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INHERITANCE OF MAJOR GENES FOR RICE BLAST RESISTANCE IN SOME EGYPTIAN VARIETIES

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ABSTRACT: *Japanese differential varieties, known to contain specific blast resistant genes, were used in crosses with Egyptian varieties to understand the inheritance of major genes for rice blast resistance. Three types of experimental crosses were conducted: (resistant x resistant); (resistant x susceptible) and (susceptible x susceptible). Genetic analysis of their F1 and F2 populations showed that the five-resistant varieties namely; Toride 1, Shin 2, Fukunishiki, Giza 177, and Sakha 103 contain either one or two different leaf blast resistant gene(s). The varieties Toride 1 and Shin 2 contain two resistance genes (AABB), while the other three varieties contained one resistance gene, which varied from Fukunishiki (BB) to Giza 177 and Sakha 103 (AA). Correlation coefficients (CCs) were estimated among the nine rice varieties for eleven agronomic characters with blast infection. Positive correlations of three vegetative characters; heading date, plant height and flag leaf area with blast infection were observed. Thousand-grain weight had highly negative CC with blast infection while unfilled grains per panicle expressed positive correlation.*

Key words: Rice varieties, Resistant, Susceptible, Blast inheritance .

INTRODUCTION

Rice blast, caused by the fungus *Pyricularia grisea,* is the most devastating rice disease worldwide. In Egypt, Sehly *et al.*, (1988) found that the percentage of yield losses in grain yield of untreated plots with susceptible c.v. Giza 159 was 23%, 31.89% and 9.14% in 1982, 1983 and 1984, respectively. The most economical way of controlling this disease is by growing resistant varieties (Bastawisi, 1988, Correa *et al.*, 1995 and Aidy *et al.*, 2000). However, in most cases, the resistance of these varieties breaks down few years after they are released (Maximos, 1974, Lee *et al.*, 1976; Bonman and Rush 1985; and Ahn and Mukelar 1986 and Aidy *et al.*, 2000). Complete resistance to rice blast may be conferred by dominant, incomplete dominant or recessive genes (Mackill and Bonman, 1992). Fifteen major genes for blast resistance have been identified and symbolized by Pi numbers (Kinoshita 1989). Breakdown of the resistance of an improved variety frequently occurs some years after its release, therefore, genetic analysis of a variety resistance has exceptional importance.

The possible blast disease infection influence on the agronomic characters was studied before (Kiyosawa *et al.*, 1983 and Abd El-Khalek, 2001). It is useful to know how selection of any agronomic trait in a breeding program influences the blast disease resistance and to determine if it would be possible to use other traits as indicator of blast resistance.

The main goal of this study was to understand the genetic basis of major blast resistance in some rice Egyptian varieties and few exotic varieties (Japanese differential varieties). Also, correlation coefficients were estimated among the nine rice varieties and their 36 F1 hybrids for eleven agronomic characters with blast resistance.

MATERIALS AND METHODS

This study was carried out at the Experimental Farm of Rice Research and Training Center (RRTC), Sakha, Kafr El-Sheikh, Egypt, during the rice growing seasons 1998, 1999, 2000 and 2001. Nine varieties were chosen to study their major genes inheritance. Four of them from the Japanese differential and they are known to contain specific blast resistant genes; Fukunishiki (Pi-z), PiNo.4 (Pi-ta2), Shin 2 (Pi-ks) and Toride 1 (Pi-zt) (or Pi-2, Pi-4a, Pi-1 and or Pi-2 respectively, Kiyosawa *et al.*, 1983). Giza 159, Giza 171, Giza 176, Giza 177 and Sakha 103 as Egyptian varieties were used. The nine parental varieties were evaluated in two successive seasons of 1998 and 1999. A half diallel cross was conducted among the nine parents in 1998 to produce 36 crosses. The hybridization technique of Jodon (1938) and modified by Butany (1961), using the hot water method for emasculation, was utilized. The parental varieties and the resulting 36 crosses were arranged in a randomized complete block design experiment with three replications in 1999. The spreader variety Giza 159 was grown around the experiment and high doses of fertilizer were added to increase infection rate. The parents, F1 and F2 materials were planted and evaluated in the season of 2000. Each F2 population consisted of more than 200 plants and blast reaction was recorded according to the standard evaluation system for rice in a scale of 0-9 (International Rice Research Institute, 1996).

