EFFECT OF WILD ABORTIVE CYTOPLASM INDUCING MALE STERILITY ON RESISTANCE / TOLERANCE AGAINST SIX RACES OF BACTERIAL LEAF BLIGHT IN SOME BASMATI RICE HYBRIDS

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ABSTRACT

Three cytoplasmic male sterile (cms or A) lines and their maintainers (B) lines were used as testers and crossed with 17 restorers (R) lines to study the association of wild abortive (WA) cytoplasm with genetic vulnerability to six BLB races viz., PXO61, PXO86, PXO79, PXO71, PXO112, & PXO99. Significant variation was observed among R lines for all the BLB races. Tester variances were both significant and non-significant depending on the race or tester. Line x tester variances were significant in most cases except two, one in case of IR58025A & B against race 3 and one in case of IR68280A & B for race 2. The difference in mean lesion length in 46 A x R and B x R F_1 crosses of IR70372A x restorers & IR70372B x restorers was negative & significant where as positive & significant difference in mean lesion length was observed in 42 A x R and B x R F_1 crosses. Only 13 A x R F_1 crosses showed non significant difference in mean lesion length when compared to their corresponding B x R F_1 crosses. However, on over all basis the difference in mean reaction of A x R and B x R F_1 crosses against six BLB races was significant for race 2, 3 & 6 and non-significant for race 1, 4 and 5. In case of IR58025A & IR58025B, difference in mean lesion length of 40 A x R and B x R F_1 crosses of IR58025A x restorers & IR58025B x restorers was negative & significant difference where as positive & significant difference in mean lesion length was observed in 42 F_1 crosses. In 15 cases the difference in mean lesion length of A x R and B x R F_1 crosses was non significant. However, on over all basis, the difference in mean lesion length of A x R and B x R F_1 crosses was negative & highly significant for race 5 only where as highly significant & positive difference was found for races 1, 2 &, 3 and non significant for two races; 4 & 6. Similarly in case of IR68280A & IR68280B, the difference in mean lesion length in 42 A x R and B x R F_1 crosses of IR68280A & restorers and IR68280B & restorers was highly significant & negative where as positive & significant difference in mean lesion length was found in 29 A x R and B x R F_1 crosses and non significant difference was observed only in 14 A x R and B x R F_1 crosses. On over all bases, the difference in mean reaction of A x R and B x R F_1 crosses of IR68280A & restorers and IR68280B & restorers was negative and highly significant for races 1, 3, & 4 and non-significant for races 2, 5 and 6. These results clearly indicate that the inconsistent behavior of all the three sets of A x R & B x R F_1 crosses against six BLB races is suggesting nucleo-cytoplasmic interaction rather than the association of WA cytoplasm parental cms (A) lines with susceptibility to bacterial leaf blight races.

Key words: Cms lines, Maintainer, Testers, Restorer, Wild abortive cytoplasm, Nucleo-cytoplasmic interaction and BLB.

INTRODUCTION

Bacterial leaf blight (BLB) caused by *Xanthomonas oryzae* pv. oryzae (XOO) is one of the oldest and important diseases of rice. It occurs globally from Asia to Africa and the America. Its distribution ranges from 20ºS in Queensland, Australia to 58ºN Heilang Jiang, China (Zhang Qi and Lin Shinchen, Chinese Academy of Agriculture Sciences), T.W. Mew (Per communication 1984) and from sea level to the Tibetan Plateau. It usually occurs more in wet season than in the dry season and in low lands than in favorable upland rice areas. Some reports available in literature also indicate that BLB some times causes considerable yield losses and impair grain quality particularly in Basmati rice varieties.

Incidence of BLB disease in Pakistan has increasing trend in recent years particularly in rice growing area of the Kallar belt as reported by Khan *et al*., (1998), They observed the appearance of BLB disease in all northern Districts in rice growing areas of the Punjab during their survey conducted in the crop season of 1997 and 1998. In Muridke, Narang and adjoining areas BLB was observed in patches showing 5-10 % disease. Khan *et al*., (2000) evaluated 39-lines / varieties (24 entries from RRI, Kala Shah Kaku and 15 from Nuclear Institute of Agriculture and Biology) against BLB at NIAB but non of the lines / varieties could express resistance against this disease. Only Basmati 370 was recorded as moderately resistant. Akhtar *et al*., (2003) reported that bacterial leaf blight (BLB) of rice incited by Xanthomonas oryzae pv. oryzae created a serious situation in rice during the crop year 2002. The survey was conducted in Punjab, Sindh, Balochistan, NWFP and

Azad Jammu & Kashmir during the year 2002 to study the latest situation of this menace. The disease incidence in Punjab ranged from 15-100, 10-70, 10-90, 15-65, 0-50, 0-100, 30-80, 50-70 & 40-50 in Sargodah, Hafizabad, Sheikhupura, Sialkot, Narowal, Gujrat, Lahore, Kasur and Okara, respectively where as severity of disease (%of infected tissue / area expressed on 0-9 scale) ranged from 1-7, 1-5, 1-5, 1-3, 0-5, 0-9, 3-3.5 and 3-5, respectively. Therefore, identification of resistant sources of bacterial leaf blight is very important for developing basmati rice hybrids.

