Landraces and Wild Relatives of Rice as Sources of Useful Genes

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Abstract

The distribution of resistance to two major rice pests in landraces was compared with that in the wild relatives of rice. The brown planthopper (BPH) is one of the most harmful rice insect pests in tropical and temperate Asia. A large number of rice landraces of the world have been screened for BPH resistance in Japan and at IRRI in the Philippines. The results obtained in the two countries showed that most of the resistant landraces originated from South India and Sri Lanka. On the other hand, broad resistance to BPH biotypes was more common in wild relatives than in cultivated rice. At IRRI, 12 species of wild rice relatives resistant to BPH were identified, out of which, four are distributed in Asia and one in tropical Australia. All of these five species occur in the areas where BPH is distributed. However, the other 7 species occurring in Africa or tropical America exhibited allopatric resistance. Tungro is one of the major virus diseases in tropical Asia. It is caused by two viruses, RTBV and RTSV, which are transmitted by leafhoppers. More than 20,000 accessions of landraces have been screened for tungro resistance at IRRI, and some accessions have been reported to be resistant to RTSV or tolerant of RTBV. However, no resistant landraces to RTBV has been detected. Two hundred and eleven accessions in 20 species, representing the genetic diversity in the genus *Oryza*, were tested for resistance to RTBV and RTSV infection. Out of them, 15 accessions in 8 species were not infected with RTBV. Five species are distributed in Asia, but the other three species occur in Africa or Central America where tungro virus disease and the vectors are not distributed. The mechanism of sympatric resistance may be different from that of allopatric resistance.

Introduction

Efficient approaches to identify resistant or tolerant sources to biotic and abiotic stresses are necessary to fully utilize the conserved germplasm. There are two groups in rice germplasm; landraces and wild relatives of rice. Landraces are local varieties of cultivated rice, *O. sativa*, and wild relatives are all the other species of *O. sativa* in the genus *Oryza*. Use of landraces as a source of resistance or tolerance to biotic and abiotic stresses is more practical than that of wild relatives because the introduction of target gene(s) from landraces to improved cultivars is much easier than that from wild relatives. Sometimes, however, it is very difficult to identify such important traits in landraces. In such cases, we must test the accessions of wild relatives for that trait to find the source. Duration of cultivation is not the only factor influencing the diversity of a crop in a region (Peeters, 1988) but it is central to coevolution between pests /pathogens and the host plants. In contrast to other major cereals, presently the main production areas for rice (*O. sativa* L.) include regions as this crop has evolved and diversified. The wild relatives of rice today show a pan-tropical distribution (Vaughan, 1989). The distribution of wild *Oryza* species across all tropical continents has probably occurred long time ago although some recent introductions of wild *Oryza*

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species with the cultigens may have occurred in the past.

More than 80,000 accessions of rice are preserved at the International Rice Research Institute (IRRI); about 2,000 accessions each of *O. glaberrima* and wild relatives, and the others belonging to *O. sativa* (IRRI, 1989). Rice germplasm has been extensively evaluated at IRRI. Comprehensive studies on the sources of resistance in rice to diseases and insect pests were reported by Chan *et al*. (1975,1982).

This paper discusses the distribution of resistance to the brown planthopper (BPH) and tungro in landraces and wild relatives of rice.

Resistance to brown planthopper

BPH is distributed in Asia, Pacific islands and North Australia. Since Athwal *et al*. (1971) identified the *Bph-1* and *bph-2* genes in Mudgo and ASD 7, respectively, nine resistance genes have been identified to date. Four or more BPH biotypes were reported. Biotype 1 is widely distributed in East and Southeast Asia; biotype 2 originated in the Philippines after widespread cultivation of varieties with *Bph-1* gene and biotype 3 was produced in laboratories in both Japan and the Philippines. Biotype 4 is found only in South Asia. The varieties have been classified into three groups in the Philippines and Japan as follows: (1) *Bph-1* group; resistant to biotypes 1 and 3 but susceptible to biotype 2, (2) *bph-2* group; resistant to biotypes 1 and 2 but susceptible to biotype 3, and (3) the group with *Bhp-3, bph-4, bph-8* or *Bph-9*; resistant to all three biotypes. The other three genes, *bph-5, Bph-6* and *bph-7* convey resistance to biotype 4 only.