Pearson correlation coefficients were estimated among the nine rice varieties and their 36 F1 hybrids for eleven agronomic characters namely; heading date, plant height, number of tillers per plant, flag leaf area, grain yield per plant, 1000 grain weight, panicle weight, number of panicles per plant, number of filled grains per panicle, panicle length and number unfilled grains per panicle.

RESULTS

Nine varieties were chosen to study major genes inheritance for blast resistance. Four of them were from the Japanese differential varieties that were known to contain specific blast resistant genes, while the rest of the varieties were Egyptian ones. Table (1) represents the pedigree and blast reaction of two years evaluation of these varieties. Five varieties were scored as resistant varieties (R); They are Fukunishiki, Shin2, Toride 1, Giza 177 and Sakha 103, while four were scored as susceptible varieties (S); Giza 159, Giza 171, Giza 176 and Pi No 4.

Table (1): Origin, parentage and blast reaction based on two years evaluation of the studied nine parental rice varieties.

No.	Variety	Origin	Parentage	*Blast reaction
1	Giza 159	Egypt	Giza 14/Agami M1.	7
2	Giza 171	Egypt	Nahda / Calady 40	7
3	Giza 176	Egypt	Calrose 76/Giza 172//Gz 242	5
4	Pi No.4	Japan	TA 820b / Norin 8	5
5	Giza 177	Egypt	Giza171/YomjiNo.1//Pi No.4	3
6	Toride1	Japan	Tkm1/Norin 8*5	3
7	Shin 2	Japan	Kamano-O/Kairyoaikoku	2
8	Fuknishiki	Japan	Kinkius45/Kinkius11//Zenth/3/Kinkius 45/Kinkius11/4Hatsunishiki	2
9	Sakha 103	Egypt	Giza 177/Suweon 349	2

*Blast reaction 1 to 3 = Resistance
*Blast reaction 4 to 10 = Susceptible

Thirty-six cross combinations of the nine resistant and susceptible varieties were established. The F1 and F2 generations of the thirty-six crosses were performed to study the inheritance of resistance to leaf blast under natural field conditions. The 36 crosses were classified into three groups; 1) resistant x resistant (10 crosses), 2) resistant x susceptible (20 crosses) and 3) susceptible x susceptible (six crosses).

Group 1: resistant x resistant crosses:

Ten crosses were conducted to study the inheritance of resistance to blast using the five resistant varieties namely; Toride 1, Shin 2, Fukunishiki, Giza 177 and Sakha 103 (Table 2). The obtained data showed that all parents and their F1 generations were resistant and this indicated that the used parents carry dominant genes for resistance with resistance completely dominant over susceptibility for leaf blast. Data obtained from F2 generations can be categorized into two groups based on segregation ratios. The first group, included eight F2 populations, segregated in a ratio of 1 R to 0 S (Table 2), indicating that the resistance gene (s) in those parents could be the same or allelic. On the other hand, the second group of F2 populations segregated in a ratio of 15 R to 1 S included two populations produced from the crosses Fukunishiki x Giza 177 and Fukunishiki x Sakha 103 (crosses number 8 and 9, table 2). The ratio 15 (R) to 1 (S) suggested that two genes of leaf blast resistance were segregating in these crosses and that each gene can express resistance in its genetic parental background.

Group 2: resistant x susceptible crosses:

Twenty crosses were produced among five resistant varieties (Toride 1, Shin 2, Fukunishiki, Giza 177 and Sakha 103), and four susceptible varieties (Giza 159, Giza 176, Giza 171 and PiNo 4). In all cases, the F1 hybrids were resistant (Table 3) indicating that resistance was dominant over susceptibility.

