

Comparison of the common root rot reaction of barley lines and cultivars in northwestern Alberta and central Saskatchewan

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The ranking of barley lines and cultivars for common root rot reaction was similar at Beaverlodge, Fort Vermilion, Saskatoon, and Scott in spite of differences in the level of disease among locations. Although there was an inconsistent correlation between disease rating and grain yield loss, increased disease intensity was generally associated with increased yield loss. Yield loss was related to the reduction in numbers of heads but not to the reduction in thousand kernel weight. *Fusarium culmorum* was isolated in equal or greater frequency than *Cochliobolus sativus* from subcrown internodes from Beaverlodge, while at the other locations *C. sativus* was isolated most frequently. In greenhouse tests, isolates of these two fungi were highly variable in pathogenicity but there was no difference between isolates taken from the Peace River area and those from the southern prairies. This study indicates that selection for common root rot resistance in barley could be done at any of these locations in western Canada.

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En dépit d'un degré d'infection variable entre les divers sites, Beaverlodge, Fort Vermilion, Saskatoon et Scott, le rang des cultivars et des lignées d'orge d'après leur susceptibilité à la pourriture commune des racines est demeuré le même. Bien que la corrélation entre le rang et la baisse de rendement en grains soit variable, l'accroissement de l'intensité de la maladie s'accompagne généralement d'une baisse de rendement. Cette dernière est liée à une diminution du nombre d'épis et non à une réduction du poids de mille grains. A Beaverlodge, le champignon *Fusarium culmorum* fut isolé à partir d'entre-noeuds situés sous le collet aussi souvent ou plus fréquemment que *Cochliobolus sativus* alors qu'aux autres sites, *C. sativus* prédominait. Des tests de pathogénicité réalisés en serres ont montré que les isolats de ces deux champignons étaient extrêmement variables; nous n'avons cependant noté aucune différence entre les isolats prélevés dans la région de Peace River et ceux prélevés dans la région sud des Prairies. Cette étude montre que, chez l'orge, la sélection pour l'amélioration de la résistance à la pourriture commune des racines peut être entreprise à l'un ou l'autre des sites étudiés.

Common root rot is an important disease of wheat and barley in the Canadian prairies where it is estimated to cause a 10.3% annual yield loss in spring barley (Piening et al. 1976) and a 6.1% loss in spring wheat (Ledingham et al. 1973). The relative importance of the two causal organisms, *Cochliobolus sativus* (Ito & Kurib.) Dreschl. ex Dastur (imperfect stage: *Bipolaris sorokiniana* (Sacc. in Sorok.) Shoem.) and *Fusarium culmorum* (W. G. Sm.) Sacc., varies between areas. In the southern and central prairies *C. sativus* was isolated most frequently from infected wheat and barley and *F. culmorum* rarely or not at all (Broadfoot 1934, Harding 1972, 1973, Sallans & Tinline 1965, Tinline et al. 1979, Tyner 1956). Only occasionally was the incidence of *F. culmorum* similar to *C. sativus* in the south, while in the Peace River area of northwestern Alberta, *F. culmorum* was isolated most frequently (Tinline et al. 1979, Tyner 1956).

Although immunity to common root rot has not been demonstrated, a range of disease reaction occurs in cultivars and lines of wheat and barley (Piening 1973, Tinline & Ledingham 1979, Sallans & Tinline 1969). The usefulness of resistant genotypes will depend upon how well resistance is maintained across the prairie barley growing regions.

Sallans and Tinline (1969) showed that the ranking for reaction of wheat lines was the same at 15 locations across the prairies including Beaverlodge in the Peace River area. It would appear, therefore, that selection for resistant genotypes could be done at any location. The situation in barley is less well resolved. A preliminary report by Tinline et al. (1979) indicated that the reaction of cultivars to common root rot was different at Beaverlodge than at locations in the southern prairies. They postulated that resistance to the two pathogens in barley was determined by different genes.

