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Inheritance of Resistance to Bacterial Leaf Blight, *Xanthomonas Oryzae* (Uyeda et Ishiyama) Dowson, in Rice

I. Allelic Relationships of Resistance Genes in Donor Varieties[1)]

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Synopsis. Allelic relationships of genes for resistance to bacterial leaf blight were studied in several varieties. Sigadis and TKM 6 have same genes for resistance. BJ 1 on the other hand has different genes for resistance. Wase Aikoku 3 and PI 215936 have non-allelic genes. Sigadis and PI 215936 also have non-allelic genes. Zenith and B 589 A 4-18-1 have allelic genes. Allelic relationships of genes for resistance in Zenith and Sigadis are not clear.

Introduction

The high yielding rice varieties perform best with high rates of fertilizers, weed control, and proper water management. Such cultural practices, as well as the tropical climate, however, favor the development of diseases and pests. The susceptibility of many new varieties and the improved cultural practices used in growing them has increased the incidence of bacterial leaf blight in the monsoon season. This disease has been a serious problem for many years in Japan where the improved cultural practices were introduced much earlier. According to Wakimoto (1967) at least 300,000 to 500,000 hectares, or nearly 10 percent of the rice crop in Japan is annually affected by this disease to varying degrees.

To reduce yield losses, the breeding program of the International Rice Research Institute (IRRI) and the national breeding programs of most Asian countries are trying to develop varieties with multiple resistance to major diseases and insects including bacterial leaf blight (Khush and Beachell 1972). Several varieties are being used as common sources of resistance. We examined the allelic relationships of genes for resistance to bacterial leaf blight in the donor varieties as part of the IRRI breeding program.

Materials and Methods

The seven varieties used in the study come from different countries and represent distinct geographical areas (Table 1). BJ 1, Sigadis and TKM 6 belong to the indica group of rices. Wase Aikoku 3 and PI 215936 belong to the japonica group and are mainly grown in temperate areas. Zenith and B 589 A 4-18-1 resulted from indica-japonica hybridizations and were bred in U. S. A. B 589 A 4-18-1 and Zenith are related as the former originated from Bbt 50/2×(Bruinmessie Sel×Zenith).

The F_1 and F_2 populations from the following cross combinations were studied: Sigadis ×BJ 1, Sigadis×TKM 6, Sigadis×PI 215936, Sigadis × Zenith, Zenith × B 589 A 4-18-1 and Wase Aikoku 3×PI 215936.

At least 10 plants of each variety and each F_1 generation were grown during the wet season of 1970 (June to December) at the IRRI farm and scored for reaction to bacterial leaf blight. F_2 populations were grown in the wet season of 1971. At least 10 plants of the parental varieties were grown along with the F_2 populations.

The reaction of each plant to bacterial leaf blight was determined by artificially inoculating three flag leaves with isolate B 15-37 maintained at IRRI on Wakimoto agar medium. The bacterial suspension was transferred to the surface of Wakimoto agar medium and

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Table 1. Origin and agronomic characteristics of the varieties resistant to bacterial leaf blight used in the study

Variety	Country of origin	IRRI Acc. No.	Variety group	Plant type
BJ 1	India	3711	Indica	Tall, high tillering, droopy leaves
Sigadis	Indonesia	5324	Indica	Tall, high tillering, droopy leaves
TKM 6	India	237	Indica	Tall, high tillering, weak stems
Zenith	U.S.A.	131	Indica-japonica	Medium tall, intermediate tillering
B 589 A 4-18-1	U.S.A.	9797	Indica-japonica	Medium tall, intermediate tillering
Wase Aikoku 3	Japan	525	Japonica	Medium tall, low tillering
PI 215936 (Tainan-iku 487)	Taiwan	146	Japonica	Medium tall, intermediate tillering

incubated at 28 to 30°C for 48 hours. The bacterial cells suspended in distilled water and adjusted to a concentration of approximately 10^8 cell/cc.

The multi-needle inoculation method (Muko and Yoshida 1951; IRRI 1966) was used for inoculating the flag leaves. For inoculation a pad with six needles mounted on it in two rows is fixed on the thumb while another pad with a cushion of cotton covered with cheese cloth is fixed on the middle finger. These pads are periodically soaked with the inoculum and the flag leaves are punctured midway between the junctura and the tip on either side of the midrib.

Reaction was scored 20 days after inoculation on a scale of 0-9 based on the extent to which the lesion spread downward from the point of inoculation. A score of 0 indicated the most resistant reaction, and 9, the most susceptible (IRRI 1966).

Results

The reactions of the parental varieties, and of the F_1 and F_2 populations of various cross combinations are given in Table 2. Most plants of Sigadis, BJ 1, TKM 6, and PI 215936 had disease scores of 3 and 4, while most plants of Zenith and Wase Aikoku 3 had 1 and 2, respectively. The F_1 plants of all cross combinations were classified as resistant. In general, a few F_1 plants were somewhat more resistant than either parent.