1 Distribution of BPH resistance in landraces

Kaneda *et al*. (1981) reported the results of screening of 3,300 landraces and breeding lines from different regions of the world. Heinrichs *et al*. (1985) also listed the resistant varieties with the reaction to three biotypes at IRRI, the Philippines. Their results almost agreed with each other (Table 1). Most of the resistant landraces originated from Kerala, Tamil Nadu and Andhra Pradesh States in Southern India and Sri Lanka. Based on the reaction patterns of these landraces to different biotypes the proportion of resistance genes found in the Sri Lankan landraces was different from that in India. Forty seven per sent of the Sri Lankan landraces were found to harbour the *bph-2*, in contrast to only 10% of the Indian landraces tested.

South India and Sri Lanka may be considered as a secondary center for rice diversity with a wealth of wild species and rice cultivation dating back to more than several thousand years. Under intensive cultivation BPH biotypes and resistant landraces evolved. Palk Strait between Sri Lanka and India, although narrow, acts, as a barrier to biological movement. There are many differences between the flora of Sri Lanka and Tamil Nadu. Currently Sri Lankan breeders are using sources of resistance to BPH from India, such as Ptb 33, since the Sri Lankan landraces are now susceptible to the BHP diversity of Sri Lanka.

2 Distribution of BPH resistance in wild relatives

Based on the IRRI data (Table 2), resistance to each BPH biotype is encountered about 30 times more frequently in populations of wild rices than in landraces. The reaction pattern of RRR or broad resistance to BPH biotypes is about 38% in wild relatives but less than 1% in the landraces of rice. The value of 38% was extremely high as compared with others.

Heinrichs *et al*. (1985) listed 12 *Oryza* species and one natural interspecific hybrid group resistant to BPH. Four species, *O. nivara, O. ridleyi, O. officinalis,* and *O. minuta*, and the natural interspecific hybrid group are distributed in Asia, whereas *O. australiensis* in tropical Australia. This distribution may be considered to reflect sympatric resistance since these species are found in the distribution area of the BPH. However, the other species of Africa, *O. brachyantha, O. barthii, O. punctata*, and African strains of *O. eichigeri* and tropical America, *O. glumaepatula, O. latifolia* and *O. alta* exhibit allopatric resistance (Table 3). *O. latifolia* showed a special reaction pattern even though the species is distributed in tropical America; four, four and five accessions exhibited RSR, RRS and RRR, respectively, indicating that the BPH is compatible with *O. latifolia* and the resistance is not a species characteristic (Table 3).

Table 1 Distribution of BPH resistant landraces in India and Sri Lanka

Country of origin	Location of tes	Reaction of rice to three biotypes			
		RSR[1]	RRS[2]	RRR[3]	Total
India	NARC[4]	12	5	20	37
		(32%)	(14%)	(54%)	
	IRRI[5]	25	5	32	62
		(40%)	(8%)	(52%)	
	Total	37	10	52	99
	(Ave. %)	(37.4)	(10.1)	(52.5)	
Sri Lanka	NARC[4]	24	49	15	88
		(27%)	(56%)	(17%)	
	IRRI[5]	57	84	52	193
		(29.5%)	(43.5%)	(27%)	
	Total	81	133	67	281
	(Ave. %)	(28.8)	(47.3)	(23.8)	

1) gene related to reaction of rice ; *Bph-1,*
2) gene related to reaction of rice ; *bph-2,*
3) genes related to reaction of rice ; *Bph-3, bph-4, bph-8, Bph-9,* unknown resistance gene, or two or more genes,
4) data from Kaneda *et al*. (1981)
5) data from Heinrichs *et al*. (1985)