The present study was done to investigate further the reaction of barley cultivars and lines at locations in the Peace River and in the central prairies to determine the extent of the differences found in the two areas. Lines that had shown good resistance in the central prairies were also included to check if this level of resistance would be maintained in the Peace River area. Isolations from subcrown internodes were made to determine the frequency of *C. sativus* and *F. culmorum*. Pathogenicity tests with several isolates of the two pathogens were performed in the greenhouse to determine if differences in virulence occur among isolates from the two regions.

Materials and methods

Common root rot rating tests. In 1981, the Western Cooperative Six-row Barley Test (36 entries), the Two-row Western Cooperative Barley Test (31 entries), a Barley Cultivar Test (20 entries), and a Selected Line Test (21 entries) were rated at Agriculture Canada Research Stations at Beaverlodge and Saskatoon and at the Experimental Farms at Fort Vermilion and Scott. The Barley Cultivar Test consisted of cultivars commonly grown in the prairie region or recently licensed cultivars, and the Selected Line Test consisted of lines that had had lower root rot ratings than the cultivar Bonanza in 2 or more years of field testing at Saskatoon and Scott. The same tests with 36, 30, 20, and 35 entries, respectively, were rated at the same locations in 1980 except for the Selected Line Test, which was not grown at the Fort Vermilion site. In 1979, the Western Cooperative Six-row Barley Test (30 entries) and Two-row Western Cooperative Barley Test (30 entries) were evaluated at Beaverlodge, Saskatoon, and Scott.

Entries were seeded 4-8 cm deep as 2 m single row plots, with 125 seeds per row, in a randomized block design with four replications. Rows were spaced 23 cm apart. Exceptions were at Beaverlodge where in 1979, four row plots, 5 m long (350 seeds per row) were used and where in 1980 and 1981, 3-m single row plots (175 seeds per row) were used.

One person rated all the plots in the field by pulling plants at the milk stage (Feekes' scale 11.1) or later. A disease rating was determined, based on the frequency of plants out of 40 that had lesions covering 50% or more of the subcrown internode (Ledingham et al. 1973).

Samples of subcrown internodes from each test and location in 1980 and 1981 were plated (Harding 1972) to record the number of internodes yielding *C. sativus* and red-pigment-producing *Fusarium* spp. In 1980 from 50 to 70 randomly chosen internodes from one entry in each test at all locations were plated, as follows, Bonanza in the Cooperative Six-row, Klages in the Two-row Cooperative, BT653Y in the Cultivar Test, and Melvin in the Selected Line test. In 1981, 100 randomly chosen internodes from two entries in each test at all locations were plated, as follows, BT001 and BT334 in the Cooperative Six-row, TR441 and TR905 in the Two-row Cooperative, Galt and Gateway 63 in the Cultivar Test and Melvin and SF78225 in the Selected Line Test.

Yield loss tests. In 1980, six barley cultivars, Betzes, Bonanza, Fairfield, Galt, Gateway 63, and Olli, were sown in four-row plots, 5 m long at

Saskatoon and at Fort Vermilion, and in six-row plots, 3 m long at Beaverlodge, in a randomized block design with six replications. The row spacing was 23 cm and the seeding rate was 70-80 seeds/m length of row. At about the firm dough stage (Feekes' scale 11.2) a 4-m length of the center two rows of each plot at Saskatoon and Fort Vermilion and a 2-m length of the center four rows of each plot at Beaverlodge were pulled and the plants were dried. One person sorted the plants into four categories, clean (no symptoms), slight, moderate, and severe, according to the extent of root rot symptoms on the subcrown internodes (Ledingham et al. 1973). Calculations of disease rating, and yield loss as a percentage of obtainable yield, were based on the method used by Tinline and Ledingham (1979). Samples of subcrown internodes from each location were plated.

