Effect of Organic Residues on Snowmold of Winter Wheat

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ABSTRACT

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Surface application or incorporation into the top 25 mm of soil of several organic materials after seeding winter wheat generally increased the severity of snowmold caused by *Fusarium nivale* and *Typhula idahoensis*. Chitin amendment resulted in the most severe snowmold caused by both pathogens. Wheat and barley residues also increased snowmold, but appeared to increase pink snowmold caused by *F. nivale* more than by *Typhula*. Ground alfalfa hay amendment generally had no effect on snowmold. Flaming the soil after seeding to remove surface residues nullified the residue effect and provided partial control of snowmold. Organic amendments apparently provided a nutrient substrate for extensive saprophytic growth prior to parasitic activity.

Additional key words: biological control, crop rotation, sclerotia.

Various organic materials have been proposed as soil amendments to stimulate microbial activity and to effect biological control of soil-borne pathogens (5, 6, 9). The influence of a specific crop sequence rather than the time between plantings of a particular crop also suggests the importance of organic residues on disease incidence and severity (9). We have observed the effects of specific crop sequences on the severity of snowmold of winter wheat caused by psychrophilic *Typhula idahoensis* Remsberg (speckled snowmold) and *Fusarium nivale* (Fr.) Cesati (pink snowmold) for several years. Alfalfa or other legumes immediately preceding wheat in the rotation markedly reduced snowmold (8, 12). However, alfalfa is not readily established or economically feasible for much of the arid, high-altitude, nonirrigated wheat land (8).

Snowmold is primarily a disease that results in maceration of foliar tissues by pathogen-produced extracellular enzymes (13). Early seeded fall wheat with extensive foliage pressed to the soil surface by early snows often is more severely molded than plants with only 2-3 leaves prior to snowfall (2, 3, 7, 10, 12), although very early seeded plants may regrow from surviving crown tissues and produce a modest crop (2). Since *Typhula* sclerotia, the primary source of inoculum, buried deeper than 22-25 mm in soil seldom germinate or become parasitic (2, 3), the pathogenic relationship appears to involve phenomena at the soil-plant foliage interface.

Although fewer sclerotia of *Typhula* survived burial in alfalfa soils than in wheat soils, Huber and McKay (8) associated the reduced disease severity following alfalfa with induced sclerotial dormancy (fungistasis) imposed by colonizing psychrophilic bacteria. If disease severity could be reduced by broadcasting a specific residue over the soil surface, disease control benefits of crop rotation may be achieved where otherwise not feasible. Likewise, if disease severity could be reliably predicted, then greater progress in breeding programs for resistance could be anticipated. This study was initiated to evaluate the effect of various organic amendments on the incidence and severity of snowmold under field conditions.

MATERIALS AND METHODS

Ground (7.6 mm) mature plant residues of wheat, barley, and alfalfa and regular and deproteinized chitin were broadcast over the soil surface after planting and then mixed with the surface soil with a hand rake. Four replicate plots, each 3.1 × 6.2 m, of each treatment were established in a random block design at various locations in south central (Camas County) and southeastern (Fremont and Teton Counties) Idaho where snowmold is a potential hazard for wheat production. A rate of 220 kg/ha crop residue was used, since this rate achieved maximum effect in preliminary studies (Table 1). All amendments were applied 5 to 8 weeks (20 October to 10 November) after seeding (4-12 September) which permitted the selection of areas with uniform stand. Visual estimates of disease severity were made within 2 weeks after spring snowmelt and again 4-5 weeks later after potential regrowth from crown tissues could be evaluated. Separate readings were recorded where possible for pink snowmold (caused by *F. nivale*) and speckled snowmold (caused by *T. idahoensis*). Both fungi frequently occurred together and separate evaluations were not possible. Grain quality evaluations (% protein and sedimentation) were made by Mr. Martin Wise, Idaho Wheat Quality Laboratory, Aberdeen.

In order to estimate the effect of amendments on sclerotial production by *Typhula*, all plant tissue was removed carefully from three 0.093 m^2 areas of soil for each treatment and sifted through a series of screens to recover sclerotia. In addition, the top 6-7 mm of soil was screened for sclerotia and their numbers were recorded. To remove surface residue and fall foliage from some treatments, a single nozzle (16-cm diameter flame) "fence row" propane burner was used. The "light" burn treatment consisted of surface flaming from 30-cm nozzle height at 2 mph. The "heavy" burn was at 1 mph. Yield data were obtained by harvesting 2 m^2 from the center of each plot. Several locations were not harvested because extensive winter kill had occurred.