Some reports available in the literature reveal that some cytoplasmic male sterile lines possessing wild abortive cytoplasmic male sterility (cms) system have resistance against certain insects and diseases. Kumar et.al. (1996) observed that two early duration (110 & 115 days) cms line viz., APMS1A (ARC) and APMS2A possess field resistance to gallmidge and bacterial leaf blight. Similarly another cms line, (APMS5A) of long duration (147 days) possessed resistance against brown plant hopper, BLB and rice tungro virus.

Scott and Futrell (1975) determined that nuclear gene resistance could overcome part but not all of the susceptibility associated with 'T' cytopl;asm to the disease *Bipolaris maydis*, Race T. Fleming *et al* (1960) found significant cytopasmic effect in double cross maize hybrids for agronomic traits and resistance against bud worm damage. Singh (1965, 1966) proposed that some cytoplasm may interact more frequently with nuclear genes to produce reciprocal effects in maize. Corn hybrids were devastated in 1970 by Southern corn blight disease (Helminthosporium maydis Nisik et Miyake), Ullistrup (1972). Although several cytoplasmic male sterility systems (cms) have been developed in rice, yet Wild Abortive (WA) cytoplasmic male sterility system is the most commonly used in China and other countries (Yuan 1977, Yuan and Virmani 1988). This cause hybrid rice potentially vulnerable to disease and insects susceptibility to which cytoplasmic male sterility may be found associated with.Initially rice hybrids were considered to be more susceptible to insects and diseases. Mew et.al., (1988) reported that in China, the incidence of stem borer, white backed plant hopper, leaf folder, bacterial leaf blight and virus diseases was more frequent on hybrid rices than the inbred rices. Out breaks of diseases such as downy mildew, false smut and kernal smut occurred frequently on hybrid rice. However, studies in China (Mew and Khush., 1981) and at IRRI (Virmani 1994) did not find any evidence to associate any disease or insect susceptibility in rice with WA cytoplasm that has been used most commonly for developing commercial rice hybrids. Certain rice hybrids have been found to possess resistance / tolerance against diseases and insects which indicate that new rice hybrids can be developed with required level of resistance / tolerance to major diseases and insects by selecting the appropriate parental lines. Therefore, the present study was undertaken to determine the association of WA cytoplasmic male sterility system with susceptibility to six races of bacterial leaf blight in Basmati rice hybrids.

MATERIALS AND METHODS

Preparation of Plant material: Ninety-eight F_1 crosses (49 A x R & 49 B x R crosses) and 23 parental lines (3 A & 3 B lines and 17 restorer lines) (IR68280A & restorers) were used for this study. Seeds of all the parental lines and their F_1 (A x R & B x R) crosses were sown in the seed boxes in the screen house of IRRI, Plant Breeding Genetics and Biochemistry Division for screening against 6 races of bacterial leaf blight viz. PXO61, PXO86, PXO79, PXO71, PXO112 and PXO99. Twenty-one days old seedlings were transplanted in single row plots in the concrete beds. Each single row plot consisted of five plants with 30 x 20 cm spacing. Single seedling was planted to each hill.

Preparation of inoculum: The bacterial strains maintained in the Bacterial Leaf Blight Laboratory of the Division of Plant Breeding, Genetics and Biochemistry at IRRI were used for this study. The bacteria of each strain were cultured on modified Wakimoto medium (WF-P) and incubated at 30ºC for 2-3 days. The inoculum was prepared by suspending each pure culture in sterile distilled water. Using a spectrophotometer, the absorbance of the inoculum was adjusted to A – 0.05 (620 mm) which correspond to a concentration of about 10^8 cells per millimeter

Inoculation of Plant materials: The parental lines and F_1 crosses were inoculated at booting stage (70 days after seeding) by clipping of the leaves 2-3 cm from the tip by a pair of sterilized scissors dipped in bacteria suspension. Inoculation of plants was done using six Philippine races (PXO61, PXO86, PXO79, PXO71, PXO112 and PXO99) and disease reaction was assessed 15 days after inoculation Scoring of the test materials: Disease resistance / susceptibility of the test materials was scored by using 1-9 scale described in Modified Standard Evaluation System for rice by International Rice Research Institute, (IRRI), 1996.

Statistical Analysis: Data were statistically analyzed using line x ester analysis with IRRI Stat program. Differences in cms lines, their maintainers and A x R & B x R F_1 crosses derived from them were determined by comparing their mean values and the significance of differences in mean values were computed using t- test.

