

GENETIC BASE OF BLAST RESISTANCE IN CULTIVATED RICE VARIETIES IN SRI LANKA AND BREEDING STRATEGIES FOR DURABLE RESISTANCE TO BLAST

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ABSTRACT

Twenty two cultivated rice varieties and their parent varieties were screened for blast resistance under Uniform Upland Blast Nursery Technique at the Rice Research and Development Institute, Batalagoda and at Gatambe, Peradeniya during Yala 1989 and Maha 89/90 seasons to assess the extent of genetic diversity of blast resistance within cultivated rice varieties and to discuss possible means of improving blast resistance in newly developing varieties. Locational difference of varietal reaction to blast was observed between Batalagoda and Gatambe, indicating the presence of different blast race compositions at the two screening sites. When the blast reactions of cultivated rice varieties at both locations are taken together, only six varieties out of 22 had retained their blast resistance to date from the year of their release for cultivation. Loss of blast resistance in six parent varieties has resulted in loss of blast resistance in 16 cultivated varieties indicating the narrow genetic diversity for blast resistance and resulting genetic vulnerability. The blast resistance in six cultivated rice varieties which retained their resistance to date appears to have been derived from six parent varieties. Full complement of blast resistance possessed in the parent varieties has not been incorporated into cultivated improved varieties mainly due to the inefficiency of blast screening method presently used. Among several strategies discussed, distinct gene deployment in different maturity groups may help to prolong the blast resistance in newly developing varieties.

KEY WORDS: Blast resistance, Breakdown of resistance, Genetic diversity, Genetic vulnerability

INTRODUCTION

Rice blast disease caused by *Magnaporthe grisea* (anamorph: *Pyricularia grisea*) Sacc. is an important disease in rice growing countries worldwide including Sri Lanka (Ou, 1985). Use of resistant varieties is the most effective, economical and preferred means of disease management as majority of rice growers in developing countries cannot afford to use fungicides. Therefore, in all national and international

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rice improvement programmes, breeding for blast resistance is an important breeding objective.

In Sri Lanka, traditional rice cultivars grown prior to 1950's were highly susceptible to blast disease (Senadhira *et al.*, 1980). Therefore, incorporation of blast resistance into new varieties through hybridization was begun from the very inception of rice hybridization programme during early 1950's. In view of this, a policy decision was taken by the Department of Agriculture that when recommending new improved varieties for cultivation, they should possess built-in resistance to blast. As a result, rice variety H₄ with resistance to blast together with many improved characteristics was developed and recommended for cultivation during the late 1950's (Senadhira *et al.*, 1980). Since then upto the late 80's over a period of three decades, about 30 new improved rice varieties have been bred and recommended for cultivation by the Department of Agriculture, Sri Lanka. However, occurrence of blast disease on most of these varieties has been reported in recent years. Similarly, in many other countries, Colombia (Ahn and Mukelar, 1986; CIAT, 1982) Philippines, South Korea, and Japan (Ou, 1985) rapid breakdown of varietal resistance to blast have been recorded.

The loss of blast resistance in rice varieties could either be due to breakdown of resistant genes in cultivars or emergence of new races with increased virulence within pathogen populations or a combination of both. Frequent occurrence of mutations within blast pathogen populations has been attributed to emergence of new virulent races (Kiyosawa, 1976). Prior to the establishment of the National Rice Improvement Programme of Sri Lanka in the early 1950's, around 150 indigenous rice varieties, probably with diverse genetic background were cultivated by farmers in Sri Lanka. However, with the introduction of semi-dwarf, new improved rice varieties beginning early 1970's, the overall genetic base of the cultivated rice varieties at present has been drastically narrowed (Jayawardene *et al.*, 1987). An analysis of genetic ancestry of cultivated varieties clearly indicates that except for two varieties, all the others have a uniform cytoplasm derived from an Indonesian variety "Cina" (Jayawardene *et al.*, 1987). In spite of this narrow cytoplasmic and genetic uniformity, and limited stability of blast resistance among cultivated rice varieties, use of genetic resistance will continue to be the best method for blast disease management. No attempt has been made in Sri Lanka to investigate the status of genetic resistance to blast in cultivated varieties. A clear picture of the genetic base with regard to blast resistance in presently cultivated rice varieties will provide important clues and

evidences as to what approaches and strategies could be adopted to strengthen the degree of blast resistance and to improve the durability of resistance in future varieties. Thus the objective of this study was to investigate the extent of genetic diversity for blast resistance in some cultivated rice varieties and to discuss the possible strategies to improve the durability of blast resistance in new varieties that are being developed in Sri Lanka.