RESULTS

Effect of organic residues.—Wheat plants in plots amended with wheat or barley residues were severely molded by *F. nivale* at all eleven locations even though the nontreated check plots were molded only moderately at several of the locations (Fig. 1, Table 2). *Typhula* snowmold also was increased after application of wheat or barley residues but less so than was *F. nivale*. Severe pink snowmold occurred after residue amendment in both of these areas which had been previously considered predominantly *Typhula* (speckled) snowmold areas. Alfalfa residues did not significantly reduce snowmold (Table 2). Chitin amendment greatly increased the severity of snowmold at all locations (Table 2). Increased rate (1,100 versus 220 kg/ha) and increased purity (regular versus deproteinized) of chitin resulted in increased disease severity even though the nonamended plots were molded only moderately (35% plant kill). The mycelial mat developing under the snow frequently was more dense on amended than on nonamended plots. Years with relatively open winters which permitted the ground to freeze were less conducive to snowmold than years when the soil was insulated by early snowfall on unfrozen ground. Regrowth sometimes occurred from crown tissues even though initial readings indicated more severe damage.

Effect of flaming.—Under the moderately severe snowmold conditions which generally occurred, flaming the soil surface provided reasonable control of snowmold (Table 3). Reduced snowmold was also reflected in increased yield and quality of the hard red winter wheat cultivars grown at the test locations. Although flaming burned the leaves 2-6 mm below the soil surface, 5-8 cm regrowth above the soil surface prior to snowcover was evident. This regrowth appeared to be darker green with a dense brown margin, which is characteristic of a wound reaction at the burned tip. This growth was also upright or "tufty" rather than prostrate like the nonburned wheat.

TABLE 1. Treatments, rates, and locations used to evaluate the effect of organic amendments on snowmold of wheat

Treatment	Rate (kg/ha)	Number of locations	Years tested	Snowmold incidence
None (check)		11	3	mild-to-severe
Barley	220	11	3	mild-to-severe
Wheat straw	220	11	3	mild-to-severe
Alfalfa hay	220	8	3	mild-to-severe
Chitin, regular	220	2	1	mild
Chitin, regular	1,100	2	1	mild
Chitin, deproteinized	220	2	1	mild
Chitin, deproteinized	1,100	2	1	mild
Surface flaming	light	4	2	moderately severe
Surface flaming	heavy	4	2	moderately severe

TABLE 2. Incidence and severity of snowmold of winter wheat after organic amendment

	Snowmold incidence				
	Mild	Moderately severe			
Amendment	(%)	(%)	Yield (quintals/ha)	Protein (%)	Sedimentation values
None[x]	10 a	54 a[u]	23[x]	9.7 ab	30 bc
Alfalfa[s,x]	5 a	51 a	23	10.1 c	32 c
Barley[s,x]	30 b	74 b	11	9.8 b	29 ab
Wheat[s,x]	57 c	89 c	8	9.5 a	27 a
None	35 a[v,y]	71 a[w,z]			
Regular chitin[s]	60 b[v]	86 b[w]			
Regular chitin[t]	71 bc[v]	97 c[w]			
Deproteinized chitin[s]	75 b[v]	88 b[w]			
Deproteinized chitin[t]	96 d[v]	100 c[w]			

[s]Rate: 220 kg mature plant residue or chitin per hectare.
[t]Rate: 1,100 kg chitin per hectare.
[u]Values not followed by the same letter are significantly different, $P = 0.05$.
[v]Average of six locations and two years.
[w]Average of two locations, one year.
[x]Average of eight locations, three years.
[y]Teton County, Idaho.
[z]Camas County, Idaho.

Although the number of sclerotia produced during the winter was similar for all treatments, production of sclerotia was greater on earlier seeded wheat which had more foliage. The actual number varied from year to year and by locations, although more sclerotia generally were produced at the southeastern Idaho (Teton or Fremont County) locations than at the southcentral (Camas County) plots. Counts of sclerotia were as high as 28,000/0.093

