イネいもち病菌菌系の胸子形成におよぼす宿主の抑制効果の品種間差異

誌名	日本植物病理學會報 = Annals of the Phytopathological Society of Japan
ISSN	00319473
著者	清沢, 茂久 趙, 正翼
巻/号	39巻4号
掲載ページ	p. 305-311
発行年月	1973年9月

日植病報 39: 305-311 (1973)
Ann. Phytopath. Soc. Japan 39: 305-311 (1973)

Varietal Difference of Inhibitory Effect of Rice Plant on the Sporulation of Blast Fungus

Shigehisa KIYOSAWA* and Chung Ik CHO**

清沢茂久*・趙正　翼**:

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Abstract

Resistance of five or ten rice varieties to lesion formation and to sporulation of three blast fungus strains on host plants was tested in a greenhouse. Varietal difference of resistance to sporulation was found in a few experiments, but varietal difference of resistance to lesion formation was difficult to find, because of a large variation of pathogenicity index (aggressiveness) by which varietal resistance was estimated. However, correlation of field resistance was higher with resistance to lesion formation than with resistance to sporulation. Correlation between resistance to lesion formation and that to sporulation was not found. (Received November 2, 1972)

Field resistance, which has recently been revalued to control crop disease by breeding, consists of ability to inhibit lesion formation and sporulation of fungus strains on the host[5]. In the previous paper[6], the sporulation of rice blast fungus on the host from the viewpoint of sporulating ability of fungus was studied. In the study, the authors showed that inter-strain difference of the fungus was found both in the aggressiveness and sporulating ability, but the former was a very variable character when measured by the number of susceptible type lesions and was difficult to estimate in a simply designed experiment. The final object of this series of study is to evaluate field resistance of many varieties. However, as the resistance of the host to lesion formation of the fungus seems difficult to measure as shown in the previous paper[6], it is particularly aimed to evaluate the resistance of the host to the sporulation of the fungus in the present paper.

Materials and Methods

As the plant materials, rice varieties, Norin 6, Norin 8, Norin 22, Shin 2 and Ginga, were used in one series of experiments, and in another series of experiments additional five varieties, Homare Nishiki, Aichi Asahi, Kanto 51, Norin 17 and Kusabue, were used. It is well known that among them Aichi Asahi, Norin 17 and Kusabue are highly susceptible, Norin 6 is susceptible, Norin 8 is moderately susceptible, Norin 22 and Shin 2 are moderately resistant, and Ginga and Homare Nishiki are resistant in the field[4]. Kanto 51 is more resistant than Kusabue[2,3].

As the fungal meterials, Ken 53-33, Ina 72 and Ken 54-20 were used in the first series and Ken 53-33, Hoku 1-k^+ and Ken 54-20-k^+ in the second series of experiments. Here, Ken 54-20-k^+ means a mutant from Ken 54-20 which overcomes *Pi-k* resistance gene. These fungus strains are virulent to the varieties used in the corresponding series.

The methods used in the experiments were the same as those in the previous paper[1], except for

* National Institute of Agricultural Sciences, Hiratsuka, Kanagawa, Japan
** Honam Crop Experiment Station, Iri, Korea

exclusive employment of Thermomixer for releasing spores from lesions and the use of a larger number of lesions (20 lesions) for measuring sporulation. Pathogenicity index was obtained by counting the lesion number on 68 plants which were grown in two seedling boxes.

Results

Comparison of resistance of the five varieties, Norin 6, Norin 8, Norin 22, Shin 2 and Ginga, to the sporulation of the three fungus strains were made in three separate experiments. The results are shown in Table 1. In single experiments, a significant difference is found between fungus strains, but not between varieties (Table 2). This indicates that difference in the amount of sporulation is smaller between varieties than between fungus strains, and that a single experiment in such a design is too few to obtain varietal difference in the sporulation, accordingly of resistance to sporulation.

Variance analysis was made on the pooled results on the sporulation of the three fungus strains on the five varieties (Table 2). The analysis indicates that there are found significant differences of sporulation between varieties and between fungus strains.

On the other hand, resistance of these five varieties to lesion formation of the three fungus strains was evaluated by pathogenicity index as shown in Tables 3 and 4. Varietal differences are recognized in a single experiment and in pooled results (over all experiments in the table). It is noted that a significant difference between fungus strains in one experiment is lost when the results of the two experiments are analyzed as a whole. This perhaps indicates that there is a large environmental variation in aggressiveness* of fungus strains expressed by the equation for pathogenicity index, $b+10\,bg+30\,bG+40\,pG$.