The recovery of 29 susceptible plants with disease scores of 5 to 7 in the F_2 of Sigadis×BJ 1 indicates that genes governing resistance in Sigadis and BJ 1 are non-allelic. The entire population of 595 F_2 plants from the cross Sigadis×TKM 6 was resistant, indicating that the two varieties have the same gene or genes

Table 2. Classification of plants according to their reaction to *Xanthomonas oryzae*

Variety/cross	0	1	2	3	4	5	6	7	8	9	Total
Sigadis				5	5						10
BJ 1			1	7	3						11
TKM 6			3	6	1						10
Zenith		8	2								10
B 589 A 4-18-1		1	3	6							10
Wase Aikoku 3			8	2							10
PI 215936				7	4						11
Sigadis×BJ 1 (F_1)		2	6	3	2						13
Sigadis×BJ 1 (F_2)	1	148	190	132	47	21	7	1			547
Sigadis×TKM 6 (F_1)		4	2	1							7
Sigadis×TKM 6 (F_2)	4	130	192	264	4	1					595
Sigadis×PI 215936 (F_1)			1	4	6						11
Sigadis×PI 215936 (F_2)	1	20	62	170	73	38	26	11			401
Sigadis×Zenith (F_1)	3	3	1	4							11
Sigadis×Zenith (F_2)		123	205	124	47	6	4				509
Zenith×B 589 A 4-18 (F_1)	4	4	4	2							14
Zenith×B 589 A 4-18 (F_2)	5	438	108	7							558
Wase Aikoku 3×PI 215936 (F_1)		12	2								14
Wase Aikoku 3×PI 215936 (F_2)	7	306	99	38	58	49	12	3	1		573

for resistance. In the F_2 population of 401 plants from the Sigadis × PI 215936 cross, 75 plants were susceptible. Evidently these two varieties have different genes for resistance.

Ten out of 509 F_2 plants from the Sigadis × Zenith cross had disease scores of 5 or 6. Since so few plants were in this category and they were not highly susceptible, they could have been misclassified. It appears that Sigadis and Zenith have the same gene or genes for resistance. This observation needs verification, however.

All plants in the F_2 population of Zenith × B 589 A 4-18 were resistant, indicating that the resistance genes in these two varieties are allelic. Out of 573 F_2 plants of the cross Wase Aikoku 3 × PI 215936, 65 were susceptible. These two varieties therefore must have non-allelic genes for resistance.

Discussion

Several studies on the inheritance of resistance to bacterial leaf blight have been reported (MURATA 1967; HEU, CHANG and BEACHELL 1968; SAKAGUCHI, SUWA and MURATA 1968; PADMANABHAN, MISHRA and DEVADATH 1971; MURTY and KHUSH 1972). These studies dealt mainly with the inheritance patterns of resistance. Our study is the first attempt to determine the allelic relationships of resistance genes of varieties of diverse geographical origin.

The results indicate that two different sources of resistance are available within the indica group of varieties, one represented by Sigadis and TKM 6 and the other by BJ 1. Zenith and B 589 A 4-18, two closely related varieties, have identical genes for resistance. Zenith and Sigadis may have the same gene or genes for resistance, too. Wase Aikoku 3 and PI 215936, both of japonica origin, have non-allelic genes for resistance, as have Sigadis and PI 215936. Thus at least three diverse sources of resistance to bacterial leaf blight are available. These genes for resistance have been transferred to high yielding varieties with improved plant type at IRRI. The resistance genes of TKM 6 have been incorporated into IR 20, a high yielding variety with resistance to some diseases and insects.

Since bacterial populations are dynamic, the resistance conveyed by a particular gene may break down when a more virulent strain of the bacterium develops. Other sources of resistance with non-allelic genes may continue to be resistant and can immediately replace the genotypes that have become ineffective. The three sources of resistance identified in our study are being combined with genes for resistance to other major diseases and insects to ensure the continuous availability of varieties resistant to bacterial leaf blight.

Transgressive segregation for higher levels of resistance in several cross combinations indicates the presence of modifiers with small effect in addition to major genes. Such modifiers generally provide some field tolerance or generalized resistance and reinforce the action of major genes. These minor genes should be accumulated in high yielding varieties to build generalized resistance or stable resistance.

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Summary

Allelic relationships of genes for resistance to bacterial leaf blight were investigated in seven resistant varieties. On the bases of reactions of F_2 populations of crosses between resistant varieties, it was concluded that Sigadis and TKM 6 have same gene for resistance. BJ 1 on the other hand has different genes for resistance. Wase Aikoku 3 and PI 215936 have non-allelic genes. Sigadis and PI 215936 also have non-allelic genes. Zenith and B 589 A 4-18-1 have the same gene for resistance. Allelic relationships of genes for resistance in Sigadis and Zenith are not clear.

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イネの白葉枯病抵抗性の遺伝

I. 抵抗性交配母本の中の抵抗性遺伝子の対立関係

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イネ白葉枯病 [*Xanthomonas oryzae* (UYEDA et ISHIYAMA) DOWSON] に対する抵抗性源としての利用価値を知るために, 種々の国から白葉枯病抵抗性の7品種 [BJ 1, Sigadis, TKM 6 (以上 indica), 早稲愛国3号, PI 215936 (以上 japonica), Zenith, B 589 A 4-18-1 (以上 indica-japonica 雑種からアメリカにて育成)] を集め, それらの間の抵抗性遺伝子の対立関係について分析した。

これらの品種の間で, Sigadis×BJ 1, Sigadis×TKM 6, Sigadis×PI 215936, Sigadis×Zenith, Zenith×B 589 A 4-18-1, 早稲愛国3号×PI 215936 の F_1 と F_2 を作り, それに親品種を加えて IRRI 保有の菌株 B 15-37 を止葉に多針法で人工接種して, 20日後に反応を 0~9 に分級した。

その結果, Sigadis と TKM 6 は同じ抵抗性遺伝子をもち, BJ 1 は上記の2品種とは異なる遺伝子をもつことを明らかにした。さらに PI 215936 は早稲愛国3号とも Sigadis とも異なる遺伝子をもち, Zenith と B 589 A 4-18-1 は同一の抵抗性遺伝子をもつ。Sigadis と Zenith の抵抗性遺伝子の対立関係については明瞭な結果はえられなかったが, 同じ遺伝子である可能性がある。従って, 少なくとも三つの白葉枯病抵抗性に関する異なった遺伝子源が存在するものと考えられる。