MATERIALS AND METHODS

Blast screening results of 16 rice varieties together with Pachchaiperumal and Tetep the standard blast susceptible and resistant varieties respectively, screened under Uniform Upland Blast Nursery Technique (UUBNT) at Rice Research and Development Institute (RRDI) Central Rice Breeding Station (CRBS), Batalagoda from the year of their release upto 1989 were compared with the results of blast nurseries generated using the same varieties during Yala 89 (dry season, April-September) and Maha 89/90 (wet season, October-March) to examine the changes of blast reaction in these varieties. In addition, the blast screening results of some 19 parent rice varieties screened under UUBNT at CRBS, Batalagoda and at Gatambe, Peradeniya in mid 70's were also used in this study. Twenty two cultivated rice varieties together with their immediate and ancestral parent varieties were screened for blast disease under natural infection using UUBNT at two locations; CRBS, Batalagoda and Gatambe, Peradeniya during Yala 1989 and Maha 1989/90. The nurseries were established in such a way that each cultivated variety had its immediate and ancestral parent varieties in close proximity in order to expose them for uniform blast infection and development. One month before the beginning of the test nurseries, standard blast susceptible rice variety Pachchaiperumal was sown in adjacent beds to enable the occurrence and development of blast in order to provide a sufficient level of disease pressure. The experiment had three replicates of each varietal entry in each season.

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RESULTS AND DISCUSSION

Breakdown of Genetic Resistance to Blast in Cultivated Rice Varieties

Blast reactions of 16 cultivated rice varieties together with Pachchaiperumal and Tetep screened at CRBS, Batalagoda under UUBNT over a 15 year period are presented in Table 1. Varieties, Bg 380, Bg 400-1, Bg 450, Bg 94-1, Bg 34-6, Bg 34-8 and Bg 276-5 that were resistant to blast at the time of their release, have lost their blast resistance after some time while the rest have retained their resistance. Similarly, the blast reactions of 19 parent varieties used in the parentage of cultivated rice varieties under the present study, and Pachchaiperumal and Tetep screened at CRBS, Batalagoda over two seasons (Maha 1974/75 and Maha 1989/90) and at Gatambe, Peradeniya over three seasons (Yala 1970, Maha 1974/75 and Maha 1989/90) are presented in Table 2. Close examination of the data in Table 2. revealed that at CRBS, Batalagoda, varieties M 302, Ptb 33, Engatek, H8, H 501, IR 5, BPI 76 and Tetep have retained their blast resistance over the 15 year period while IR 262, Remadja, Ob 678, Ld 66, IR 8, Kn 361-1-1-8-6, H5, TN1 and Ld 125 have lost their resistance somewhere during this period. On the other hand at Gatambe, Peradeniya, only varieties Ptb 33, Engatek, Kn 361-1-1-8-6, IR 5, BPI 76, and Tetep have retained their resistance over the 20 year period while others have lost their resistance somewhere during this period. It is unlikely that any evidence is available to support the fact that the reason for breakdown of resistance for blast in the above rice varieties is due to the change in genetic make-up of those varieties, as rice, being a self-pollinated crop, breeds true to type maintaining its genetic make-up over generations. However, according to the studies conducted to determine blast race composition at above locations, there is some evidence to indicate that the blast race composition has been changed over the years at the above locations (Atkins *et al.*, 1967; Dissanayake, 1990 unpublished).

The blast disease occurrence and development at both locations during 89 Yala and 89/90 Maha were satisfactory for reliable recording of blast reactions of rice varieties tested. A locational difference in blast reaction of certain rice varieties have been observed between Batalagoda and Gatambe (Wickramasingha and Dissanayake, 1995). Therefore the blast screening results cannot be generalized over locations so that they are presented and discussed on locational basis. For the convenience of discussion,

the 22 recommended rice varieties in the present study were classified into three groups based on their blast reaction and that of their parent varieties as follows.