Table 2 Number of accessions in landraces and wild relatives showing resistance to BPH (from database for GEU program at IRRI, 1991)

	Landraces			Wild relatives		
	Tested	Resistant	(%)	Tested	Resistant	(%)
Biotype[1]						
1	44,335	682	(1.5)	723	302	(41.8)
2	10,053	187	(1.9)	724	242	(33.4)
3	13,021	236	(1.8)	730	272	(37.3)
Reaction patterns[2]						
	7,022			579		
RSR[3]		121	(1.7)		14	(2.4)
RRS		83	(1.1)		3	(0.5)
RRR		48	(0.7)		219	(37.8)

1) reactions of accessions to each biotype
2) reactions to 3 biotypes (biotype 1, 2, and 3)
3) for the resistance genes, see the footnotes[1)-3)] in Table 1

Resistance to tungro

Tungro occurs in South and Southeast Asia. Since the late 1960s, it has caused serious damage to rice production in Bangladesh, India, Indonesia, Malaysia, Philippines, and Thailand (Hibino and Cabunagan, 1986). Grain yield can be reduced to a level as high as 100% in doubly infected plants (Hasanuddin *et al*., 1989). Tungro is a disease complex associated with rice tungro bacilliform virus (RTBV) and rice tungro spherical virus (RTSV) (Saito, 1977 ; Hibino *et al*., 1978). The major symptoms are stunting and yellow or yellow-orange discoloration of leaves. Panicle exertion is delayed and often in-

Table 3 Number of accessions in wild relatives of rice resistant to BPH (data from Heinrichs *et al*., 1985)

Species complex Taxa	Genome group	Reaction patterns to BPH[1]		
		RSR	RRS	RRR
O. brachyantha	FF	0	0	2
O. sativa complex				
O. nivara	AA	1	0	9
Natural hybrids	AA	0	1	3
O. barthii	AA	1	0	2
O. glumaepatula	AA	0	0	1
O. ridleyi complex				
O. ridleyi	tetraploid	0	0	2
O. officinalis complex				
O. officinalis	CC	2	0	37
O. eichingeri	CC	0	2	5
O. minuta	BBCC	0	0	28
O. punctata	BB, BBCC	0	5	7
O. latifolia	CCDD	4	4	5
O. alta	CCDD	0	0	1
O. australiensis	EE	0	0	4

1) for the resistance genes, see the footnotes[1)-3)] in Table 1.

complete, and panicles are short and show a low spikelet fertility. Plants infected with RTBV alone develop similar but milder symptoms than those caused by double infection, whereas RTSV alone causes no clear symptoms, except for mild stunting (Hibino, 1989).

The tungro virus complex is transmitted by six leafhopper species, of which the green leafhopper (GLH) *Nephotettix virescens* (Distant) is the major vector of tungro. RTBV depends on RTSV for its acquisition and transimission by GLH. It is transmitted only when the vector has been exposed to RTSV-infected plants before feeding on RTBV-infected plants (Hibino *et al*., 1978).

1 Resistance of landraces to tungro

During the last two decades, more than 20,000 accessions of landraces from the International Rice Germplasm Center at IRRI were screened for tungro resistance. Some landraces have been found to be resistant to or tolerant of tungro at IRRI. No variety, completely resistant to RTBV, has been detected. However, low overall infection with RTBV and RTSV, low or no infection with RTSV and tolerance for RTBV were observed (Hibino *et al*., 1990). A few accessions of landraces resistant to this virus originated from Northeast India, Bangladesh and Indonesia, where the virus occurs (IRRI, 1989).