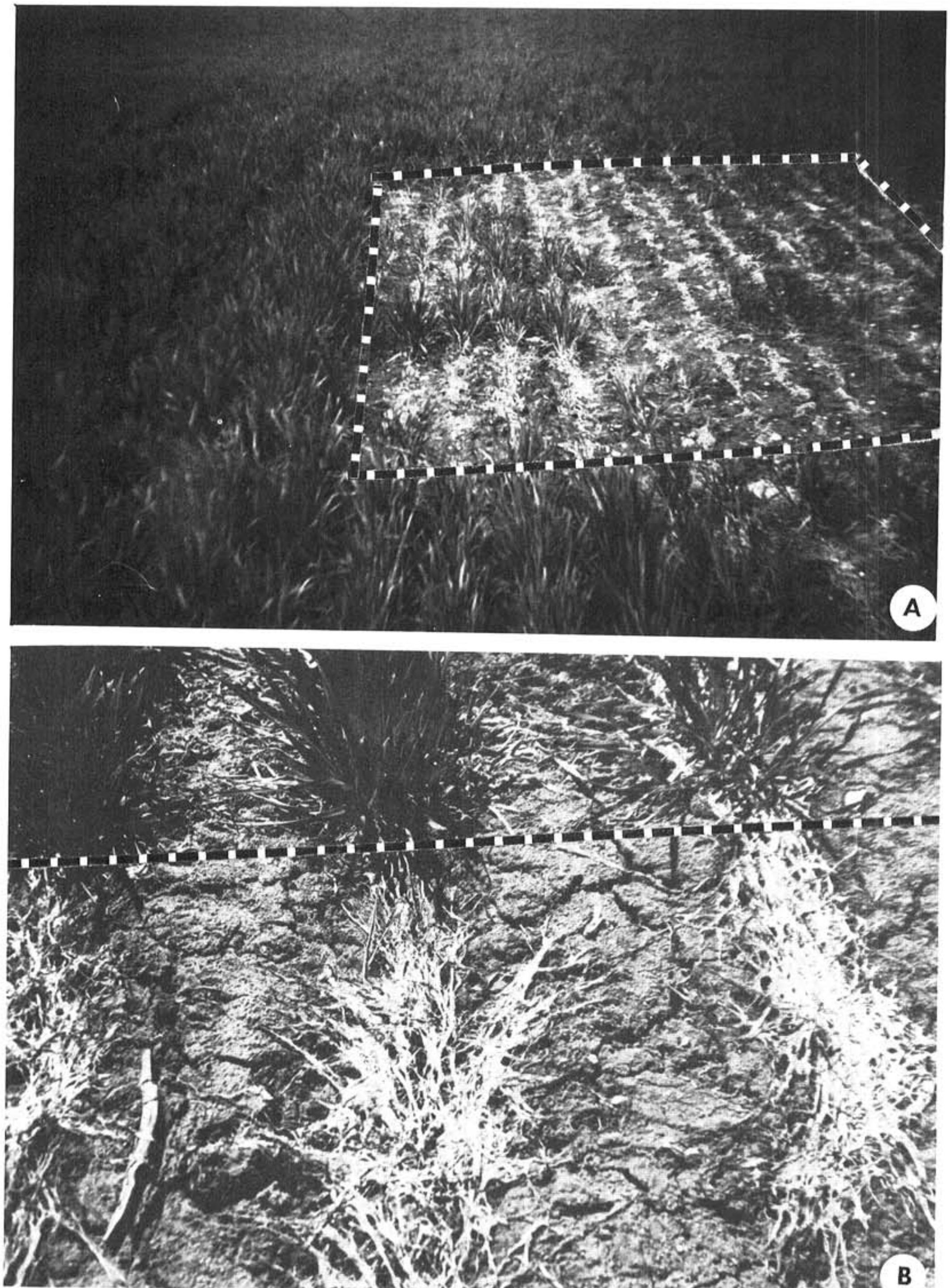

Fig. 1-(A, B). Increased snowmold of winter wheat after surface application of ground wheat or barley straw in the fall: **A**) a residue-amended plot surrounded by untreated wheat; **B**) residue-amended wheat, foreground, untreated wheat above the dotted line.

m². In several years, tissue maceration was so extensive after snowmelt that it was difficult to identify where the plants had been located in the amended plots. This was the situation in all the chiten-amended plots, so sclerotia counts were not made. Sclerotia production was less in tissues infected by both *F. nivale* and *T. idahoensis* than in those infected only by *Typhula*. *Typhula* appeared to be the predominant pathogen unless organic amendment was applied or surface residues were present. Wheats seeded later survived in all locations and snowmold was not increased with amendments on late-planted seedings.

Effect of snowmold on grain quality.—Snowmold not only reduced yields, but also reduced the quality of harvested grain. Even though plants that survived snowmold and regrew from the crown had less competition, grain quality, as measured by protein and sedimentation, was reduced disproportionate to stand (Tables 2, 3). Similar effects of reduced quality were observed in the two locations with mild snowmold which only destroyed the older foliage but had no effect on stand or total yield.