- Varietal Group 1. Those varieties that have retained blast resistance to date while one or more of their immediate or ancestral parents also having resistance to blast to date.
- Varietal Group 2. Those varieties that have lost blast resistance over the years while none of their immediate or ancestral parents having resistance to blast to date.
- Varietal Group 3. Those varieties that have lost blast resistance over the years while one or more of their immediate or ancestral parents having resistance to blast to date.

Status of Genetic Resistance to Blast in Cultivated Rice Varieties Based on the Reactions at RRDI, Batalagoda.

Blast reaction of cultivated rice varieties classified into three varietal groups based on their blast reactions as discussed above, and that of their parents at the time of varietal release and at present (1989/90) are presented in Table 3. The summary observations in Table 3 indicates that the breakdown of resistance for blast in three parent varieties, namely IR 262, Ob 678, and IR 8 could be the reason for the loss of blast resistance in 11 cultivated varieties (Varietal group 2 and 3 in Table 3) showing the genetic vulnerability due to narrow genetic base for blast resistance in cultivated rice varieties. A close look at the varietal group 3 (Peiris and Jayawardena, 1986) in Table 3 suggests that the parent varieties, M 302, H4, Engatek, H8 and H501 probably have not contributed their resistance factors into cultivated varieties in varietal group 3.

Status of Genetic Resistance to Blast in Cultivated Rice Varieties Based on Blast Reactions at Gatambe, Peradeniya

Blast reactions of cultivated rice varieties classified into three groups based on their blast reaction and that of their parent varieties as discussed above at the time of varietal release and at present (89/90) are presented in Table 4. Close observation of results in Table 4 reveals that the break-down of blast resistance in

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six parental varieties, namely M 302, IR262, Ob 678, IR8, H501 and H8 is associated with 16 cultivated rice varieties in varietal group 2 and 3 which have become susceptible for blast over the years.

Genetic Vulnerability

When the blast reactions of cultivated rice varieties at both locations are considered, it is clear that out of 22 cultivated rice varieties used in the present study, only six varieties, namely Bg 379-2, Bg 300, Bg 301, Bg 3-5, Bg 38 and Bw 272-6B continue to possess resistance to blast at both locations and their resistance may have probably been derived from few parental sources namely Ptb 33, Tetep, Kn 361-1-1-8-6 and Engatek which also have maintained resistance to Blast to date. Similarly, the genealogy analysis of recommended rice varieties in Sri Lanka reveals that genetic base of those varieties is very narrow and also their cytoplasmic background is nearly uniform (Peiris and Jayawardene, 1986). This situation is very alarming as genetic and cytoplasmic uniformity in crop varieties has attributed for several disastrous plant disease epidemics such as Coffee rust epidemic of Ceylon in 1876 and Southern corn leaf blight epidemic in USA in 1971 (Schiber, 1975; Hooker, 1974). Therefore, rice breeding programme should be directed towards widening the genetic base and diversifying the cytoplasmic origin in new varieties that are being developed.

Breeding Strategies for Improvement of Blast Resistance

The overall narrow genetic background and the cytoplasmic uniformity of the currently cultivated rice varieties have been demonstrated in a previous study (Pieris and Jayawardene, 1986; Jayawardene *et al.*, 1987). The observations in the present study show a similar picture with regard to the genetics of blast resistance. Therefore, future breeding strategies should focus at broadening the genetic and cytoplasmic background of new varieties that are being developed not only for blast resistance but also for other important pests and diseases as well. A few strategies which are generally adopted for stabilization and control of plant diseases in relation to blast disease management in rice are discussed below.

