EB1880

PLANT DISEASE

SNOW MOLD DISEASES OF WINTER WHEAT IN WASHINGTON

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Snow mold diseases of wheat are some of the most dramatic and devastating diseases of plants. In the Pacific Northwest (PNW), the snow molds are important in areas where snow falls on unfrozen or lightly frozen soil and persists for 100 days or more. Snow mold was prevalent in Washington from the 1940s through the 1970s, but occurred infrequently during the 1980s. In 1995, we converted a disease observation nursery on the farm of Adelbert Jacobsen near Mansfield, to yield trials so we would have a more accurate way of evaluating varieties and breeding lines for resistance to snow mold. Significant losses due to snow mold occurred in parts of Douglas and Okanogan counties in both 1995 and 1996. Snow mold was a significant problem over a much wider area of the state in 1997 due to snow cover that lasted for 150 days in some areas. This bulletin describes occurrence of the snow mold diseases in the PNW, their symptoms, and methods of control.

Snow mold was first recognized as a disease problem in the PNW in 1923 from wheat grown in Fremont and Teton counties of southern Idaho. Prior to this time, the disease was thought to be a form of winterkill. In 1924 and 1929, respectively, snow molds were observed on wheat grown near Chelan, Washington, and in Gallatin County, Montana. Although work describing the pathogens and diseases they cause was conducted during the 1920s and 1930s, the perceived importance of snow molds by growers increased substantially during the 1940s. Research into control began in Washington state when Drs. Charles S. Holton, with the U.S. Department of Agriculture, and Roderick Sprague, with Washington State College, (now Washington State University), began to search for a control.

Four different snow mold diseases, all caused by soil-borne fungi, occur in Washington: pink snow mold (*Microdochium [Fusarium] nivale*), speckled snow mold (*Typhula idahoensis*, *T. ishikariensis*, and *T. incarnata*), snow scald (*Myriosclerotinia borealis*), and snow rot (*Pythium iwayami* and *P. okanoganense*). In addition to speckled snow mold, *T. incarnata* is often found causing a root and crown rot of wheat and barley in the absence of snow cover.

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Pink snow mold is the most widespread of these diseases, occurring on wild grasses, lawns, and winter wheat throughout the PNW. On wheat, however, pink snow mold is less destructive than speckled snow mold (primarily *T. idahoensis* and *T. ishikariensis*), which is restricted to higher elevation areas in Washington (Douglas, Okanogan, Lincoln, Chelan, Grant, and Spokane counties), Idaho (Teton, Fremont, Bonneville, and Caribou counties), and Montana (Gallatin County). In addition to the PNW, both speckled and pink snow molds occur in Alaska, Canada, Japan, Scandinavia, Central and Eastern Europe, and parts of the former U.S.S.R.

Speckled snow mold on turf and crown, and root rot of wheat and barley (both caused by *T. incarnata*) are widespread throughout much of the PNW, but do not usually cause significant losses of wheat. Snow scald and snow rot are limited in distribution and their overall impact on winter wheat production is minimal. This bulletin will focus on speckled snow mold and pink snow mold.

Symptoms

Snow mold diseases destroy the leaves and crowns of host grasses under snow. Following snowmelt, the leaves of plants with speckled snow mold are matted to the soil and covered with a whitish gray fungal growth (Fig. 1).

The fungal growth disappears after a few days of dry, sunny weather, and numerous dark-colored bodies the size of radish seeds known as sclerotia become visible over the surface of infected plants (Fig. 2). Sclerotia of *T. idahoensis* and *T. ishikariensis* are more or less round and dark brown to black, whereas those of *T. incarnata* are irregularly shaped, reddish brown, and more abundant on roots and between sheaths in the crown than *T. idahoensis* and *T. ishikariensis*.

Immediately following snowmelt, plants with pink snow mold have a whitish fungal growth covering the leaves. The fungal growth soon turns a characteristic salmon color, resulting in the name "pink" snow mold (Fig. 3). Leaves and leaf sheaths with pink snow mold remain intact and turn a light to dark brown color, as opposed to the disintegration that occurs with speckled snow mold. Disease severity ranges from relatively small lesions on leaves to complete destruction of the foliage and dead plants.