Table 1. The amounts of sporulation per lesion of 3 fungus strains on 5 varieties in 3 experiments ($\times 10^2$)

Fungus strain	Expt. No.	Variety					
		Norin 6	Norin 8	Norin 22	Shin 2	Ginga	Mean
Ken 53-33	I	266	147	141	195	233	196.4
	II	296	218	219	170	60	192.6
	III	486	284	317	189	341	323.4
	Mean	349.3	216.3	225.7	184.7	211.3	
Ina 72	I	285	302	223	181	248	247.8
	II	602	459	358	287	191	379.4
	III	386	410	339	374	461	394.0
	Mean	424.3	390.3	306.7	280.7	300.0	
Ken 54-20	I	24	17	8	11	17	15.4
	II	103	69	72	60	119	84.6
	III	35	5	15	69	39	32.6
	Mean	54.0	30.3	31.7	46.7	58.3	
Grand mean		275.9	212.3	188.0	170.7	189.9	

*: Used on the basis of van der Plank's definition[7] in which pathogenicity is divided into the two, virulence (roughly meaning qualitative pathogenicity) and aggressiveness (quantitative pathogenicity).

Table 2. Variance analyses on the amount of sporulation per lesion on 5 varieties

Factor	Each experiment				Over all experiments	
	Degrees of freedom	Mean square			Degrees of freedom	Mean square
		I	II	III		
Variety (V)	4	2,314.8	19,024.1	4,641.3	4	15,181.6*
Fungus strain (F)	2	74,516.6**	111,221.1**	183,465.7**	2	339,204.3**
Experiment (E)					2	36,639.1**
V×F					8	4,821.1
F×E					4	14,996.6
E×V					8	53,992.9
Error	8	1,498.5	7,117.2	4,814.6	16	4,304.6

Table 3. Aggressiveness[α)] of 3 fungus strains on 5 varieties in 2 experiments

Fungus strain	Expt. No.	Variety					
		Norin 6	Norin 8	Norin 22	Shin 2	Ginga	Mean
Ken 53-33	I	343.7	313.4	197.1	222.6	122.6	239.9
	II	207.0	239.0	198.3	186.3	94.3	185.0
	Mean	275.4	276.2	197.7	204.5	108.5	
Ina 72	I	68.2	67.1	87.2	55.6	65.6	68.7
	II	370.5	383.2	253.5	249.0	223.5	295.9
	Mean	219.4	225.2	170.4	152.3	144.6	
Ken 54-20	I	186.3	263.8	123.3	161.6	63.3	159.7
	II	246.5	310.3	177.3	223.5	198.5	231.2
	Mean	216.4	287.1	150.3	192.6	130.9	
Grand mean		237.1	254.7	180.3	180.0	128.0	

α): Aggressiveness was expressed by the equation of pathogenicity index, b+10 bg+30 bG+40 pG

Table 4. Variance analyses on the aggressiveness of 3 fungus strains on 5 varieties

Factor	Each experiment			Over all experiments	
	Degrees of freedom	Mean square		Degrees of freedom	Mean square
		I	II		
Variety (V)	4	8,279.1	9,218.2**	4	17,215.8**
Fungus strain (F)	2	36,658.8**	15,703.3**	2	2,276.1
Experiment (E)				1	49,556.4**
V×F				8	1,351.5
F×E				2	49,915.1**
E×V				4	160.4
Error	8	2,705.4	1,012.9	8	2,399.7

Table 5. The amount of sporulation per lesion of 3 fungus strains on 10 varieties in 2 experiments ($\times 10^2$)

Fungus strain	Expt. No.	Variety										Mean
		Homare Nishiki	Aichi Asahi	Kanto 51	Norin 8	Norin 6	Norin 22	Norin 17	Kusabue	Ginga	Shin 2	
Ken 53-33	I	270	265	251	165	309	168	255	330	157	209	237.9
	II	104	114	58	36	210	138	80	216	94	62	111.2
	Mean	187.0	189.5	154.5	100.5	259.5	153.0	167.5	273.0	125.5	135.5	
Ken 54-20-k^+	I	192	182	253	160	363	193	179	173	177	234	210.6
	II	76	76	112	162	178	242	121	126	66	178	133.7
	Mean	134.0	129.0	182.5	161.0	270.5	217.5	150.0	149.5	121.5	206.0	
Hoku 1-k^+	I	28	20	67	19	98	30	37	44	54	52	44.9
	II	24	24	32	40	120	40	24	20	13	16	35.3
	Mean	26.0	22.0	49.5	29.5	109.0	35.0	30.5	32.0	33.5	34.0	
Grand mean		115.7	113.5	128.5	97.0	213.0	135.2	116.0	151.5	93.5	125.2	

