A New Snow Mold of Wheat and Barley Caused by Foot Rot Fungus, *Ceratobasidium gramineum*

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Key words: snow mold, wheat, barley, *Ceratobasidium gramineum*.

Among five snow molds reported to date in Japan¹⁾, *Pythium* snow rot caused by *Pythium* spp., Typhula snow blight by *Typhula incarnata* and pink snow mold by *Fusarium nivale* were found to occur in Fukui Prefecture²⁾. In the prefecture the author has surveyed the occurrence of snow molds of wheat and barley from 1981 to 1986 and found a unique type of snow mold in 1983 which was distinct from the already-known snow molds. A further survey revealed that this type of snow mold occurred in various places in Fukui Prefecture and also in Niigata Prefecture (T. Yaoita, personal communication). *Rhizoctonia* sp. was most frequently isolated from the rotted leaves of barley and wheat. By the inoculation and identification tests, it was revealed that this fungus was a causal agent of this snow mold and also that of foot rot of wheat and barley.

Yasuo *et al.*³⁾ reported that foot rot of wheat and barley occurred from just after seed germination until early winter and also during early spring, and that it became latent during mid- and late-winter. No reports have been available to show that this fungus causes snow mold of cereals under snow cover condition. Therefore, its detail is described in the present paper. Part of the work has been reported elsewhere⁴⁾.

Symptoms. Infected leaves were rotted entirely showing a dark-green appearance just after snow melted. After drying, they turned pale gray to pale yellow (Fig. 1). Surviving leaves had ellipsoidal lesions with a narrow brown margin on which pale gray mycelial mat was usually observed at the center (Fig. 2). Leaf sheaths frequently showed a brownish appearance. The development of symptoms became stagnant after snow melted, but in late April ellipsoidal lesions were found on the leaf sheaths near soil level. This snow mold is distinguishable from pink snow mold by the color of rotted leaves, because the latter becomes pinkish or pale red. Similar lesions were often found on leaves infected with *T. incarnata*, but in this case millet-like sclerotia were formed on the rotted plants. On the other hand, no sclerotia can be found on plants infected with the present snow mold at least just after snow melts. It was also distinguishable from *Pythium* snow rot because no oospores and many septate hyphae were found in rotted leaves.

This disease occurred on both wheat and barley, but more frequently on the latter. It frequently occurred in well-drained upland paddy fields.

Pathogenicity. Barley was inoculated with an isolate of this snow mold, HS8404, and that of foot rot fungus, C-1-1, which were obtained, respectively, from a lesion of snow mold and foot rot of barley in a field of the Fukui Agricultural Experiment Station as follows. The isolates grown on wheat bran-sand mixture at 20 C for 2 weeks were used as inocula. At the first experiment, seeds of barley (cv. Benkei mug) were planted in a 15×5×10-cm plastic box

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1) Tomiyama, K. (1965). Ann. Phytopath. Soc. Japan 31: 200-206. 2) Takamatsu, S., Kawakubo, Y. and Imamura, K. (1986). Bull. Fukui Agr. Exp. Sta. 23: 27-40. 3) Yasuo, S., Yamaguchi, T., Ishii, M. and Yanagita, K. (1971). J. Cent. Agr. Exp. Sta. 15: 65-92. 4) Takamatsu, S. (1986). Ann. Phytopath. Soc. Japan 52: 121 (Abstr.).

Fig. 1. Damage to growing barley in field by *Ceratobasidium gramineum* (arrow).

Fig. 2. Symptoms of snow mold on barley by *Ceratobasidium gramineum*.

(10 seeds/box) in early March, and incubated outdoors for a month until seedlings attained the 3~4-leaf stage. The daily mean temperatures of the season were between 3.5 and 13.3 C, which corresponded with those of late November and early December in this district. Then, the entire seedlings were bent to contact with a thin layer of the inoculum which had been applied previously onto the soil surface (20 g/box) and covered with a pad of wet absorbent cotton to simulate snow cover. The box with inoculated seedlings was incubated for 40 and 60 days in a cold (0~1 C), dark room which was similar to snow-covered condition. The experiment was conducted with four replicates (40 plants/fungus). Detail of the method was described previously^{5,6}. As shown in Table 1, both isolates killed all the barley plants within 40 days under snow-covered condition. At the second experiment, about 50 mg of the inoculum were inserted between leaf sheath and culm at the position 5~10 cm upper from soil surface of barley (cv. Minori mugi) grown in a field in early May. The inoculated parts were surrounded with paper wetted by sterilized distilled water and further covered with parafilm (10 plants/fungus). Both isolates formed lesions of foot rot in the inoculated parts 1 week later. The same fungi were reisolated from the infected parts in both experiments.

Identification. Mycelium on potato-dextrose agar (PDA) was hyaline at first and be-

5) Takamatsu, S. (1983). Proc. Assoc. Pl. Prot. Hokuriku 31: 79-81. 6) Ichitani, T., Takamatsu, S. and Stamps, D.J. (1986). Ann. Phytopath. Soc. Japan 52: 209-216.

Table 1. Damage of barley (cv. Benkei mug) caused by inoculation of snow mold (isolate HS8404) and foot rot fungus (C-1-1) under snow-covered condition

Isolate	Incubation period (days) at 0~1C		
	40	50	60
HS8404	0/40 ^{a)}	0/40	0/40
C-1-1	0/40	0/40	0/40
None	40/40	40/40	40/40

a) No. of surviving plants / No. of plants tested.

