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WINTER WHEAT TOLERANCE TO SNOWMOLD IN 1969[1]

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SUMMARY

Winter wheats with good survival to conditions of pink snowmold, Fusarium nivale, standing water, and the footrot Cercosporella herpotrichoides were P.I. 178383, Odin, Bezosztaja, Ridit, and derivatives of these wheats. Evidence is presented for resistance segregation patterns and for geographical distribution of wheat gene pools for tolerance to soil organisms in wheats from northern Europe, Russia, Turkey, the Western U.S., and the Orient.

Snowmolds (*Fusarium nivale* (Fr.) Cesati, *Typhula idahoensis* Remsberg) were prevalent in much of the Western Region in the spring of 1969. From observations at Moscow, Idaho (Tables 1 and 2), and other experiment stations in the west, it was apparent that the tolerance of wheats to snowmolds and related soil organisms made a world-wide pattern of multigenic stairsteps of increased resistance similar to that previously seen for stripe rust (POPE, 1968). Increments of tolerance to snowmold (and I think this fits for most diseases) it like the visible portions of a drowned pyramid. Under severe disease conditions only a few superbly resistant wheat types, such as C.I. 14106 (SUNDERMAN and McKAY, 1968) will survive. Under milder levels of disease, more and more resistant types can be recognized, just as one can see more of a drowned pyramid as the water level of a lake recedes.

GENE POOLS FOR SNOWMOLD TOLERANCE

Genes contributing to snowmold tolerance are widespread in the world's wheats. Clues to recognizable pools of such genes (better described as gene frequency topographical maps) are described below.

(1) Dwarf-smut-resistant wheats. D.W. Sunderman at Aberdeen, Idaho, screened the bulk of the world wheat collection under severe snowmold conditions (SUNDERMAN and McKAY, 1968), He recovered C.I. 14106 and other strains that were also resistant to dwarf smut. His snowmold-tolerant wheats are remarkably similar in phenotype to the certain P.I.-numbered wheats, such as P.I. 178383 originally selected for bunt resistance at Pendleton, Oregon, by C.R. Rohde in 1953 (personal communication).

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Dwarf smut, snowmold, and stripe rust are all diseases of wheat related to a similar environment; i.e., persistent snow cover, wet cold springs, cool growing season. It takes only a little imagination to visualize that both the wheats screened for snowmold resistance by bulk technics by Sunderman, and those screened for resistance to dwarf smut by J.A. Hoffmann (personal communication) during the years 1959-1970 at Pullman, Washington, were samples from the same gene pool, typified by wheats from Turkey and Iran.

(2) Bruehl wheats. Wheats selected from the world wheat collection by G.W. Bruehl (BRUEHL *et al.*,1966) at Washington State University using growth-chamber technics have good resistance to snowmold but rank behind C.I. 14106 (BRUEHL, 1967). Several of these wheats are resistant to dwarf smut and have a Turkish origin.

(3) Wheats from Western Russia. Progeny of hybrids with 'Bezosztaja' WA4836, P.I. 302424, showed high levels of survival to snowmold and standing water at Moscow, Idaho. It must be representative of a gene pool from Western Russia not particularly associated with conditions favorable to dwarf smut, since it is highly susceptible to this disease.

(4) Wheats from Northern Europe. The Swedish wheat 'Odin' P.I. 264272 (and a local farmer selection called 'Swedish Type' ID725061, C.I. 17250) survived well itself and performed well in crosses as represented indirectly in the short wheat WA4765 developed by O.A. Vogel. Therefore, the Swedish wheats, and the northern European wheats in general, represent another pool of genes for tolerance to soil organisms, including snowmold, as well as their more widely known tolerance to the footrot *Cercosporella herpotrichoides* Fron (BRUEHL *et al.*, 1968). These genes are fortunately housed in far more sturdy-strawed agronomic types than the Turkish wheats. Dr. J.C. Zadoks, Wageningen, Netherlands (in Idaho in August, 1969), suggested that the Swiss wheats with a somewhat different breeding history may represent yet another source of genes for tolerance to soil organisms.