(a). Pyramiding of "major genes" (vertical resistance)

Major genes for blast resistance have been identified, but individually they have been repeatedly assailed as race specific and therefore, short lived (Bonman and McKill, 1988). However, many researchers have postulated a pyramid of major genes to constitute a stable basis for blast resistance (Nottingham, 1993). In this approach, the first step has to be the identification of functionally different major genes in parental sources. However, successful pyramiding of these genes is severely limited by the lack of suitable screening techniques. The present blast screening technique cannot be used to identify and differentiate advanced breeding lines pyramided with identical genes or functionally different genes. An example in present study provides evidence for this fact very clearly. Varieties Bg 400-1 and Bg 450 probably have not captured the full complement of resistant factors from available donor parents in their parentage (varietal group 3 in Table 3). In other words, variety Bg 400-1 probably has derived its resistance only from donor parent Ob 678 but not from M 302 or H4 though they are in its parentage. Similarly, Bg 450 may have derived its resistance only from donor variety Ob 678 but not from Engatek or H8 though they are in its parentage. If blast resistant factors would have come from M 302 and H4, at the time of developing Bg 400-1, that particular Bg 400-1 could have remained resistant to blast even at present at CRBS, Batalagoda. Similar argument could be made to Bg 450 and other varieties in varietal group 3 at both locations (Tables 3 and 4).

The undesirable phenotypic background of the donor parents severely restrict their direct utilization in cross combinations, thus necessitating the transfer of their resistance to improved phenotypes. However, it is highly questionable whether the improved phenotypes capture the full complement of resistance from donor parents. Therefore, until a suitable screening technique is developed, this strategy is of limited value. However, Centre International de Agriculture Tropical (CIAT) has been successful in developing improved rice breeding lines with pyramided genes for blast resistance (CIAT, 1982).

(b). Back crossing for Concentration of Slow-blasting Components

Breakdown of varietal resistance to rice blast disease has been often attributed to the failure of varieties to capture the entire complement of genetic factors for resistance from the respective parent sources in their parentage (Nottingham, 1993).

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Existence of slow-blasting characters, originally presented as horizontal resistance by Van der Plank (1975) have been mainly found only in tall, upland rice varieties (Bidaux, 1976; Villareal, 1980). Bidaux (1976) identified slow blasting varieties using apparent infection rate "r". Villareal (1980) identified several slow blasting components in several varieties. CIAT rice breeding programme had attempted developing varieties with concentrated slow blasting components, but were not successful in view of the several reasons (CIAT, 1982). Identification of slow blasting segregants in segregating populations is difficult particularly in bulk breeding systems. It might be somewhat easier in a pedigree system of breeding where discrete progeny rows can be evaluated for identification of lines with slow blasting components. However, success of this practice entirely depends on uniform occurrence of blast disease in the field which is not found in Sri Lankan rice breeding stations. The rice breeding programme of Sri Lanka adopt a modified bulk selection method in which the breeders reject single plants on the basis of panicle blast in bulk populations (upto F4 generations) and on the basis of seedling and panicle blast in progeny lines (F5 generation onward). However, panicle blast occurrence in the rice breeding fields is irregular and unpredictable and moreover, resistance at panicle stage does not necessarily predict resistance at seedling stage and vice versa. Therefore, this strategy cannot be practically adopted in our breeding programme for improving blast resistance.

(c). **Combination of Major Genes with Slow-blasting Components (Horizontal resistance)**

The combination of major genes (vertical resistance) with slow-blasting components (minor genes) is believed to provide increased stability of the resistance mechanism to blast, because the genes for vertical and horizontal resistance in combination increase the effectiveness of each other. CIAT rice breeding programme (CIAT, 1982) attempted adopting this strategy, but found it difficult to detect the combinations of the two types of resistance in a given pedigree line, as the lower level of horizontal resistance is masked by the presence of vertical genes (vertifolia effect). Under such circumstances, it is proposed to select for vertical resistance and hope for the best. Therefore, the practical outcome of using this strategy in a breeding programme is not predictable.

(d). Multilines

The concept of multilines was suggested by Jensen (1952) and Borlaug (1959) as a mean of controlling air borne plant diseases. This concept has been successfully applied in controlling rust disease of Oats. The concept involves the development of several isolines through back crosses where each line is a geographically diverse source of resistance to rust. A mixture of these lines are released as a commercial variety. Although this concept worked well with Oats, whether a sufficient load of gene complement of the non-recurrent donor parent can be derived through a backcross programme is questionable and is a major limitation to the multiline approach. Practical problems in developing individual distinct rice lines for blast resistance and subsequent management of multilines by the national seed production programme limits its widespread use and farmer acceptability.