Pathogenicity tests. For *F. culmorum*, 36 isolates from the Peace River and 11 isolates from the southern prairies were tested, and for *C. sativus*, 53 isolates from the Peace River and 48 isolates from the southern prairies. These isolates were recovered by the hyphal tip method from colonies growing from naturally infected subcrown internodes collected from the rating tests at the various locations each year. Fifteen seeds of Melvin barley were disinfected for 10 min with 0.1% $HgCl_2$, rinsed with sterile water, and then treated with Vitaflo Drill Box (carbathiin:thiram). These were placed on soil-less mix (Stringam 1971) in 13 cm diameter plastic pots and covered with 6 cm of an inoculating medium made up of soil-less mix:sand, 2:1, plus inoculum. For isolates of *F. culmorum* 500 spores were added/cm³ of inoculating media, and for *C. sativus* 250 spores/cm³ were used. Noninfested medium was used for the control. Inoculum was prepared by scraping and suspending in 0.1% Tween 20 solution spores of 10 to 20-day-old cultures grown on minimal agar medium (Tinline et al. 1960). The suspension was filtered through four layers of cheesecloth and the concentration was adjusted using a hemacytometer. Pots were placed in a greenhouse in which daylight was supplemented with 16 h light at 18-35°C. After emergence, plants were thinned to 10 per pot. After flowering (Feekes' scale 10.5.1), the subcrown internodes were rated for common root rot symptoms either by the four-category system (Ledingham et al. 1973) or by the Horsfall and Barratt system (Couture 1980). Isolations were made from the internodes to confirm the identity of the causal organisms. Four or five replicates (pots) of each isolate were used in a test. Each isolate was included in three or more tests although not all isolates were tested together because of limited space.

Results and discussion

In 1980 and 1981, the disease ratings in the Barley Cultivar Tests (Table 1) and the Barley Selected Line Tests (Table 2) varied considerably among locations. However, in different years and at different locations, the ranking of cultivars and lines was generally consistent, confirming earlier reports (Piening 1973, Tinline & Ledingham 1979). Bonanza usually had the lowest rating while Galt, Gateway 63, Melvin, and Olli usually had the highest ratings (Table 1). Some entries in the Selected Line Test, e.g. 148 and F15-1, generally had lower root rot ratings than Bonanza (Table 2). Data for the Western Cooperative Six-row Barley Test (Table 3) and the Two-row Western Cooperative Barley Test (Table 4) also showed that disease levels vary among years and locations, but that the ranking of entries was similar.

The consistent reaction of entries in the tests among locations was indicated by the significant correlations between locations in all years in all tests except for the Two-row Western Cooperative Barley Test (Table 5). In this test, Saskatoon and Scott were correlated in all 3 years, Beaverlodge and Fort Vermilion were not correlated, and

between the Peace River region and the central prairies there was a significant correlation in 5 out of 10 instances. The lack of correlation in the Two-row test may be due in part to the much narrower range of reaction in this test than in the other three sets of tests. The 46 significant correlations out of 51 comparisons indicate that there was a relationship between the disease rating of lines at one location with that of another. However an analysis of variance showed that the location \times entry interaction was significant for all tests, which indicates that the differences between entries were not the same at all locations. Thus the ranking of entries generally remained the same but the differences between them varied from location to location. There are also some entries which do not fit this pattern. For instance, Galt was one of the most severely diseased cultivars at all locations except at Beaverlodge, where it was only moderately diseased (Tables 1, 6). Norbert and Johnston were moderately diseased at all locations except for Fort Vermilion, where there was less disease on these two entries (Table 1). Sallans and Tinline (1969) also reported a significant location \times entry interaction for common root rot of wheat.

