An evaluation of winter wheat for resistance to the snow mold fungi *Microdochiurn nivale* (Fr.) Samu & Hall and *Typhula ishikariensis* Imai

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Forty-seven cultivars or breeding lines of winter wheat, 2 cultivars of winter rye and 1 cultivar of triticale were evaluated for resistance or tolerance to ***Microdochiurn nivale*** and ***Typhula ishikariensis*** at Arkell and Elora, Ontario in 1985. All inoculated plants exhibited >50% foliar necrosis 4 to 5 days after snow melt (ca. 135 days after inoculation) at both locations. Observations made 6 weeks later indicated that several entries exhibited an enhanced capacity to produce new foliage. The cultivars of winter rye were generally more resistant to both pathogens than the wheats. Twelve entries of wheat exhibited no significant reduction in the number of heads formed per plant in plots infested with ***Microdochiurn.*** Four entries were tolerant to ***Typhula.*** The cultivar Albidum-11 exhibited tolerance to both pathogens.

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On a évalué la resistance ou la tolerance de 47 cultivars ou lignees genealogiques de blé d'hiver, de deux cultivars de seigle d'hiver et d'un cultivar de triticale a ***Michodochiurn nivale*** et a ***Typhyla ishikariensis,*** a Arkell et a Elora (Ontario), en 1985. Aux deux endroits, plus de 50% du feuillage de toutes les plantes inoculées était necrose 4 a 5 jours apres la fonte des neiges (environ 135 jours après l'inoculation). Des observations réalisées 6 semaines plus tard indiquent que plusieurs entrees avaient une capacite accrue de produire de nouvelles feuilles. Les cultivars de seigle d'hiver étaient généralement plus resistants aux deux agents pathogenes que les cultivars de blé. On n'a observe aucune reduction significative du nombre d'épis par plant chez 12 entrees de blé cultivés sur des parcelles infestées par ***Microdochiurn.*** Quatre entrees se sont révélés tolerants a ***Typhula.*** Le cultivar Albidum-11 a montre une tolerance aux deux agents pathogènes.

introduction

Winter losses limit winter wheat production in Canada (Smith 1981; Andrews *et al.* 1986). Causes of these losses include direct low-temperature kill, hydration injury (flooding), desiccation, soil heaving and/or infection by low-temperature-tolerant plant pathogenic fungi (snow mold fungi).

The snow mold fungi, ***Microdochiurn nivale*** (Fr.) Samu & Hall., ***Typhula incarnata*** Lasch. ex. Fr. and ***T. ishikariensis*** Imai Var. ***ishikariensis*** have been observed frequently on winter wheat in Ontario (W.L. Seaman, personal communication). Losses that result from infection by these fungi have not been determined. However, surveys have revealed that snow molds occur annually between 43° and 46" N latitude, and, among fields, the incidence of disease ranges from low to high depending on the duration of snow cover (W.L. Seaman, personal communication).

Current recommendations for control of snow molds of wheat include early seeding (Bruehl 1982) and a rotation with legumes (Wiese 1977). The use of resistant cultivars is also recommended (Bruehl 1982); however, their availability is limited. For example, the cultivar Sprague is the only soft white winter wheat in North America that is recommended specifically for planting in areas with histories of losses caused by snow mold fungi (Bruehl 1982). As a result of this limitation, and a lack of information on how cultivars grown in Ontario respond to infection, the present study was conducted to evaluate cultivars and lines of winter wheat for resistance or tolerance to *M. nivale* and *T. ishikariensis*.

The Canadian Winter-Hardiness Cereal Nursery was used as a source of genetic variation for this study. The nursery consisted of a collection of cultivars and breeding lines of winter cereals (mostly wheat) from the USA, Sweden, Finland, USSR, Japan, and Canada that have exhibited winter hardiness and/or resistance to snow mold fungi under various conditions. These cultivars and breeding lines have been planted in locations across Canada to evaluate their survival under Canadian conditions. Since low-temperature hardiness and snow mold resistance are unrelated (Bruehl *et al.,* 1966), this group of winter cereals must be evaluated specifically for resistance or tolerance to snow mold fungi as well as for resistance to abiotic factors associated with winter kill.

Materials and methods

Field plots

In 1984, 50 entries in the Canadian Winter-Hardiness Cereal Nursery were evaluated for resistance to *M. nivale* and *T. ishikariensis* at the Ontario Ministry of Agriculture and Food research stations near Arkell, Ontario and Elora, Ontario. The experimental design was a split-block with 6 blocks. Inoculation or fungicide treatments were the main treatments and cultivars or breeding lines (entries) were the subtreatments. Each plot contained 50 entries. Plot dimensions were 1.8 m × 2.6 m with 0.4 m between plots within a block and 1.0 m between

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blocks. Plants of the 50 entries, within each plot, were arranged randomly in rows (groups of 10 plants) 10-15 cm long, with a depth of 5 rows and a breadth of 10 rows per plot. Rows were approximately 25 cm apart. Plots were separated by a guard row of winter wheat cv. Fredrick.