Table (2): Type of infection of F1 and F2 generations produced from resistance x resistance crosses

No.	Crosses	F_1	Type of infection for F2							Phenotypic distribution		Tested ratio	X^2 value	Probability value
			1	2	3	4	5	6	7	R	S	R : S		
	Resistance X Resistance.													
1	Toride1 x Shin 2	R	50	102	100	--	--	--	--	252	0	1 : 0		
2	Toride1 x Fukinishiki	R	100	140	46	--	--	--	--	286	0	1 : 0		
3	Toride1 x Giza 177	R	115	176	59	--	--	--	--	320	0	1 : 0		
4	Toride1 x Sakha 103	R	114	126	58	--	--	--	--	298	0	1 : 0		
5	Shin 2 x Fukinishiki	R	100	121	42	--	--	--	--	263	0	1 : 0		
6	Shin 2 x Giza 177	R	95	110	70	--	--	--	--	275	0	1 : 0		
7	Shin 2 x Sakha 103	R	84	116	115	--	--	--	--	315	0	1 : 0		
8	Fukinishiki x Giza 177	R	100	82	80	10	4	2	1	262	17	15 : 1	0.012	0.914
9	Fukinishiki x Sakha 103	R	80	150	70	12	5	--	--	300	17	15 : 1	0.425	0.514
10	Giza 177 x Sakha 103	R	160	100	--	--	--	--	--	260	0	1 : 0		

Two types of F2 progeny segregation were occurred in this group for blast reaction (Table 3). The first type gave a segregation ratio of 15 R to 1 S in F2 progenies and included the resistant parents namely, Toride 1 and Shin 2 crossed by susceptible parents namely, Giza 159, Giza 176, Giza 171 and PiNo 4 (crosses 1 to 8 in table 3). The F2 progenies of these crosses showed that the used resistant parents (Toride 1 and Shin 2) carry two dominant resistance genes, while the susceptible parents (Giza 159, Giza 171, Giza 176 and PiNo 4) carry their recessive alleles. The second type of F2 population gave a segregation ratio of 3 R to 1 S and produced from crosses of resistant parents, Fukunishiki, Giza 177, and Sakha 103 with the same susceptible parents (crosses 9 to 20 in table 3). The F2 progenies of these crosses indicated that the resistance transferred from these parents to their offspring was proven to be dominant in its nature and might be controlled by one major gene.

Group 3: susceptible x susceptible crosses:

Six crosses were resulted from diallel crosses among all susceptible varieties namely; Giza 159, Giza 171, Giza 176 and Pi No 4 (Table 3). The F1 plants of all crosses were susceptible, while F2 populations showed no resistant plants. These results showed that all the susceptible parents carry recessive genes for leaf blast resistance.

Association of blast disease infection with vegetative, yield and yield's component characters:

Pearson correlation coefficients were estimated among the nine rice varieties and their 36 F1 hybrids for 11 agronomic characters (Table 4). Three types of significant correlation were observed; highly positive, positive and highly negative correlations.

A highly significant positive correlation between blast reaction and heading date was achieved. This result revealed that the long duration of rice plant increased infection with blast disease. This phenomenon may be due to the long period where the vegetative parts are exposed to the blast fungus infection. A significant positive correlation between blast infection and plant height was observed. This result indicated that the long stature varieties showed more susceptibility to the blast infection than short ones. This may be due to the fact that vegetative parts of long varieties are more exposed to infection than the short ones. At the same time, the correlation between blast reaction and flag leaf area was positively significant i.e., by increasing the flag leaf area, the blast susceptibility increased. This positive correlation of the three vegetative characters; heading date, plant height and flag leaf area with blast infection indicated that not only the importance of these characters for blast resistance but also the possibility of using these characters for indirect selection for blast resistance.