Table 1. Common root rot reaction of entries in the Barley Cultivar Test at four locations in 1980 and 1981

Cultivar/ line	Disease rating							
	Saskatoon		Scott		Beaverlodge		Fort Vermilion	
	1980	1981	1980	1981	1980	1981	1980	1981
Beacon	36	22	21	32	25	16	18	6
Bedford	16	11	14	13	24	14	14	11
Betzes	23		28		29		15	
Bonanza	6	13	6	16	7	11	3	3
Conquest	23		8		16		6	
Elrose	14	25	31	28	16	20	24	18
Fairfield	23	32	12	29	21	14	31	13
Fergus	19		28		17		20	
Galt	74	58	57	51	18	28	41	49
Gateway 63	55	49	40	56	49	40	34	52
Hector	14		14		23		17	
Johnston	29	41	33	39	30	21	19	13
Jubilee	41	43	39	44	30	19	43	65
Klages	23	17	28	18	16	16	13	19
Klondike	29	29	27	29	31	16	18	21
Melvin	41	55	39	50	31	27	49	63
Norbert	13	56	27	44	38	22	9	16
Olli	56	67	53	68	65	39	55	54
Summit	19	23	18	18	9	18	24	11
BT653Y	69		59		49		63	
Argyle		25		16		11		3
Harrington		35		35		21		18
TR446		24		29		14		24
TR450		19		19		16		21
TR451		22		26		13		13
LSD 0.05	16.2	14.4	12.9	14.8	14.0	9.8	11.2	14.8
0.01	21.6	19.2	17.2	19.7	18.6	13.1	14.9	19.6

In the yield loss test (Table 6) the ranking of the six cultivars on the basis of disease rating was similar to that in the Barley Cultivar Test. Significant correlations ($P < 0.01$, $n = 36$) for disease ratings occurred among all locations. The correlations between Saskatoon and Beaverlodge, Saskatoon and Fort Vermilion, and Beaverlodge and Fort Vermilion, were 0.759, 0.633, and 0.667, respectively. These results are similar to those reported for wheat (Sallans & Tinline 1969), but not for barley (Tinline et al. 1979).

Tinline et al. (1979) reported that barley cultivars reacted differently to common root rot at Beaverlodge than at locations in the southern prairies. The different results between these studies and those of Tinline et al. (1979) might be due to a number of factors. The common root rot reaction in barley is known to be highly variable (Tinline & Ledingham 1979). In the present study considerable variability in root rot reaction is also evident among years and between sites at the same location in the same year. For instance, if the disease rating for entries in the

Table 2. Common root rot reaction of entries in the Barley Selected Lines Test at three locations in 1980 and four locations in 1981

Cultivar/ line	Disease rating						
	Saskatoon		Scott		Beaverlodge		Fort Vermilion
	1980	1981	1980	1981	1980	1981	1981
148	8	5	12	16	8	11	3
992	16	8	11	19	7	9	12
1698	19	11	5	11	7	12	9
4421	18		13		24		
4444	13		18		9		
4451	17		18		21		
4796	23		21		19		
6602-2-4-4	29		23		14		
6602-2-4-5	24		19		9		
7554H-8	27		26		15		
B76-725-1	18		18		11		
BRC42-1	7	3	27	18	13	8	1
DS4-1-1	42		51		24		
E12-11	18	6	16	19	7	8	7
E15-8	10		16		16		
E15-23	13	6	13	33	14	8	0
E15-29	9	8	8	21	8	10	15
E65-4	25		36		19		
E67-2	14		20		8		
E67-12	13		16		8		
E78-2	7	4	11	21	16	8	5
E86-2	17	11	14	14	9	13	14
E86-17	18		13		9		
F13-1	20		24		5		
F14-3	14		14		9		
F15-1	7	6	11	19	4	10	9
F19-5	21		13		6		
F19-8	20		24		6		
F19-9	18		26		7		
F27-4	21		24		14		
F66-13	19		23		5		
S77151	15		19		7		
S78505	8	9	16	12	3	11	5
Bonanza	11	21	7	19	3	13	6
Melvin	49	52	66	53	18	29	38
4394		13		11		5	5
4401		8		20		13	9
79493		10		11		10	9
753B-1		21		21		19	1
E15-1		10		16		11	2
E15-22		7		17		3	4
E67-10		11		24		8	8
SF78225		10		23		16	11
LSD 0.05	11.4	7.6	13.0	10.2	8.9	8.7	11.9
0.01	15.1	10.1	17.2	13.6	11.8	11.5	15.8

