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# Genetic Analysis of Myanmer Rice Cultivars for Resistance to Bacterial Blight

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Rice cultivars from Myanmer were classified into five groups based on their reaction pattern to bacterial blight (BB) races by ENDO *et al.* (1991). A random sample of cultivars from each group was genetically analyzed to verify their grouping. The selected cultivars were crossed with IR 24 which is susceptible to all Philippine races of BB. The $F_1$ and $F_2$ populations were inoculated by clipping method (KAUFFMAN *et al.* 1973). The segregation data revealed that single dominant genes conferred resistance in cultivars belonging to CAS 209, TKM 6 and Java 14 groups and single recessive gene conveyed resistance in cultivars belonging to DZ 192 group. The cultivars belonging to Mond Ba group were found to have two dominant genes for resistance. Allelic relationships of genes of cultivars belonging to different groups were tested by inoculating $F_1$ and $F_2$ population from crosses of these cultivars with respective tester of each group. The results revealed that all the cultivars belonging to Java 14, TKM 6, DZ 192 and CAS 209 groups had *Xa-3, Xa-4, xa-5* and *Xa-10* genes for resistance and cultivars belonging to Mond Ba group had both *Xa-4* and *Xa-10* for resistance. The results confirmed that cultivars with *Xa-10* and *Xa-4* predominated amongst BB resistant cultivars from Myanmar and the frequency of cultivars with *Xa-3* and *xa-5* was very low.

KEY WORDS: *Oryza sativa,* bacterial blight, *Xanthomonas campestris* pv. *oryzae,* resistance gene, varietal differentiation, genetic analysis.

## Introduction

As suggested by KHUSH (1977), rice cultivars with different genes for resistance to Philippine races of bacterial blight (BB), *Xanthomonas campestris* pv. *oryzae,* have distinct geographical distribution. The geographic distribution of cultivars with different genes for resistance was systematically investigated recently (OGAWA *et al.* 1986, BUSTO *et al.* 1990). Four major cultivar groups based on reaction pattern in Philippine races of BB, i.e. those belonging to Java 14, TKM 6, DZ 192 and CAS 209 groups were found to be predominant and distributed widely in Asia. Somewhat smaller groups of cultivars, designated as Mond Ba, DV 85, Makhmal Mehi and BJ 1 groups were identified by OGAWA *et al.* (1991) on the basis of genetic analysis of cultivars using Philippine races of BB. Following genes confer resistance to BB races in each cultivar group; *Xa-3* in Java 14, *Xa-4* in TKM 6, *xa-5* in DZ 192, and *Xa-10* in CAS 209, both *Xa-4* and *Xa-10* in Mond Ba, both *xa-5* and *Xa-7* in DV 85, both *Xa-4* and *xa-5* in Makhmal Mehi, both *xa-5* and *xa-13* in BJ 1 groups.

On the basis of reaction pattern of Myanmer cultivars to four BB races from Philippines, ENDO *et al.* (1991) found that 44 belonged to CAS 209 group, 33 to TKM 6 group, 9 to DZ 192 group, 3 to Java 14 group and 4 to Mond Ba group. This study was undertaken to verify the grouping of these cultivars from genetic analysis.

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## Materials and Methods

A random sample of cultivars from Myanmer belonging to five cultivar groups i.e. CAS 209, TKM 6, Mond Ba, DZ 192 and Java 14 group was selected for study (Table 1). These

Table 1. Bacterial blight resistant rice cultivars from Myanmar used in the study and their respective group based on reaction pattern to BB races from Philippines