Table (3): Type of infection of F1 and F2 generations produced from resistance x susceptible and susceptible x susceptible crosses.

No.	Crosses	F1	Type of infection for F2							Phenotypic values		Tested ratio R : S	x^2	Probability value
	Resistance X Susceptible.		1	2	3	4	5	6	7	R	S			
1	Toride1 x Giza 159	R	68	102	85		10	3	2	255	15	15:1	0.222	0.637
2	Toride1 x Giza 176	R	32	157	18	8	11	1	1	207	13	15:1	3.410	0.064
3	Toride1 x Giza 171	R	54	115	125	10	6	2	2	294	20	15:1	0.007	0.930
4	Toride1 x Pi no 4	R	60	161	45	5	8	7	3	266	23	15:1	1.439	0.230
5	Shin 2 x Giza 159	R	67	102	110	4	8	6	4	279	22	15:1	0.576	0.447
6	Shin 2 x Giza 176	R	43	164	60	5	2	3		267	10	15:1	3.290	0.069
7	Shin 2 x Giza 171	R	30	230	67	7	7	6	3	327	23	15:1	0.062	0.803
8	Shin 2 x Pi no 4	R	100	85	70	10	5	8	2	255	23	15:1	3.420	0.064
9	Fukinishiki x Giza 159	R	60	71	63	30	18	18	3	194	67	3:1	0.214	0.643
10	Fukinishiki x Giza 176	R	80	107	46	50	16	9	5	233	80	3:1	0.521	0.214
11	Fukinishiki x Giza 171	R	52	67	70	8	40	10	8	189	66	3:1	0.105	0.744
12	Fukinishiki x Pi no 4	R	33	92	75	22	10	14	13	200	59	3:1	0.512	0.473
13	Giza 177 x Giza 159	R	80	66	68	35	25	11	4	214	75	3:1	0.139	0.708
14	Giza 177 x Giza 176	R	47	103	86	28	32	20	6	236	86	3:1	0.501	0.479
15	Giza 177 x Giza 171	R	90	84	49	15	20	25	11	223	60	3:1	0.113	0.736
16	Giza 177 x Pi no 4	R	100	89	44	50	22	18	7	233	97	3:1	0.931	0.334
17	Sakha 103 x Giza 159	R	48	78	86	36	29	10	3	212	78	3:1	0.556	0.455
18	Sakha 103 x Giza 176	R	80	94	43	30	24	15	8	217	79	3:1	0.222	0.637
19	Sakha 103 x Giza 171	R	77	110	37	42	20	13	7	224	82	3:1	0.527	0.467
20	Sakha 103 x Pi no 4	R	89	96	58	40	33	10	4	243	87	3:1	0.227	0.772
	Susceptible X Susceptible.													
1	Giza 159 x Giza 176	S				18	112	80	50	0	260	0:1		
2	Giza 159 x Giza 171	S				45	140	80	30	0	295	0:1		
3	Giza 159 x Pi no 4	S				71	123	41	17	0	251	0:1		
4	Giza 176 x Giza 171	S				98	104	61	22	0	285	0:1		
5	Giza 176 x Pi no 4	S				137	58	51	28	0	274	0:1		
6	Giza 171 x Pi no 4	S				55	147	98	50	0	350	0:1		

Table (4): Pearson correlation coefficients between agronomic characters and blast infection trait derived from means for 11rice varieties.

No.	Agronomic characters	Blast infection
1	Heading date (days)	0.279**
2	Plant height (cm)	0.213*
3	Number of tillers /plant	0.185
4	Flag leaf area (cm2)	0.222*
5	Grain yield /plant (gm)	- 0.036
6	1000 grain weight (gm)	- 0.287**
7	Number of panicle /plant	0.157
8	Number of filled grains/panicle	0.126
9	Panicle length (cm)	0.423
10	Panicle weight (gm)	- 0.087
11	Number of unfilled grains/panicle	0.252*

* = Correlation is significant at 0.05 level of probability

** = Correlation is significant at 0.01 level of probability

While one yield character, 1000-grain weight, showed highly negative correlation with blast infection i.e., blast reaction decreased the 1000-grain weight, another yield character, the number of unfilled grains per panicle, expressed positive correlation.