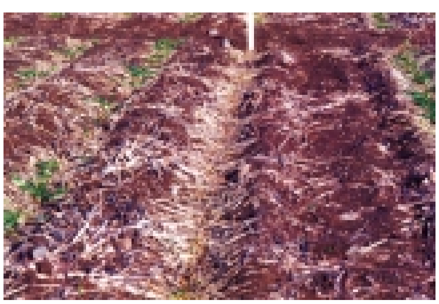

Figure 1.
Damage to winter wheat by speckled snow mold is apparent following snowmelt.

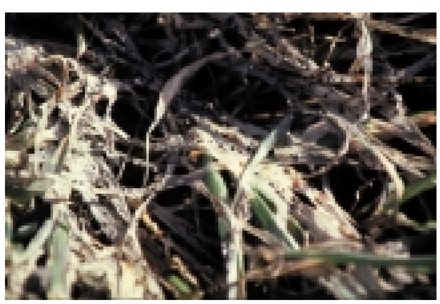

Figure 2.
Sclerotia of the snow mold pathogens are visible on infected plants soon after snowmelt.

Figure 3.
Symptoms of pink snow mold following snowmelt.

Disease Development

The fungi causing speckled snow mold survive between crops as sclerotia in soil and infested host debris. Although sclerotia can germinate in the fall and produce airborne spores, most infections are the result of fungal strands (hyphae) growing from sclerotia in soil under the snow. Germination of sclerotia and infection of plants begin within one month after snowfall and continue as long as snow cover persists. Invasion of crowns and death of plants occur after about three months of snow cover; consequently, damage from speckled snow mold increases with longer snow cover.

The fungus causing pink snow mold survives between crops primarily in residue from previously infected plants. Infection of leaves occurs during cool, wet weather in the fall before and after snowfall. Fungal filaments growing from infested residue near the soil surface penetrate leaves and continue to grow in infected plants as long as the snow persists. The pink snow mold fungus also produces airborne spores, but most of these spores are released during spring or summer and are, therefore, not important for development of snow mold. These spores can be important, however, for the development of head scab in areas with warm and moist environmental conditions during flowering.

Development of snow mold is favored by rain during the autumn and snow falling on unfrozen or lightly frozen soil that persists for approximately 100 days or more. Deep snow cover insulates plants and soil, maintaining temperatures close to 32° F with relative humidity near saturation, both of which are favorable to growth of these fungi. Deep snow also ensures contact between leaves and soil, thus allowing an entry point for the fungi, while at the same time preventing photosynthesis, which is thought to make plants more susceptible to infection due to a depletion of carbohydrates in the crown. Frozen soil, intermittent snow cover, or less persistent snow cover reduce the severity of snow mold.

Economic Importance

Occurrence of snow molds is sporadic. In years when disease is severe, entire fields may be killed and require reseeding, whereas in other years the diseases do not occur or are insignificant. In Douglas County from 1947 to 1966 (19 crop years), speckled snow mold was severe in four years, moderate in eight years, light in three years, and not present in four years. In other words, snow mold caused significant losses more than half of this time period.

Statewide, it is estimated that about 200,000 acres are chronically affected by the snow molds. Although precise estimates for dollar loss do not exist, in 1953, Sprague estimated annual losses due to speckled snow mold at about $300,000 and for pink snow mold, up to $1 million (1953 dollars). In 1953, Dr. Hugh C. McKay and John M. Raeder estimated annual losses due to speckled snow mold in southern Idaho from $50,000 to $800,000.

Control

Early research focused on cultural practices including seeding date, crop rotation, fertilizer application, residue management, fall fungicide application, and the application of blackeners to snow to hasten snowmelt. Later, disease resistance was sought as a control.

Cultural practices.

An association between early seeding and improved spring recovery of snow mold infected plants was made soon after the disease was recognized. Two schools of thought emerged on how best to manage seeding dates. Early seeding (early to late August) results in large, well-tillered plants that tolerate the disease and recover in the spring better than late seeded plants. In contrast, late seeding (October 1-15) results in small plants that may escape the disease entirely. Late seeding has not been recommended in Washington because yield potential is less than with early seeding, especially in non-snow mold years, and although small plants may escape disease, most die when infected.

Planting method, that is, deep-furrow or double disc had no effect on disease as long as plants emerged and became established soon after seeding. Likewise, clean tillage and stubble mulch had no direct effect on disease as long as plants were established soon after seeding. Application of nitrogen and phosphorus fertilizers had no direct effect on disease development, but were valuable for more rapid recovery of diseased plants in the spring.