RESULTS AND DISCUSSION

Results presented in table 1, 2 & 3 revealed that R lines showed significant variation for all the BLB races

studied except race 2 (PXO86). Tester variances were both significant and non-significant depending upon the race or tester. In case of line x testers, variances were significant for all races except for race 2 (PXO86) in case of IR68280A & B and for race 3 (PXO79) in case of IR58025A & B where the variances were non significant (table 2 & 3). These results indicated that the experimental materials used for present study had significant variation for host as well as pathogen to draw the appropriate conclusion.Results given in the table 4 depicted that mean difference in lesion length of cms (A) line, IR70372A and it's maintainer (B) line IR70372B was negative & significant against race 6 (PXO99) and positive & significant for race 2 (PXO86) while mean difference was non significant for remaining four races viz. race 1, 3, 4 & 5 (POX61, PXO79, PXO71 & PXO112). In case of IR58025A & B, the difference in mean lesion length was positive and significant against race 1, 2 & 3 where as negative and significant mean difference was observed against race 5 (PXO112) only. Among all the three A lines, IR68280A gave better results because difference in mean lesion length of IR68280A & B was highly significant and negative against race 3 & 4 ((PXO79 & PXO71). However, on over all bases, the mean difference in lesion length of the three A and B lines was negative & significant in four cases and non-significant in 10 cases against six BLB races. Positive & significant difference in mean lesion length of A & B lines was found in four cases only. These results showing inconsistent behavior of all the three A & B lines clearly indicated that WA cytoplasm has no association to susceptibility against BLB races. Reddy *et al*.(1988) also found similar findings in A & B lines for their susceptibility to BLB races. Kumar et.al., (1996) observed that two early duration (110 & 115 days) cms line viz., APMS1A (ARC) and APMS2A possess field resistance to gallmidge and bacterial leaf blight. The results described in table-5 revealed that eight out of 17 A x R F_1 (IR70372A x restorers) crosses of showed negative & highly significant difference in mean lesion length when compared to their corresponding B x R F_1 (IR70372B x restorers) crosses and 7 A x R F_1 crosses showed positive & significant difference against race 1. Non-significant difference in mean lesion length was found only in two A x R & B x R F_1 crosses. For race 2, six A x R F_1 crosses showed negative & highly significant difference in mean lesion length as compared to their corresponding B x R F_1 crosses and 10 A x R F_1 crosses showed positive & highly significant difference in mean lesion length as compared to their corresponding B x R F_1 crosses. Only one A x R F_1 cross showed non significant difference in mean lesion length as compared to their corresponding B x R F_1 crosses. In case of race 3 eight out of 17 A x R F_1 crosses showed negative & highly significant difference in mean lesion length when compared to their corresponding B x R F_1 crosses and six A x R F_1 crosses showed positive & highly significant difference in mean lesion length as compared to their corresponding B x R F_1 crosses. Where as difference in mean lesion length of 2 A x R & B x R F_1 crosses was non significant.

For race 4, five A x R F_1 (IR70372A x restorers) crosses out of 17 showed negative and highly significant difference in mean lesion length as compared to their corresponding B x R F_1 (IR 70372B x restorers) crosses and eight out of 17 A x R F_1 (IR70372A x restorers) crosses showed positive & highly significant difference in mean lesion length as compared to their corresponding B x R F_1 (IR70372B x restorers) crosses. Only two A x R F_1 cross showed non significant difference in mean lesion length as compared to their corresponding B x R F_1 crosses. For race 5, eight out of 17 A x R F_1 crosses showed negative & highly significant difference in mean lesion length when compared to their corresponding B x R F_1 crosses. Similarly eight out of 17 A x R F_1 crosses showed positive & significant difference against this race and non significant mean difference in mean lesion length was shown only by one A x R & B x R F_1 cross. For race 6, 11 A x R F_1 crosses out of 17, showed negative & highly significant difference in mean lesion length when compared to their corresponding B x R F_1 crosses and only four A x R F_1 crosses indicated significant and positive difference in mean lesion length as compared to their B x R F_1 crosses. Where as nonsignificant difference in mean lesion length was indicated by 2 A x R & B x R F_1 crosses only. On overall basis, the difference in mean.

Table 1: ANOVA for lines (R lines), testers (IR70372A & IR70372B) and line x testers for six races of BLB.

SOV	DF	Mean squares					
		Race 1	Race 2	Race 3	Race 4	Race 5	Race 6
Replications	2	1.1^{ns}	1.7^{ns}	5.9^{ns}	8.8^{ns}	12.4^{ns}	32.2^{ns}
Lines	16	153.7^{**}	115.0^{**}	102.2^{**}	103.9^{**}	107.8^{**}	110.1^{**}
Testers	1	1.4^{ns}	112.2^{*}	29.7^{ns}	2.7^{ns}	6.1^{ns}	81.2^{*}
Line x Testers	16	164.8^{**}	68.1^{**}	30.0^{**}	44.0^{*}	95.5^{**}	50.9^{**}
Residual	66	7.8	28.7	9.7	19.4	9.8	11.9

* = Significance at 5% ** = Significance at 5%, ns= not Significance

Table 2: ANOVA for lines (R lines), testers (IR58025A & IR58025B) and line x testers for six races of BLB.

