Studies on the Genes for Blast-Resistance Transferred from *Indica* Rice Varieties by Backcrossing

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Synopsis. Blast-resistant lines selected from several crosses between *japonica* and *indica* varieties were proved to carry an identical gene for resistance. The significance of these experimental results was discussed from the standpoint of breeding for blast-resistance.

The blast disease causes serious losses in rice production in Japan. The breeding for blast-resistance is important for stabilizing rice cultivation. Several resistant varieties derived from the crosses between Chinese and Japanese varieties have recently suffered damage due to prevalence of virulent strains of blast fungus (HIRANO, 1967). It may be practicable from the standpoint of breeding to select new varieties with multi-racial resistance to major strains of blast fungus prevalent in this country.

It has been known that some *indica* varieties were promising as gene resources for multi-racial resistance (YAMASAKI and NIIZEKI, 1964). In breeding programmes making use of these *indica* varieties, new genes for resistance were successfully transferred to *japonica* varieties. A selected line from a cross *Norin 8* (*japonica*) × *TKM. 1* (*indica*) was promising for multi-racial resistance and designated as *Toride 1* (NAGAI, *et al.*, 1970). This line carried a single dominant gene for resistance, designated as *Pi-z^t* (YOKOO and KIYOSAWA, 1970).

The objective of this investigation is to identify the genes for blast-resistance of several lines selected from different crosses between *japonica* and *indica* varieties by the use of a mutant strain for pathogenicity of blast fungus.

Materials and Methods

Eight *indica* rice varieties introduced from four different countries in Asia, which were

resistant to seven strains of the typical races in Japan, were crossed with two Japanese leading varieties. Hybrid plants resistant to the fungus strain Ken 53-33, which had the widest host range among the seven fungus strains, were selected and crossed repeatedly to either of *japonica* parents in successive backcross generations. Three- or four-time backcrosses reproduced the morphological characteristics of the recurrent parent with successful transfer of blast-resistance from the donor parent. One or two lines segregating for resistance to Ken 53-33 were selected from each of the crosses and inoculated with a pathogenic mutant strain of Ken 53-33 for the purpose of determining the identity of their resistance genes.

According to the gene-for-gene theory for host-parasite relationship (FLOR, 1956), the resistance gene in the host can be identified by the selective pathogenicity of races of the parasite. This principle was applied to rice blast disease and it was suggested that genes for resistance of selected lines might be identified by making use of a mutant strain for pathogenicity of blast fungus (KIYOSAWA, 1968). If a variety carrying a single gene for resistance to a particular fungus strain shows susceptibility to its pathogenic mutant strain isolated from the lesions formed on another resistant variety, then the former variety is supposed to carry the gene identical with that of the latter variety.

The spontaneous mutant Ken 53-33-*zt*⁺ isolated from a susceptible lesion formed on a sister line of *Toride 1* had selective patho-

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genicity to the gene *Pi-z^t* (NIIZEKI, *et al.*, unpublished).

The inoculation was carried out by injecting the spore suspension of each fungus strain into the inside of young folding leaves or by spraying the spore suspension on seedlings at the four- to five-leaf stage. One week after inoculation, susceptible lesions were counted and plants were classified into six groups with respect to resistance in the case of inoculation by injection and into two groups by spraying.

Results and Discussion

Reactions of the parental varieties and *Toride 1* to the typical seven strains of blast fungus are presented in Table 1. The *indica* varieties used as donors showed moderate to high resistance to all seven fungus strains. Two *japonica* varieties used as recurrent parents were susceptible to all or some fungus strains, and they were susceptible to Ken 53-33 which was used for the gene identifica-

tion.

Selected lines from each cross were subjected to the inoculation by spraying the spore suspension of Ken 53-33. As shown in Table 2, segregations for resistance to this strain showed a good fit to the 3:1 ratio, indicating that the resistance was controlled by a single dominant gene. The same materials were inoculated with a pathogenic mutant of Ken 53-33, Ken 53-33-*zt*⁺. Selected lines from five crosses showed no segregation for resistance to the mutant strain and were completely susceptible, while monogenic segregations were observed in the other three crosses (Table 2).

The fact that selected lines from the five crosses were segregating for resistance to the original fungus strain and fixed to susceptibility to its pathogenic mutant strain indicated that the gene *Pi-z^t* was included in all the five crosses. Donor parents in these crosses transmitted the single identical gene to their backcrossed hybrid progenies. In another

Table 1. Rice varieties used and their reactions to the typical seven strains of blast fungus

Name of variety	Race*	T-1	T-2	C-3	N-1	N-2	N-3	N-4
	Strain	Ken 53-33	P-2 b	Ina 72	Hoku 1	Ken 54-20	Ken 54-04	Ina 168
	Origin							
CO. 4	India	R ^h	R ^h	R ^h	R ^h	M	MR	R
Leuang Tawng 77-12-5	Thailand	R ^h	R ^h	MR	R	M	MR	MR
Chao Leuang 11	Thailand	R ^h	R ^h	MR	R ^h	MR	MR	R ^h
Morak Sepilai	Malaysia	R ^h	R ^h	R ^h	R	R ^h	R ^h	M ^h
Kontor	Malaysia	R ^h	R ^h	MR	R ^h	R ^h	R ^h	R ^h
Engkatek	Malaysia	R ^h	R ^h	R ^h	R ^h	R ^h	R ^h	R ^h
Tjahaja	Indonesia	R ^h	R ^h	R ^h	R	MR	MR	R
Sigadis	Indonesia	R ^h	R ^h	R ^h	R ^h	MR	R ^h	R ^h
Norin 25	Japan	S	S	S	S	S	S	S
Fujisaka 5	Japan	S	M	M	S	M	M	M
Toride 1**	Hybrid	R ^h	R ^h	R ^h	R ^h	R ^h	R ^h	R ^h
TKM. 1	India	R ^h	R ^h	R ^h	R ^h	R ^h	R ^h	R ^h
Norin 8	Japan	S	S	S	S	S	S	S

Note) A Part of this table was compiled from the unpublished data by S. KIYOSAWA.