| Cultivar | Accession[1)] | Cultivar | Accession[1)] |
|---|---|---|---|
| *CAS 209 Group* | | *TKM 6 Group* | |
| AC224 (C21-102) | 00724 | Kyankpyu | 04144 |
| Ngasein Thidat-1[2)] (C24-102) | 04936 | Kyaukpyu A27-4 | 05927 |
| Ngasein Thidat-2 (C24-102) | 05885 | Kalagyi | 33147 |
| C34-13 | 06797 | Kaukthwe Pyu | 33203 |
| B24-92 | 06801 | Phalaungsar | 33578 |
| B47-53 | 06802 | Apyo-Caw-Gyi | 49386 |
| C28-15 | 14009 | C28-16 | 44580 |
| Ngakwe Thetyin | 33477 | Ngachima | 49958 |
| Tyb 11 | 33821 | Rogol EB23 | 50081 |
| B24-92 | 49472 | Kyat Cho-2 | 58044 |
| Jadamugato | 49714 | Ahmee-Puthe | 05735 |
| Magasank C12 | 49938 | Naungtu T1-6 | 06250 |
| Nga-Myin Sive | 49959 | Bubawpho | 32990 |
| Chin Mee Byauk | 57882 | Gokaung | 33079 |
| Chin Meedon | 57883 | Hnankar Htun | 33108 |
| Maw Tike | 58114 | Let Taw Ywe Baw | 33306 |
| Ta Lay War | 58227 | Mayzi | 33373 |
| Haoru | 33090 | Myaukma | 33412 |
| Kalalan | 33154 | Tyc 4 | 33824 |
| Letyonshay | 33310 | D17-18 | 49611 |
| Natpyi Hmwe | 33440 | | |
| Ngalongyi | 33479 | *DZ 192 Group* | |
| Ngasein Theedat | 33502 | Okshit (Mayin) | 07813 |
| Ngaya Ngase | 33516 | Byatyin | 33010 |
| Nwachi Manine | 33531 | Mayinni | 33368 |
| Seinpulay | 33642 | Ngasein Kalagyi | 33498 |
| Shweni | 33686 | Poppa | 33592 |
| Tazintan | 33771 | Myawutyi | 33416 |
| Theedat Ngasein-1 | 33779 | | |
| Theedat Ngasein-2 | 33780 | *Mond Ba Group* | |
| Tinmaw | 33806 | Ngasein Thidat-1[2)] (C24-102) | 04936 |
| | | Yakuhine Malay | 33855 |
| *Java 14 Group* | | | |
| Byatshwewa | 33008 | | |
| Ba Shay (Bo Loy) | 57860 | | |

[1)] Accession number at IRGC of IRRI.
[2)] Some plants of this accession had *Xa-10* and others had *Xa-10* and *Xa-4*. Therefore, this accession is listed under two groups.

cultivars were crossed with IR 24, which is susceptible to all six Philippine races of BB, and $F_1$ and $F_2$ populations were inoculated with appropriate races to study the inheritance of resistance. The cultivars were also crossed with appropriate testers to investigate the allelic relationships of their genes for resistance with known genes. For example, cultivars of Java 14 group were crossed with IR-BB 103, cultivars of TKM 6 group were crossed with IR-BB 4 or IR 20, cultivars of DZ 192 group were crossed with IR-BB 5 or IR 1545-339, cultivars of CAS 209 group were crossed with IR-BB 10 and cultivars of Mond Ba group were crossed with both IR-BB 4 and IR-BB 10. IR-BB 103, IR-BB 4, IR-BB 5 and IR-BB 10 are near isogenic lines (NILs) with *Xa-3, Xa-4, xa-5* and *Xa-10,* respectively (Ogawa *et al.* 1988).

$F_1$ progenies derived from the crosses with IR 24 and NILs were inoculated at adult stage with four Philippine races of BB; race 1 (isolate PXO61), race 2 (isolate PXO86), race 3 (isolate PXO79), and race 4 (isolate PXO71). A few crosses were inoculated with race 5 (isolate PXO112) at adult stage to further detect sub-grouping if any. $F_2$ populations of these crosses were inoculated either at seedling stage or at adult stage depending upon the degree of resistance in test cultivars. Crosses with cultivars of CAS 209, DZ 192, and Mond Ba groups were evaluated at seedling stage because these cultivars show stable resistance at seedling stage (Ogawa *et al.* 1991, Endo *et al.* 1991). Hybrid populations from the crosses involving cultivars of TKM 6 and Java 14 groups were mainly inoculated at adult stage. All the hybrid populations were inoculated with different races according to the reaction pattern of respective groups.

The clipping method (Kauffman *et al.* 1973) was used for inoculation of plants. The inocula were prepared as suspension with $10^7$ to $10^8$ cell/m*l* after incubation at 27°C for 2 days. Resistance was assessed at 18 days after inoculation. Standard methods for growing plants as described by Endo *et al.* (1991) were followed. Segregation ratios were computed on the basis of frequency distribution of lesion length combined with visual observations, following the methodology discribed by Ogawa *et al.* (1990).

## Results

### Genetic analysis of the cultivars belonging to CAS 209 group

Out of 44 cultivars belonging to this group, 31 cultivars were randomly selected for genetic analysis. The $F_1$ hybrids of these cultivars with IR 24 showed resistance to races 2 and 5 but were susceptible to races 1 and 3. The $F_2$ population segregated in a ratio of 3 resistant : 1 susceptible upon inoculation with race 2 (Table 2). As discussed by Endo *et al.* (1991), cultivars of CAS 209 group are resistant to races 2 and 5. However, it was not known whether resistance to races 2 and 5 was governed by same gene or by different genes. Therefore $F_2$ populations from five crosses were inoculated with races 2 and 5. These $F_2$ populations segregated plants with RR or SS reactions only to two races and no recombinant types were found. The $F_2$ population from the cross of Tinmaw was analyzed for joint segregation for reaction to race 1, 2, 3 and 5. Only the plants with either SRSR or SSSS reaction were observed in a ratio of 3 : 1 ($\chi^2$ = 0.67), and no recombinant types were observed. These results show that resistance to races 2 and 5 in these cultivars is

conferred by the same dominant gene.