Table 3. Common root rot reaction of entries in the Western Cooperative Six-row Barley Test at three locations in 1979 and at four locations in 1980 and 1981

B.T. number and cultivar	Disease rating											
	Saskatoon			Scott			Beaverlodge			Fort Vermilion		
	1979	1980	1981	1979	1980	1981	1979	1980	1981	1980	1981	
001	O.A.C. 21	38	33	14	11	37	15	18	16	18	27	14
120	Argyle	11	14	35	4	16	18	12	9	14	4	9
123		27	26		3	21		4	2		9	
124		18			5			10				
209		15			3			9				
210		34			16			21				
308	Bonanza	16	15	18	3	18	13	4	1	13	3	19
323	Klondike	39			8			4				
334	Johnston	31	42	41	13	49	43	11	8	18	24	17
336		28	41		9	46		8	9		24	
337	Leduc	41	28	29	4	39	26	3	17	20	32	28
341		16			5			14				
342		16	16		4	13		11	3		11	
428		49			26			18				
429		43			24			8				
431		25			20			6				
432		17			2			4				
433		29			9			9				
434		23			6			9				
435		44			15			18				
436		28			0			13				
506		38	38	42	6	41	34	13	8	23	18	19
507	Empress	29	32	26	20	24	37	18	21	25	30	36
508		23			3			16				
618	Diamond	46	41	31	37	58	47	13	6	32	19	26
655	Otal	52	49		21	57		48	21		52	
656		68			42			58				
657		66	68	56	22	58	53	23	27	44	58	63
658		70	51		21	59		26	19		38	
813		38			9			33				
211			35			19			6		8	
343			19	19		19	14		3	10	11	1
344			17			17			6		17	
345			21			31			6		15	
346			26	21		29	20		5	19	17	6
347			23			21			5		9	
437			13			22			7		16	
438			30	23		23	28		11	16	18	13
439			38	44		47	46		6	20	33	25
440			22			32			8		17	
441			42			43			12		42	
442			52			45			13		28	
509			49			55			9		35	
510			19	14		26	20		8	13	18	15
511			55			63			22		49	
512			61			64			21		57	
513			25	21		32	28		6	19	9	4
514			37	25		23	24		11	19	20	10
619			26			26			4		33	
653Y			67			69			29		54	
659			63			39			56		43	
906			25			26			5		11	
348				39			46			19		34
349				51			36			18		23
350				48			39			16		15
351				14			26			9		5
352				14			22			12		9
353				9			6			11		10
443				41			60			34		48
444				44			49			25		44

Table 3. Continued

B.T. number and cultivar	Disease rating											
	Saskatoon			Scott			Beaverlodge			Fort Vermilion		
	1979	1980	1981	1979	1980	1981	1979	1980	1981	1980	1981	
445			27			26				12		16
446			30			22				22		11
447			29			11				17		8
515			33			39				30		34
516			25			21				14		14
517			28			28				13		26
620			31			31				23		22
621			35			33				29		19
622			24			17				16		17
907			28			23				13		16
908			18			11				9		8
909			20			21				16		15
LSD	0.05	17.0	13.2	13.1	12.4	16.6	12.2	13.6	7.9	10.5	12.1	18.4
	0.01	22.5	17.5	17.3	16.4	22.0	16.2	18.1	10.4	13.9	16.1	24.4

Table 4. Common root rot reaction of entries in the Two-row Western Cooperative Barley Test at three locations in 1979 and four locations in 1980 and 1981