Inoculation was carried out by injecting the spore suspension into the inside of young folding leaves.

Reaction: R^h=Highly resistant, R=Resistant, MR=Moderately resistant, M=Medium, MS=Moderately susceptible, S=Susceptible.

*: Race is a group of fungus strains classified by the pathogenic reactions to rice differential varieties.

**: *Toride 1* is a backcrossed hybrid selected from the *Norin 8* × *TKM. 1* cross with the former variety as a recurrent parent.

Table 2. Reactions of backcrossed hybrids to the strain Ken 53-33 and its pathogenic mutant Ken 53-33-*zt*⁺

Original cross	Generation	Reaction to			
		Ken 53-33		Ken 53-33- <i>zt</i> ⁺	
		Resist.	Suscept.	Resist.	Suscept.
<i>Norin 25</i> × <i>CO.4</i>	B_4F_2	144	43	0	142
		149	33	0	141
<i>Fujisaka 5</i> × <i>Leuang Tawng</i> 77-12-5	B_3F_2	151	46	0	115
		152	42	0	145
<i>Chao Leuang 11</i> × <i>Fujisaka 5</i>	B_3F_2	139	47	0	116
		141	51	0	130
<i>Morak Sepilai</i> × <i>Fujisaka 5</i>	B_4F_2	145	51	0	140
		143	46	0	140
<i>Fujisaka 5</i> × <i>Kontor</i>	B_4F_2	138	45	0	134
		118	53	0	108
<i>Norin 52</i> × <i>Engkatek</i>	B_4F_2	55	28	100	21
<i>Norin 52</i> × <i>Tjahaja</i>	B_4F_4	125	55	130	56
<i>Norin 25</i> × <i>Sigadis</i>	B_4F_3	151	41	118	35

Note) In each cross hybrids were backcrossed to the corresponding *japonica* recurrent parent three- or four-times in successive generations. Inoculation was done by spraying the spore suspension of each pure culture of blast fungus strain.

breeding work, the blast-resistant line, *Toride 2*, was selected from backcrossed progenies of an Indian variety *CO. 25* with *Norin 8* as a recurrent parent. This line has also been found to carry the identical gene *Pi-z^t* (KIYOSAWA and YOKOO, 1970).

The distinct differentiation for pathogenicity was observed among pathogenic races of blast fungus. It could be deduced from the co-evolutional relationship in the host-parasite system that pathogenic races of the "Japonica" group were much virulent to *japonica* rice varieties, but less to *indica* ones (MORISHIMA, 1969). Of interest and significant is the fact that many *indica* rice varieties with different geographic origins in Asia were found to carry the identical gene for resistance in common. It seemed that this gene designated as *Pi-z^t* was widely distributed among *indica* varieties of rice.

The recent result of gene analysis for blast-resistance showed that the modern resistant varieties derived from crosses with different Chinese varieties carried the identical gene for blast-resistance (KIYOSAWA, 1967). This

fact, however, had not been recognized and only the same gene had been transferred from different Chinese varieties into Japanese varieties. This might explain the fact that some varieties selected from different Japanese-Chinese crosses coincidentally became susceptible due to prevalence of virulent strains of blast fungus.

It is desirable to discriminate new genes for resistance from those introduced already, by the use of pathogenic mutants of blast fungus at the early stage of breeding or before starting breeding. From this point of view, the lines of the other three crosses of *Engkatek*, *Tjahaja* and *Sigadis* with *Norin 25* were considered to be promising as new gene resources for blast-resistance because their genes were proved to be different from the gene *Pi-z^t*.

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イネの日・印交雑によって新たに導入したいもち病抵抗性遺伝子

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イネの *indica* 品種のもつもち病抵抗性遺伝子を日本の品種にとり込む研究を行なった。わが国の代表的な7つのもち病菌系に抵抗性を示す8つの *indica* 品種(第1表)に日本の品種をくりかえし戻し交雑して、これらの菌系に対して抵抗性を示し形態的には日本の品種に似た系統を育成した。

いもち病菌の病原性に関する突然変異菌系を用いて、これらの育成系統のいもち病抵抗性遺伝子の異同を調べ

た結果、第2表に示したように8つの組合せのうち5つの組合せから選抜した系統がいずれも「とりで1号」のもつ $Pi-z^t$ と同じ遺伝子をもっていることがわかった。突然変異菌系に対して抵抗性に関して分離した他の3つの組合せの系統は $Pi-z^t$ 以外の遺伝子を持つていると考えられた。起原の異なる *indica* 品種に同じ抵抗性遺伝子が分布していたことは、今後 *indica* 品種から抵抗性遺伝子を導入していく際にとくに留意すべき事実である。