The $F_1$ progenies from the crosses of 20 cultivars of this group with IR-BB 10 were resistant to race 2, and $F_2$ populations did not segregate for susceptibility (Table 3). These results show that these cultivars have *Xa-10* for resistance. $F_2$ populations from the inter-

Table 2. Disease reaction of $F_1$ and $F_2$ progenies from the crosses of cultivars of CAS 209 group with IR 24

| Cross | Race used | Reaction of $F_1$ hybrids | Reaction of $F_2$ population[1] | | | |
|---|---|---|---|---|---|---|
| | | | R | S | $\chi^2$ (3 : 1) | P |
| IR 24/AC224 (C21-102) | 2 | R | 122 | 32 | 1.46 | 0.2～0.3 |
| IR 24/Ngasein Thidat-1 | 2 | R | 410 | 141 | 0.10 | 0.7～0.8 |
| IR 24/Ngasein Thidat-2 | 2 | R | 253 | 100 | 2.09 | 0.1～0.2 |
| IR 24/C34-13 | 2 | R | 379 | 124 | 0.03 | 0.8～0.9 |
| IR 24/B24-92 (Acc. 06801) | 2 | R | 119 | 48 | 1.25 | 0.2～0.3 |
| | 5 | R | 91 | 30 | <0.01 | 0.9< |
| IR 24/B47-53 | 2 | R | 232 | 81 | 0.13 | 0.7～0.8 |
| IR 24/C28-15 | 2 | R | 108 | 30 | 0.78 | 0.3～0.4 |
| IR 24/Ngakwe Thetyin | 2 | R | 105 | 37 | 0.09 | 0.7～0.8 |
| IR 24/Tyb11 | 2 | R | 145 | 43 | 0.45 | 0.5～0.6 |
| IR 24/B24-92 (Acc. 49472) | 2 | R | 140 | 38 | 1.27 | 0.2～0.3 |
| IR 24/Jadamugato | 2 | R | 114 | 49 | 2.23 | 0.1～0.2 |
| IR 24/Magasank C 12 | 2 | R | 140 | 38 | 1.27 | 0.2～0.3 |
| IR 24/Nga-Myin Sive | 2 | R | 368 | 119 | 0.08 | 0.8～0.9 |
| | 5 | R | 166 | 56 | 0.01 | 0.9< |
| IR 24/Chin Mee Byauk | 2 | R | 192 | 68 | 0.18 | 0.6～0.7 |
| | 5 | R | 155 | 46 | 0.48 | 0.4～0.5 |
| IR 24/Chin Meedon | 2 | R | 368 | 109 | 1.17 | 0.2～0.3 |
| | 5 | R | 355 | 113 | 0.18 | 0.6～0.7 |
| IR 24/Maw Tike | 2 | R | 235 | 95 | 2.53 | 0.1～0.2 |
| IR 24/Ta Lay War | 2 | R | 184 | 67 | 0.38 | 0.5～0.6 |
| IR 24/Haoru | 5 | R | 40 | 12 | 0.10 | 0.7～0.8 |
| IR 24/Kalalan | 2 | R | 50 | 23 | 1.65 | 0.1～0.2 |
| IR 24/Letyonshay | 2 | R | 81 | 20 | 1.46 | 0.2～0.3 |
| IR 24/Natpyi Hmwe | 2 | R | 230 | 66 | 1.15 | 0.2～0.3 |
| IR 24/Ngalongyi | 2 | R | 263 | 77 | 1.00 | 0.3～0.4 |
| IR 24/Ngasein Theedat | 2 | R | 243 | 72 | 0.77 | 0.3～0.4 |
| IR 24/Ngaya Ngase | 2 | R | 209 | 77 | 0.56 | 0.4～0.5 |
| IR 24/Nwachi Manine | 2 | R | 159 | 44 | 1.20 | 0.2～0.3 |
| IR 24/Seinpulay | 2 | R | 241 | 65 | 2.31 | 0.1～0.2 |
| IR 24/Shweni | 2 | R | 179 | 67 | 0.66 | 0.4～0.5 |
| IR 24/Tazintan | 2 | R | 109 | 39 | 0.14 | 0.7～0.8 |
| IR 24/Theedat Ngasein-1 | 2 | R | 141 | 50 | 0.14 | 0.7～0.8 |
| IR 24/Theedat Ngasein-2 | 2 | R | 139 | 45 | 0.03 | 0.8～0.9 |
| IR 24/Tinmaw | 2 | R | 111 | 47 | 1.90 | 0.1～0.2 |
| | 5 | R | 97 | 43 | 2.44 | 0.1～0.2 |

[1] R = resistant; S = susceptible; P = probability

crosses of some of the cultivars belonging to this group were also studied (Table 3) and none of them segregated for susceptibility. These data confirmed the result of allele tests with *Xa-10*.

