日本のコムギうどんこ病菌 (Erysiphe graminis f. sp. tritici) のレースについて

誌名	日本植物病理學會報 = Annals of the Phytopathological Society of Japan
ISSN	00319473
著者	奥, 尚 難波, 成任 山下, 修一
巻/号	53巻4号
掲載ページ	p. 470-477
発行年月	1987年10月

日植病報 53：470-477 (1987)
Ann. Phytopath. Soc. Japan 53：470-477 (1987)

Physiologic Races of *Erysiphe graminis* f. sp. *tritici* in Japan

Takashi OKU*, Shigetou NAMBA*, Shuichi YAMASHITA* and Yoji DOI*

Abstract

Physiologic specialization of *Erysiphe graminis* f. sp. *tritici* collected from fields in Japan during 1962, 1967 and 1984-1986 was examined by detached leaf culture method. Seven wheat cultivars carrying a single gene for resistance, Axminster×Cc^8, Ulka×Cc^8, Asosan×Cc^8, Chul×Cc^8, Khapli×Cc^8, Hope and Sapporo-haru-komugi were used as basic differentials, and twenty races were identified. Taking the distribution of races in Europe and also the breeding program of resistant cultivars into consideration, cultivars, Normandie, Halle Stamm 13471, C. I. 12633, Weihenstephaner M_1, Arthur, Vernal, 0224/52 and Transec were used as additional differentials. However, all additional differentials were highly or moderately resistant to all races found in Japan. Chul×Cc^8 (resistance gene: *Pm*3b) was resistant to all races identified in Hokkaido region, and was susceptible to all races in Chugoku region. It was noted that all cultivars in basic differentials were susceptible to some races found in Japan. Evidences obtained in this study indicate the guideline for breeding program of resistant wheat cultivars against powdery mildew disease. Namely, a major gene for resistance should be used in combination with other major gene(s) especially with that of foreign cultivars or wild relatives, in addition to the other trait responsible for so-called quantitative resistance known as slow-mildewing or durable resistance.

(Received March 25, 1987)

Key words: *Erysiphe graminis* f. sp. *tritici*, physiologic race, differentials, wheat.

Introduction

The use of resistant cultivars or varieties is one of the most desirable method for controlling plant diseases from the economical and the environmental standpoint. However, in some diseases of important crops such as powdery mildew, rust, blast of cereals, late blight of potato, and so on, the success or unsuccess by this method is dependent on the pathogenicity of races of the pathogen which are distributed in the district.

The damage of wheat by powdery mildew in Japan is increasing in recent years as the cultivation area has been increasing. The average crop loss of wheat by this disease is estimated ca. 20% if no control measure will be adopted[41].

The physiologic specialization of powdery mildew fungus of wheat, *Erysiphe graminis* f. sp. *tritici*, was first demonstrated by Waterhouse in Australia[37], followed by scientists in the United States[20] and Germany[35]. In those days, the identification of physiologic races was conducted by using respective set of differential tester cultivars

* Faculty of Agriculture, University of Tokyo, Bunkyo-Ku, Tokyo 113, Japan 東京大学農学部

(differentials) in each country[19,27-29,31]. A set of differentials used in Germany was modified by Leijerstam in Sweden[17,18], but Wolfe[38] finally established a set of 8 cultivars as differentials from those of German and Scandinavian cultivars of which resistance genes were taken into considerations. By using this set of differntials, Wolfe identified thirty-eight races in north-western Europe[39].

In the United States, Briggle[6-8,16] developed near-isogenic lines of wheat carrying one gene for resistance in each line. By using these lines, the yearly change and the frequency of variation of virulence gene in powdery mildew fungus (*E. graminis* f. sp. *tritici*) have been estimated in North America[1,21,33]. Thus, in Europe and the United States, these differential systems have contributed largely to the breeding program of resistant cultivars of wheat against this disease.

On the other hand, no information has been avairable in Japan on physiologic races of *E. graminis* f. sp. *tritici*.

In the present paper, we propose an useful set of differential tester cultivars for identifying physiologic races of *E. graminis* f. sp. *tritici* in Japan, and report results of surveys of races by using this differential set.