Fig. 3. Average linear growth rate of two isolates of snow mold and foot rot fungus of barley on PDA between 1 and 35 C. ●: Isolates of snow mold (HS8404, HS8501), ○: Isolates of foot rot fungus (C-1-1, C-2-2).

came pale brown about 2 weeks later at 24 C. Sclerotia about 0.5~1.0 mm in diam. with lusterless surface were formed on mycelial mat developing on the medium.

Growth rate of isolates of snow mold, HS8404 and HS8501, and that of foot rot fungus, C-1-1 and C-2-2, on PDA was examined at 1~35 C (Fig. 3). All isolates grew with a similar rate. Optimum temperature for mycelial growth of the former fungus was between 21~24 C. Radial growth rate was 6~7 mm/24 hr at the optimum temperature and about 0.9 mm/24 hr at 1 C. No hyphal growth was observed at 35 C. Three isolates of an anastomosis group of binucleate *Rhizoctonia* AG-D⁷⁾ which is a foot rot fungus of wheat and barley, grew at the same rate as the snow mold fungus at 1~10 C.

The width of main hyphae ranged 3.5~7.5 μ m in three isolates of the respective snow mold and foot rot fungus, being similar to that of three isolates of AG-D (3.0~5.8 μ m) and different from that of two isolates of an anastomosis group of *R. solani*, AG-2-1 (6.3~10.5 μ m).

Hyphal anastomosis tests were conducted with each of three isolates of snow mold and foot rot fungus against 6 anastomosis groups of *R. solani* and 5 groups of binucleate *Rhizoctonia*, as described by Ogoshi⁸⁾. As indicated in Table 2, all test isolates of both fungi fused with binucleate *Rhizoctonia* AG-D (a foot rot fungus of wheat and barley), but not with all other *Rhizoctonia*. Hyphal fusion was also observed between isolates of snow mold and foot rot fungus.

From the above results, the pathogen of this snow mold is identified as *Ceratobasidium*

7) Ogoshi, A., Oniki, M., Sakai, R. and Ui, T. (1979). Trans. mycol. Soc. Japan 20: 33-39. 8) Ogoshi, A. (1976). Bull. Natl. Inst. Agric. Sci. Ser. C 30: 1-63.

Table 2. Anastomosis of isolates of snow mold and foot rot fungus of barley with several anastomosis group of *Rhizoctonia* spp.

Anastomosis group of <i>Rhizoctonia</i>	Isolate of <i>Rhizoctonia</i> ^{a)}	Isolate of snow mold			Isolate of foot rot fungus		
		HS8401	HS8404	HS8501	C-1-1	C-1-2	C-2-2
AG-1	C-325	— ^{b)}	—	—	—	—	—
	C-527	—	—	—	—	—	—
AG-2-1	Fc-2	—	—	—	—	—	—
	SH-32	—	—	—	—	—	—
AG-2-2	C-103	—	—	—	—	—	—
	R-K-1	—	—	—	—	—	—
AG-3	ST-2	—	—	—	—	—	—
AG-4	F-10	—	—	—	—	—	—
	C-549	—	—	—	—	—	—
AG-5	ST-8	—	—	—	—	—	—
	SH-30	—	—	—	—	—	—
AG-A	C-638	—	—	—	—	—	—
	C-641	—	—	—	—	—	—
AG-Ba	C-145	—	—	—	—	—	—
	C-484	—	—	—	—	—	—
AG-Bb	C-511	—	—	—	—	—	—
	C-345	—	—	—	—	—	—
AG-D	C-449	+	+	+	+	+	+
	C-589	+	+	+	+	+	+
AG-G	C-592	—	—	—	—	—	—
	C-653	—	—	—	—	—	—

a) Isolates sent by Dr. M. Oniki, Research Institute for Spices and Medicinal Crops, Indonesia.

b) —: no anastomosis; +: anastomosis.

gramineum Oniki, Ogoshi et Araki⁹⁾ (Syn. *Corticium gramineum* Ikata et T. Matsuura) which has been known as a foot rot fungus of wheat and barley.

Besides *Typhula* spp., three unidentified basidiomycetous fungi, called low-temperature basidiomycete, were described as snow mold pathogens of cereals in Canada¹⁰⁾. Since these fungi have clamp connections in their hyphae, they evidently differed from the present *C. gramineum* with no clamp connection. As far as literature published to date has been surveyed, the present paper seems to give the first description on the snow mold of cereals caused by *Cerato-basidium*.

The author wishes to thank Dr. M. Oniki, Research Institute for Spices and Medicinal Crops, Indonesia, for sending the isolates of anastomosis groups of *Rhizoctonia* and for his helpful advice during this work. Thanks are also to Dr. H. Kunoh, Mie University, for critical reading of the manuscript.

9) Oniki, M., Ogoshi, A. and Araki, T. (1986). Trans. mycol. Soc. Japan 27: 147–158. 10) Ward, E.W.B., Lebeau, J.B. and Cormack, M.W. (1961). Can. J. Bot. 39: 297–306.

和 文 摘 要

高松 進：ムギ類株腐病菌 *Ceratobasidium gramineum* によって引き起こされるムギ類の新雪腐症状

1983 年に福井県内のオオムギおよびコムギ畑において既知の雪腐病とは異なる雪腐症状の発生を認めた。融雪直後の茎葉は暗緑色に腐敗しており、乾くと灰白色ないし黄白色になる。生き残った葉には楕円形の病斑が形成される。病斑の周囲には明瞭な褐色のふちどりがあり、中央部に灰白色ないし淡褐色の菌糸塊が見られる。菌糸融合などの諸性質を検討した結果、病原菌はムギ類の株腐病をおこす *Ceratobasidium gramineum* Oniki, Ogoshi et Araki (Syn. *Corticium gramineum* Ikata et T. Matsuura) と同一種であることが明らかになった。

(Received October 25, 1988)