## Genetic analysis of the cultivars belonging to TKM 6 group

Of the 33 cultivars of this group, 20 were randomly selected for genetic analysis. The $F_1$ hybrids of crosses of 17 cultivars with IR 24 were resistant to races 1 and 5, moderately resistant (MR) to race 4, and susceptible to races 2 and 3, when they were inoculated at adult plant stage. The $F_2$ populations from 17 crosses segregated in a ratio of 3R : 1S for race 1 (Table 4). Seven $F_2$ populations were inoculated with races 1 and 5. These $F_2$

Table 3. Disease reaction of $F_2$ populations from the crosses of CAS 209 group cultivars with IR-BB 10.

| Cross | No. of populations used | Race used | Reaction of $F_2$ population[1] | |
|---|---|---|---|---|
| | | | R | S |
| IR-BB 10/Ac224 (C21-102) | 1 | 2 | 100 | 0 |
| IR-BB 10/Ngasein Thidat-1 | 1 | 2 | 387 | 0 |
| IR-BB 10/Ngasein Thidat-2 | 5 | 2 | 257 | 0 |
| IR-BB 10/C34-13 | 2 | 2 | 131 | 0 |
| IR-BB 10/B24-92 (Acc. 06801) | 1 | 2 | 132 | 0 |
| IR-BB 10/Ngakwe Thetyin | 2 | 2 | 107 | 0 |
| IR-BB 10/Tyb 11 | 1 | 2 | 207 | 0 |
| IR-BB 10/B24-92 (Acc. 49472) | 3 | 2 | 36 | 0 |
| IR-BB 10/Magasank C 12 | 2 | 2 | 247 | 0 |
| IR-BB 10/Chin Mee Byauk | 1 | 2 | 139 | 0 |
| IR-BB 10/Chin Meedon | 1 | 2 | 279 | 0 |
| IR-BB 10/Maw Tike | 1 | 2 | 210 | 0 |
| IR-BB 10/Ta Lay War | 1 | 2 | 291 | 0 |
| IR-BB 10/Letyonshay | 3 | 2 | 315 | 0 |
| IR-BB 10/Natpyi Hmwe | 1 | 2 | 150 | 0 |
| IR-BB 10/Ngasein Theedat | 1 | 2 | 300 | 0 |
| IR-BB 10/Nwachi Manine | 1 | 2 | 178 | 0 |
| IR-BB 10/Seinpulay | 1 | 2 | 309 | 0 |
| IR-BB 10/Shweni | 1 | 2 | 261 | 0 |
| IR-BB 10/Tazintan | 2 | 2 | 265 | 0 |
| | 1 | 5 | 131 | 0 |
| IR-BB 10/Thonh Nanpaw | 2 | 5 | 183 | 0 |
| Theedat Ngasein-1/IR-BB 10 | 3 | 2 | 175 | 0 |
| | 3 | 5 | 192 | 0 |
| Theedat Ngasein-2/B47-53 | 2 | 2 | 531 | 0 |
| B47-53/Kalalan | 1 | 2 | 60 | 0 |
| B47-53/Maung Nyo | 1 | 2 | 117 | 0 |
| Letyonshay/Ngalongyi | 1 | 2 | 301 | 0 |
| B24-92/Ngaya Ngase | 1 | 2 | 31 | 0 |

[1] R = resistant; S = susceptible

populations segregated plants with RR or SS reactions to two races and no recombinant types were observed. Moreover, the $F_2$ population from the cross of cultivar, D17-18 with IR 24 was inoculated with three races (1, 2 and 5). There were 136 RSR plants and 49 SSS plants ($\chi^2$ = 0.22) in this population and no recombinant types were observed. These results show that cultivars of this group have one dominant gene for resistance and this gene confers resistance to races 1 and 5 and moderate resistance to race 4. The $F_1$ progenies from the crosses of 13 cultivars of this group with either IR-BB 4 or IR 20 were resistant to race 1, and $F_2$ populations did not segregate for susceptibility (Table 5). These results show that these cultivars have *Xa-4* for resistance.