SOV	DF	Mean squares					
		Race 1	Race 2	Race 3	Race 4	Race 5	Race 6
Replications	2	6.1 ns	35.3 ns	1.4 ns	6.4 ns	100.8**	44.9*
Lines	16	264.3**	67.3**	63.8**	134.5**	187.3**	97.0**
Testers	1	92.2**	45.5 ns	84.8*	4.6 ns	48.0 ns	5.9 ns
Line x Testers	16	73.0**	36.8*	27.1ns	52.1**	29.3*	28.4*
Residual	66	6.8	16.0		18.9	16.1	12.8

* = Significance at 5% * = Significance at 5%, s= not Significance

Table 3: ANOVA for lines (R lines), testers (IR68280A & IR68280B) and line x testers for six races of BLB.

SOV	DF	Mean squares					
		Race 1	Race 2	Race 3	Race 4	Race 5	Race 6
Replications	2	9.2 ns	6.6 ns	43.0 ns	35.2 ns	22.7 ns	4.8 ns
Lines	16	230.7	32.9 ns	94.4**	153.6**	59.6**	94.9**
Testers	1	38.7 ns	27.8 ns	94.0*	336.4**	0.5 ns	2.2 ns
Line x Testers	16	67.7**	22.0 ns	42.9*	36.4*	33.6*	60.7**
Residual	66	13.1	28.8	18.0	15.3	16.6	10.3

* = Significance at 5% ** = Significance at 5%, ns= not Significance

Table 4: Mean lesion length (cm) in cms (A) and maintainer (B) lines against six races of BLB.

Variety	Race 1	Race 2	Race 3	Race 4	Race 5	Race 6
IR70372A	9.9	15.3	13.2	12.7	9.4	16.4
IR70372B	9.7	13.2	14.3	13.1	8.9	18.2
Difference	0.2ns	2.1*	-1.1 ns	-0.4 ns	0.5 ns	-1.8*
IR58025A	11.5	13.8	15.4	11.3	9.1	13.8
IR58025B	9.5	12.3	13.5	11.8	10.5	14.3
Difference	2.0**	1.5 *	1.9*	-0.5 ns	-1.4*	-0.5 ns
IR68280A	9.9	12.8	13.6	9.7	8.9	12.4
IR68280B	11.2	13.9	15.6	13.6	8.8	12.8
Difference	-1.3 ns	-1.1 ns	-2.0**	-3.9**	0.2 ns	-0.4 ns

reaction of A x R & B x R F_1 crosses was negative & significant against three races (PXO86, PXO79 & PXO99) and similarly non significant for three races (PXO61, PXO71 and PXO112) also. This inconsistent reaction of A x R & B x R F_1 crosses of IR 70372A x restorers & IR 70372B x restorers indicate nucleo-cytoplasmic interaction rather than the effect of Wild Abortive cytoplasm of the cms line, IR70372A suggesting non association of the cms line with genetic vulnerability to all BLB races studied. Singh (1965, 1966) reported similar findings that some cytoplasm may interact more frequently with nuclear genes to produce reciprocal effects in maize. Scott and Futrell (1975) determined that nuclear gene resistance could overcome part but not all of the susceptibility associated with 'T' cytopl;asm to the disease *Bipolaris maydis*, Race T. The results presented in table 6, depicted that six out of 17 A x R F_1 (IR58025A x restorers) crosses exhibited significant and negative mean difference in lesion length as compared to their corresponding B x R F_1 (IR58025B x restorers) crosses against race 1. Eight A x R F_1 crosses out of 17 revealed significant & positive mean difference when compared to their corresponding B x R F_1 crosses and only three out of 17 A x R F_1 crosses exhibited non significant difference in mean lesion length as compared to their corresponding B x R F_1 crosses. For race 2, seven out of 17 A x R F_1 crosses expressed significant and positive mean difference in lesions length as compared to their corresponding B x R F_1 crosses. Only four A x R F_1 crosses indicated negative and significant difference in mean lesion length when compared to their corresponding B x R F_1 crosses. Non significant differences was observed between four A x R and B x R F_1 crosses only. In case of race 3, positive and significant mean differences in lesion length were found between 11 A x R & B x R F_1 crosses whereas only four A x R F_1 crosses out of 17 exhibited negative and highly significant difference in mean lesion length as compared to their corresponding B x R F_1 crosses. Only two A x R F_1 crosses revealed non significant difference in mean

lesion length when compared to their corresponding B x R F_1 crosses.