In the fall (see Table 1 for specific dates), plant emergence was assessed, each row was thinned to 10 plants, and 100 kg/ha of 6-24-24 was broadcast on the plots. In early December, a snow fence was erected on the windward side of the plots to promote deep snow cover.

Table 1. Treatment dates and general information for the snow mold trials conducted at Arkell and Elora, Ontario.

Dates and Information	Locations	
	Arkell	Elora
Year	1984-85	1984-85
Soil type	Burford loam	London loam
Planting dates	2019/84	19/9/84
Emergence counted	10/10/84 to 11/10/84	15/10/84 to 16/10/84
Fungicide treatment & inoculation	29/11/84	29/11/84
Isolates:		
Microdochiurn nivale	F028	F028
Typhula spp.	T039	T039
Fertilization:		
Fall - 100 kg/ha - 6-24-24	22/10/84	22110/84
Spring - 90 kg/ha - 34-0-0	23/4 185	2314/84
Initial rating	11/4/85	1514/85
Final rating	2315/85	2415/85

Inoculum preparation

Inoculum consisted of mixed grain infested with mycelium of the snow mold fungi. The grain mixture for *Typhula* was 50% wheat, 25% oats and 25% cracked corn. The mixture for M *nivale* was 50% cracked corn, 25% wheat and 25% oats. Prior to adding the fungi, the mixtures of grain were soaked in deionized water overnight and placed in 1 litre mason jars (750 cm^3 grain per jar). The jars were sealed with a foam plug, capped with aluminum foil and autoclaved at 121°C for 45 minutes. The grain was allowed to cool for 24 hours and then autoclaved again at 121°C for 30 minutes.

Isolate F028 of M *nivale* and isolate T039 of *T. ishikariensis* var. *ishikariensis* were cultured on potato dextrose agar (PDA) and BASM agar (15 g Difco agar, 10 g Difco malt extract, decanted water from 120 g diced potatoes boiled in 500 ml dH_2O, 500 ml dH_2O [Smith, 1981]), respectively. An actively growing mycelial plug was removed from a culture and placed in a mason jar (one isolate/jar). The grain cultures of *Typhula* were incubated at 10°C and the grain cultures of *Microdochium* were incubated at 14°C for 3 months. Prior to inoculation of plants in the field, the inoculum was removed from the mason jars and allowed to air-dry overnight. The inoculum was then ground in a Waring blender (chop cycle, 10 seconds) to break up any large clumps.

Treatments

Treatments consisted of inoculations with *M. nivale* or *Typhula.* Plants in uninfested plots, and in plots treated with fungicide, served as controls. The fungicide was an inorganic mercury (Mersil, 34% mercury equivalent, with 14% as mercuric chloride and 28% as mercurous chloride; May and Baker Canada Inc.) applied at a rate of 12.5 g a.i./ha in 1600 L H_2O/ha with a CO_2 propelled back-pack sprayer at 207 kpa.

Fungicide and inoculation treatments were applied on 29 November before the snow fence was erected. Inoculum was applied by hand at a rate of 300 cm^3 per plot to ensure an even distribution of the pathogens in the plots. Inoculum was not applied to plots that served as uninfested controls and fungicide-treated controls.

Assessment of foliar necrosis

In April, 4-5 days after snow-melt, each row of plants was evaluated for severity of foliar necrosis using the Horsfall-Barratt rating scale (Horsfall and Cowling, 1978). This rating was used to determine the resistance of each cultivar to foliar necrosis induced by the snow mold fungi. A second rating (4-6 weeks later, see Table 1) was used to assess the growth potential of each cultivar after infection.

Assessment of yield

Detiffe, et *al.* (1984) reported that, in winter barley, the yield component most affected by snow mold infection was the number of heads produced. Therefore, in July, the number of heads per row (10 plants) was counted.

Data analysis

When the F-test from an ANOVA was significant ($P=0.05$) for treatments and cultivars, further analysis was performed using Duncan's new multiple range test (Steele and Torrie, 1980) or the Scott-Knott cluster analysis procedure (Gates and Bilbro, 1978). Percentage values, presented as estimates of the incidence of foliar necrosis were transformed prior to ANOVA, using the Freeman-Tukey method for arcsine transformation (Mosteller and Youtz, 1961). This transformation was used to reduce heterogeneity of variance normally associated with percentage data (Little and Hill, 1978). Values for the number of heads formed per plant were not transformed prior to analysis. Poor emergence resulted in missing data at the Arkell location. As a result, cluster analysis could not be used. Therefore, Duncan's new multiple range test was used as a mean separation procedure. Cultivars or breeding lines were deleted from analysis if poor emergence in the fall resulted in fewer than four replications per entry, or fall emergence was less than 8 plants/row (omitted only from analysis of yield data).