(5) Wheats from the Western United States. There is a range in tolerance to snowmold in winter wheats of the Pacific Northwest ranging from the poorest in 'Rio" C.I. 10061, very poor in 'Itana" C.I. 12933, 'Burt' C.I. 12696, and their derivatives, to fair in 'Cheyenne' C.I. 8885, and still better in 'Ridit' C.I. 6703 and Ridit derivatives. The western white wheats and club wheats have some tolerance, ranking between Itana and Cheyenne. 'Brevor' C.I. 12385 is the best of this group. None of these wheats will survive severe snowmold, but their contributions can be clearly seen in certain crosses grown under severe snowmold conditions. This was also noted by BRUEHL *et al.*,(1966). These wheats are expressing differences at the low end of the resistance spectrum, just as the Bruehl and Sunderman selections are showing differences at the high end of the spectrum.

(6) Wheats in the International Stripe Rust Nursery. A pattern of survival by country of origin is shown in the listing of those entries of the 1969 International Winter Wheat Stripe Rust Nursery that had good spring survival under conditions of pink snowmold, standing water, and probably *Cercosporella* footrot (Table 2). Large sections of this nursery were completely dead. The two Russian wheats P.I. 74094 and 74096 (Items 18 and 19) were superior to all other entries, having a vigorous normal growth in the spring.

(7) Spring Wheats. If the above analysis of the location of the gene pools influencing soil organisms is correct, then these genes are so widespread they must also be in spring wheats. Two likely candidates are the Canadian hard red spring wheat 'Cadet' C.I. 12053, which has a reputation for footrot tolerance, and the old white wheat 'Sonora' C.I. 3036, which through its derivative 'Sonora 37' C.I. 11902

Table 1. Differential survival to pink snowmold *(Fusarium nivale)* and standing water in early-planted wheat (September 6, 1968) at Moscow, Idaho, in 1969.

Item No.	Variety	C.I., P.I. or state no.	March 27 % green plants	March 27 % mouse damage	Aug. 7 % stand
	I. Varieties with snowmold tolerance				
1	PI 178383 (Turkey)	178383	70	90	30
2	Bezosztaja WA4836 (Russia)	302424	30	90	10
3	14/53//Odin/3/13431	WA4765	30	90	10
4	PI 192335 (Sweden)	192335	3	80	5
5	178383/Cheyenne//3*Tendoy ID5011	17246	10	0	50
6	Nrn10/Brv14/2/Wichita/3/Delmar	ID0057	5	--	15
	II. Other Varieties				
7	Omar	13072	5	50	10
8	Itana	12933	3	3	--
9	Nrn10/Staring//2*Cheyenne ID5006	17248	2	5	3
10	Nrn10/Brv14//5* Burt	13739	t	20	t
11	Wanser	13844	2	--	t
12	McCall	13842	t	--	t
13	Marquillo/Oro/2/Oro/Tenmarq	12406	t	--	t
	III. F_2 Bulk combinations: A. Good x poor				
14	Bezosztaja x ID 5006		10		10
15	WA4765/ID5006		5		3
16	ID5011/ID5006		20		30
	B. Good x fair				
17	Gaines//Burt/178383 CI 13837		20		50
18	Omar/Idaed 59//Omar/3/WA4765		20		20
19	Nrn10/Brv14//7*Burt/3/CI 13837/4/ID0057		30		50
20	178383/Golden//Whitecoin/3/PI 192335		20		60
	C. Good x good				
21	ID5011/WA4765		60		70
22	F_3 Bezosztaja/13837		70		80
	IV. Three-way crosses				
23	Bezosztaja/13837//WA4765		3	most	10
24	Bezosztaja/13837//WA4765 ID71043	17252	50	least	50

produced great vigor in a three-way cross to the winter wheats 'Golden' C.I. 10063 and 'Tendoy' C.I. 13426. In Moscow, Idaho, in 1962, F_2 bulks of the spring wheat varieties 'Marquis' C.I. 3641, 'Lemhi' C.I 11415, and 'Idaed' C.I. 11706, each crossed to Cheyenne, showed differential winter survival in favor of Marquis. This was attributed to cold-temperature tolerance, but it is equally likely that it was counfounded with tolerance to soil organisms.