Table 4. Disease reaction of $F_1$ and $F_2$ progenies from the crosses of cultivars of TKM 6 group with IR 24

| Cross | Race used | Reaction of $F_1$ hybrids[2] | Reaction of $F_2$ population[1] | | | |
|---|---|---|---|---|---|---|
| | | | R | S | $\chi^2$ (3 : 1) | P |
| Kyankpyu/IR 24 | 1 | R | 135 | 30 | 4.01 | 0.03～0.05 |
| IR 24/Kyankpyu A27-4 | 1 | R | 323 | 96 | 0.97 | 0.3～0.4 |
| IR 24/Kalagyi | 1 | R | 154 | 36 | 3.71 | 0.05～0.1 |
| IR 24/Kaukthwe Pyu | 1 | R | 169 | 48 | 0.96 | 0.3～0.4 |
| | 5 | R | 65 | 17 | 0.80 | 0.3～0.4 |
| IR 24/Phalaungsar | 5 | R | 118 | 26 | 3.10 | 0.05～0.1 |
| IR 24/Apyo-Daw-Gyi | 1 | R | 318 | 102 | 0.11 | 0.7～0.8 |
| | 5 | R | 93 | 33 | 0.10 | 0.7～0.8 |
| IR 24/C28-16 | 1 | R | 226 | 91 | 2.32 | 0.1～0.2 |
| | 5 | R | 200 | 84 | 3.17 | 0.05～0.1 |
| IR 24/Ngachima | 1 | R | 167 | 50 | 0.44 | 0.5～0.6 |
| | 5 | R | 60 | 15 | 1.00 | 0.3～0.4 |
| IR 24/Rogol EB23 | 1 | R | 188 | 64 | 0.06 | 0.8～0.9 |
| IR 24/Kyat Cho-2 | 1 | R | 234 | 80 | 0.04 | 0.8～0.9 |
| | 5 | R | 197 | 69 | 0.13 | 0.7～0.8 |
| IR 24/Ahmee-Puthe | 1 | — | 52 | 17 | <0.01 | 0.90< |
| IR 24/Naungtu T1-6 | 1 | R | 76 | 30 | 0.62 | 0.4～0.5 |
| IR 24/Bubawpho | 5 | — | 96 | 30 | 0.10 | 0.7～0.8 |
| IR 24/Gokaung | 1 | R | 128 | 34 | 1.39 | 0.2～0.3 |
| IR 24/Hnankar Htun | 1 | R | 121 | 43 | 0.13 | 0.7～0.8 |
| IR 24/Let Taw Ywe Baw | 5 | R | 158 | 58 | 0.40 | 0.5～0.6 |
| IR 24/Mayzi | 1 | R | 165 | 58 | 0.12 | 0.7～0.8 |
| IR 24/Myaukma | 1 | R | 194 | 58 | 0.53 | 0.4～0.5 |
| | 5 | R | 312 | 93 | 0.90 | 0.3～0.4 |
| IR 24/Tyc 4 | 1 | R | 134 | 41 | 0.23 | 0.6～0.7 |
| IR 24/D17-18 | 1 | R | 143 | 61 | 2.61 | 0.1～0.2 |
| | 5 | R | 136 | 49 | 0.22 | 0.6～0.7 |

[1] R = resistant; S = susceptible; P = probability;
[2] — = not tested

## Genetic analysis of the cultivars belonging to Mond Ba group

Cultivars; Ngasein Thidat-1 (C24-102) and Yakhine Malay of this group were analyzed. The $F_1$ progenies from the crosses of these cultivars with IR 24 were resistant to races 1, 2 and 5, moderately resistant to race 4, but were susceptible to race 3. The $F_2$ progenies of these crosses segregated in a ratio of 3R : 1S upon inoculation with race 1 as well as with race 2 (Table 6). When the $F_2$ populations were inoculated with race 1 as well as race 2, RR, RS, SR and SS plants were observed. However due to the death of some plants, segregation ratio could not be calculated. These results indicate that the resistances of these cultivars to each of the races 1 and 2 is conferred by two dominant genes.

All the $F_2$ plants from the crosses of these two cultivars with IR-BB 4 were resistant to race 1, thereby showing that resistance to race 1 in these cultivars was conferred by *Xa-4*. Similarly, all the $F_2$ plants from the crosses of these cultivars with IR-BB 10 were resistant to races 2 and 5. These results show that *Xa-10* conveys resistance to races 2 and 5 in these cultivars. Thus, these cultivars have *Xa-4* and *Xa-10* for resistance to races 1 and 2 respectively, and both of these genes confer resistance to race 5.