Results

Arkell

The initial and final Horsfall-Barratt (H-B) ratings were made 133 and 175 days after inoculation, respectively. Due to poor seedling emergence 10 entries were omitted from the analysis of data collected from plots infested with *Microdochium.*

Table 2. Incidence of foliar necrosis on winter cereals 133 and 175 days after inoculation with ***Microdochium nivale*** at Arkell, Ontario in 1984*.

Cultivar or breeding line**	Foliar necrosis (%) 133 days	175 days
Sprague	72 a	22 abcde
Augusta	84 b	25 abcde
Musketeer Rye	84 bc	2 a
Hokuei	88 bcd	23 abcde
Frankenmuth	90 bcd	52 ef
CI-14106	91 bcd	6 abcde
Hybrid-481	91 bcd	6 abcde
Odesskaya-16	92 bcd	3 ab
JO-3057	93 bcd	40 abcdef
WT84	95 bcd	22 abcde
Genesse	95 bcd	38 abcdef
Tulun-407	95 bcd	9 abcde
Kharkov 22MC	95 bcd	6 abcde
Albidum-11	95 bcd	3 ab
Sundance	96 bcd	2 a
Gordon	96 bcd	7 abcde
Starke-2	96 bcd	25 abcde
Krasnodarskaya-39	96 bcd	4 ab
Jo-3022	96 bcd	3 ab
Olympia	97 cd	3 ab
PPG-559	97 cd	76 f
Ulyanovka	97 cd	40 def
Moskowskaia	97 cd	29 abcde
93-Hong	97 cd	72 f
Norstar	98 d	27 abcde
Fredrick	97 d	42 abcdef
WT166	98 d	27 abcde
Lennox	98 d	18 abcde
Bruehl VM801046	98 d	22 abcde
Jo-3067	98 d	4 ab
Beltskaya	98 d	4 ab
Yorkstar	99 d	4 ab
Tecumseh	99 d	42 abcdef
Albasskaya	99 d	46 cdef
Argee	99 d	27 abcde
Winalta	99 d	43 bcdef
Lutescens-230	99 d	4 ab
Bruehl VM801147	99 d	13 abcde
OAC Wintri Triticale	99 d	4 ab
Redwin	100 d	80 f

*Inoculum consisted of autoclaved mixed grain infested with isolate F028.

**Due to poor seedling emergence, ten entries were omitted from the analysis.

Values represent non-transformed mean percent foliar necrosis based on the Horsfall-Barratt grading system (Horsfall and Cowling, 1978).

Data were transformed for the purpose of statistical analysis using the Freeman-Tukey (1950) acsine formula.

Means followed by the same letter are not significantly different (P = .10, Duncan's new multiple range test).

Table 3. Incidence of foliar necrosis on winter cereals 133 and 175 days after inoculation with ***Typhula ishikariensis*** at Arkell, Ontario in 1984*.

Cultivar or breeding line**	Foliar necrosis (%) 133 days	175 days
Olympia	79 a	2 a
Kodiak Rye	86 a	2 a
Alabasskaya	87 a	38 abcde
CI-14106	93 b	6 ab
Odesskaya-16	94 b	22 abc
Albidum-114	94 b	26 abcd
Fredrick	94 b	76 cde
Lutescens-230	96 b	42 abcde
Krasnodarskaya-39	96 b	22 abcd
Houser	96 b	27 abcd
Musketeer Rye	96 b	2 a
Moskowskaia	97 b	52 abcde
PPG-559	97 b	22 abcde
WT84	97 b	52 abcde
Tulun-407	98 b	26 abcde
Frankenmuth	98 b	55 abcde
Tecumseh	98 b	58 abcde
Norstar	98 b	82 e
Genesse	98 b	64 abcde
Bruehl VM801046	98 b	29 abcde
Beltskaya	98 b	24 abcd
Redwin	98 b	27 abcd
Jo-3067	98 b	21 abcd
Albidum -11	98 b	48 abcde
Kharkov 22MC	99 b	43 abcde
Ulyanovka	99 b	29 abcde
Hokuei	99 b	42 abcde
OAC Wintri Triticale	99 b	27 abcd
Lennox	99 b	43 abcde
WT166	99 b	36 abcde
Starke-2	99 b	80 cde
Lovrin-11	99 b	51 abcde
Sprague	99 b	22 abcd
93-Hong	99 b	55 abcde
Hybrid-481	100 b	37 abcde
Sundance	100 b	77 cde
Yorkstar	100 b	84 e
Favor	100 b	81 de
Augusta	100 b	48 abcde
Kharkov/Ulyanovka	100 b	27 abcd
Argee	100 b	54 abcde
Winalta	100 b	76 cde

*Inoculum consisted of mixed grain infested with isolate T039.