Crop rotation provides time for infested crop debris to decompose and for sclerotia to die. Fields in which spring cereals or legumes were grown in place of winter wheat, and not sown following a crop destroyed by snow mold, had less snow mold in subsequent years. Controlling weeds during the rotation is important, however, since many grasses are susceptible to snow mold and can provide inoculum for subsequent crops.

Fungicides.

Holton and Sprague tested fungicides for control of snow mold from 1944 until the late 1950s. Several fungicides containing mercury effectively controlled snow mold when applied in the fall before snowfall; however, the unpredictability of snow mold occurrence coupled with the high cost of $5 to $7 per acre (1950s' dollars) prevented them from being widely adopted by growers. Only growers in areas where snow mold was severe nearly every year and who could not grow spring wheat used fungicides. The economics of wheat production in the chronic snow mold area have not changed and there are no fungicides currently registered for snow mold control.

Snow blackeners.

Spreading dark colored materials such as coal dust, fly ash, or lamp black to hasten snowmelt has been used to control snow mold. William R. Fischer and Dr. George W. Bruehl tested several different materials, application methods, and rates of application in the early 1960s. Although they were able to hasten snowmelt by up to 20 days, they were unable to demonstrate a clear economic return due to unpredictable weather conditions after dusting. In some cases, snow after dusting covered the blackeners and prevented them from melting the snow. In others, the wheat did not respond to early snow removal because of cold, wet weather afterwards.

Dry coal dust applied at 150 to 200 lbs per acre is adequate to cover snow and hasten melting. Coal milled larger than 200-mesh flowed well from hoppers and settled well on the snow; however, finer materials present drifting problems. Slurries of blackeners work well, but the weight of the water may increase the cost of application. Low sun angles on steep north slopes prevent dusting from greatly accelerating snowmelt and the temptation should be avoided. In addition, it may require several farmers working together to obtain a cheap supply of blackeners.

Disease resistance.

Although reports in the 1940s indicated some Japanese wheat varieties were resistant to the snow molds, none of the reports were substantiated. A dedicated search for disease resistance began in earnest in 1960 when Sprague planted 5,200 wheat lines from the USDA world collection in a plot near Mansfield. He planted another 4,000 lines the following year at the same location, but died before seeing the results. Dr. George W. Bruehl culminated the search for a snow mold resistant variety adapted to the PNW in 1972 with release of Sprague, which was named in honor of Roderick Sprague. Only 15 of the original 8,200 lines screened for resistance to snow mold were considered promising sources of resistance and these have been used in breeding programs since.

The value of resistance for control of snow mold is both visually (Figs. 4 and 5) and economically dramatic (Table 1). Figure 4 illustrates recovery of a snow mold resistant variety about one month after snowmelt, compared with a susceptible variety. (Figure 5). The photographs in Figures 6 & 7 were taken at a nursery on the University of Idaho Experiment Station in Tetonia, a high elevation site where snow mold is very severe nearly every year. Under these harsh conditions, the resistant variety Sprague survived (Figure 6), but the susceptible variety Nugaines was killed by snow mold (Figure 7). Snow mold was not as severe in 1996 at the nursery near Mansfield, as at the Tetonia location; however, yield of the resistant varieties Sprague and Eltan was significantly better than Moro and Stephens (Table 1), but equal to or slightly less than Edwin (formerly WA7834) and Bruehl (formerly WA7833). As a result of this work, the club wheat Edwin was released in 1998, and club wheat, Bruehl was released in 1999. These lines have very good snow mold resistance and yields competitive with Sprague and Eltan (Table 1). There has never been a club wheat released with snow mold resistance equal to or better than Sprague.

Figure 4.
Recovery of a snow mold resistant variety following snowmelt is characterized by vigorous growth.

Figure 5.
Lack of vigorous regrowth by a snow mold susceptible variety.

Figure 6.
Nearly complete recovery of a plot of Sprague winter wheat by speckled snow mold.

Figure 7.
Nearly complete destruction of a plot of Nugaines winter wheat by speckled snow mold.

Maturity date is an important characteristic of snow mold resistance. Severe snow mold delays maturity and is especially apparent with susceptible varieties. In 1997, maturation of Eltan, Moro, and Stephens was approximately two weeks later than Sprague, Edwin, and Bruehl.