(8) Wheats from the Far East. 'Norin 27' P.I. 182581 (Table 2, Item 28) typifies wheats from the Orient representing another gene pool for tolerance to soil organisms. 'Suwon 92' C.I. 12666 from Korea contributed tolerance to *Cercosporella* footrot to the short club wheat 'Paha' C.I. 14485 (ALLAN *et al.*, 1971). 'Seu Seun' P.I. 157584 contributed good emergence and tolerance to soil troubles to the Texas variety 'Sturdy' C.I. 13684, and 'Norin 10' C.I. 12699 was a parent of 'Gaines' C.I. 13448.

INTERACTION OF FOOTROT, SNOWMOLD AND STANDING WATER

Both pink snowmold, *Fusarium nivale*, and the footrot organism *Cercosporella herpotrichoides* are normal components of the soil complex in the Moscow plots where these wheats were grown. Symptom expression varied according to planting date. In the early September seeding the symptoms were pink snowmold and dead plants. Field mice working under the snow in late winter invaded one side of this planting (Table 1). The mice ignored plots with a high percent of dead plants, implying that only those wheats tolerant to these conditions were still green enough at that time to be attractive as food. In the International Stripe Rust Nursery seeded in an adjacent plot 3 weeks later, the visible symptoms were still pink snowmold, with a gradient of damage matching the pattern of standing water. P.I. 192335 (Table 1, Item 4), 'Cappelle Desprez' P.I. 260896 (Table 2, Item 22), and 'Whilhelmina' P.I. 162595 (Table 2, Item 33), each of which have some tolerance to footrot (BRUEHL *et al.*,1968), had only a 3, 5, and 0% stand, respectively, implying that the main damage here was not from *Cercosporella* alone.

In the rest of the field with plantings made till the end of October, the symptoms were the presence and absence of spring vigor, with water effects evident from one or two inches change in soil surface contour. The only wheats with good spring vigor were (1) P.I. 178383 and its derivatives such as 'Moro' C.I. 13740, (2) the Swedish wheats and their derivatives such as WA4765, (3) Bezosztaja, and (4) Ridit. This unusual superiority of Ridit matched its long-time persistence as a commercial wheat in the snowmold areas of Camas County in southern Idaho.

SEGREGATION PATTERNS

F_2 progeny from crosses involving snowmold-tolerant parents showed three patterns of segregation, according to the level of snowmold tolerance of the second parent. In this situation, the contribution from 'Omar' C.I. 13072, Gaines and P.I. 192335 could be recognized (Table 1, Items 17-18). F_2 bulks of the relatively poor ID5006 C.I. 17248, crossed to WA4765, Bezostaja, and ID5011, C.I. 17246, gave 5, 10, and 20% spring-surviving green plants, respectively (Table 1, Items 14-16).

In contrast, derivatives of P.I. 178383 combined with the Swedish-type resistance of WA 4765 or Bezosztaja gave high levels of surviving plants. When these three resistant wheats were combined in a 3-way cross, there was a wide range in percent of survival in different F_2 bulks, implying the segregation of different resistant genotypes from the three parent wheats (Table 1, Items 23-24).

Table 2. Wheat stands at Moscow, Idaho, in the 1968-69 International Winter Wheat Stripe Rust Nursery under conditions of pink snowmold *(Fusarium nivale)*, standing water, and unknown troubles. Entries not listed had less than 30% stand. Planted September 30, 1968.