**Due to poor seedling emergence, eight entries were omitted from the analysis.

Values represent non-transformed mean percent foliar necrosis based on the Horsfall-Barratt grading system (Horsfall and Cowling, 1978).

Data were transformed for the purpose of statistical analysis using the Freeman-Tukey (1950) arcsine formula.

Means followed by the same letter are not significantly different (P = .10, Duncan's new multiple range test).

Table 4. Comparison of the mean number of heads formed per plant in plots infested with ***Microdochiurn nivale*** or ***Typhula ishikariensis*** and in uninfested control or fungicide treated plots at Arkell, Ontario in 1984*.

Cultivar or Breeding Line**	Control	Fungicide	*M. nivale*	*Typhula*
Winalta	—	3.5 a	1.1 b	—
Sundance	3.5 a	3.4 a	3.2 a	0.6 b
Lennox	3.4 a	3.9 a	2.4 b	2.9 a
Genesse	—	2.3 a	1.4 a	1.0 b
OAC Wintri Triticale	2.4 a	1.7 a	1.7 a	—
Bruehl VM801046	3.8 a	3.2 a	3.1 a	2.8 a
Kharkov 22MC	2.9 a	—	2.2 a	1.3 a
Sprague	2.9 a	—	2.9 a	0.9 b
CI-14106	3.8 a	—	3.1 a	—
Hokuei	—	3.1 a	2.8 a	2.1 b
Lutescens-230	2.7 a	—	2.2 a	2.1 a
Redwin	1.0 a	—	0.5 a	—
Albidum-11	2.9 a	2.5 a	2.8 a	2.4 a
Alabasskaya	3.0 a	3.0 a	1.6 a	2.1 a
WT84	2.0 a	2.6 a	1.7 a	0.9 b
WT166	3.1 a	—	1.2 a	0.5 b
Tulun-407	3.1 a	3.6 a	2.2 a	2.3 a
Hybrid-481	2.7 a	2.7 a	3.3 a	2.2 a
Jo-3022	1.3 a	—	2.1 a	—
Odesskaya-16	3.3 a	—	3.0 a	—
Argee	2.7 a	—	2.4 a	2.8 a
Yorkstar	—	3.1 a	1.9 a	0.8 b
93-Hong	0.7 a	—	1.1 a	—
Augusta	3.3 a	3.1 a	1.9 a	2.9 a
Bruehl VM801147	—	3.1 a	2.2 a	—
Frankenmuth	3.0 a	2.7 a	2.1 a	2.5 a
Norstar	—	3.0 a	—	0.3 b
Albidum-114	—	3.1 a	—	1.2 b
Ulyanovka	2.4 a	—	—	1.9 a
Tecumseh	—	3.6 a	—	3.4 a
Favor	—	2.2 a	—	2.5 a
Lovrin-11	2.0 a	2.1 a	—	2.2 a

* **Treatments included mixed grain infested with *M. nivale* (isolate F028), *T. ishikariensis* (isolate T039) or an application of the fungicide Mersil (12.5 g a.i./ha).**

** **Cultivars or Breeding lines with less than 80% emergence in more than 2 replicated plots were omitted from the analysis. Means followed by the same letter are not significantly different ($P = 0.05$, Duncan's new multiple range test).**

Analysis of the initial H-B ratings, for plants inoculated with ***Microdochiurn,*** revealed that the cultivar Sprague exhibited significantly less foliar necrosis than the other 39 entries (Table 2). Analysis of the final H-B ratings, recorded 42 days after the initial ratings, indicated that all entries exhibited growth and development of symptomless foliage. This resulted in a reduction in the intensity of foliar necrosis. Plants of seventeen entries exhibited < 10% foliar necrosis when the final H-B ratings were recorded (Table 2).

Forty-two entries were evaluated in plots infested with ***Typhula***. At the initial rating, plants of Kodiak rye, and plants of Olympia and Alabasskaya winter wheat exhibited significantly less foliar necrosis than plants of the remaining 39 entries (Table 3). Forty-two days later, plants of 2 cultivars of winter rye (Kodiak and Musketeer), 1 cultivar of winter wheat (Olympia) and 1 breeding line of wheat (CI 14106) had less than 10% foliar necrosis (Table 3).

