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Rice Cultivar Groups in Myanmar Based on Reaction to Bacterial Blight

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Rice cultivars from Myanmar were evaluated for resistance to four Philippine races of bacterial blight pathogen (*Xanthomonas campestris* pv. *oryzae*) with clipping inoculation method (KAUFFMAN *et al.* 1973). Out of 1473 cultivars screened at seedling stage. 337 cultivars were initially categorized into five groups by their differential reactions to races 1, 2, 3, and 4 e.g. SRSS, RSSM, RRSM, RRRM (or RRRR) and MMMM. The MMMM reaction at seedling stage was further classified either into RRRR with browning reaction around lesions or moderately resistant cultivars (non-classified) on the basis of repeated tests at adult stage. As discussed by OGAWA *et al.* (1991), the RRRR reaction with the browning around the lesions is similar to that of Java 14 group. The cultivars of this group were considered to have *Xa-3* for resistance. The reaction SRSS is similar to that of CAS 209 (*Xa-10*) group. Likewise, the reaction patterns of RSSM, RRSM, and RRRM (without browning) resembled the reaction patterns of TKM 6 (*Xa-4*), Mond Ba (both *Xa-10* and *Xa-4*), and DZ 192 (*xa-5*) groups, respectively. Out of 337 cultivars screened at adult stage, 218 were susceptible. Of the 119 resistant cultivars, 44 were placed in CAS 209 group, 33 in TKM 6, 4 in Mond Ba group, 9 in DZ 192 group, 3 in Java 14 group, and 26 as non-classified cultivars. The raction of the cultivars of each group was compared with that of each of the near-isogenic lines having a specific gene for the cultivar groups. Homogeneity of each group was confirmed through variance analysis over three seasons. Thus, the cultivars of CAS 209 and TKM 6 groups were predominant with a small number of cultivars belonging to Java 14 and DZ 192 groups.

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

Introduction

Studies on distribution of genes for resistance to bacterial blight (BB) in rice cultivars were started recently (OGAWA *et al.* 1986). OGAWA *et al.* (1991) classified rice cultivars into eight major groups e.g. Java 14, TKM 6, DZ 192, CAS 209, Mond Ba, DV 85, Makhmal Mehi, and BJ 1 groups based on the reaction to four Philippine races of BB. It was found that each cultivar group linked to different ecotypes of rice. Cultivars of Java 14 group mainly belonged to japonica including so-called tropical upland, bulu and javanica (GLASZMANN 1987). Cultivars of TKM 6 group were mostly found in typical indica including aman and tjereh. DZ 192 group cultivars mostly belonged to so-called aus.

In the cultivated rice, *Oryza sativa* L., many ecotypes are known such as japonica and indica, Hsein and Keng in China, aus, boro and aman in Bangladesh and so on. Several centers of genetic diversity have been proposed such as India (CHATTERJEE 1951), China (TING 1957), Indo-china (HAMADA 1949), or multiple centers of diversity (CHANG 1976). Recently based on isozyme polymorphism, NAKAGAHRA (1978, 1987) proposed that the center of genetic diversity of rice was situated in an area consisting of northern part of Myanmar

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(Burma), Laos, and Yunnan province of China. Meanwhile it was found that the known genes for resistance to BB (*Xa-1* to *Xa-12*) were not effective for races of BB in Myanmar (YAMAMOTO *et al.* 1989). Therefore, we initially investigated the distribution of known genes for resistance to BB amongst the cultivars from Myanmar, which may be a center of genetic diversity of rice, and to explore the possibility of identifying new genes from amongst these cultivars. This paper deals with the frequency of each reaction pattern to BB amongst Myanmar rice cultivars.

Materials and Methods

This study was carried out at International Rice Research Institute (IRRI), Los Banos, Laguna, Philippines during 1987～1989.

Preliminary screening at seedling stage

We initially screened 1473 cultivars originating from Myanmar, which are preserved in International Rice Germplasm Center (IRGC) of IRRI. Each cultivar was seeded in wooden boxes (60 × 45 × 10cm in size, 10～12 cultivars/box). Prior to seeding, seeds of each entry were examined individually based on grain characteristics described in IRGC data files. Clipping inoculation method (KAUFFMAN *et al.* 1973) was used for inoculation. The seedlings were inoculated at about 28 days after seeding when 4 to 5 leaves had developed. Before the inoculation, seedlings of each entry were divided into four groups. One group was inoculated with one race. Bacterial isolates, PXO61, PXO86, PXO79, and PXO71, were used as representatives of Philippine races 1, 2, 3, and 4, respectively. Modified WAKIMOTO's medium was used for the incubation. The Inoculum was prepared as a 10^7 to 10^8 cell/m*l* suspension after incubation for 2 days at 27°C. Seedling reactions were evaluated visually at 14 days after inoculation (DAI). The entries which showed resistance (R) or moderate resistance (M) to at least one of the four races were tested at adult stage. Susceptible (S) plants to all races were discarded.