2 Resistance of wild relatives to tungro

The resistance of wild relatives and African cultivated race, *O. glaberrima* to tungro was evaluated (Kobayashi *et al*., 1993 a). Representing the genetic diversity in the genus *Oryza*, 211 accessions were tested for resistance to RTBV and RTSV infection. Of these, 51 and 15 accessions were not infected with RTSV and RTBV, respcetively, when plants were inoculated with viruliferous GLH. Three accessions of *O. rufipogon* were not infected with either RTSV or RTBV (Table 4). Either, two accesions of *O. officinalis* and each of *O. rhizomatis* and *O. brachyantha* were not infected. Although a large number of accessions in landraces have been evaluated, no accession resistant to RTBV has been found. The wild species identified as highly resistant to tungro are useful donors in developing tungro-resistant rice germplasm.

Table 4 Number of accessions in wild relatives of rice resistant to tungro

Species complex Taxa	No. of accessions tested	Non-infected with RTBV	 RTSV
O. brachyantha	5	1	5
O. sativa complex			
O. nivara	56	0	5
O. rufipogon	20	3	10
Natural hybrids	35	0	6
O. glaberrima	4	0	0
O. barthii	9	0	3
O. meridionalis	2	0	0
O. longistaminata	9	0	3
O. ridleyi complex			
O. longiglumis	3	1	0
O. ridleyi	5	2	0
O. officialis complex			
O. officinalis	15	4	6
O. rhizomatis	6	1	1
O. eichingeri	5	0	2
O. malampuzhaensis	3	0	1
O. minuta	13	0	6
O. punctata	7	0	2
O. latifolia	5	1	1
O. alta	3	2	0
O. grandiglumis	2	0	0
O. australiensis	4	0	2
Tatal	211	15	53
(Ave. %)		(7)	(25)

ELISA method was used to detect virus infection.

Fifteen accessions of eight species of wild rice resistant to RTBV were reexamined to determine whether the resistance was due to vector resistance and/or virus resistance (Kobayashi *et al.*, 1993 b). Of the 15 accessions, three of *O. rufipogon* showed low or moderate level of antibiosis to the major vector *N. virescens*; they were resistant to infection with tungro virus particles, regardless of vector resistance (Table 5). Three accession of *O. officinalis* showed high levels of antibiosis to *N. virescens*, but they showed low levels of antibiosis to *N. nigropictus*. These *O. officinalis* accessions were not infected with RTBV in the inoculation test by *N. nigropictus*. One *O. ridleyi* accession showed a moderate level of antibiosis to *N. nigropictus* and no infection with RTBV in the inoculation test. These results suggest that the resistance to RTBV infection of these seven accessions does not depend on the vector resistance but resistance to virus infection. These wild rice accessions could be useful in developing rice cultivars with high resistance to tungro.

Discussion

This paper dealt with the distribution of resistance genes to BPH and tungro in landraces and wild relatives of rice.

Table 5 Antibiosis to vectors and tungro resistance of accessions in wild relatives

Species	IRGC Acc. No.	Origin	*N. virescens*			*N. nigropictus*		
			Anti-biosis	Infection[1] (%) with		Anti-biosis	Infection[2] (%) with	
				RTBV	RTSV		RTBV	RTSV
O. rufipogon	105908	Thailand	M[3]	0	0	–	–	–
	105909	〃	L	0	0	–	–	–
	105910	〃	M	0	0	–	–	–
O. officialis	104672	Malaysia	MH	0	5	M	10	19
	105100	Brunei	MH	0	0	L	0	0
	105365	Thailand	H	0	0	L	0	0
	105376	〃	MH	0	3	L	0	0
O. rhizomatis	103421	Sri Lanka	H	0	0	L	0	0
O. longiglumis	105146	Indonesia	H	0	33	H	14	100
O. ridleyi	100821	Thailand	H	0	9	M	0	7
	101453	Malaysia	H	0	3	MH	4	7
O. latifolia	105139	Guatemala	H	0	4	H	7	17
O. alta	100967	Surinam	H	0	10	H	7	15
	105685	Brazil	MH	0	11	H	7	0
O. brachyantha	100115	Guinea	H	0	0	–	0	0
O. sativa								
TNI		Taiwan	L	100	60	L	69	46
Utri merah	16680	Indonesia	L	20	10	–	24	0
ARC11554	21473	India	MH	33	17	L	15	0

1) inoculated with viruliferous *N. virescens*,

2) inoculated with viruliferous *N. nigropictus*.