Due to poor seedling emergence (< 80%), yield data from fourteen of the 40 entries inoculated with ***Microdochiurn*** were not analyzed. Only three cultivars of winter wheat, Winalta, Lennox and Yorkstar, exhibited a significant reduction in the number of heads formed per plant compared to the uninoculated control and/or fungicide treatments (Table 4).

The entries Norstar, Sundance, Genesse, Sprague, Hokuei, WT84, WT166, Yorkstar, and Albidum-114 winter wheats exhibited a significant reduction in the number of heads formed per plant in plots infested with ***Typhula*** as compared to the uninoculated and/or fungicide treatments (Table 4). Unfortunately, the four entries that exhibited the best recovery (Olympia, CI 14106, Kodiak rye and Musketeer rye) did not have adequate replication to facilitate statistical analysis of yield data.

Table 5. Incidence of foliar necrosis on winter cereals 137 and 176 days after inoculation with ***Microdochium nivale*** at Elora, Ontario in 1984[*].

Cultivar or breeding line	Foliar necrosis (%)	
	137 days	176 days
Kodiak Rye	74 a	18 a
Musketeer Rye	77 a	2 a
Argee	86 b	21 a
Gordon	87 b	24 a
Olympia	88 c	11 a
Jo-3057	88 c	36 a
Hybrid-481	89 c	33 a
Albidum-114	90 c	36 a
Odesskaya-16	90 c	7 a
CI-14106	91 c	14 a
Bruehl VM801046	93 c	18 a
Ulyanovka	93 c	45 b
Lutescens-230	93 c	15 a
Albidum-11	93 c	15 a
Tulun-407	93 c	58 b
Alabasskaya	93 c	35 a
Lutescens-116	93 c	11 a
Sprague	94 c	19 a
Roughrider	94 c	76 b
WT84	94 c	36 a
Beltskaya	94 c	39 a
Favor	94 c	55 b
Hokuei	94 c	32 a
Yorkstar	94 c	36 a
JO-3067	95 c	30 a
Norstar	95 c	21 a
Jo-3022	95 c	39 a
Sundance	95 c	21 a
Frankenmuth	95 c	55 b
Starke-2	95 c	55 b
Bruehl VM801047	96 c	58 b
Lutescens-329	96 c	18 a
Redwin	96 c	47 b
Winalta	96 c	14 a
Krasnodarskaya-39	96 c	30 a
Moskowskaia	96 c	58 b
Kharkov/Ulyanovka	96 c	34 a
PPG-559	96 c	52 b
Penzanskaya Morostoikaya	96 c	33 a
Lennox	96 c	21 a
Kharkov 22MC	96 c	32 a
Augusta	97 c	69 b
Genessee	97 c	65 b
Lovrin-11	97 c	49 b
OAC Wintri Triticale	98 c	60 b
Houser	98 c	25 a
Fredrick	97 c	81 b
Tecumseh	98 c	50 b
WT166	98 c	53 b
93-Hong	98 c	81 b

* Inoculum consisted of autoclaved mixed grain infested with isolate F028.

Values represent non-transformed mean percent foliar necrosis based on the Horsfall-Barratt grading system (Horsfall and Cowling, **1978**).

Data were transformed for the purpose of statistical analysis using the Freeman-Tukey (**1950**) arcsine formula.

Means followed by the same letter are not significantly different ($P = .10$ Scott-Knott cluster analysis method).

Elora

One hundred and thirty seven days after inoculation with ***Microdochium,*** plants of Kodiak and Musketeer rye and plants of Argee and Gordon winter wheats exhibited significantly less foliar necrosis than plants of other cultivars or breeding lines (Table 5). Thirty-nine days later, 32 entries in the nursery exhibited significantly less foliar necrosis than the remaining 18 entries (Table 5).

At the initial H-B rating of plants inoculated with ***Typhula,*** Kodiak and Musketeer rye exhibited significantly less foliar necrosis than the other entries (Table 6). Thirty-nine days later, plants of 16 entries had significantly less foliar necrosis (Table 6).

Analysis of the yields revealed a significant reduction in the number of heads formed in 13 and 20 entries in the plots infested with ***Microdochium*** and ***Typhula,*** respectively (Table 7).

Discussion

The Canadian Winter-Hardiness Cereal Nursery is a collection of cultivars and breeding lines from around the world that possess some superior overwintering characteristics. Entries that have been reported to exhibit resistance to snow mold fungi are listed in Table 8.