Inoculation test at adult stage

Cultivars which showed resistance to at least one race at seedling stage were grown in buckets with each of about 11.4*l* capacity. Four plants of one entry were planted in one bucket. Prior to inoculation, tillers of individual plant were divided into four groups and each group of tillers was bound with different colored-ties. The color coded groups of tillers were inoculated with specific races of BB at booting stage. Upper 3 to 4 leaves including flag leaf, were inoculated. Mostly the Philippine races 1, 2, 3 and 4 of BB were used. However, Philippine races 5 (isolate PXO112) and 6 (isolate PXO99) were used for inoculation in a few cases to confirm the reaction patterns of cultivar groups to these races. Lesion length was measured at 18 DAI. Resistance was evaluated on the basis of lesion development and symptom observation. The criteria used for the assessment of resistance were as follows; 1) average lesion length was shorter than that of susceptible check, 2) the lesion development stopped at 14 to 18 DAI, and 3) the margin of lesion was brownish, yellowish or clearly distinct from healthy leaves.

Near-isogenic lines and breeding lines developed under a collaborative project between IRRI and Japan (OGAWA *et al.* 1988, OGAWA and YAMAMOTO, 1989) were used as checks for estimating genes conferring the resistance in test cultivars. The near-isogenic lines used were: IR-BB 3 for *Xa-3*, IR-BB 4 for *Xa-4*, IR-BB 5 for *xa-5*, IR-BB 7 for *Xa-7*, and IR-BB 10 for *Xa-10* (Table 1).

If a susceptible plant was present in an entry, it was removed. Sometimes plants within an entry showed differential disease reaction. It was divided into two sub-entries. Screening was repeated at least two times over five seasons.

Test of homogeneity for cultivar groups and the estimation of genetic and environmental components

The entries were inoculated during five seasons (1987 dry and wet seasons; 1988 dry and wet seasons; 1989 dry season). The lesion length was measured during each season and variance for lesion length was calculated over three seasons (1987 wet season; 1988 dry season; 1989 dry season) to estimate environmental effects and to confirm the classification of each cultivar into specific groups. The variance for lesion length was partitioned into several components, e.g. seasonal variance, variance among cultivar groups, interaction variance, and variance within cultivar groups. Then environmental, major gene and interaction effects were estimated, assuming that the variance among groups represents major gene effect, and variance within group was attributed to differences in genetic backgrounds. Cultivars were randomly selected from respective groups in proportion to the number of cultivars belonging to the group. For determining variation within a cultivar, measurements of three plants were used. Random model was assumed and modified split-plot design was employed for analysis of variance.

Results

Of 1473 cultivars screened at seedling stage, 1136 cultivars were susceptible to all tested races and were discarded. Remaining 337 cultivars were grouped into five different reaction types on the basis of reaction to Philippine races 1, 2, 3, and 4, e.g. SRSS, RSSM, RRSM, RRRM and MMMM. The number of cultivars assigned to each reaction group was 43, 29, 10, 10, and 245, respectively.

Table 1. Pedigree of near-isogenic lines with a specific gene for resistance to bacterial blight (OGAWA *et al.* 1988)

Designation	Cross	Gene
IR-BB 3	IR 24/Chugoku 45//4*IR 24	*Xa-3*
IR-BB 4	IR 24/IR 20//4*IR 24	*Xa-4*
IR-BB 5	IR 24/IR 1545-339//4*IR 24	*xa-5*
IR-BB 7	IR 24/DV85//4*IR 24	*Xa-7*
IR-BB 10	IR 24 /CAS 209//4*IR 24	*Xa-10*

4*IR 24 : four times back-cross with IR 24

The inoculations at adult stage confirmed these groupings. The reaction pattern of SRSS was similar to that of CAS 209 group. Likewise the reaction patterns of RSSM, RRSM and RRRM resembled the reaction patterns of TKM 6, Mond Ba, and DZ 192 groups, respectively (OGAWA *et al.* 1991). The cultivars belonging to MMMM group at seedling stage were further classified into 29 MMMM (or RRRR) and 218 SSSS groups on the basis of adult stage reaction and 218 cultivars with SSSS reaction were discarded. Some of the cultivars of the MMMM group at adult stage showed browning reaction around the margins of lesions which is the characteristic of Java 14 group. On the basis of repeated inoculations at adult stage during different seasons and the stability of reaction over seasons, it was possible to separate cultivars with RRRR-reaction from cultivars with MMMM reaction. The reaction of cultivars at seedling stage coincides well with the reaction at adult stage test, except cultivars with RRSM and with MMMM reactions.