Materials and Methods

Collection and storage of cultures. For identifying physiologic races of wheat mildew in Japan, inoculation experiments were made on 18 conidium and 19 ascospore samples collected from 12 prefectures in the period 1962, 1967 (given by Dr. U. Hiura) and 1984-1986. All cultures were obtained through single colony or single spore isolation on wheat cv. Norin 4 (*Triticum aestivum* L.). The plants were inoculated using sterile soft hair pencil at one- to two-leaf stage seedlings which were grown in 30× 300 mm test tubes plugged with sterile cotton at 20 C under the artificial illumination (3,000 lux, 16 hr/day). Three days after inoculation of each culture, test tubes were maintained at 5 C under the constant illumination of 2,000 lux, and cultures were transferred to new plants every month.

Differential tester cultivars. Basic and additional differentials used in this study were as follows;

Basic differentials:

Axminster×Cc^8 (C. I. 14114, resistance gene: *Pm*1)[7,22], Ulka×Cc^8 (C. I. 14118, *Pm* 2)[7,22], Asosan×Cc^8 (C. I. 14120, *Pm*3a)[7,22], Chul×Cc^8 (C. I. 14121, *Pm*3b)[7,22], Khapli× Cc^8 (C. I. 14123, *Pm*4a)[7,22,24], Hope (C. I. 8178, *Pm*5)[16,38] and Sapporo-haru-komugi (one dominant, Dr. H. Yoshida personal communication).

Additional differentials:

Normandie (C. I. 13128, *Pm*1, 2 and 9)[22,25,38], Halle Stamm 13471[38], C. I. 12633 (*Pm*2 and 6)[4,22], Weihenstephaner M_1 (*Pm*4b)[24,38], Arthur (C. I. 14425)[34], Vernal (C. I. 3686)[34], 0224/52 (P. I. 245110)[34] and Transec (*Pm*7)[4,12,23].

Susceptible controls:

Chancellor (C. I. 12333), Little Club (C. I. 4066), Norin 4 and Norin 61.

Inoculation and identification of cultures. Five seedlings per each differential

tester cultivar were cultured in a plastic box (200×300×100 mm) containing sterilized soil. Inoculum was obtained by inoculating 10-day-old Norin 4 seedlings grown in a clay pot (110 mm in diameter) containing sterilized soil. Each pot was covered with an isolation box to prevent contamination.

Inoculations were performed by shaking infected plants (Norin 4) over the 8-day-old seedlings of differential tester cultivars permitting the conidia to fall on them in the inoculation room, and inoculated first leaf of seedlings was cut off and put into an 18×180 mm test tube poured with 2 ml water (detached leaf culture method). Infection types were identified 8-9 days after inoculation by using '0-4' scale[10]. For the purpose of race classification, however, the reactions were described as resistant or susceptible. The resistant class covers the range '0-2' on scale, '3-4' susceptible[38].

Environmental conditions through the series of experiments were described above.

Table 1. Physiologic races of *Erysiphe graminis* f. sp. *tritici* found in Japan

Race	Basic differentials							
	Control	Axminster×Cc^{8}	Ulka×Cc^{8}	Asosan×Cc^{8}	Chul×Cc^{8}	Khapli×Cc^{8}	Hope	Sapporo-haru-komugi
1	S [a)]	−	−	−	−	−	−	−
2	S	S	−	−	−	−	−	−
3	S	S	−	S	−	−	−	−
4	S	S	−	−	−	−	S	−
5	S	S	−	S	S	−	−	−
6	S	S	−	S	−	S	−	−
7	S	−	S	S	−	S	−	−
8	S	S	−	−	−	S	S	−
9	S	S	−	S	−	−	S	−
10	S	S	−	S	S	−	−	S
11	S	S	−	S	−	S	S	−
12	S	S	−	S	S	−	S	S
13	S	S	−	S	S	S	−	S
14	S	S	−	−	−	S	−	−
15	S	S	−	S	−	−	S	S
16	S	S	−	S	−	S	S	S
17	S	−	−	S	−	S	S	−
18	S	S	−	−	S	S	−	−
19	S	S	−	−	S	−	−	−
20	S	−	−	S	−	S	S	S

a) Symbols S and − indicate susceptible and resistant, respectively.