According to the H-B ratings made 4-5 days after snow melt, all entries in the Canadian Winter-Hardiness Cereal Nursery that were exposed to ***Microdochium*** or ***Typhula*** exhibited considerable foliar necrosis (>50%) at both locations. This suggested that none of the entries were resistant. However, H-B ratings made 4-6 weeks later, indicated that several entries exhibited an enhanced capacity, relative to other lines, to produce new foliage. This potential for regrowth (i.e., crop recovery) was used along with yield, to select entries with tolerance to snow mold fungi. Jamalainen (1974) and Bruehl (1982) have also identified resistance or tolerance to snow molds

Table 6. Incidence of foliar necrosis on winter cereals 137 and 176 days after inoculation with ***Typhula ishikariensis*** at Elora, Ontario in 1984*.

Cultivar or breeding line	Foliar necrosis (%)	
	137 days	176 days
Kodiak Rye	53 a	2 a
Musketeer Rye	81 b	2 a
Bruehl VM801046	93 c	21 a
Lutescens-329	94 c	35 a
Beltskaya	94 c	31 a
Bruehl VM801047	94 c	41 b
Jo-3057	95 c	54 b
Sundance	95 c	19 a
Sprague	95 c	26 a
Albidum-11	95 c	15 a
Kharkov 22MC	95 c	41 b
Krasnodarskaya-39	95 c	34 a
Albidum-114	95 c	22 a
Hybrid-481	96 c	55 b
Argee	96 c	55 b
Odesskaya-16	96 c	41 b
CI-14106	96 c	33 a
Olympia	96 c	17 b
Houser	96 c	18 a
Winalta	96 c	24 a
Frankenmuth	96 c	63 b
Hokuei	96 c	47 b
Yorkstar	96 c	55 b
Lutescens-116	97 c	51 b
Norstar	97 c	22 a
Genesse	97 c	54 b
WT84	97 c	9 a
Tulun-407	97 c	62 b
Gordon	97 c	48 b

continued ...

Table 6 - continued

Cultivar or breeding line	Foliar necrosis (%)	
	137 days	176 days
Jo-3067	97 c	55 b
Alabasskaya	97 c	41 b
Lennox	97 c	55 b
Roughrider	97 c	46 b
Lovrin-11	97 c	47 b
Moskowskaia	98 c	61 b
Favor	98 c	69 b
Penzanskoya Morozostoikaya	98 c	69 b
Starke-2	98 c	47 b
Jo-3022	98 c	49 b
Tecumseh	98 c	61 b
PPG-559	98 c	70 b
Lutescens-230	98 c	70 b
WT166	98 c	57 b
OAC Wintri Triticale	98 c	34 a
Augusta	99 c	72 b
Redwin	99 c	75 b
93-Hong	99 c	94 b
Ulyanovka	100 c	79 b
Fredrick	100 c	99 b
Kharkov/Ulyanovka	100 c	79 b

*** Inoculum consisted of mixed grain infested with isolate T039. Values represent non-transformed mean percent foliar necrosis based on the Horsfall-Barratt grading system (Horsfall and Cowling, 1978).**
Data were transformed for the purpose of statistical analysis using the Freeman-Tukey (1950) arcsine formula.
Means followed by the Same letter are not significantly different (P = .10, Scott-Knott cluster analysis method).

based on the ability of an infected plant to regrow from the crown. The cultivars Musketeer and Kodiak rye and Argee, Gordon and Sprague winter wheats exhibited significantly less foliar necrosis in the initial rating of plants inoculated with ***Microdochiurn*** at the Arkell and Elora locations. In the plots infested with ***Typhula,*** the cultivars Kodiak and Musketeer rye and Olympia and Alabasskaya winter wheat exhibited superior winter survival, according to the initial H-B rating. Kodiak rye was the only cultivar that was consistant in reaction at both locations.

In the plots infested with ***Microdochiurn,*** Odesskaya-16 was the only winter wheat that exhibited no significant reduction in yield and had < 10% foliar necrosis 6 weeks after snowmelt at both locations. The rye cultivar, Musketeer, the triticale cultivar OAC Wintri and the winter wheat entries, Sundance, Olympia, Jo-3022. Albidum-11, Krasnodarskaya-39, Jo-3067, Beltskaya, Lutescens-230, Yorkstar, Kharkov-22 MC, CI 14106, Hybrid-481, Gordon and Tulun-407 exhibited < 10% foliar necrosis at the final rating at Arkell or Elora in 1985.

In the plots infested with ***Typhula,*** the rye cultivars Musketeer and Kodiak as well as the winter wheats, Olympia and CI 14106 exhibited < 10% foliar necrosis at the last rating at Arkell in 1985. Unfortunately, yields could not be analyzed for these cultivars at the Arkell location. At the Elora location, only the rye cultivars Musketeer and Kodiak and one winter wheat breeding line (WT84) exhibited < 10% foliar necrosis according to the last H-B rating. All three of these entries exhibited no significant reduction in yield at Elora.