Table 6. Variance analyses on the amount of sporulation on 10 varieties

Factor	Each experiment			Over all experiments	
	Degrees of freedom	Mean square		Degrees of freedom	Mean square
		I	II		
Variety (V)	9	4,834.5	4,123.6	9	6,991.1**
Fungus strain (F)	2	109,084.6**	26,582.7**	2	118,615.7**
Experiment (E)				1	76,112.8**
V×F				18	2,438.6*
F×E				9	17,283.1**
E×V				2	1,996.5
Error	18	1,571.4	1,816.1	18	1,014.5

Table 7. Aggressiveness of 3 fungus strains on 10 varieties in 2 experiments

Fungus strain	Expt. No.	Variety										Mean
		Homare Nishiki	Aichi Asahi	Kanto 51	Norin 8	Norin 6	Norin 22	Norin 17	Kusabue	Ginga	Shin 2	
Ken 53-33	I	324	302	304	326	274	298	286	286	258	310	296.8
	II	183	430	234	345	386	280	383	484	219	565	350.9
	Mean	253.5	366.0	269.0	335.5	330.0	289.0	334.5	385.0	238.5	437.5	
Ken 54-20-k^+	I	278	318	188	342	322	320	290	280	292	332	296.4
	II	357	867	164	620	590	508	682	217	295	689	498.9
	Mean	317.5	592.5	176.0	481.0	456.0	414.0	486.0	248.5	293.5	510.5	
Hoku 1-k^+	I	140	220	284	273	209	122	200	175	91	152	186.6
	II	85	164	77	133	139	126	134	171	43	137	120.9
	Mean	122.5	192.0	180.5	203.0	174.0	124.0	167.0	173.0	67.0	144.5	
Grand mean		231.2	383.5	208.5	339.8	320.0	275.7	329.2	268.8	199.7	364.2	

Table 8. Variance analyses on the aggressiveness of 3 fungus strains on 10 varieties

Factor	Each experiment			Over all experiments	
	Degrees of freedom	Mean square		Degrees of freedom	Mean square
		I	II		
Variety (V)	9	2,009.6	39,093.6*	9	25,634.3*
Fungus strain (F)	2	40,260.9**	362,813.3**	2	312,680.5**
Experiment (E)				1	60,865.4*
V×F				18	10,372.5
F×E				2	90,393.8**
E×V				9	15,468.9
Error	18	2,168.2	15,593.0	18	7,388.8

In the second series of experiments, ten varieties were compared in relation to the sporulation of three fungus strains on these varieties in two separate experiments. The results are shown in Table 5. A significant difference in the amount of sporulation is found between fungus strains but not between varieties in single experiments (Table 6). Variance analysis in which the two experiments are treated as replication (Table 6) indicates that there is a significant difference even between varieties.

The pathogenicity index measured in the same experiments showed a tendency similar to the results obtained in the former series of experiments (Tables 7 and 8), except for a significant inter-strain difference found in the pooled result.

Discussion

In the present study, five or ten rice varieties were tested for their resistance to lesion formation and sporulation of three blast fungus strains on the host varieties. Significant differences in the amount of sporulation were obtained always between fungus strains, but not between varieties in individual experiments. Variance analysis, in which two or three experiments were treated as replication, showed that there are significant differences between varieties and between fungus strains. This indicates that there are varietal difference in resistance to sporulation and interstrain difference in sporulating ability on the host. The latter could be detected in a single experiment in a design such as used in the present study, but the former could be done only after a few experiments. This is a reflection of a larger difference between fungus strains than between varieties. However, it must be noticed that a significant difference observed in individual experiments is often lost in pooled analysis because of a large experimental error.

On the other hand, pathogenicity index calculated by the equation b+10 bg+30 bG+40 pG indicated that inter-strain difference was detected in each experiment, but varietal difference could not be found so easily in individual experments. In both series of experiments, significant varietal difference of pathogenicity index (resistance to lesion formation) was found in one experiment, but not in another experiment. In variance analysis, in which two experiments were treated as replication, a significant difference of pathogenicity index was found between varieties, but not found between fungus strains in one series. This agrees with the conclusion obtained in the previous paper[6], in which pathogenicity index was reported to be a very variable character as compared with the amount of sporulation.