## Genetic analysis of cultivars belonging to DZ 192 group

Six cultivars; Okshit (Mayin), Byatyin, Mayinni, Ngasein Kalagyi, Poppa and Myawutyi, were genetically analyzed. The reaction of $F_1$ hybrids of the remaining cultivars with IR 24

Table 5. Disease reaction of $F_2$ populations from the crosses of TKM 6 group cultivars with IR-BB 4 or IR 20

| Cross | No. of populations used | Race used | Reaction of $F_2$ population[1)] | |
|---|---|---|---|---|
| | | | R | S |
| IR 20/Kyankpyu | 1 | 1 | 93 | 0 |
| IR 20/Kaukthwe Pyu | 2 | 1 | 227 | 0 |
| IR 20/Apyo-Caw-Gyi | 1 | 1 | 260 | 0 |
| | 1 | 5 | 262 | 0 |
| IR 20/C28-16 | 1 | 1 | 246 | 0 |
| IR-BB 4/D17-18 | 1 | 1 | 232 | 0 |
| | 1 | 5 | 216 | 0 |
| IR-BB 4/Ngachima | 1 | 1 | 273 | 0 |
| IR 20/Kyat Cho-2 | 2 | 1 | 180 | 0 |
| | 2 | 5 | 211 | 0 |
| IR-BB 4/Ahmee-Puthe | 1 | 1 | 103 | 0 |
| IR-BB 4/Naungtu T1-6 | 2 | 1 | 236 | 0 |
| IR-BB 4/Bubawpho | 2 | 5 | 234 | 0 |
| IR-BB 4/Gokaung | 1 | 1 | 220 | 0 |
| IR-BB 4/Hnankar Htun | 2 | 1 | 398 | 0 |
| IR-BB 4/Let Taw Ywe Baw | 2 | 1 | 569 | 0 |
| | 1 | 5 | 156 | 0 |
| IR-BB 4/Mayzi | 2 | 1 | 103 | 0 |

[1)] R = resistant; S = susceptible

Table 6. Mode of inheritance and allelic relationships of genes of resistant cultivars in Mond Ba group

| Cross | Race used | Reaction of $F_1$ hybrids | Reaction of $F_2$ population[1] | | | |
|---|---|---|---|---|---|---|
| | | | R | S | $\chi^2$ (3 : 1) | P |
| *Mode of inheritance* | | | | | | |
| IR 24/Ngasein Thidat-1 (C24-102) | 1 | R | 101 | 28 | 0.75 | 0.3~0.4 |
| | 2 | R | 187 | 68 | 0.38 | 0.5~0.6 |
| IR 24/Yakuhine Malay | 1 | R | 156 | 46 | 0.53 | 0.4~0.5 |
| | 2 | R | 41 | 15 | 0.10 | 0.7~0.8 |
| *Allelism to Xa-4* | | | | | | |
| IR-BB 4/Ngasein Thidat-1 (C24-102) | 1 | R | 584 | 0 | | |
| IR-BB 4/Yakuhine Malay | 1 | R | 275 | 0 | | |
| *Allelism to Xa-10* | | | | | | |
| IR-BB 10/Ngasein Thidat-1 (C24-102) | 2 | R | 142 | 0 | | |
| IR-BB 10/Yakuhine Malay | 2 | R | 266 | 0 | | |
| | 5 | R | 235 | 0 | | |

[1] R=resistant; S=susceptible; Probability

Table 7. Mode of inheritance and allelic relationships of genes of resistant cultivars in DZ 192 group

| Cross | Race used | Reaction of $F_1$ hybrids | Reaction of $F_2$ population[1] | | | |
|---|---|---|---|---|---|---|
| | | | R | S | $\chi^2$ (1 : 3) | P |
| IR 24/Okshit (Mayin) | 2 | S | 76 | 226 | <0.01 | 0.9< |
| IR 24/Byatyin | 2 | S | 70 | 194 | 0.32 | 0.5~0.6 |
| IR 24/Maynni | 2 | S | 52 | 156 | 0.00 | 1.0 |
| IR 24/Ngasein Kalagyi | 2 | S | 34 | 88 | 0.54 | 0.4~0.5 |
| IR 24/Poppa | 2 | S | 57 | 178 | 0.07 | 0.7~0.8 |
| IR 24/Myawutyi | 1 | S | 55 | 123 | 3.30 | 0.05~0.1 |
| | 2 | S | 60 | 118 | 7.20 | <0.01 |
| | 3 | S | 52 | 130 | 1.24 | 0.2~0.3 |
| IR1545-339/Okshit (Mayin) | 2 | R | 317 | 0 | | |
| IR1545-339/Byatyin | 2 | R | 183 | 0 | | |
| | 5 | R | 173 | 0 | | |
| IR1545-339/Lalai | 2 | R | 77 | 0 | | |
| | 5 | R | 246 | 0 | | |
| IR1545-339/Kain kuin | 2 | R | 485 | 0 | | |
| IR1545-339/Ngesein Kalagyi | 1 | R | 140 | 0 | | |
| | 2 | R | 213 | 0 | | |
| IR-BB 5/Mayinni | 2 | R | 138 | 0 | | |