Yield is the most important component of winter cereal production. Entries in the nursery that displayed no significant reduction in yield compared to control or fungicide treated plants are listed in Table 9. The breeding line Albidum-11 was the only entry that exhibited tolerance to isolates of both species of snow mold fungi tested. The entries in Table 9 are by no means the extent of useful material from the nursery. Entries that were not replicated adequately because of poor emergence may also be useful, but they must undergo further testing.

Table 7. Comparison of the mean number of heads formed per plant in plots infested with ***Microdochium nivale*** or ***Typhula ishikariensis*** and in uninfested control or fungicide treated plots at Elora, Ontario in 1985*.

Cultivar or Breeding Line	Control	Fungicide	*M.* ***nivale***	***Typhula***
Norstar	3.3 a	3.0 a	3.3 a	3.0 a
Winalta	1.6 a	2.8 a	2.0 a	2.2 a
Sundance	2.8 a	3.8 a	3.2 a	3.7 a
Lennox	4.8 a	3.6 ab	2.4 b	1.5 b
Fredrick	1.2 a	1.6 b	0.5 a	0.5 a
Genesse	1.7 a	2.5 a	1.5 a	1.0 a
Musketeer Rye	5.6 a	4.2 a	6.1 a	4.4 a
Kodiak Rye	4.8 a	4.6 a	5.1 a	4.3 a
OAC Wintri Triticale	2.5 ab	3.5 a	1.2 b	1.6 a
Bruehl VM801046	4.7 a	3.6 ab	2.7 b	2.4 b
Kharkov 22MC	2.2 ab	3.1 a	1.7 b	2.2 a
Sprague	2.4 a	2.2 a	1.6 a	2.7 a
CI-14106	1.8 a	3.3 a	2.6 a	2.0 a
Hokuei	3.3 a	3.5 a	2.2 a	1.2 b
Lutescens-230	2.4 a	3.5 a	2.2 a	1.2 b
Redwin	1.5 a	1.9 a	1.6 a	0.7 b
Albidum-11	3.4 a	4.4 a	3.4 a	3.6 a
Albidum-114	3.6 a	3.4 a	3.3 a	2.5 a
Lutescens-329	3.8 a	3.8 a	3.2 a	2.1 a
Alabasskaya	1.8 b	4.3 a	1.8 b	1.4 b
Ulyanovka	3.3 a	2.6 a	2.2 a	0.8 b
Kharkov/Ulyanovka	2.2 a	3.2 a	1.8 a	0.9 b
Roughrider	1.8 a	2.1 a	0.9 a	1.8 a
WT84	2.2 a	2.6 a	2.4 a	3.0 a
WT166	2.7 a	2.7 a	1.0 b	1.1 b
Tulun-407	3.1 a	2.9 a	2.1 a	1.0 b
Olympia	3.0 a	3.3 a	1.9 a	1.9 a
Beltskaya	3.4 a	2.6 a	2.0 a	1.4 a
Moskowskaia	2.2 a	2.4 ab	1.3 a	1.2 a
Hybrid-481	2.6 ab	3.4 a	2.0 b	1.7 b
Tecumseh	2.9 a	3.0 a	1.6 a	1.6 a
Jo-3022	2.7 a	2.6 a	1.7 a	1.5 a
Jo-3057	3.4 a	2.9 ab	2.0 b	1.7 b
Jo-3067	3.2 a	3.0 a	2.1 a	1.4 b
Odesskaya-16	4.1 a	2.9 a	3.6 a	1.8 a
Penzanskaya Morozostoikaya	2.5 a	3.1 a	1.9 a	0.7 b
Lutescens-116	2.6 a	2.5 a	2.8 a	0.8 b
PPG-559	2.0 ab	2.8 a	1.1 b	1.3 b
Starke-2	2.6 a	1.7 ab	0.9 b	1.7 a
Argee	2.9 a	3.7 a	2.6 a	1.8 a
Favor	1.7 a	1.7 a	1.7 a	0.9 a
Gordon	3.4 a	3.0 a	2.4 a	0.9 b
Houser	1.6 a	3.1 a	2.3 a	1.9 a
Yorkstar	2.9 a	2.2 a	1.5 a	1.3 a
93-Hong	0.2 b	1.0 a	0.5 ab	0.4 ab
Augusta	2.5 a	2.3 a	1.4 a	0.7 a
Bruehl VM801147	3.4 a	3.4 a	1.4 b	0.7 a
Krasnodarskaya-39	3.6 a	3.6 a	2.6 a	1.7 b
Lovrin-11	0.5 a	1.5 a	0.7 a	1.4 a
Frakenmuth	3.6 a	2.5 ab	1.8 b	1.8 b

*** Treatments included mixed grain infested with *M. nivale* (isolate F028), *T. ishikariensis* (isolate T039) or an application of the fungicide Mersil (12.5 g a.i./ha).**

Within a row, means followed by the same letter are not significantly different (P = 0.05, Duncan's new multiple range test).