The cultivar group with MMMM reaction at adult stage was designated as non-classified (NC) group temporarily, since no corresponding cultivar group has been reported earlier (OGAWA *et al.* 1991) and it is necessary to analyze genetically. Consequently out of 119 resistant cultivars, 44 were classified into CAS 209 group, 33 into TKM 6 group, 4 into Mond Ba group, 9 into DZ 192 group, 3 into Java 14 group and 26 into NC group, respectively. Plants of cultivar, Ngasein Thidat C 24-102 were sub-divided into two sub-entries. One of the sub-entries was classified into CAS 209 group, while the other into Mond Ba group.

Homogeneity of cultivar groups

Each cultivar group mentioned above was tested for the homogeneity through analysis of variance. We assumed the presence of major genes for resistance in each cultivar group e.g. *Xa-10* in CAS 209 group, *Xa-4* in TKM 6 group, both *Xa-10* and *Xa-4* in Mond Ba group, *xa-5* in DZ 192 group and *Xa-3* in Java 14 group. The reaction of each cultivar group was compared with that of corresponding near-isogenic lines. The reaction of NC group was compared to that of IR-BB 3.

Variation in lesion length for different crop seasons was analyzed keeping in view the contribution of major genes (Table 2). Variance within groups was significant, interacting specifically to the expression of each assumed major gene. That is, significant difference was recognized when the expression of major gene resistance was absent (in compatible combination), while no significant difference was noted with the presence of major gene resistance (incompatible interactions). Relative contribution of environmental variation was estimated as 26%, 10%, 9%, and 7%, in respect to races 1, 2, 3, and 4. On the other hand, major genes contributed 50%, 80%, 85% and 90% of the variation, respectively for races 1~4. Genotype and environment interactions accounted for 3 to 24% of the variation. Among the seasonal effects, generally dry season influenced lesion development to a lesser extent, while during wet season, the disease development was faster. This trend was clear when compatible combinations between host and bacterium were studied. Relatively minor differences were observed when major gene resistance was present. Among the cultivar groups, the resistance of CAS 209 was least affected by environment. Resistance of DZ 192 and of Java 14 was relatively stable over seasons. However, the resistant reactions of TKM 6 and NC groups

Table 2. Analysis of variance for lesion length over different seasons, computed with random samples from each cultivar group

Sources of Variance	df	Mean Squares			
		Race 1	Race 2	Race 3	Race 4
Season (S)	2	9495.3**	4739.6**	1870.6**	1392.0**
Among Group (G)	6	8097.5**	15153.1**	6959.1**	7526.3**
S × G	12	1122.7**	607.8**	206.6**	126.5**
Error (a)	42	37.0**	33.9	47.2	33.3
Within group	303	72.1**	65.0**	87.2**	68.3**
CAS 209	84	132.7**	11.4	111.0**	86.3**
TKM 6	69	33.4	103.5**	90.6**	55.1*
Mond Ba	9	10.0	20.9	151.7**	50.0
DZ 192	21	14.1	16.1	4.3	37.7
Java 14	3	16.0	6.0	18.3	21.1
NC group	63	55.2	83.1**	107.1**	93.5**
Susceptible	54	103.1**	100.4**	93.9**	90.4**
Pooled Error (b)	606	44.6	39.7	51.0	36.7

Mean square of lesion length for races 1,2,3 and 4 shows the single and double asterisks, significant difference by F-tests at 5% and at 1% level, respectively.
NC: non-classified

varied more from season to season.