DISCUSSION

Organic amendments incorporated into the soil, or left on the soil surface increased the severity of snowmold, especially that caused by *F. nivale*. These materials probably provided a nutrient base for saprophytic growth of the pathogens and a substrate which could induce extracellular pectolytic and cellulolytic enzyme activity (7, 13) and thereby increased the incidence of infection. Increased enzymatic activity was apparent after chitin amendment by the severe leaf tissue maceration that had occurred. Higher levels of glucose and lower metabolic rates under snow has been associated with wheat cultivars resistant to snowmold (3). Resistance in these cultivars may be a function of feed-back repression of macerating enzyme activity (11). Although alfalfa induced in vitro extracellular enzyme production by the snowmold pathogens (13), its failure to increase snowmold was consistent with reduced snowmold when a legume immediately preceded wheat in the rotation.

Tillage practices which leave residues on the soil surface can be expected to increase snowmold severity as shown by the low rate of residue (220 kg/ha) required for severe snowmold in these studies. In other studies (7) disease severity varied in proportion to the amount of residue left on fall-clipped plots. Tillage and cultural practices differ in the two wheat production areas evaluated in these studies, which may account for some of the disease differences observed. Moldboard plowing is the preferred tillage practice in southcentral Idaho (Camas County) where fall snows frequently cover unfrozen ground and persist well into the spring, providing optimum conditions for snowmold (3, 7, 10). In contrast, many growers in southeastern Idaho "stubble-mulch" or chisel-plow their land to keep residues on the soil surface as a deterrent to erosion. Although heavy snows persist throughout the winter, heavy frost in the fall generally precedes snowcover—a condition not conducive to snowmold (3, 10, 12). Wheat in unfrozen soils protected by snowcover, or in frozen soils which thaw under the snow, is severely molded and maceration of tissues is more extensive than that observed in southcentral Idaho. The ability to utilize "trashy fallow" or other tillage practices which leave residues on the soil surface in southeastern Idaho is influenced primarily by the environmental conditions (early soil freezing) rather than differences in pathogens. The prominence of *T. idahoensis* in these areas probably reflects its greater activity at lower temperatures (3, 10, 14) compared with that of *F. nivale*. The low rainfall and short growing season characteristic of both areas necessitates summer fallowing between wheat crops. Wet soil conditions in the spring provides little opportunity for crop rotation.

Early seeding is recommended in Washington (2, 4) where regrowth occurs from surviving crown tissue even though aboveground tissue is destroyed. Early seeded wheat in Idaho (12) and other areas (7, 10, 14) suffers the greatest damage from snowmold. Early seeded wheat also is more severely damaged by wheat streak mosaic virus and *Ophiobolus* root and crown rot (take-all). The greatest probability of escaping snowmold under Idaho conditions is late seeding where only two to five leaves develop prior to snowfall (3, 8, 12). Even if earlier seeding was possible, the reduced quality from loss of nutrients stored in fall foliage indicated in this study may render such a practice unadvisable with bread-type wheats.

The removal of foliage by flaming undoubtedly accounts for partial reduction in snowmold. In addition, the altered physiology of flamed plants indicated by the deeper green color of regrowth and dense brown margin at the burned tips may render them less susceptible. The more upright growth habit is another possible factor in reducing disease severity. Although sclerotia on the soil surface may have been destroyed with the heavy burn, it is not likely that sclerotia 2-4 mm below the soil surface were destroyed.

Organic amendments have been proposed for

TABLE 3. Yield, quality, and snowmold of winter wheat after fall flaming

Treatment	Snowmold (%)	Yield (quintals/ha)	Protein (%)	Sedimentation values	Test weight (kg/l)
None[x]	60 a[y]	17 a	9.8 a	34 a	61
Light burn	20 b	29 b	9.9 a	36 a	62
Heavy burn	10 c	41 c	11.5 b	48 b	63
None[z]	53 a				
Light burn	25 b				
Heavy burn	25 b				

[x]Camas County, Idaho in 1970.
[y]Values not followed by the same letter are significantly different, $P = 0.05$.
[z]Average of two years, four locations.

biological control of many soil-borne plant pathogens (1, 6, 9) because of increased microbial activity after amendment. Increased competition and growth of potential antagonists have been proposed as mechanisms of control (1, 6). These mechanisms apparently were not generally functional at the low temperatures encountered with snowmold. Specific effects of the various residues were apparent in these studies where snowmold was increased most by chitin, but also increased after application of wheat and barley straws. The ability to somewhat selectively increase pink snowmold by applying low rates of wheat or barley straw should also facilitate screening plants for resistance to *F. nivale*.

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