Results

Reactions of basic differentials against physiologic races so far identified in Japan are represented in Table 1. Geographic distribution of races is given in Fig. 1. Samples were not collected from Tohoku, Hokuriku, Shikoku and Kyushu regions.

Twenty races were identified by basic differentials from conidium and ascospore samples in 1962, 1967 and 1984-1986. Samples from Hokkaido region were identified as races 4, 8, 9, 11, 15 and 16, which were characterized by the avirulence against Ulka×Cc^{8} (resistance gene: *Pm*2) and Chul×Cc^{8} (*Pm*3b), and the virulence against

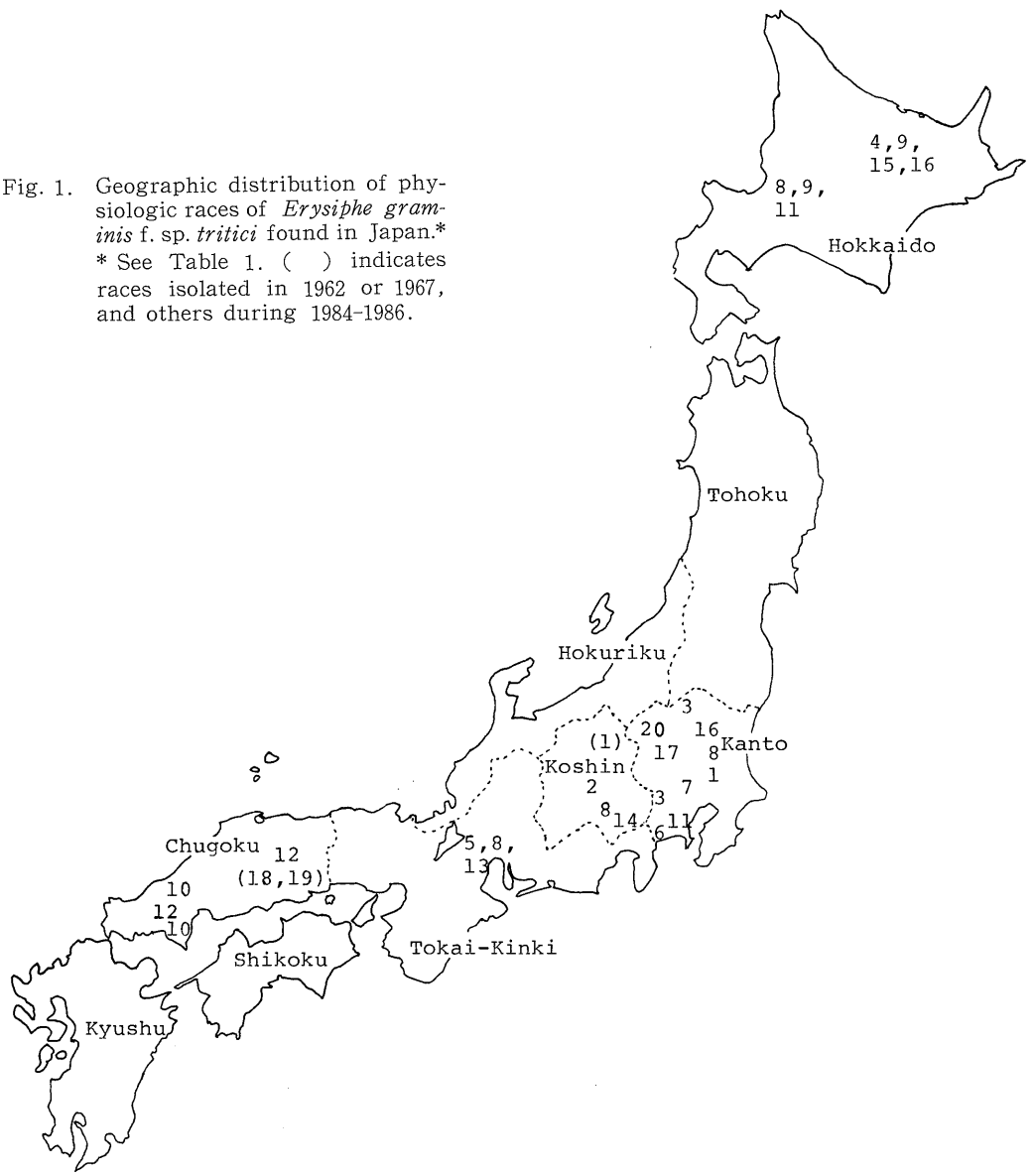

Fig. 1. Geographic distribution of physiologic races of *Erysiphe graminis* f. sp. *tritici* found in Japan.* * See Table 1. ( ) indicates races isolated in 1962 or 1967, and others during 1984-1986.