Reactions to races 1 to 6 and Characteristics of Different Cultivar Groups

The reactions of CAS 209 group cultivars to 6 races were evaluated along with IR-BB 10 (Table 3). It is obvious that all cultivars of this group showed resistance to races 2 and 5, while the lesion lengths of all the cultivars upon inoculation with races 1, 3, 4, and 6 were as long as those of IR 24. No significant differences were recognized between the reaction of cultivars belonging to this group as well as of IR-BB 10. Thus, the reaction of CAS 209 group was confirmed to be SRSSRS to races 1, 2, 3, 4, 5 and 6, respectively. No browning or yellowing reactions were observed at the margin of lesions, and lesion development stopped at 10 to 14 DAI. All the cultivars of this group have intermediate plant height and slender to medium grains. Susceptible plants were observed within several accessions of this group.

TKM 6 group cultivars were confirmed to be RSSMRS to races 1 to 6. The reaction of these cultivars to race 1 was similar to that of IR-BB 4. The resistance to race 4 was moderate and varied from cultivar to cultivar (Table 4). The resistance of most of the cultivars to race 5 was clear, though lesion lengths of Rogol EB23 and Kyat Cho-2 were slightly longer. All the cultivars showed susceptibility to race 6. The reaction became clear around 14 DAI. Most of the cultivars were intermediate in height with slender to medium grains.

The reaction of Mond Ba group cultivars is shown in Table 5. The reaction to race 2 was similar to that of IR-BB 10. The reaction to race 1 was identical to that of IR-BB 4.

Table 3. Disease reaction of cultivars of CAS 209 group to 6 Philippine races of BB at adult stage

Cultivar Name	Acc. Number	Lesion Length[1] (cm) when inoculated with					
		Race 1	Race 2	Race 3	Race 4	Race 5	Race 6
AC224							
C 21-102	00724	24.0	2.1	20.4	27.7	2.1	24.7
Ngasein Thidat.							
C24-102	04936	23.8	3.6	24.2	25.3	2.5	27.7
Machitpon	33333	32.3	2.0	32.8	27.1	4.1	38.4
Shweni	33686	23.7	2.1	25.0	20.4	1.4	21.5
Tazintan	33771	20.7	1.6	15.6	25.6	1.1	19.9
IR-BB 10		22.0 (S)[2]	1.9 (R)	23.1 (S)	26.9 (S)	0.6 (R)	30.0 (S)
IR 24 (Check)		20.8	21.5	22.2	21.6	21.8	22.4
Lsd	5%	6.1	5.8	6.5	5.6	—	—
	1%	8.1	7.6	8.6	7.3	—	—

Other cultivars classified as belonging to CAS 209 group[3]:

Ngasein Thidat C24-102 (Acc. 05885), C34-13 (Acc. 06797), B24-92 (Acc. 06801), B47-5 (Acc. 06802), C28-15 (Acc. 14009), Ngakwe Thetyin (Acc. 33477), Tyb 11 (Acc. 33821), B24-92 (Acc. 49472), Jacamugato (Acc. 49714), Magasank C.12 (Acc. 49938), Nga-Myin Sive (Acc. 49959), Chin Mee Byauk (Acc. 57882), Chin Meedon (Acc. 57883), Maw Tike (Acc. 58114), Ta Lay War (Acc. 58227), Detkwa (Acc. 33035), Haoru (Acc. 33090), IB56-8 (ACC. 33136), Kalalan (Acc. 33154), Lagaea (Acc. 33297), Letyonshay (Acc. 33310), Let Ywe Zin (Acc. 33312), Maung Nyo (Acc. 33351), Myaunggya (Acc. 33414), Natpyi Hmwe (Acc. 33440), Ngaldngyi (Acc. 33479), Ngasein Theedat (Acc. 33502), Ngasein Theedat (C-29) (Acc. 33503), Ngaya Ngase (Acc. 33516), Nwachi Manine (Acc. 33531), Seinpulay (Acc. 33642), Sitpwa (Acc. 33715), Tataungpo (Acc. 33736), Tataungpo (Acc. 33737), Theedat Ngasein (Acc. 33779), Theedat Ngasein (Acc. 33780), Thonh Nanpaw (Acc. 33800), Tinmaw (Acc. 33806), Zenbut (Acc. 33927)

1) Lesion length is the average lesion length over more than two seasons of inoculation test.
2) R = resistance, S = Susceptible
3) Cultivar name (Acc.; accession number at IRRI)

The reaction to races 3 and 6 was susceptible. Thus, the reaction of this group was confirmed to be RRSMRS to six Philippine races. All the cultivars of this group were typical indicas.