T.R. number and cultivar	Disease rating										
	Saskatoon			Scott			Beaverlodge			Fort Vermilion	
	1979	1980	1981	1979	1980	1981	1979	1980	1981	1980	1981
001 Hannchen	24	9	6	12	9	17	14	21	18	28	27
206 Norbert	67			17			31				
210	17			5			24				
211	10			4			20				
430 Elrose	33	13		23	29		21	19		19	
435	44			8			13				
441 Harrington	16	15	15	7	29	18	26	13	14	21	9
443	33			7			12				
445	41			29			29				
446	33	29	16	23	36	14	13	15	14	28	36
447	33			16			29				
448	43	25		13	26		22	16		30	
449	42			9			21				
450	21	10	7	7	16	20	24	18	11	16	17
451	25	23	9	6	13	13	31	14	11	8	14
452	31			17			24				
453 Scout	23	19	10	17	19	23	23	14	12	19	11
454	28			8			15				
455	43			12			19				
506 Fairfield	31	14	22	10	11	18	19	13	13	9	20
521	29	8		14	12		35	16		29	
522	29			19			24				
524	12			3			19				
525	18	6		4	10		19	14		15	
526	29			13			15				
527	21			15			13				
603	34			19			37				
604 Abee	17	16	15	9	14	14	12	6	6	6	10
905 Klages	29	18	6	18	14	24	9	8	11	24	14
907 Summit	15	31		4	26		19	12		33	
212		24	24		21	27		16	12	17	12
213		22			16			17		11	
214		21			28			28		38	
456		22	15		18	18		21	13	17	11
457		20			35			19		38	
458		16	8		8	6		11	4	14	11

Table 4. Continued

T.R. number and cultivar	Disease rating											
	Saskatoon			Scott			Beaverlodge			Fort Vermilion		
	1979	1980	1981	1979	1980	1981	1979	1980	1981	1980	1981	
459		21			9			17		11		
460		18			20			18		19		
461		29	28		56	24		29	18	26	24	
462		18	17		16	18		18	11	14	13	
463		22			15			18		34		
528		9			14			15		18		
529		16	18		20	13		14	9	51	12	
605		14			19			13		33		
606		17			29			13		30		
918		16			14			11		19		
215			31			28			9		16	
216			35			26			8		28	
217			26			26			11		18	
464			15			10			12		6	
465			12			9			7		13	
466			14			19			11		16	
467			9			14			6		21	
468			24			29			13		39	
469			14			14			8		15	
470			40			23			18		29	
530			8			19			6		18	
531			4			8			7		6	
919			11			14			12		6	
920			12			8			6		9	
921			9			7			11		9	
922			26			15			34		20	
LSD	0.05	13.8	13.2	10.7	9.1	13.0	11.0	16.4	9.1	8.9	19.4	14.1
	0.01	18.4	17.5	14.2	12.1	17.2	14.6	21.7	12.0	11.8	25.6	18.7

Yield Loss Test and for the same six cultivars in the Cultivar Test are compared, a significant correlation occurs at Saskatoon ($r = 0.984$) but not at Fort Vermilion ($r = 0.599$) or at Beaverlodge ($r = 0.116$). Also disease levels in the present study were lower at Beaverlodge than in the previous study (Tinline et al. 1979). Possibly cultivars that show some resistance at low disease levels react differently at high disease levels.

The yield loss test showed that levels of disease were similar at Saskatoon and Fort Vermilion but lower at Beaverlodge (Table 6). Bonanza was also the least diseased cultivar, and Galt, the most severely diseased. Grain yield losses varied among cultivars and locations. Losses were highest in Galt and lowest in Betzes, and amongst the three locations the greatest loss was at Fort Vermilion and the least at Beaverlodge.