As far as race 4 is concerned, eight out of 17 A x R F_1 (IR58025 A x restorers) crosses showed negative & highly significant difference in mean lesion length when compared to their corresponding B x R F_1 crosses (IR58025B x restorers) and 7 A x R F_1 crosses showed highly significant & positive difference in mean lesion length as compared to their corresponding B x R F_1 crosses. However, non-significant difference in mean lesion length was found only in one A x R & B x R F_1 cross. In case of race 5, 10 out of 17 A x R F_1 crosses (IR58025A x restorers) showed negative & highly significant difference in mean lesion length when compared to their corresponding B x R F_1 crosses (IR58025 B x restorers) and 4 A x R F_1 crosses showed highly significant & positive difference in mean lesion length as compared to their corresponding B x R F_1 crosses. However, non significant difference in mean lesion length was depicted by three A x R & B x R F_1 crosses. For race 6, eight out of 17 A x R F_1 crosses (IR58025A x restorers) showed negative & highly significant difference in mean lesion length when compared to their corresponding B x R F_1 crosses (IR58025 B x restorers) and 5 A x R F_1 crosses showed highly significant & positive difference in mean lesion length as compared to their corresponding B x R F_1 crosses. Only two A x R F_1 crosses depicted non significant difference in mean lesion length as compared to their corresponding B x R F_1 crosses. On over all bases, A x R & B x R F_1 crosses showed highly significant & negative difference in mean length against race 5 only. Highly significant and positive difference was found against races 1, 2 & 3 and non significant difference was found against races 2 & 6. The different behavior of all the A x R and B x R crosses of IR58025A and IR58025B do not reveal affect of wild abortive cytoplasm it rather indicate the nucleocytoplasmic influence for resistance / tolerance against all the BLB races. Scott and Futrell (1975) determined that nuclear gene resistance could overcome part but not all of the susceptibility associated with 'T' cytoplasm to the disease *Bipolaris maydis*, Race T. Fleming *et al* (1960) found significant cytopasmic effect in double cross maize hybrids for agronomic traits and resistance against bud worm damage. Singh (1965, 1966) reported similar findings that some cytoplasm may interact more frequently with nuclear genes to produce reciprocal effects in maize.

The results described in table 7 revealed that six out of 15 A x R F_1 (IR68280A x restorers) crosses exhibited negative and significant mean difference in lesion length when compared to their corresponding B x R F_1 (IR68280B x restorers) crosses against race 1. Similarly six out of 15 A x R F_1 crosses exhibited positive and significant mean difference in lesion length as compared to their corresponding B x R F_1 crosses. Non significant difference in mean lesion length was observed only between three A x R and B x R F_1 crosses. For race 2, seven out of 15 A x R F_1 crosses revealed significant and negative mean difference in lesion length as compared to their corresponding B x R F_1 crosses. Only three A x R F_1 crosses indicated significant and positive mean difference in lesion length as compared to their corresponding B x R F_1 crosses and five A x R F_1 crosses out of 15 showed non significant difference in mean lesion length when compared to their corresponding B x R F_1 crosses. In case of race 3, like race 2, seven out of 15 A x R F_1 crosses revealed significant and negative mean difference in lesion length as compared to their corresponding B x R F_1 crosses. Five A x R F_1 crosses indicated significant and negative mean difference in lesion length as compared to their corresponding B x R F_1 crosses and only three out of 15 A x R F_1 crosses showed non significant difference in mean lesion length when compared to their corresponding B x R F_1 crosses. In case of race 4, 10 out of 15 A x R F_1 (IR68280A x restorers) crosses revealed significant and negative mean difference in lesion length as compared to their corresponding B x R F_1 crosses. Only two A x R F_1 crosses indicated significant and positive mean difference in lesion length as compared to their corresponding B x R F_1 crosses and only three out of 15 A x R F_1 crosses showed non significant difference in mean lesion length when compared to their corresponding B x R F_1 crosses. For race 5, four out of 15 A x R F_1 crosses showed significant and negative mean difference in lesion length as compared to their corresponding B x R F_1 crosses and seven A x R F_1 crosses indicated significant and positive mean difference in lesion length as compared to their corresponding B x R F_1 crosses. Only four out of 15 A x R F_1 crosses showed non significant difference in mean lesion length when compared to their corresponding B x R F_1 crosses. In case of race 6, eight out of 15 A x R F_1 crosses indicated significant and negative mean difference in lesion length as compared to their corresponding B x R F_1 crosses and six A x R F_1 crosses showed significant and positive mean difference in lesion length as compared to their corresponding B x R F_1 crosses. Only one A x R (IR68280A x IR68459-13-1-2) F_1 cross out of 15, showed non significant difference in mean lesion length when compared to it's corresponding B x R F_1 ((IR68280A x IR68459-13-1-2) cross. However on overall basis, the difference in mean lesion length of A x R & B x R F_1 (I68280A x restorers & IR68280B x restorers) & crosses was highly significant and negative against 3 races 1, 3 & 4 (PXO61, PXO79 & PXO71) and non significant for race 2, 5 & 6 respectively (PXO86, PXO112, & PXO99). These results indicated that the cytoplasm of IR 68280A was not associated with genetic vulnerability to the BLB races studied. All the above results provided clear evidence that WA cytoplasm of all cms lines; IR70372A,