Item no.	Variety	P.I., C.I. or state no.	Source	IWWSRN no.	March 27 % Gr. plts.	March 27 Vigor 0-100	July 30 Stripe rust[1]
1	Omar mutant (Check)	14197	Wash.	1020	60	7	3/80
2	Turkey selection	10100	Colorado	1012	80	4	1/30
3	Diosecka	182850	Czechosl.	1013	90	6	0/20
4	Cappelle Desprez	260897	France	1014	5	4	0/10
5	Druchamp P.I. 174622	13723	France	1016	1	1	----
6	Omar/Cheyenne	ID 2-205	Idaho	1032	90	8	0/80
7	Omar/Cheyenne	ID 2-223	Idaho	1033	20	5	0/40
8	178383/Cheyenne	ID52-1322	Idaho	1034	90	8	0/30
9	Ridit/2*Cheyenne	ID 54-35	Idaho	1045	90	8	1/50
10	Ponca/3/McMur./Exch./ 2/Redm.	Kans 5942	Kansas	1055	80	8	0
11	Quana/Tenmarq/2/Marquillo/Oro/ 3/Med/Hope/2/3*Pawnee	Kans62332	Kansas	1056	90	7	0/10
12	Omar mutant (check)	14197	Wash.	1060	20	8	3/80
13	Harvest Queen/Kawvale	12284	Kansas	1061	80	6	1/20
14	Itana/3*178383	MT14-22	Montana	1068	90	6	0/10
15	Westmont/2* 178383	MT6-5-2	Montana	1075	98	6	0/10
16	Westmont/3* 178383	MT7-14-15	Montana	1090	90	8	0/10
17	PI 57149	7096	Russia	1106	0	-	----
18	PI 74094	9299	Russia	1107	99[2]	12	1/30
19	PI 74096	9301	Russia	1108	99[2]	10	1/20
20	PI 94417	94417	Russia	1109	50	10	0/30
21	Apollo	117603	Austral.	1126	70	6	0/20
22	Wegierska 2/11	129531	Austria	1136	70	6	1/20
23	Chartres Desprez	174614	France	1139	90	8	3/60 dry
24	No. 203	119133	China	1242	60	5	2/40
25	Evolution	191409	France	1275	60	4	0/10
26	Strube's Dickkopf II	180590	Germany	1290	80	6	0/10
27	6335/44	180608	Germany	1292	70	5	1/30
28	Norin No. 27	182581	Japan	1295	60	5	0/20
29	Redmond	13737	Oregon	1299	40	5	0/5
30	Omar mutant (check)	14197	Wash.	1300	50	4	2/60 dry
31	Oscista Triunf. Mikulice	192578	Portugal	1306	97	10	1/40 dry
32	Maskowskaia Osimy Russak 052	191281	Russia	1332	90	10	1/30
33	Wilhelmina	162595	England	1401	0	-	----
34	Sampo	181460	Finland	1402	90	10	1/20
35	Ankar	192416	Portugal	1409	70	5	2/20
36	Birgitta 0865	192413	Portugal	1410	90	6	2/20
37	V.30-168/087/2/Svea 11	192417	Portugal	1421	80	8	2/20
38	Moskowskaia	191275	Russia	1425	80	6	1/20
39	Odin	197732	Sweden	1428	95	8	1/10
40	Scandia	18362	Sweden	1429	95	5	1/10
41	Omar/Sp Prol/2/2*Omar	WA68-14249	Wash.	1488	80	6	1/10
42	Ridit WA68-14138	6703	Wash.	1557	80	5	2/30
43	Luke VH66437	14586	Wash.	1562	90	8	0/10
44	178383/2*Omar/2/13438 Sel. 986		Oregon	1568	90	6	0/10

[1]Stripe rust expressed as pustule type/percent.

[2]Best in nursery.

IDENTIFYING PARTIAL RESISTANCES BY ADDITION AND SUBTRACTION TECHNIQUES

Direct comparison of wheats of diverse origins under severe snowmold conditions will locate highly resistant strains but will ignore partial resistances below the level of tolerance required at that location. Exotic wheats lacking tolerance to other growing hazards, such as low temperature (e.g., P.I. 178383), may be eliminated before getting a chance to express their potential against snowmold.

Therefore, as a technique to avoid elimination on non-adaptation and to avoid the conspicuous threshold effects in snowmold, one can compare unknown wheats in bulk F_2 or later-generation bulks by their capacity to "add to" or "subtract from" the performance of a set of common parents. This will work for any character under observation and is, in effect, a measure of combining ability. For example, in 1969, a population of Gaines crossed to the spring wheat 'Idaed 59' C.I. 13631 had very few surviving plants, while, in a population where Idaed 59 was crossed to the Swedish type, over one-half the progeny rows had a good stand. The dilution of Gaines by Idaed 59 essentially ruined the winter-surviving capacity of the population, while the comparable dilution of the Swedish wheat left a large proportion of the plants with more than the minimum growth capability required for the hazards of that season.

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