[1] R=resistant; S=susceptible; Probability

was also determined. The $F_1$ hybrids of these cultivars with IR 24 were susceptible to races 1, 2, 3, 4 and 5, and $F_2$ populations segregated in the ratio of 1R : 3S when they were inoculated with race 2 (Table 7). The $F_1$ and $F_2$ plants from the cross IR 24/Myawutyi were inoculated with races 1, 2 and 3. The $F_1$ showed SSS reaction and $F_2$ population segregated in the ratio of 57RRR : 151SSS ($\chi^2$ = 0.6). These results show that the recessive gene in this cultivar confers resistance to races 1, 2 and 3.

Six cultivars; Okshit (Mayin), Byatyin, Mayinni, Ngasein Kalagyi, Lalai and Kaikuin were crossed with IR1545-339 or IR-BB 5 for allelic tests. The $F_2$ populations of these crosses did not segregate any susceptible plants when they were inoculated with races 1, 2 or 5. Thus, it is clear that the recessive gene in these cultivars is *xa-5* and that *xa-5* confers resistance to races 1, 2 and 5.

### Genetics of cultivars belonging to Java 14 group

Three cultivars, Byatshwewa, Kyeni and Ba Shay (Bo Loy) were classified as belonging to this group. Two of these cultivars were genetically analyzed. The average lesion length of $F_1$ plants of IR 24/Byatshwewa upon inoculation with races 1, 2, 3 and 4 was in between those of both parents, suggesting that an incomplelely dominant gene confers resistance in Byatshwewa. The $F_2$ population showed more or less continuous distribution for lesion length. All the plants in the $F_2$ population from Byatshwewa/ IR-BB 103 were resistant to races 1, 2 and 3. Furthermore a browning reaction around the lesions was observed in all the $F_2$ plants.

The $F_1$ population of the cross Ba Shay (Bo Loy)/ IR-BB 103 showed RRRR reaction to races 1, 2, 3 and 5 when they were inoculated at adult stage, and all the $F_2$ plants were resistant to race 2 and showed browning reaction around the lesions. These results show that the gene for resistance to BB races in Byatshwewa and Ba Shay (Bo Loy) is *Xa-3*.

## Discussion

Bacterial blight resistant cultivars from Myanmar were first classified into varietal groups on the basis of their reaction to four BB races from Philippines (Endo *et al.* 1991). A random sample of cultivars from each group was genetically analyzed. Thus, 31 out of 44 cultivars of CAS 209 group, 20 out of 33 of TKM 6 group, two out of four Mond Ba group, six out of nine of DZ 192 group and two of three of Java 14 group were studied. The results revealed that the reaction pattern to four Philipine races could be accurately used to predict the resistance gene of the cultivars. Thus all the cultivars of CAS 209 group were found to have *Xa-10*. All the cultivars of TKM 6 group had *Xa-4*. The two cultivars of Mond Ba group had *Xa-4* as well as *Xa-10*. All the cultivars of DZ 192 group possessed *xa-5*, and both the cultivars of Java 14 group were found to have *Xa-3*.

To-date, eight genes for resistance to Philippine races of BB have been identified (Petpisit *et al.* 1977, Olufowote *et al.* 1977, Sidhu *et al.* 1978, Yoshimura *et al.* 1983, Ogawa *et al.* 1987, Taura *et al.* 1987). So far, only a few cultivars with *Xa-10* gene were known. However, a high proportion of resistant cultivars from Myanmar belonged to CAS 209 group and had *Xa-10* for resistance. Thus, the gene center for *Xa-10* is considered to be Myanmar.

The second most predominant group of resistant cultivars in Myanmar was TKM 6 group. DZ 192 group which predominated in neighboring Eastern India and Bangladesh was represented by only a few cultivars. Similarly, only a few cultivars of Java 14 group were found. It is noteworthy that no cultivar with *Xa-7* was found amongst Myanmar cultivars. Absence of cultivars with *xa-13* and *Xa-14* may be due to the fact that races 5 and 6 which identify such cultivars were not utilized for screening the Myanmar cultivars. Thus it would be worthwhile to screen the Myanmar germplasm with races 5 and 6 to determine if BJ 1 group (*xa-13*) and TN 1 group (*Xa-14*) are represented amongst the Myanmar cultivars.

