂集団におけるフィリピン産レース１、２、４および５に対する反応を調べた結果、レース５に対して抵抗性98個体および感受性97個体に分離した（Fig.２）。これは1個の優性遺伝子による分離比1：1に適合した。

フィリピン産イネ白葉枯病菌を用いた接種の結果見出されたTN１のレース５（PXO112）に対して抵抗性を、レース１、２、３、４および６に高い感受性を示す反応は1個の新しい優性遺伝子により制御されたものである。その抵抗性遺伝子をRice Genetics Cooperativeの命名法に従いXa-14と命名した（Taura et al. 1987）。