The reaction of DZ 192 group cultivars was confirmed to be RRRMRS to races 1 to 6 (Table 6). In nine cultivars of this group, lesion lengths upon inoculation with races 1, 2, 3, and 5 were as short as those of IR-BB 5, while the lesion length upon inoculation with race 4 varied depending upon the variety. Of the four cultivars inoculated with race 6, Myawutyi showed resistance to race 6 also. The lesions developed smoothly without browning nor zig-zag shape. The reaction was recognized clearly at 10 to 14 DAI. The cultivars of this group were short to intermediate in height with slender to medium grains.

Table 4. Disease reaction of cultivars of TKM 6 group to 6 Philippine races of BB at adult stage

Cultivar Name	ACC. Number	Lesion Length[1] (cm) when inoculated with					
		Race 1	Race 2	Race 3	Race 4	Race 5	Race 6
Kaukthwe Pyu	33203	8.4	23.0	26.2	11.2	8.1	30.8
D17-18	49611	7.7	22.4	23.4	15.4	7.6	28.5
Rogol EB23	50081	9.5	21.5	20.8	15.6	14.0	25.2
Kyat Cho-2	58044	8.0	23.4	18.5	10.9	15.5	28.3
Bawyurin	32972	9.3	19.4	17.7	14.4	6.2	19.0
Let Taw Ywe Baw	33306	6.4	21.3	24.6	12.0	1.6	23.1
IR-BB 4		5.3 (R)[2]	21.2 (S)	25.4 (S)	12.0 (M)	4.2 (R)	18.9 (S)
IR 24 (Check)		20.8	21.5	22.2	21.6	21.8	22.4
Lsd	5%	6.1	5.8	6.5	5.6	—	—
	1%	8.1	7.6	8.6	7.3	—	—

Other cultivars classified as belonging to TKM 6 group[3];

Kyankpyu (Acc. 04144), Kyaukpyu A27-4 (Acc. 05927), B36-8 (Acc. 06070), Kalagyi (Acc. 33147), Phalaungsar (Acc. 33578), Apyo-Caw-Gyi (Acc. 49386), C 28-16 (Acc. 49580), Kank-Sangyi 2C 107 (Acc. 49755), Kunwah B61 (Acc. 49830), Ngachima (Acc. 49958), Khao Thi Rate (Acc. 58041), Ahmee-Puthe (Acc. 05735), Anbaw C7 (Acc. 06069), Nalngtu T1-6 (Acc. 06250), Bubawpho (Acc. 32990), Gokaung (Acc. 33079), Hnankar Htun (Acc. 33108), Lonthwe Shwewa (Acc. 33329), Mayzi (Acc. 33373), Myaukma (Acc. 33412), Nga-Kywe (Acc. 33470), Pindosein (Acc. 33585), Taylay (Acc. 33769), Tyc 4 (Acc. 33824), Tathalay Lonethwe (Acc. 33863), Yathalay Lonethwe (Acc. 33867), 291 (Acc. 33931)

[1] Lesion length is the average lesion length over more than two seasons of inoculation test.
[2] R = resistance, S = Susceptible, M = moderate
[3] Cultivar name (Acc.; accession number at IRRI)

The lesion lengths of cultivars of Java 14 group were as short as those of IR-BB 3 and were significantly shorter than those of IR 24 (Table 6). One cultivar, Byatshwewa, showed resistant reaction to race 6 also. Browning reaction around the margin of lesions was clear with zig-zag lesion development. The resistance was stable over seasons. The cultivars of this group had intermediate to tall plant stature with round grain shape and were late in maturity.

The lesion length of cultivars of NC group was longer than those of IR-BB 3, but shorter than those of IR 24. Moreover the lesion length varied from cultivar to cultivar (Table 7). The reaction of many cultivars of this group to race 5 was found to be R rather than MR. Some cultivars appeared MR to race 6 also. The cultivars showed browning reaction around the lesions and the lesions showed zig-zag margins. These symptoms are similar to those of Java 14 group. Morphologically all the cultivars were intermediate to tall and late in maturity. Grains were mostly medium to round but some were slender. Five cultivars namely

Table 5. Disease reaction of varieties of Mond Ba group to 6 Philippine races of BB at adult stage