Axminster×Cc^8 (*Pm*1) and Hope (*Pm*5). Samples from Kanto and Koshin regions were identified as races 1, 2, 3, 6, 7, 8, 11, 14, 16, 17 and 20 characterized by the avirulence to Chul×Cc^8. Race 7 detected in Tokyo was the only one carrying virulence against Ulka×Cc^8 (*Pm*2) in Japan. Races 5, 8 and 13, avirulent to Ulka×Cc^8 were detected from conidium isolates collected at Tokai-Kinki region. Races 10 and 12 in 1985, 18 and 19 in 1962 were isolated from Chugoku region. Former two races attack Axminster×Cc^8, Asosan×Cc^8 (*Pm*3a), Chul×Cc^8 and Sapporo-haru-komugi. Sapporo-haru-komugi was mainly used as a gene source of mildew resistance for breeding program in Japan. Derivatives from Sapporo-haru-komugi, such as Haru-hikari, Haru-yutaka, Ushio-komugi were, therefore, susceptible against races attack Sapporo-haru-komugi. But latter two races, isolated in 1962 when Ushio-komugi was not put to practical use in this region, did not attack Sapporo-haru-komugi (Table 2).

On the other hand, all of the cultivars belonging to the additional differentials were highly or moderately resistant to all races detected in Japan (data is not shown).

Table 2. Reaction of Sapporo-haru-komugi and its derivatives against races of *Erysiphe graminis* f. sp. *tritici*

Cultivar	Infection type[a] against race				
	10[b]	12[b]	16[c]	18[d]	19[d]
Sapporo-haru-komugi	4	4	3-4	0-1	1
Norin 3	4	4	3-4	0-1	0-1
Norin 29	4	4	4	0-1	0-1
Norin 35	4	4	4	0-1	0
Norin 75	3-4	4	4	0	0
Ushio-komugi	4	4	4	0-1	0-1
Haru-hikari	NT[e]	4	4	0	0
Haru-yutaka	4	4	4	0	0

a) 0-2 : resistant, 3-4 : susceptible (after Finkner *et al.*[10] and Wolfe[38]).
b) Isolated in 1985 in Chugoku region.
c) Isolated in 1986 in Hokkaido region.
d) Isolated in 1962 in Chugoku region.
e) Not tested.

Discussion

According to Wolfe[38], the detached leaf culture method for analysis of physiologic races proved satisfactory results in terms of plant reactions and highly advantageous for saving time and space, compared with the whole-seedling methods in a greenhouse. Our modified method may be more convenient than Wolfe's because a large number of cultivars can be treated at once.

This investigation was carried out to know the existance and distribution of physiologic races of *Erysiphe graminis* f. sp. *tritici* in Japan. As the result, twenty races were identified from conidium and ascospore samples. Remarkable differences in virulence were found between races identified in Hokkaindo and Chugoku region against

Chul×Cc[8] (*Pm*3b), though practically avairable cultivars in each region were not carrying *Pm*3b (Table 3). Canadian survey[1,21] showed that Chul×Cc[8] was resistant in nearly all regions, like our results in Hokkaido. These may indicate the effect of environmental conditions, especially low temperature, on the lack of pathogenicity of *E. graminis* f. sp. *tritici* against *Pm*3b.

Our basic differentials used in this experiment seems to be very useful to analyse the predominant races and also yearly change of virulence genes of *E. graminis* f. sp. *tritici* in relation to the change of cultivars[33,40] in every district of Japan.

In the present experiment, we used both conidium and ascospore samples. However, strictly speaking, conidium samples seem to be more suitable than ascospore samples to identify physiologic races of field isolates, because a possibility remains that the pathogenicity of ascospore varies in cleistothecia[30]. Contrary, ascospore samples are advantageous over conidium samples in some respects. The long life of cleistothecia[26] is convenient for storage. Moreover, careful examination on the variability in ascospores which occurs by genetic recombination can be used to forecast the appearance of new races.