Occurrence of cultivars belonging to five different groups based on the reaction to BB, along with evidence from other sources such as esterase polymorphism (NAKAGHARA 1978), low temperature sensitivity (CHUONG and OMURA 1982), acid phosphatase polymorphism (CHERN and KATAYAMA 1982) and variation in amylose content (KATSUTA *et al.* 1989) show that Myanmar is within or near the center of genetic diversity of *O. sativa*. Thus the germplasm from Maynmar is of great value in rice improvement.

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# ミャンマー起源稲における稲白葉枯病抵抗性品種群の遺伝子同定

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フィリピン産稲白葉枯病菌レースをを用いた抵抗性反応型から分類したミャンマー起源稲5品種群（ENDO *et al.* 1991）の抵抗性遺伝子を同定する目的で，ランダムに各品種群から品種を選定し，遺伝子分析をおこなった．選定した品種と感受性品種であるIR 24を交配し，その交配$F_1$，$F_2$世代個体にせん葉接種（KAUFFMAN *et al.* 1973）した．$F_1$の反応型と$F_2$での分離比から遺伝様式を決定した所，CAS 209品種群(44品種中31品種)，TKM 6品種群（33品種中20品種），Java 14品種群(3品種中2品種)の抵抗性は，一優性遺伝子により支配されていることが明らかとなった．Mond Ba品種群（4品種中2品種）のレース1，2に対する抵抗性は2つの優性遺伝子支配であった．一方，DZ 192品種群9品種とIR 24との交配$F_1$個体は全て感受性であり，6交配組み合せの$F_2$個体での分離比は一劣性遺伝子により支配されている事を示した．また，CAS 209品種群はレース2と5に抵抗性，他のレースに感受性であったが，この抵抗性が同一遺伝子に支配されているかどうかを確認するために，5交配組み合せにレース2と5を同時接種し，TinmawとIR 24の交配組み合せではレース1，2，3，5を同時接種し，組換型が分離しない事を確認した．同様にTKM 6品種群のレース1，5に対する抵抗性，レース4に対する中度抵抗性は同一遺伝子支配である事を確認し，DZ 192品種群のレース1，2，3，5に対する抵抗性は一遺伝子支配である事を確認した．次に，CAS 209は*Xa*-10を，TKM 6は*Xa*-4を，DZ 192は*xa-5*を，Java 14は*Xa-3*をもち，*Mond Ba*は*Xa*-10と*Xa-4*の両遺伝子をもつので，これら遺伝子の準同質遺伝子系統またはIRRI判別品種をもちい，対立性検定を行った．その結果，CAS 209品種群中21品種とIR-BB 10（*Xa*-10）との交配$F_1$，$F_2$世代にレース2または5を接種したところ，全個体が抵抗性反応を示し，これらの品種中の優性遺伝子は*Xa*-10である事がわかった．同じく，TKM 6品種群中14品種とIR-BB 4（*Xa-4*）またはIR 20との対立性検定の結果，これらの品種のもつ優性遺伝子は*Xa-4*であることがわかった．また，DZ 192品種群中6品種とIR-BB 5（*xa-5*）またはIR 1545-339との交配$F_1$，$F_2$世代の全個体は抵抗性反応を示し，これらの品種の劣性遺伝子は*xa-5*であり，*xa-5*はレース1，2，5に抵抗性を示すことが確認された．Java 14品種群中2品種のIR-BB 103との対立性検定からは，これらの品種の優性遺伝子が*Xa-3*であることがわかった．Mond Ba品種群中2品種とIR-BB 10並びにIR-BB 4との対立性検定から，これらの品種は*Xa-10*と*Xa-4*を共にもち，レース1に対する抵抗性は*Xa-4*により，レース2に対する抵抗性は*Xa-10*により，レース5に対する抵抗性は*Xa-10*と*Xa-4*の両優性遺伝子により支配されている事が確認された．また，遺伝子分析の結果，*Xa-7*は認められなかった．

今日までに，フィリピン産レースで判別可能な遺伝子は8遺伝子あり，そのうち主要4遺伝子がミャンマーにみられた．主要4遺伝子中，*Xa-10*が優先的に分布しており，ついで*Xa-4*が多いことが確認された．バングラデシュ，インドなど近隣諸国に多い*xa-5*は少なく，japonica型に主として分布する*Xa-3*も少なく，前報で推定した稲生態型分化との関連からミャンマー起源稲の遺伝資源としての価値は高いと考えられた．