Cultivar Name	Acc. Number	Lesion length[1] (cm) when inoculated with					
		Race 1	Race 2	Race 3	Race 4	Race 5	Race 6
Ngasein Thidat C 24-102	04936	5.5	1.9	20.0	12.7	—	—
Yepwa	33897	4.7	2.9	10.3	5.2	6.0	(16.6)
XA 108	46790	4.9	2.0	17.2	9.9	0.3	(11.3)
Yakhine Malay	33855	8.3	1.7	(14.5)	12.5	1.2	(19.2)
IR-BB 4		5.3 (R)[2]	21.2 (S)	25.4 (S)	12.0 (M)	4.2 (R)	18.9 (S)
IR-BB 10		22.0 (S)	1.9 (R)	23.1 (S)	26.9 (S)	0.6 (R)	30.0 (S)
IR 24 (Check)		20.8	21.5	22.2	21.6	21.8	22.4
Lsd	5%	6.1	5.8	6.5	5.6	—	—
	1%	8.1	7.6	8.6	7.3	—	—

1) Lesion length is the average lesion length over more than two seasons of inoculation test.
2) R=resistance, S=Susceptible, M=Moderate
3) Parentheses in the figure refer to the average of two seasons or one season only.

Khun Ni Gyi, Phi Zaw, Halingyi 1, Ywet Thay Wa, and Zine Din appeared to be indicas on the basis of plant type and grain shape. Four cultivars, Palak E. 19, Yat Sauk Saba, Ngayapo Ahmweto, and Thit pin showed relatively short lesions but lesion length varied from season to season. Therefore, these cultivars were also included in this group.

Thus, almost 37% (n=44) of the resistant cultivars from Myanmar were considered to belong to CAS 209 group, 28% to TKM 6 group (n=33) and 7.5% to DZ 192 group (n=9). Only 2.5% and 3.3% of the cultivars belonged to Java 14 and Mond Ba groups. Another group designated as NC group was present in the cultivars originating from Myanmar and 22% of the resistant cultivars were assigned to this group.

Discussion

This is the first study in which rice cultivars belonging to a particular country have been classified into cultivar groups based on their reaction to different races of BB from the Philippines. The analysis of variance for reaction to BB races showed great homogeneity of rice cultivars within a group. The major gene effects particularly for reaction to races 2, 3, and 5 were quite high. The cultivars belonging to non-classified group showed more variance due to season effects.

Differential reactions to BB races in rice are conditioned by specific genes for resistance. Rice cultivar CAS 209 is resistant to BB race 2 of the Philippines and is one of the IRRI differentials for identifying BB races. It has one dominant gene for resistance to race 2. This gene was designated *Xa-10* by YOSHIMURA *et al.* (1983). Till recently only CAS 209 was

Table 6. Disease reaction of cultivars of DZ 192 and Java 14 group to 6 Philippine races of BB at adult stage

Cultivar Name	Acc. Number	Lesion length[1] (cm) when inoculated with					
		Race 1	Race 2	Race 3	Race 4	Race 5	Race 6
(DZ 192 group)							
Okshit (Mayin)	07813	4.5	5.4	2.7	8.6	6.2	—
Byatyin	33010	6.4	5.4	5.5	(9.9)	4.2	(22.9)
Lalai	33151	3.5	4.6	4.7	9.4	2.6	—
Kaukyin	33209	6.3	6.5	4.5	13.0	5.8	—
Mansat-3	33341	4.3	3.2	5.6	16.0	(2.0)	—
Mayinni	33368	6.0	5.1	5.4	21.8	(6.3)	—
Myawutyi	33416	4.0	4.4	5.2	12.1	3.5	4.3
Ngasein Kalagyi	33498	5.5	3.9	2.8	13.6	2.5	(19.2)
Poppa	33592	6.2	6.2	4.3	—	8.3	23.9
(Java 14 group)							
Byatshwewa	33008	6.5	6.8	7.0	7.2	(5.5)	(6.8)
Kyeni	33283	5.8	5.0	4.9	4.7	—	—
Ba Shay (Bo Loy)	57860	5.0	6.3	7.2	8.8	—	—
IR-BB 3		6.0	3.5	3.7	2.5	5.1	24.0
		(R)	(R)	(R)	(R)	(R)	(S)
IR-BB 5		2.8	2.3	2.0	4.6	2.1	17.9
		(R)[2]	(R)	(R)	(R)	(R)	(S)
IR 24 (Check)		20.8	21.5	22.2	21.6	21.8	22.4
Lsd	5%	6.1	5.8	6.5	5.6	—	—
	1%	8.1	7.6	8.6	7.3	—	—

1) Lesion length is the average lesion length over more than two seasons of inoculation test.
2) R=resistance, S=Susceptible
3) Parentheses in the figure refer to the average of two seasons or one season only.