Table 5: Mean lesion length (cm) of A x R & B x R crosses of IR70372A and IR70372B with 17 restorers against six races of BLB

Restorer lines	Race1			Race2			Race3			Race4			Race5			Race6		
	Ax R	Bx R	Diff	Ax R	Bx R	Diff	Ax R	Bx R	Diff	Ax R	Bx R	Diff	Ax R	Bx R	Diff	Ax R	Bx R	Diff
IR67423-47-3-1	4.7	5.7	-1.0*	6.0	4.3	1.7**	16.1	4.7	11.3**	23.7	13.0	10.7**	12.7	16.3	-3.7**	6.0	6.0	0.0^{ns}
IR67423-226-3-2-3-2	19.0	14.0	5.0**	18.7	18.3	0.7^{ns}	13.3	7.3	6.0**	18.3	25.7	-7.3**	17.0	8.0	9.0**	14.7	14.3	0.3^{ns}
IR67423-234-3-2-3-2	24.7	1.3	23.3**	15.0	8.3	6.7**	15.7	17.3	-1.7**	21.3	27.0	-5.7**	19.3	24.0	-4.7**	14.3	12.7	1.7**
IR67888-127-3	12.3	21.3	-9.0**	16.0	13.3	2.7**	11.0	12.0	-1.0*	20.0	19.3	0.7^{ns}	11.7	14.3	-2.7**	11.0	12.7	-1.7**
IR67900-10-3	3.3	4.7	-1.3**	12.3	25.0	-12.7**	9.7	5.0	4.7**	13.0	19.0	-6.0**	20.7	15.0	5.7**	17.0	17.3	-0.3^{ns}
IR67904-79-2	15.7	19.3	-3.7**	15.7	14.7	1.0*	8.7	14.0	-5.3**	16.3	14.7	1.7**	14.7	8.7	6.0**	13.3	12.0	1.3**
IR67924-17-2-2	15.7	17.3	-1.7**	16.3	19.7	-3.3**	11.0	13.3	-2.3**	14.7	20.3	-5.7**	14.0	18.7	-4.7**	16.3	10.3	6.0**
IR67417-2-1	0.0	21.3	-21.3**	12.3	17.3	-5.0**	4.0	3.3	0.7^{ns}	0.0	11.0	-11.0**	0.0	8.7	-8.7**	0.0	12.7	-12.7**
IR68457-10-2	2.7	19.0	-16.3**	11.7	21.0	-9.3**	4.3	18.0	-13.7**	19.3	21.7	-2.3**	20.7	18.0	2.7**	20.0	19.0	1.0*
IR68459-13-1-2	23.0	7.0	16.0**	19.7	11.0	8.7**	2.0	13.3	-11.3**	22.7	17.0	5.7**	28.3	14.3	14.0**	17.0	19.0	-2.0**
IR68461-34-1-3	12.7	3.0	9.7**	9.0	11.7	-2.7**	17.3	4.0	13.3**	17.7	18.0	-0.3^{ns}	12.3	22.0	-9.7**	17.7	18.7	-1.0*
IR68737-61-1-3	4.7	5.0	-0.3^{ns}	8.3	4.3	4.0**	3.3	2.3	1.0*	10.0	17.3	-7.3**	13.3	12.7	0.7^{ns}	22.7	19.7	3.0**
IR67418-20-3-1-3	7.0	4.7	2.3**	9.3	8.0	1.3*	7.7	2.7	5.0**	14.3	16.0	-1.7**	16.7	12.7	4.0**	10.0	12.3	-2.3**
IR67418-238-6-6-3-2	5.7	4.7	1.0*	11.3	12.0	-0.7^{ns}	1.7	7.0	-5.3**	10.7	13.0	-2.3**	14.7	7.7	7.0**	11.0	17.3	-6.3**
IR67419-144-2-3-2-3	7.0	4.3	2.7**	11.0	9.7	1.3*	4.0	2.0	2.0**	19.0	20.0	-1.0*	16.3	7.7	8.7**	9.0	15.3	-6.3**
IR67420-48-3-6-3	3.7	5.7	-2.0**	11.0	10.7	0.3^{ns}	7.3	15.7	-8.3**	14.3	20.7	-6.3**	12.7	8.0	4.7**	11.0	14.7	-3.7**
IR67422-226-3-5-2	7.3	6.7	0.7^{ns}	-	-	-	22.7	9.3	13.3**	23.3	15.3	8.0**	15.0	7.7	7.3**	14.0	9.3	4.7**
Mean	9.9	9.7	0.2^{ns}	12.7	13.1	-0.3^{ns}	9.4	8.9	0.5^{ns}	16.4	18.2	-1.8**	15.3	13.2	2.1*	13.2	14.3	-1.1*

* = Significant at 5%, ** = significant at 1% ns = not significant A x R = IR70372A x Restorers, B x R = IR70372B x Restorers