Discussion

Results of F1 generation resulted from the ten R X R crosses that produced all resistant plants (Table 2) agree with Omar *et al.* 1970, Maximos 1974, Balal *et al.* 1977, Aidy 1984 and Maximos *et al.*1985. Even using specific races for the infection, Bastawisi 1988, Aidy *et al.*1994 and Shi *et al.* 1994 found that all the F1 plants produced from resistant parents were resistant.

All resistant parents and their F1 generations (R X R) were found to be resistant (Table 2), indicating that these parents carry dominant gene(s) for resistance and resistance is completely dominant over susceptibility for leaf blast. All susceptible parents and their F1 generations (S X S) were shown to be susceptible (Table 3), indicating that these susceptible parents carry recessive gene(s) for resistance to leaf blast.

The results of F2 generations produced from (R x R) that showed no segregation with 100% resistance (crosses 1 to 7 and 10, table 2) suggesting that resistance gene(s) presented in those parents could be the same or allelic. While, the results of F2 generations produced from R x R that showed segregating ratio of 15 (R) to 1 (S) (crosses 8 and 9, table 2) suggested the presence of two leaf blast resistance genes that could express resistance in its genetic parental background. Consequently, resistance in these varieties is expressed by two different genes (A and B) that might, or might not, have been shuffled between them.

Results of F1 generation resulted from the twenty R X S crosses that produced all resistant plants (Table 3) agree with results of Omar *et al.*, (1970); Maximos, (1974); Balal *et al.*, (1977); Kiyoswa *et al.*, (1983); Aidy, (1984); Maximos *et al.*, (1985); Yu *et al.*, (1987); Ise, (1993); Shi *et al.*, (1994); Pan *et al.*, (1996); El Malky, (1997) and Abd El-Khalek, (2001) and confirm the dominance of resistance over susceptibility. Results of group 2 (R x S) explained the results of group 1 (R x R). The results of F2 generations resulted from (R x S) that showed the segregating ratio of 15 R to 1 S (Crosses 1 to 8, table 3) suggested that each resistant parent (Toride 1 and Shin 2) carried two dominant resistance genes (e.g., A and B), while the susceptible parents (Giza 159, Giza 171, Giza 176 and PiNo 4) carry their recessive alleles.

Varieties Giza 177 and Sakha 103, when crossed to each other, gave a ratio of 1 R to 0 S in F2 generation (Cross 10, table 2) indicating that they carry the same resistance gene(S) (A or/and B). On the other hand, when they were crossed with Fukunishiki, each cross gave a ratio of 15 R to 1 S in F2 generation, indicating that Fukunishiki variety contains a different resistance gene (B or A) in trans position to resistance gene of Giza 177 or Sakha 103 i.e., if Fukunishiki is AAbb the second parent (Giza 177 or Sakha 103) would be aaBB and that the allelic relationship was complete dominance.

These data suggest that the genetic constitution of resistance of these varieties could be as follows: Toride1 (AABB), Shin2 (AABB), Fukunishiki (aaBB), Giza 177 (AAbb), Sakha 103 (AAbb), Giza 159 (aabb), Giza 171 (aabb), Giza 176 (aabb) and Pi No.4 (aabb).