Table 5. Correlations between locations of common root rot disease ratings in various barley tests

Year	Test	Number of entries (n)	Correlations between					
			Saskatoon and Scott	Saskatoon and Beaverlodge	Saskatoon and Fort Vermilion	Scott and Beaverlodge	Scott and Fort Vermilion	Beaverlodge and Fort Vermilion
1979	Western Coop Barley 6-row	30	0.744**	0.635**		0.600**		
	2-row Western Coop Barley	31	0.501**	0.213		0.208		
1980	Western Coop Barley 6-row	36	0.860**	0.730**	0.856**	0.499**	0.820**	0.715**
	2-row Western Coop Barley	30	0.551**	0.206	0.154	0.489**	0.417*	0.262
	Barley Cultivar	20	0.868**	0.594**	0.822**	0.648**	0.825**	0.623**
	Selected Line	35	0.820**	0.472**		0.474**		
1981	Western Coop Barley 6-row	36	0.777**	0.621**	0.646**	0.741**	0.781**	0.785**
	2-row Western Coop Barley	31	0.595**	0.374*	0.473**	0.227	0.490**	0.329
	Barley Cultivar	20	0.945**	0.820**	0.736**	0.888**	0.789**	0.733**
	Selected Line	21	0.711**	0.839**	0.762**	0.649**	0.652**	0.696**

* and ** indicate significant correlations at the 5 and 1% level of probability, respectively.

Table 6. Disease rating and percent grain yield loss due to common root rot disease of barley cultivars at three locations in 1980

Cultivar	Disease rating				% grain yield loss			
	Saskatoon	Beaverlodge	Fort Vermilion	Mean of locations	Saskatoon	Beaverlodge	Fort Vermilion	Mean of locations
Betzes	30 ^b	11 ^{bc}	28 ^a	23	5.8 ^{ab}	1.7 ^a	11.4 ^{ab}	6.3
Bonanza	20 ^b	8 ^{ab}	31 ^a	20	9.8 ^{abc}	3.0 ^a	14.4 ^{ab}	9.1
Fairfield	35 ^b	7 ^a	40 ^b	27	4.5 ^a	2.0 ^a	14.5 ^{ab}	7.0
Galt	55 ^d	24 ^c	66 ^c	48	7.9 ^{ab}	6.2 ^b	18.1 ^b	10.7
Gateway 63	46 ^c	15 ^d	32 ^a	31	14.9 ^c	6.1 ^b	4.6 ^a	8.5
Olli	46 ^c	13 ^{cd}	44 ^b	34	12.1 ^{bc}	4.2 ^{ab}	11.2 ^{ab}	9.2
Mean	39	13	40		9.2	3.9	12.2	

a-e Values within variable and location which are followed by the same letter are not significantly different according to Duncan's multiple range test ($P = 0.01$).

Disease rating and percent yield loss were correlated at Beaverlodge ($r = 0.637$, $P < 0.01$, $n = 36$) but not at Saskatoon ($r = 0.200$) or Fort Vermilion ($r = 0.445$). This confirms the findings of Tinline and Ledingham (1979) of inconsistent correlations between disease ratings and percent yield losses. Their data showed significant correlations between disease ratings and percent yield loss in five of eight wheat tests and three of six barley tests.

Although cultivars may vary in tolerance, disease intensity does have an influence on yield loss. The mean disease rating of the six cultivars at Beaverlodge, Saskatoon, and Fort Vermilion was 13, 39, 40, respectively, and this paralleled the estimate of yield loss of 3.9, 9.2, and 12.2, respectively (Table 6). Also, as disease intensity increased from "slight" to "moderate" to "severe" the average yield losses at all locations increased from 6.7 to 13.5 to 28.6, respectively. The percent yield losses relative to clean plants for the slight, moderate, and severe categories, respectively, were 4.5, 11.5, and 29.3 at Saskatoon; 8.2, 13.4, and 26.1 at Beaverlodge; and 7.4, 15.7, and 30.4 at Fort Vermilion. These data confirm earlier work on barley (Piening 1973, Piening et al. 1976) and on wheat (Ledingham et al. 1973).

As previous workers have shown (Piening et al. 1976, Ledingham et al. 1973), yield loss was better

correlated with reduction in numbers of heads than with 1000 kernel weight reduction. Percent yield reduction was significantly correlated ($P < 0.01$) with reduction in numbers of heads at Saskatoon ($r = 0.661$), Beaverlodge ($r = 0.861$), and Fort Vermilion ($r = 0.528$). Reduction in 1000 kernel weight and yield loss was correlated at Fort Vermilion ($r = 0.374$, $P < 0.05$) but not at Saskatoon ($r = 0.044$) or at Beaverlodge ($r = 0.134$).