Additional differentials seems to be valuable for comparing physiologic races in Japan with that of in Europe[11,12,38,39] and the United States[19,29], and also for breeding program of resistant cultivars. As evidenced in this paper, all additional differentials selected from European cultivars and from cultivars reported by Scharen *et al*[34]. were resistant to all races in Japan and cultivars in basic differentials were susceptible to

Table 3. Wheat cultivars from which each race was isolated

Region[a]	Cultivar (known gene)	Origin of samples[b]	Race
Hokkaido	Chihoku-komugi (?[c])	A	4, 9, 15
	Prelude (none)	A	8
	Norin 26 (none)	A	11
	Norin 29 (SH[d])	C	16
	? (none)[e]	A	8, 9, 11
Kanto-Koshin	Norin 26	C	3
	Norin 61 (none)	A	6, 17
	Tafea 4 (none)	A	6
	? (none)	A and C	1, 2, 3, 6, 7, 8, 11, 14, 16, 17, 20
Tokai-Kinki	Norin 61	C	5, 8, 13
Chugoku	Fukuwase-komugi (none)	A	10, 12
	Shirasagi-komugi (none)	A	12
	Norin 4 (none)	C	18, 19

a) See Fig. 1.
b) A and C indicate ascospore and conidium, respectively.
c) Unidentified gene.
d) Temporary symbol.
e) Susceptible practical cultivars against all races, but names unknown.

more than a single race. These suggest that, from the view-point of breeding program of resistant cultivars, the isolation of resistance gene sources from the pathogen is most important to preserve them for a long time as resistance.

These experimental results and considerations indicate the following guideline for breeding program of resistant cultivars of wheat against powdery mildew disease. (1) Cultivars within additional differentials should not be distributed to the field in practical use, but used only donors of resistance genes. (2) A major gene for resistance should be combined with other major gene, especially genes within European cultivars and wild relatives, in addition with other trait responsible for so-called quantitative resistance[2-5,9] known as slow-mildewing[30,32] or durable resistance[4,13-15].

We are deeply grateful to Dr. U. Hiura, Institute for Agricultural and Biological Sciences, Okayama University, Dr. H. Yoshida, Hokuriku Agricultural Experiment Station and Mr. Y. Amano, Hokkaido Prefectural Kitami Agricultural Experiment Station, for supply of wheat seeds and useful discussions. We are indebted also to the staff members of Department of Botany, Faculty of Agriculture, Hokkaido University and Yamaguchi Prefectural Agricultural Experiment Station for arrangements of our sampling.

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和 文 摘 要

奥　尚・難波成任・山下修一・土居養二：日本のコムギうどんこ病菌（*Erysiphe graminis* f. sp. *tritici*）のレースについて

日本各地で1962, 1967, 1984～1986年に発生したコムギうどんこ病菌（*Erysiphe graminis* f. sp. *tritici*）のレースを判別品種の第1葉への接種による切葉培養検定法で調べた。基準判別品種には単一の抵抗性遺伝子を持つ Axminster×Cc^8, Ulka×Cc^8, Asosan×Cc^8, Chul×Cc^8, Khapli×Cc^8 の各同質遺伝子系統および Hope, 札幌春小麦の7品種を用い，付加的判別品種として，欧州のレースと国内のコムギ育種計画を考慮し，Normandie, Halle Stamm 13471, C. I. 12633, Weihenstepaner M_1, Arthur, Vernal, 0224/52 および Transec の8品種を用いた。付加的判別品種は，いずれの菌系に対しても抵抗性を示したが，基準判別品種によって，20のレースが確認された。Chul×Cc^8（抵抗性遺伝子：*Pm*3b）に対して，北海道のレースはいずれも非病原性であったが，中国地方のレースは病原性を示した。一方，全てのレースに対して抵抗性を示した基準判別品種はなかった。従って，うどんこ病抵抗性コムギ品種の育種には，複数の主働抵抗性遺伝子の利用，外国品種や近縁野生種の持つ新たな抵抗性遺伝子の導入，さらに量的抵抗性の利用などが必要と考えられた。