Growing resistant varieties is the most effective and affordable control measure for snow mold. Presently, Sprague and Eltan are the predominate varieties grown in the snow mold areas of Washington. Both varieties have shortcomings. Sprague is more resistant than Eltan, but has weak straw and a tendency to lodge. Eltan is less resistant and matures later when injured by snow mold, but has excellent yield potential and end-use quality. A concentrated effort is currently underway to select resistant varieties with better snow mold resistance, stronger straw with less tendency for lodging, high yield potential, and good end-use quality. We are very optimistic that the two new lines in Table 1 will be effective replacements for the current snow mold resistant varieties. We see these as the first in a succession of varieties that will eventually afford growers in snow mold areas a choice in variety and market class equal to other production areas of the state.

Replanting

As the snow cover retreats and damage from snow mold becomes evident, the decision of whether or not to replant is difficult for growers. The wheat will look very bad as the snow melts and may even look worse for the first few days after the snow is gone. Cold conditions after snowmelt can further weaken the wheat plants. Warm conditions hasten the decomposition of the badly affected leaves. In addition, one has to line up additional seed at the same time everyone else is buying spring wheat seed. All of this leaves the grower anxious.

Stress is rarely lessened when the advice is to be patient. It takes two to three weeks for the stressed plants to show signs of recovery. It also takes about that long for fields to dry enough to allow fieldwork. Although there has been little work comparing snow mold damaged winter wheat stands and yields to replanted spring wheat, some data exists from winterkill research. There, the recommendation has been six live winter wheat plants per square foot would equal a replanted spring wheat yield. This is six plants per foot of row in 12-inch rows, more in wider spacing, fewer in narrow row spacing. This is based, however, on research conducted before the advent of the new, higher yielding spring wheats. Another confounding factor is that rarely do whole fields need to be replanted. Replanting partial fields can cause harvesting difficulties due to differing maturities. It is rarely advisable to replant without destroying the remaining winter wheat. It is important to break the green-bridge between crops so an additional 10 (minimal) to 21 (preferred) days elapse before replanting.

Table 1.

Snow mold ratings, yield and test weight for winter wheat varieties and breeding lines grown near Mansfield, WA, in 1995-1996 on the Jacobsen farm.

	Market	SM Rating[c]			Yield, bu/ac			Test wt., lbs/bu		
Variety[a]	class[b]	1995	1996	1997	1995[d]	1996	1997	1995	1996	1997
Bruehl	Club	5.0	5.7	5.0	-	89.9	67.9	-	57.9	58.1
Sprague	SWW	5.3	5.5	5.8	-	77.2	52.9	-	60.6	61.7
Eltan	SWW	3.6	3.5	3.8	-	66.2	64.2	-	58.3	55.7
Edwin	Club	na[e]	3.3	4.5	-	68.8	60.9	-	61.3	61.0
Moro	Club	2.2	2.9	4.3	-	49.7	52.9	-	58.3	60.0
Stephens	SWW	Na	0	2.0	-	6.0	17.0	-	49.0	58.5

[a] *Sprague, Eltan, and Moro are commercial varieties with varying degrees of resistance to snow mold. Edwin is a snow mold resistant club wheat released in 1998, and Bruehl is a snow mold resistant club wheat that was released in 1999.*

[b] *SWW = soft white winter wheat; Club = soft white winter club wheat.*

[c] *SM = snow mold rating is a visual estimate of growth approximately one month after snowmelts that is based on both the percent recovery and vigor. The scale ranges from 0 to 8, with 0 equaling no recovery and 8 equaling complete recovery.*

[d] *Yield data were not collected in 1995.*

[e] *na = data not available; Edwin was not grown at this location in 1995.*

Recommendation

Severe snow mold years are generally good moisture years. The season is delayed, warming up later than usual, hence the long snow cover. Wait two weeks after the snow has left most of the field, then carefully survey the field. Small patches of dead wheat may not be worth replanting. Large acreage may require further consideration.

- If the wheat is totally dead, then the replant decision is a little easier. There should be good moisture and fertilizer remaining in the field, although starter fertilizer may help as last year's fertilizer may have leached a foot or two through the soil profile.

- If there are more than eight plants per square foot on average, it may not pay to replant.

- Four to eight plants per square foot require careful consider-ation. How soon can you work the field? What does the long-term weather look like, and how well does spring wheat normally yield in the field? What seed can you get? What price will wheat bring? Then comes the balancing act. Will the reduced yield from the damaged winter wheat cover the costs already invested in the field? Or will the costs of replanting and the expected increased harvest bring a better bottom line?

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