For the central prairie locations Saskatoon and Scott, and for Fort Vermilion in the Peace River area, *C. sativus* was isolated more frequently from subcrown internodes than were "red" *Fusarium* spp. in both 1980 and 1981 (Table 7). For Beaverlodge in the Peace River area, approximately equal numbers of the two causal organisms were isolated in 1980 and higher numbers of "red" *Fusarium* spp. were isolated in 1981. The red *Fusarium* were probably all *F. culmorum* since a representative sample of 12 isolates were identified as such. Sallans and Tinline (1969) isolated an equal percentage of the two causal organisms at Beaverlodge. Isolations by Tyner (1956) showed *F. culmorum* to be dominant in the Peace River area and *C. sativus* to be dominant in the southern prairies, but he did not give locations where plants were sampled. The difference between Beaverlodge and Fort Vermilion in this study suggests that considerable variation

Table 7. Percent subcrown internodes yielding *Cochliobolus sativus* and red-colored *Fusarium* spp., from plants taken from barley tests at various locations

Year	Location	Total number of internodes plated	% Red	
			% <i>C. sativus</i>	<i>Fusarium</i> spp.
1980	Saskatoon	474	70	5
	Scott	200	50	12
	Beaverlodge	496	23	18
	Fort Vermilion	448	54	4
1981	Saskatoon	788	64	2
	Scott	750	46	1
	Beaverlodge	780	15	31
	Fort Vermilion	458	40	0.4

Table 8. Analysis of variance table of the pathogenicity on Melvin barley of *Cochliobolus sativus* and *Fusarium culmorum* isolates collected from the Peace River area in northwestern Alberta and from the southern prairies in Saskatchewan

Source of variation	<i>C. sativus</i> isolates†			<i>F. culmorum</i> isolates††		
	df	MS	Fs	df	MS	Fs
Replicates	3	571.64	2.272 n.s.	4	834.42	3.527 n.s.
Isolates	90	1624.15	6.455 ***	31	1655.95	6.999 **
Between areas	1	605.42	2.406 n.s.	1	21.427	0.091 n.s.
Error	270	251.61		124	236.61	
Total	363			159		

†The number of isolates of *C. sativus* and the mean common root rot rating for the Peace River area was 46 and 67.5, respectively, and for the southern prairies 44 and 62.3, respectively. The root rot rating for the uninoculated control was 3.9.

††The number of *F. culmorum* and the mean root rot rating for the Peace River area was 21 and 45.7, respectively, and for the southern prairies was 9 and 41.6, respectively. The root rot rating was 0 for the uninoculated control and 4.8 for an isolate of a nonpathogenic *Fusarium* sp.

** and *** indicate significant differences at the 1 and 0.1% levels of probability, respectively.

n.s. indicates a nonsignificant difference ($P > 0.05$).

occurs in the Peace River area in respect to the isolation of *C. sativus* or *Fusarium* spp.

The pathogenicity tests showed that significant differences occurred among isolates of both fungal species, but there was never a significant difference between the two areas (Table 8). Because of the similarity in all tests, a summary of only two tests is presented. For these tests, the average disease rating for isolates collected from the Peace River and from southern Saskatchewan was 67.5 and 62.3, respectively, for *C. sativus*, and 45.7 and 41.6, respectively, for *F. culmorum*. While ratings at the two locations may not differ, the data indicate that the causal fungi are highly variable.

This study shows that common root rot intensity generally remains comparable among lines of barley at widely separated locations in western Canada, despite the diversity in climate, soil, and causal agents. Locations differed in the level of infection and the degree of difference for disease ratings among lines was not the same at each location. This indicates that selection for common root rot resistance in barley could be done at any of these locations in western Canada, but only the ranking and not the actual ratings would be applicable from one location to another.

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