known to show this reaction and it was considered a small group (OGAWA *et al.* 1991). However, on the basis of this study, 44 additional cultivars have been added to this group. In fact CAS 209 group is dominant amongst the resistant cultivars from Myanmar. Out of 119 resistant cultivars studied, 44 cultivars or 37 percents belong to this group. Thus, one of the gene center for *Xa-10* should be in Myanmar. Although *Xa-10* was first identified in a cultivar from Senegal, it may have been introduced into Africa from Asia. Another dominant group amongst the resistant cultivars from Myanmar is TKM 6 group. The resistance of these cultivars is conditioned by *Xa-4* which conveys resistance to race 1 and moderate resistance to race 4. Almost 28 percents of the resistant cultivars from Myanmar belong to this group. The gene *Xa-4* is widely distributed amongst cultivars from Bangladesh, Central and South India, Sri Lanka and Indonesia. Thus, Myanmar is also extended into the

Table 7. Disease reaction of Non-classified cultivars when inoculated with 6 Philippine races of BB at adult stage

Cultivar Name	Acc. Number	Lesion length[1] (cm) when inoculated with					
		Race 1	Race 2	Race 3	Race 4	Race 5	Race 6
Shwepalin	33689	15.7	18.2	19.1	16.0	(6.9)	(19.3)
Khun Ni Gyi	58055	12.8	12.3	12.8	11.1	(2.0)	(12.6)
Phi Zaw	58177	14.4	12.6	14.3	13.0	(3.1)	(20.4)
Halingyi 1	36703	12.3	12.1	11.8	12.1	(4.6)	(17.7)
Ywet Thay wa	58259	13.9	15.5	15.5	15.0	(2.0)	(22.3)
Zine Din	58263	15.3	15.0	13.7	10.5	(2.9)	(22.0)
Thetlat Ngakyauk	33787	9.2	11.3	12.6	13.2	(3.1)	(18.7)
C44-1	06804	10.6	8.3	10.7	10.3	(7.7)	(10.4)
Balugyun	32960	12.3	12.2	16.0	17.8	(6.4)	(27.8)
Gayku Kamakyi	33078	10.0	10.0	10.5	11.0	(7.3)	(13.5)
Satya	33632	12.3	12.8	15.8	15.7	(10.7)	(14.6)
Tonkin	33813	13.2	13.9	15.4	16.2	(8.4)	(13.2)
Pokekyi	33590	13.7	13.2	14.8	15.9	(14.2)	(19.1)
Kyet Paung	58069	9.5	8.3	9.1	12.2	(10.4)	(13.6)
Balugun Kaukkyi	32959	13.7	13.5	12.9	16.1	(10.2)	(18.2)
Byat	33001	13.3	14.7	16.2	17.4	(12.5)	(18.4)
Kaukkyi Byat Wine	33190	9.5	8.8	11.3	9.0	(7.6)	(14.0)
Thatnu Sabanet	33773	10.4	8.0	9.2	10.3	(9.0)	(15.3)
Kyeeme	33282	11.7	10.2	13.0	13.4	(6.7)	(13.4)
Kaukkyiyin	33195	11.6	10.1	14.4	10.4	(7.4)	(12.3)
Ngakyweyin	33478	9.0	6.4	11.4	11.5	(3.6)	(10.8)
Palak E.19	49999	4.4	3.7	4.2	5.6	(2.5)	(19.6)
Yat Sauk Saba	58247	6.9	7.2	5.7	9.3	(5.3)	(16.6)
Pyapow Theedat	33596	4.4	5.8	6.7	10.6	—	—
Ngayapo Ahmweto	33520	6.1	5.9	5.6	7.0	(4.5)	(25.6)
Thit Pin	33791	7.3	6.9	7.4	8.1	(6.1)	(21.2)
IR-BB 3		6.0 (R)	3.5 (R)	3.7 (R)	2.5 (R)	5.1 (R)	24.0 (S)
IR-BB 5		2.8 (R)[2]	2.3 (R)	2.0 (R)	4.6 (R)	2.1 (R)	17.9 (S)
IR 24 (Check)		20.8	21.5	22.2	21.6	21.8	22.4
Lsd	5%	6.1	5.8	6.5	5.6	—	—
	1%	8.1	7.6	8.6	7.3	—	—

1) Lesion length is the average lesion length over more than two seasons of inoculation test.
2) R = resistance, S = Susceptible
3) Parentheses in the figure refer to the average of two seasons or one season only.