Table 6: Mean lesion length (cm) of A x R & B x R crosses of IR58025A and IR58025B with 17 restorers against six races of BLB

Restorer lines	Race1			Race2			Race3			Race4			Race5			Race6		
	Ax R	Bx R	Diff	Ax R	Bx R	Diff	Ax R	Bx R	Diff	Ax R	Bx R	Diff	AxR	BxR	Diff	Ax R	Bx R	Diff
IR67415-170-2-2-2	14.3	15.0	-0.7^{ns}	14.3	16.0	-1.7**	4.7	11.0	-6.3**	9.3	12.0	-2.7**	7.3	8.0	-0.7^{ns}	14.7	15.0	-0.3^{ns}
IR67423-47-3-1-1	8.0	12.0	-4.0**	4.7	6.0	-1.3**	2.0	6.3	-4.3**	11.3	15.3	-4.0**	12.0	7.7	4.3**	13.3	6.0	7.3**
IR67423-226-3-2-3-2	18.7	18.0	0.7^{ns}	9.7	14.0	-4.3**	6.0	10.0	-4.0**	11.3	18.3	-7.0**	13.7	17.3	-3.7**	11.0	15.7	-4.7**
IR67423-234-3-3-3-2	21.7	20.0	1.7**	24.0	17.3	6.7**	15.3	17.7	-2.3**	20.0	16.3	3.7**	13.0	12.7	0.3^{ns}	17.7	14.3	3.3**
IR67888-127-3	25.0	6.7	18.3**	22.3	16.7	5.7**	23.3	13.0	10.3**	22.3	22.0	0.3^{ns}	15.0	11.3	3.7**	15.3	20.7	-5.3**
IR67900-10-3	4.0	1.3	2.7**	9.3	5.0	4.3**	3.3	6.7	-3.3**	16.0	9.7	6.3**	18.3	16.7	1.7**	19.0	16.7	2.3**
IR67904-79-2	15.3	13.3	2.0**	14.7	9.0	5.7**	14.3	18.3	-4.0**	18.3	10.7	7.7**	10.0	14.0	-4.0**	12.7	10.7	2.0**
IR67924-75-4-3-2	16.3	17.7	-1.3**	16.0	14.0	2.0**	6.3	13.0	-6.7**	20.0	16.3	3.7**	18.3	22.7	-4.3**	17.7	16.3	1.3**
IR67417-2-1	1.0	2.0	-1.0*	12.7	7.3	5.3**	11.7	13.7	-2.0**	6.7	12.7	-6.0**	13.7	13.3	0.3^{ns}	6.7	9.7	-3.0**
IR68457-10-2	17.7	19.0	-1.3**	8.0	22.0	-14.0**	17.0	18.0	-1.0^{ns}	18.3	22.0	-3.7**	12.7	3.7	9.0**	23.0	16.3	6.7**
IR68459-13-1-2	12.0	1.7	10.3**	14.0	9.0	5.0**	15.0	11.3	3.7**	11.0	9.7	1.3**	15.0	11.3	3.7**	16.0	8.7	7.3**
IR68461-34-1-3	22.3	6.7	15.7**	3.0	7.0	-4.0**	15.3	16.3	-1.0^{ns}	11.3	11.3	0.0^{ns}	16.7	14.7	2.0**	17.7	13.0	4.7**
IR68737-61-1-3	1.0	5.3	-4.3**	11.3	10.7	0.7^{ns}	2.0	1.0	1.0^{ns}	13.3	15.0	-1.7**	11.0	11.7	-0.7^{ns}	13.0	17.0	-4.0**
IR67419-144-2-3-2-3	2.7	1.3	1.3**	8.0	15.7	-7.7**	3.3	9.3	-6.0**	8.3	10.7	-2.3**	10.0	13.7	-3.7**	18.3	17.3	1.0*
IR67419-234-1-2-3-2	1.7	11.3	-9.7**	6.3	11.7	-5.3**	4.3	3.0	1.3**	8.7	12.0	-3.3**	19.7	6.3	13.3**	14.0	6.0	8.0**
IR67420-48-3-6-3	9.7	8.3	1.3**	3.0	7.0	-4.0**	7.0	2.7	4.3**	-	-	-	-	-	-	14.7	12.	2.3**
IR67421-255-3-6-2	3.3	2.7	0.7^{ns}	-	-	-	3.7	6.7	-3.0**	-	-	-	-	-	-	16.3	31.4.3	2.0**
Mean	11.5	9.5	1.9**	11.3	11.8	-0.4^{ns}	9.1	10.5	-1.4**	13.8	14.3	-0.5^{ns}	13.8**	12.3**	1.4**	15.4	13.5	1.8**

* = Significant at 5%, ** = significant at 1% ns = not significant A x R = IR58025A x Restorers, B x R = IR58025B x Restorers