(e). Gene Deployment

This strategy involves the use of the distinct type of blast resistance mechanism in each variety and use of varieties in a predetermined pattern (temporal or spatial). Based on rice cultivation practices, seasonal and regional preferences for distinct location specific varieties, this strategy could be well used in Sri Lanka. Since there are distinct varieties for Maha and Yala, those varieties could be developed using distinct diverse sources of blast resistance. Even among varieties used for a particular season, varieties in different maturity periods should consist of distinct sources of blast resistance. This situation will slow down the development of new virulent races, improving the durability of blast resistance in present varieties.

CONCLUSIONS

Out of 22 rice varieties bred and recommended by the Department of Agriculture during last 3 decades, 16 varieties have lost their blast resistance after few years of cultivation. This appears to be a result of emergence of virulent races within pathogen populations. The genetic diversity for blast resistance within cultivated rice varieties appears to be very narrow falling in line with the already recorded narrow genetic base and cytoplasmic uniformity among the cultivated varieties in Sri Lanka. Among many strategies discussed, distinct gene deployment in different maturity groups may help to improve the durability of blast resistance in newly developing rice varieties.

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Table: 1 Blast reactions of some cultivated rice varieties and Pachelaperumal and Tetep at Rice Research and Development Institute, Batalagoda under Uniform Upland Blast Nursery conditions from Maha 1974/75 to Maha 1990/91 the year of release of varieties.

[illegible]

a. Evaluation based on IRRJ, Standard Evaluation System for Rice 1986.

RR = Highly Resistant

MS **=** **Moderately Susceptible**

The reactions separated by a stroke indicates showing in between reactions.

- = Screening results are not available

MR = Moderately Resistant

Table :2 Blast reactions of some parents of recommended rice varieties and Pachchaiperumal and Tetep under Uniform Upland Blast Nursery Conditions at Rice Research and Development Institute, Batalagoda and at Gatambe, Peradeniya over different seasons ^a

Parent Variety	Location				
	Batalagoda Season		Gatambe Season		
	74/75	89/90	70	74/75	89/90
	Maha	Maha	Yala	Maha	Maha
Reactions					
M 302	R	R	R	R	S
Mas	S	S	S	-	S
IR 262	R	S	R	-	S
Remadja	R	S	R	-	S
Ob 678	R	S	R	MR	S
Ptb 33	R	R	-	R	R
Engatek	MR	MR	-	R	R
H 8	R	MR	MR	-	S
Ld 66	R	S	MR	-	S
IR 8	R	S	MR	MR	S
H 501	R	MR	MR	-	MS
Kn 361-1-1-8-6	R	S	MR	MR	MR
Panduruwee	S	S	S	S	S
IR 5	MR	MR	MR	-	MR
Podi Wee A 8	S	S	S	S	S
H 5	R	S	R	-	S
TN 1	MR	S	MR	-	S
BPI 76	R	R	R	R	R
Ld 125	R	S	-	MR	S
Pachchaiperumal	S	S	S	S	S
Tetep	RR	RR	RR	RR	RR

a. Based on Standard Evaluation Systems for rice 1986.

RR = Highly Resistant	R = Resistant
MR = Moderately Resistant	MS = Moderately Susceptible
S = Susceptible	
- = Screening results are not available	

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Table 3. Blast reaction of some cultivated rice varieties and their possible donor parents at the time of varietal release and during 89/90 at RRDI, Batalagoda.