According to Kiyosawa (1981), Pan *et al.* (1991) and Imbe (1998, personal communication) the varieties Toride 1, Shin 2, and Fukunishiki contained the genes Pi-zt, Pi-ks, and Pi-z, respectively. However, under conditions of this study each variety of Toride 1 and Shin 2 contain two major resistance genes. Imbe (1998) added that Fukunishiki contains Pi-sh resistance gene and suggested that varieties Giza 177 carried Pi-ta2 and other resistance genes

Imbe (1998, personal communication) expected that susceptible varieties Giza 176, Giza 171 and Pi No 4 had (Pi-zt, Pi-ks and pi-a), (Pi-ks, Pi-a and other unknown genes) and (Pi-ta2) respectively. Consequently, genes Pi-zt, Pi-ks, pi-a and Pi-ta2 were not effective for leaf blast resistance under the Egyptian conditions used in this report, which imply that the genes of resistance found in Toride 1 and Shine 2 (A and B) can be none of Pi-zt, Pi-ks or Pi-ta2.

Further studies are needed to determine the exact major genes in these varieties. Finally, these findings could be useful to rice breeding programs for the production of new lines or varieties that can be truly resistant to leaf blast. These resistant genotypes produced from R x R which showed 100% resistance could also be used as a donor for crosses to transfer resistance genes to commercial varieties. These resistant genotypes could be used also as donors in crosses to transfer resistant genes to commercial varieties or for building pyramiding resistance to leaf blast. Aidy *et al*, (2000) reported that gene pyramiding is one form of strategies for breeding for leaf blast resistance.

The significant correlations with two yield characters (weight of the 1000 grains and number of filled grain) showed that this disease affected mainly the number of filled grain; therefore, the weight of the 1000 grains decreases with infection. In other words, it may not affect the number of the total grains but it affects the quality of the grains (Abd El-Khalek, 2001).

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توارث الجينات الأساسية لمقاومة مرض اللفحة بالأرز فى بعض الأصناف المصرية

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الملخص العربى

استخدمت أربعة أصناف من الأصناف اليابانية المفرقة وهى (شين٢ ، توريدى١ ، فيوكومنيشكي ، بى أي رقم٤) والمعروفة باحتوائها على جينات معينة لمقاومة مرض اللفحة وذلك للتهجين مع بعض الأصناف المصرية وهى (جيزة ١٥٩، جيزة ١٧١، جيزة ١٧٦، جيزة ١٧٧، سخا ١٠٣) بهدف فهم توارث الجينات الأساسية لمقاومة مرض اللفحة في الأرز.

وقد تم أجراء ثلاثة أنواع من التهجينات عبارة عن (مقاوم × مقاوم) و(مقاوم × حساس) و (حساس × حساس) وأظهرت نتائج تحليل الجيل الأول أن الهجن الناتجة من مقاوم × مقاوم كانت كلها مقاومة، كما وان الهجن الناتجة عن مقاوم × حساس كانت أيضا مقاومة بينما الهجن الناتجة عن حساس × حساس كانت كلها مصابة وهذا يدل على سيادة صفة المقاومة على صفة الحساسية.

بينما أظهرت نتائج تحليل الجيل الثاني أن هناك خمسة أصناف مقاومة وهى (شين٢ ، توريدى١ ، فيوكومنيشكى ،جيزة ١٧٧ ، سخا ١٠٣) حيث تحتوى على جين أو جينين للمقاومة لمرض اللفحة. ومن بين هذه الأصناف ، الصنفين شين٢، توريدى١ فهما يحتويان على جينين للمقاومة (AABB) بينما الأصناف فيوكومنيشكي، جيزة ١٧٧، سخا ١٠٣ تحتوى على جين مقاومة واحد والذى اختلف فى حالة فيوكومنيشكي (BB) عنه فى حالة جيزة ١٧٧ و سخا ١٠٣ (AA).

تم تقدير معامل الارتباط بين التسعة أصناف بالنسبة لإحدى عشر صفة محصولية مع الإصابة بمرض اللفحة وأظهرت النتائج وجود علاقة ارتباط موجبة ومعنوية لثلاث صفات خضرية وهى فترة النمو وطول النبات ومساحة ورقة العلم، أما بالنسبة لصفات المحصول فقد كان هناك ارتباط سالب مع وزن الألف حبة وارتباط موجب مع عدد الحبوب الغير ممتلئة فى السنبلة