Table 7: Mean lesion length (cm) of A x R & B x R crosses of IR68280A and IR68280B with 15 restorers against six races of BLB

Restorer lines	Race1			Race2			Race3			Race4			Race5			Race6		
	Ax R	Bx R	Dif	Ax R	Bx R	Dif	Ax R	Bx R	Dif	AxR	Bx R	Dif	AxR	Bx R	Dif	AxR	Bx R	Dif
IR67423-23-2-4	13.3	4.3	+9.0**	16.7	10.3	+6.3**	3.7	13.0	-9.3**	5.0	8.0	-3.0**	15.0	14.3	0.7^{ns}	12.3	11.7	0.7^{ns}
IR67423-208-2-1-2-2	3.0	3.3	-0.3^{ns}	6.7	7.0	-0.3^{ns}	9.0	8.0	1.0^{ns}	11.3	13.0	-1.7*	13.3	8.7	+4.7**	22.7	17.7	+5.0**
IR67423-226-3-2-3-2	5.7	17.7	-12.0**	10.0	10.0	0.0	7.3	13.7	-6.3**	7.3	22.3	-15.0**	12.7	15.7	-3.0**	10.0	13.7	-3.7**
IR67423-234-3-3-3-2	23.0	15.7	+7.3**	22.7	24.7	-2.0**	14.0	11.7	+2.3**	20.3	14.7	+5.7**	16.0	17.3	-1.3^{ns}	21.0	19.3	+1.7**
IR67924-17-2-2	13.7	18.3	-4.7**	11.7	15.0	-3.3**	14.7	10.0	+4.7**	12.7	11.3	+1.3**	17.3	13.3	+4.0**	21.0	16.7	+4.3**
IR67924-75-4-3-2	23.0	15.3	+7.7**	12.7	22.3	-9.7**	8.3	15.0	-6.7**	26.7	15.7	+11.0**	14.3	16.3	-2.0*	16.7	16.7	0.0
IR67417-2-1	3.7	3.3	0.3^{ns}	12.7	19.0	-6.3**	3.3	2.7	0.7^{ns}	17.0	19.0	-2.0**	17.3	17.3	0.0	14.0	16.3	-2.3**
IR68457-10-2	20.7	18.7	+2.0**	6.0	14.0	-8.0**	11.3	9.0	+2.0**	15.3	8.0	+7.3**	10.3	9.7	0.7^{ns}	20.0	17.0	+3.0**
IR68459-13-1-2	13.3	18.0	-4.7**	11.3	22.0	-10.7**	10.7	10.7	0.0	13.0	13.3	-0.3^{ns}	12.0	16.3	-4.3**	11.3	22.7	-11.3**
IR68737-61-1-3	4.7	3.0	+1.7**	8.0	5.7	+2.3**	8.3	2.0	+6.3**	8.3	14.0	-5.7**	7.7	18.0	-10.3**	11.0	9.7	+1.3*
IR67418-20-3-1-3	3.3	14.7	-11.3**	6.7	14.0	-7.3**	9.0	5.7	+3.3**	4.0	10.3	-6.3**	13.0	15.0	-2.0*	9.3	20.3	-11.0**
IR67419-144-2-3-2-3	4.0	14.3	-10.3**	5.0	15.0	-10.0**	7.3	11.7	-4.3**	14.3	8.3	+6.0**	10.3	13.3	-3.0**	10.7	14.3	-3.7**
IR67419-234-1-2-3-2	4.0	4.0	0.0	3.3	7.3	-4.0**	12.7	6.7	+6.0**	12.3	13.7	-1.3**	10.3	9.3	1.0^{ns}	6.7	6.0	0.7^{ns}
IR67420-48-3-6-3	12.7	11.3	+1.3*	4.3	9.0	-4.7**	11.7	10.0	+1.7**	8.0	10.3	-2.3**	13.7	10.7	+3.0**	10.0	16.0	-6.0**
IR67421-255-3-6-2	1.0	6.7	-5.7**	8.3	8.7	-0.3^{ns}	3.0	2.0	1.0^{ns}	11.0	9.3	+1.7**	8.7	13.3	-4.7**	7.3	16.7	-9.3**
Mean	9.9	11.2	-1.3**	9.7	13.6	-3.9**	8.9	8.8	0.2^{ns}	12.4	12.8	-0.3^{ns}	12.8	13.9	-1.1^{ns}	13.6	15.6	-2.0**

* = Significant at 5%, ** = significant at 1%, ns = not significant, A x R = IR68280A x Restorers, B x R = IR68280B x Restorers

IR58025A and IR68280A was not associated with susceptibility to 6 races of BLB. On the other hand it showed positive effect on disease resistance in several crosses. Mew (1988) also stated that there was no report or evidence in support of susceptibility to disease with WA cytoplasm in rice. Scott and Futrell (1975) observed that nuclear gene resistance could overcome part but not all of the susceptibility associated with 'T' cytopl;asm to the disease *Bipolaris maydis*, Race T.

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