Table 8. List of wheat cultivars or breeding lines in the Canadian Winter-Hardiness Cereal Nursery that have exhibited resistance to snow mold fungi.

Pathogen	Cultivar or Breeding Line	Origin	Reference
Microdochium nivale	Lennox (selection from (Mironovskaya-808)	Canada (USSR)	Gotoh 1978
	Lutescens-116	USSR	Prutskov 1973
	CI-14106	USA	Bruehl 1982
Typhula spp.	Sundance	Canada	
	Albidum-1	USSR	Prutskov 1973
	Albidum-14	USSR	Prutskov 1973
	Olympia	Finland	Jamalainen 1974
	CI-14106	USA	Bruehl 1982
Snow Molds (unspecified)	Sprague	USA	Bruehl 1982

Table 9. Cultivars or breeding lines that exhibited no significant reduction in yield (mean heads formed per plant) after inoculation with snow mold fungi at the research stations at Arkell and Elora, Ontario in 1985.

Pathogen	Cultivar or Breeding Line
Microdochium nivale	Sprague
	CI-14106
	Hokuei
	Lutescens-230
	Albidum-11
	Sundance
	WT84
	Tulun-407
	Jo-3022
	Odesskaya-16
	Argee
	Augusta
Typhula spp.	Kharkov 22MC
	Albidum-11
	Beltskaya
	Lovrin-11

The winter wheat cultivars currently available and recommended in Ontario (Fredrick, Augusta, Favor, Frankenmuth, Gordon and Houser) (Anonymous, 1986), generally did not fare well in any of the snow mold evaluations. If the limits of winter wheat production in Ontario are to be extended, plant breeders must incorporate some of the available sources of snow mold resistance or tolerance into useful cultivars.

Literature cited

1. Andrews, C.J., M.K. Pomeroy and W.L. Seaman. 1986. The response of fall-sown cereals to winter stresses in eastern Canada. Can. J. Plant Sci. 66:25-37.
2. Anonymous. 1986. Field crop recommendations. Ontario Ministry of Agriculture and Food. Publication 296.
3. Bruehl, G.W., R. Sprague, W.R. Fischer, M. Nagamitsu, W.L. Nelson and O.A. Vogel. 1966. Snow Molds of Winter Wheat in Washington. Washington Agricultural Experimental Station. Bulletin No. 677.
4. Bruehl, G.W. 1982. Developing wheats resistant to snow mold in Washington State. Plant Disease 66: 1090-1095.
5. Detiffe, H.. H. Maraite and J.A. Meyer. 1984. Influence of *Typhula* incarnata Lasch ex. Fries infection on yield of winter barley plants. Med. Fac. Landbouww. Rijksuniv. Gent. 49:237-243.
6. Gates, C.E. and J.D. Bilbro. 1978. Illustration of a cluster analysis method for mean separation. Agronomy Journal 70:462-465.
7. Gotch, T. 1978. Improvement of winter cultivars for winter hardiness and earliness. Mise. Publ. 1, Tohuku Natt. Ag. Exp. Sta. Japan.
8. Horsfall, J.G. and E.B. Cowling. 1978. Pathometry: The measurement of plant disease. Pages 120-135 in Plant Disease: An Advanced Treatise Vol. II. J.G. Horsfall and E.B. Cowling, eds. Academic Press, New York. 465 pp.
9. Jamalainen, E.A. 1974. Resistance in winter cereals and grasses to low temperature parasitic fungi. Annual Review of Phytopathology 12:281-302.
10. Little, T.M. and F.J. Hills. 1978. Agricultural Experimentation Design and Analysis. John Wiley and Sons, Inc., Toronto. 350 pp.
11. Mostellers, F., and C. Youtz. 1961. Tables of the Freeman-Tukey transformations for the binomial and Poisson distributions. Biometrika 48:433-440.
12. Prutskov, F.M. 1973. Winter Wheat. Tr. from Russian by National Technical Information Service, US. Dept. of Commerce. 330 pp.
13. Smith, D.J. 1981. Snow molds of winter cereals: guide for diagnosis, culture and pathogenicity. Can. J. Pl. Path. 3: 15-25.
14. Steele, R.G.D. and J.H. Torrie. 1980. Principles and procedures of statistics. Second edition. McGraw-Hill Book Co., New York. 683 pp.