In the previous paper[6] carried out to know inter-strain difference of aggressiveness (lesion-forming

Table 9. Correlation coefficients between various values

Experiment	Fungus strain	Between resistances to lesion formation and sporulation	Between field resistance and resistance to		Between first and second series	
			Lesion form.	Sporul.	Lesion form.	Sporul.
First series	Ken 53-33	+0.506	+0.972	+0.686	+0.473	+0.926
	Ina 72	+0.945	+0.918	+0.857		
	Ken 54-20	−0.454	+0.747	−0.335	+0.699	−0.027
	Mean*	+0.623	+0.946	+0.762	+0.712	+0.787
Second series	Ken 53-33	+0.223	+0.433	+0.620		
	Ken 54-20-k^+	+0.150	+0.286	−0.011		
	Hoku 1-k^+	+0.148	+0.836	+0.100		
	Mean	+0.108	+0.533	+0.354		

*: Grand means in Tables 1, 3, 5 and 7 were used for calculation of correlation coefficients.

ability) and of sporulating ability, a relatively low positive correlation was found between them. In the present study for determining varietal difference of resistances to lesion formation and to sporulation of the fungus strains on the host, however, no or a little correlation was found (Table 9). To know its cause, correlation coefficients were calculated between them and the field resistance estimated on the basis of experience of breeders (Table 9). As there is no good quantitative estimation of field resistance of the varieties used in the present study, the estimation used by KIYOSAWA[4] was employed after a little modification based on breeder's experience. Given grades of field resistance are as follows: Homare Nishiki, Ginga (1), Shin 2 (3), Norin 22 (3.5) Norin 8 (5), Norin 6 (6), Aichi Asahi, Kusabue and Norin 17 (7). Correlations are generally higher with pathogenicity index than with the amount of sporulation. This indicates that a better approximation can be got by measuring pathogenicity index than by counting the amount of sporulation. The higher correlation of field resistance with the pathogenicity index seems to be inconsistent with the facts that the pathogenicity index is more variable than the amount of sporulation and a significant difference in pathogenicity index was not always observed in individual experiments. This contradiction may partially be explained by the fact that there is no or a little correlation between the amount of sporulation and pathogenicity index. This probably indicates that field resistance is conditioned mainly by host resistance corresponding to fungus aggressiveness expressed in pathogenicity index and partially by host resistance to sporulation. However, the fact that there is no or a little correlation between the amount of sporulation and pathogenicity index suggests the possibility that the correlation between field resistance and resistance to lesion formation or resistance corresponding to aggressiveness of fungus strains is disarranged by resistance to sporulation in some cases. This possibility must not be ignored in future studies.

Two fungus strains, Ken 53-33 and Ken 54-20, were commonly used in both series of experiments. Correlations between the two series are relatively high in both of pathogenicity index and the amount of sporulation, except for sporulation of Ken 54-20. In the second series, Ken 54-20-k^+, a mutant in which avirulence to *Pi-k*-having variety changes into virulence, was used for Ken 54-20 in the first series. If the fact that there is no correlation between sporulating abilities of Ken 54-20 and Ken 54-20-k^+ on the host is always true, the change into virulence to *Pi-k*-controlling resistance may be associated with a change of sporulating ability. This is very important in the breeding of resistant variety, for the change of sporulating ability greatly influences stabilizing selection of virulent fungus strains. It remains also for future studies.

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和文摘要

イネいもち病菌菌系の胞子形成におよぼす宿主の抑制効果の品種間差異

清沢茂久・趙　正翼

いもち病菌の3菌系の宿主植物上での病斑形成と胞子形成へのイネの5あるいは10品種の抵抗性を温室で試験した。胞子形成に対する抵抗性の品種間差異は1回の実験では認められず，2，3回実験を繰返すことにより認められるが，病斑形成に対する抵抗性の品種間差異は，その抵抗性指標に用いた病原力の環境変異が大きいため，1回の実験で認められるときと認められないときがあった。しかしながら，圃場抵抗性との相関関係は胞子形成に対する抵抗性よりも病斑形成に対する抵抗性の方が大きかった。病斑形成への抵抗性と胞子形成への抵抗性との間に相関関係は認められなかった。