3) H, MH, M, ML, and L indicate the degree of antibiosis in each accession, namely high, medium high, middle, medium low, and low, respectively.

A large number of accession in rice landraces of the world have been screened for BPH resistance in Japan and at IRRI, the Philippines. The results obtained in the two countries showed that most of the resistant landraces originated from South India and Sri Lanka. However, the reaction patterns of these resistant landraces to the three biotypes were different between Sri Lankan and Indian landraces. In Sri Lanka, the landraces with the *bph-2* gene accounted for more than half of the total resistant landraces while in Indian landraces, the *bph-2* group was the smallest one and the largest group was resistant to all three biotypes. Why are there such differences in the distribution of BPH resistance genes between South India and Sri Lanka? The BPHs distributed in India and Sri Lanka probably belong to biotype 4. If true, why are the proportions of accessions with BPH resistance genes different between such close countries? There are many differences between the flora of Sri Lanka and Tamil Nadu. For instance, *O. officinalis* is distributed in India but not in Sri Lanka. *O. eichingeri* and *O. rhizomatis* are distributed in Sri Lanka but not in India. Landraces in both countries have been probably isolated from each other.

Wild relatives showed a worldwide distribution of BPH resistance genes, some species displaying a sympatric resistance to BPH while others an allopatric.

A few accessions of landraces resistant to tungro were also found in the areas where the vectors and virus particles are distributed. Some wild relatives also showed a sympatric resistance to tungro but others showed an allopatric resistance.

Examples given in this paper showed that limiting the search for sources of resistance to germplasm where stress is found may not always be appropriate. When sources of resistance to a stress can be found both where the stress is present and where it is absent, it may be worthwhile analysing genes different from both sources. Genes arising from coevolution in a gene-for-gene manner can be overcome by a pathogen. Stress tolerance which arises independently of the stress may be more difficult to break (Harris, 1975).

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Discussion

Morishima, H. (Japan): 1. My first question deals with the variation in resistance observed in wild rice. The allopatric distribution of resistance genes found in wild species suggests that the maintenance of resistance genes is not necessarily related to the pressure of the pest. In AA genome wild species, is the frequency of resistance genes higher in wild rice growing in Asia where the pest is present than in wild rice in pest-free areas such as Africa or America? 2. My second question is related to the difference between wild rice and cultivated rice. The frequency of resistance genes is higher in the wild relatives than in cultivars. I would like to suggest that breeders should consider the reason(s) why cultivated plants lost resistance genes during the process of domestication.

Answer : I agree with you, especially *O. rufipogon* is a valuable species for resistance to many diseases and insect pests. The percentage of detection of resistance genes was found to be 50 times higher in wild relatives compared with landraces in the case of the white back planthopper, BLB and blast.

Ganeshan, P. (Sri Lanka) : It is interesting to note that wild relatives of rice show a greater resistance to the BPH than cultivated rice varieties. Does it imply that with domestication the resistance to insect pests is reduced? Another interesting feature in cowpea reveals that the landraces obtained from Botswana and Uganda exhibited a complete resistance to alectra and striga although these parasitic plants are not distributed in these countries compared to other countries where resistance is not noticed in the presence of the plants.

Iwanaga, M. (IBPGR) : Regarding the co-evolution of plant resources and pests in terms of the mechanism of resistance, is it conceivable that the resistance may develop without pressure or under the pressure of other pests or constraints? Resistance may be due to the gene structure of the species itself. When the resistance is transferred from one species to another the resistance may be lost.