area of gene center for *Xa-4*. A few cultivars belonging to DZ 192 group from Myanmar were identified. The gene center for DZ 192 group is in nearby Bangladesh and Northeast India (KHUSH 1977). Thus, occurrence of cultivars of DZ 192 group in Myanmar is reasonable. Similarly, a few cultivars belonging to Java 14 group and Mond Ba group were identified. Cultivars belonging to Java 14 group are widely distributed in Bangladesh and Indonesia (OGAWA *et al.* 1986). It is interesting that only a few cultivars belonging to this group were identified amongst the resistant cultivars from Myanmar. One cultivar (Myanwutyi) appears to belong to BJ 1 group which have both *xa-5* and *Xa-13*.

Twenty-six or 22% of the cultivars were non-classified. Some of the cultivars of this group showed typical browning reaction around the lesions and may belong to Java 14 group. Others may have quantitative type of resistance or may have a new gene for moderate resistance. Thus, it would be interesting to analyze these cultivars genetically.

NAGAMATSU (1945) reported wide variation for grain size and shape and NAKAGHARA (1978) found high level of polymorphism for esterase isozyme amongst cultivars from Myanmar. However the frequency of each group based on BB resistance was predominant in CAS 209 (*Xa-10*) and TKM 6 (*Xa-4*) groups amongst Myanmar cultivars, not evenly balancing for all cultivar groups.

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白葉枯病抵抗性反応型によるミャンマー由来イネの品種分類

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世界各地のイネ品種における白葉枯病抵抗性遺伝子の分布を調べる目的で, まず変異の多様性中心に含まれるミャンマー由来のイネ品種についてフィリピン産白葉枯病菌レースを接種検定し, その反応型による分類を行った. IRRI保存のミャンマー由来1473品種を供試し, フィリピン産白葉枯病菌レース1, レース2, レース3, レース4を幼苗期接種（せん葉接種）し, 病斑長の伸展から抵抗性（R), 感受性（S), 中度抵抗性（M）を判別した. その結果, 337品種にSRSS, RSSM, RRSM, RRRM, MMMMの5種類の反応型を認めた. これらの反応型を示した品種を成稲期に接種し, 反応型を確認した. 上記4レースに加え, レース5, レース6も用い, 雨期, 乾期と異なる季節での接種検定から反応型を確認した. また, 各抵抗性を支配している遺伝子の安定性を分散分析により推定した. その結果, 主としてMMMM反応型の218品種は感受性と判定され, 残る119品種の反応型は, 幼苗期のそれとよく一致し, 準同質遺伝子系統の反応型をテスターとして比較するとSRSS型はIR-BB 10(*Xa-10*)にRSSM型はIR-BB 4（*Xa-4*）に、RRSM型はIR-BB 4とIR-BB 10の重複型に, また, RRRM型はIR-BB 5（*xa-5*）の反応型に相似であることがわかった. MMMM型はさらにRRRR（褐変反応型）と中度抵抗性型品種群に分類され, RRRR（褐変反応型）は, IR-BB 3（*Xa-3*）の反応型とよく一致した. 小川ら(1991)の分類に従い, IR-BB 10型をCAS 209品種群, IR-BB 4型をTKM 6品種群, IR-BB 4とIR-BB 10の重複型をMond Ba品種群, IR-BB 5型をDZ 192品種群, そしてIR-BB 3型をJava 14品種群に分類した. 中度抵抗性品種群は分類できない群として仮にnon-classified（NC）品種群と分類した. 分散分析の結果から季節変動を環境因子に, 品種群間差を主動遺伝子による変動とし, さらに品種群内変動を品種の遺伝的背景による差であると仮定すると, 抵抗性遺伝子の効果は, 50%から80%と高く, 環境因子の変動は7%から26%と低かった（Table 2). 品種群別にはCAS 209, DZ 192群の抵抗性CASは安定しており, TKM 6, NC品種群は比較的不安定であったが, 反応型による差は品種群内変動にきれいに現れ, 反応型から分類した品種群は正しく分類されていると考えられた. ミャンマー由来品種は, 44(37%)品種がCAS 209群（Table 3), 33（28%）がTKM 6群（Table 4), 4品種がMond Ba群（Table 5), 9品種がDZ 192群（Table 6), 3品種がJava 14群（Table 6）に分類され, 26品種が中度抵抗性品種群（MMMM）として分類され（Table 7), CAS 209優先型の分布が特徴的であった.