Varietal Group ^a	Cultivated Variety ^b	Blast reaction of the cultivated varieties		Blast reaction of the possible blast resistant donor parents		
		Blast reaction		Donor parent	Blast reaction	
		At the time of release	At present (89/90)		At the time of release	At present (89/90)
		Reaction			Reaction	
1	H4 (1950)	R	R	M 302	R	R
	Bg 379-2 (1980)	R	R	Ptb33	R	R
	Bg 11-11 (1970)	R	R	Engatek	R	MR
	Bg 300 (1987)	R	R	Ptb 33	R	R
	Bg 301 (1987)	R	R	M 302	R	R
	Bg 3-5 (1973)	MR	MR	Engatek	R	MR
	Bg 407 (1981)	R	R	IR5	R	MR
	Bg 38 (1981)	R	MR	M 302	R	R
	Bw 100 (1979)	MR	MR	H 501	R	MR
	Bw 272-6 B (1981)	R	R	Engatek	R	MR
2.	Bw 451 (1987)	R	R	M 302	R	R
	Bg 90-2 (1975)	MR	S	IR 262	R	S
	Bg 380 (1982)	R	S	Ob 678	R	S
	Bg 94-1 (1975)	MR	S	IR 262	R	S
	Bg 276-5 (1979)	MR	S	IR 262	R	S
	Bw 266-7 (1981)	R	S	Ob 678	R	S
	Bw 351 (1986)	R	S	Ob 678	R	S
	Bw 267-3 (1981)	R	S	IR 262	R	S
3.	Bg 400-1 (1980)	R	S	M 302	R	R
				H4	R	R
				Ob 678	R	S
	Bg 450 (1985)	R	S	Engatek	R	MR
				Ob 678	R	S
				H8	R	MR
	Bg 34-6 (1971)	MR	S	IR 8	R	S
				H 501	R	MR
	Bg 34-8 (1971)	MR	S	IR 8	R	S
				H 501	R	MR

^a cultivated varieties separated into 3 groups : Group 1 - those varieties and their parent varieties retained their blast resistance over the years; Group 2 - those varieties and their parent varieties which lost their blast resistance over the years; Group 3 - those varieties which lost their blast resistance over the years, however one or more of their parent varieties retained blast resistance at present.

^b cultivated variety and its year of recommendation within parenthesis.

Table 4. Blast reaction of some cultivated rice varieties and their possible donor parents evaluated at Gatambe, Peradeniya.

Varietal Group ^a	Cultivated Variety ^b	Blast reaction of the cultivated varieties		Blast reaction of the possible blast resistant donor parents		
		Blast reaction		Donor parent	Blast reaction	
		At the time of release	At present (89/90)		At the time of release	At present (89/90)
		Reaction			Reaction	
1.	Bg 379-2 (1980)	R	MR	Bg 96-3	R	R
				Ptb 33	R	R
	Bg 300 (1987)	R	R	Ptb 33	R	R
				Tetep	R	R
	Bg 301 (1987)	R	R	Kn 361-1-1-8-6R		MR
	Bg 3-5 (1973)	MR	MR	Engatek	R	R
				IR5	R	MR
	Bg 38 (1981)	R	R	Engatek	R	R
	Bw 276-6B (1981)	R	MR	Engatek	R	R
				BPI 76	R	R
2.	H4 (1950)	R	S	M 302	R	
	Bg 90-2 (1975)	MR	S	IR 262	R	S
	Bg 380 (1982)	R	S	Ob 678	R	S
	Bg 400-1 (1980)	R	S	Ob 678	R	
	Bg 94-1 (1975)	R	S	IR 262	R	S
	Bg 34-6 (1971)	MR	S	IR8	R	S
	Bg 34-8 (1971)	MR	S	IR8	R	S
	Bg 276-5 (1979)	MR	S	Ob 678	R	S
	Bw 100 (1979)	R	S	H 501	R	S
	Bw 351 (1986)	R	S	Ob 678	R	S
				IR 262	R	S
	Bw 267-3 (1981)	R	S	IR 262	R	S
	Bw 451 (1987)	R	S	Ob 678	R	S
				H 8	R	S
	Bg 11-11 (1970)	R	S	Engatek	R	R
				H8	R	S
3.	Bg 450 (1985)	R	S	Engatek	R	MR
				Ob 678	R	S
				H8	R	S
	Bg 407 (1981)	R	S	IR 5		
				MR	MR	
	Bw 266-7 (1981)	R	S	BPI 76	R	R
				IR 262	R	S

^a cultivated varieties separated into 3 groups : Group 1 - those varieties and their parent varieties which retained their blast resistance over the years; Group 2 - those varieties and their parent varieties which lost their blast resistance over the years; Group 3 - those varieties which lost their blast resistance over the years, but where one or more of their parent varieties retained blast resistance at present.

^b cultivated variety and its year of recommendation within parenthesis.