Interrelationship of Cultivar Reactions to Common Root Rot, Black Point, and Spot Blotch in Spring Wheat

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ABSTRACT

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The reactions of 18 spring wheat cultivars to common root rot, black point, and spot blotch caused by *Cochliobolus sativus* were determined in a series of controlled-environment studies. No strong correlations were detected for reactions to these diseases. However, a weak negative correlation was detected between black point and spot blotch ratings. Large differences in disease reactions were observed among cultivars for each disease. No cultivar was resistant to all three diseases, but the cultivar Rescue was universally susceptible. The cultivars Owens, Sinton, Neepawa, and 7825-J3D were rated most resistant to common root rot. The hard red spring wheats were uniformly susceptible to spot blotch, but the soft white spring wheat cultivars Fielder, Owens, and Dirkwin were resistant. Cadet and Glenlea consistently had the lowest incidence of black point.

The fungus *Cochliobolus sativus* (Ito & Kuribayashi) Drechs. ex Dastur (conidial state *Bipolaris sorokiniana* (Sacc.) Shoemaker; syn. *Helminthosporium sativum* Pammel, C. M. King & Bakke) can infect all the aboveground and belowground parts of wheat (*Triticum aestivum* L.). Diseases caused by *C. sativus* occur wherever wheat is grown in the form of black point, seedling blight, common root rot, or spot blotch. In western Canada, the most recent survey of hard red spring wheat (13) reported that common root rot was responsible for an annual yield loss of 5.7%. In previous years, black point caused by *C. sativus* has resulted in serious losses due to downgrading of the grain (16). Further losses caused by seedling blight can also occur when the infected grain is used as seed (14,16). Spot blotch on the leaves is a common occurrence in many areas (11). Under wet conditions, lesions on the leaves often coalesce and eventually kill the infected leaves (20). While spot blotch is known to be a widespread problem on wheat in Canada, there is little information available on its impact on yield.

Sources of resistance to common root rot (9), spot blotch (1), and black point (5) have been identified in several different types of wheat. However, sources of complete resistance to common root rot and black point have not been identified, and current Canadian wheat cultivars are considered to be only moderately resistant to these diseases. Larson and Atkinson (12) demonstrated that resistance in the wheat cultivars Apex and Cadet is controlled by the recessive allele of a major gene located on chromosome 5B. Recently, Conner and Whelan (7) showed that resistance in Cadet to black point caused by *C. sativus* is a recessive trait controlled by a gene or genes located on chromosome 5B. Adlakha et al (1) identified several wheat cultivars that were moderately resistant to spot blotch and showed that resistance was a dominant trait controlled by one gene or by two genes, depending on the resistant parent used in the cross. They also demonstrated that resistant wheat cultivars reduce the spread of spot blotch by developing fewer, smaller lesions that produce fewer spores per lesion.

The relationship of resistance to these three diseases in wheat has not been examined previously. However, a study of barley failed to demonstrate a relationship between resistances to head blight, spot blotch, and root rot (4), diseases also caused by *C. sativus*. A better understanding of the interrelationship of cultivar reactions to these three

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diseases might result in a more rapid screening methodology, since testing the reaction to spot blotch requires less time than screening for black point and root rot resistance.

This study was undertaken to determine whether a relationship for resistance to common root rot, black point, and spot blotch exists among a diverse group of wheat cultivars.

MATERIALS AND METHODS

The 18 wheat cultivars used in this study included six hard red spring wheats, 10 soft white spring wheats (6), one utility wheat, and one Canada prairie spring wheat (Table 1).

Preparation of inoculum. Five isolates of *C. sativus*, previously described by Conner and Davidson (5), were used in experiments on spot blotch and black point. Each isolate originated in infected kernels of the wheat cultivar Fielder from either Lethbridge or Vauxhall, Alberta; Saskatoon or Outlook, Saskatchewan; or Winnipeg, Manitoba. Each isolate was grown separately in 9-cm petri dishes containing Difco potato-dextrose agar under constant near-UV light (supplied by a fluorescent lamp) at 21 C. Cultures were started by flooding 10-cm petri dishes with 1 ml of a spore suspension. After 10–14 days, conidia were collected by flooding the plate with 10 ml of sterile distilled water and then scraping the agar surface with a glass slide to dislodge the conidia. Equal volumes of conidial suspension from each isolate were combined and filtered through a double layer of cheesecloth. Conidial concentration was adjusted to 5×10^4 conidia per milliliter for the black point studies or to 2×10^4 conidia per milliliter for the spot blotch tests.

Evaluation of black point. Experiments were conducted in growth cabinets initially set at 15 C with a 16-hr photoperiod and a light intensity of 300 $\mu E \cdot m^{-2} \cdot s^{-1}$. Six weeks after emergence, the temperature was raised to 21 C. Plants were grown in Hillson-style rootrainer books containing Cornell mix (2), arranged in trays of eight books each. Each book consisted of four fold-up ganged cavities ($3.8 \times 3.8 \times 12.7$ cm per cavity). One kernel was seeded per cavity and eight kernels of a specific cultivar were seeded per plot. The cultivars were arranged in a randomized complete-block design with four replications. The experiment was repeated once.

Inoculations were carried out at anthesis using the vacuum infiltration method (6). A single head from each plant was submerged in the conidial suspension for 20 sec under a vacuum of 84.6 kPa. After inoculation, the remaining uninoculated tillers were removed. The plants were harvested individually at maturity and the percentage of black point kernels in each plot was calculated. Bartlett's test for homogeneity (18) determined that cultivar variances were dissimilar. Comparison of several different transformations showed that a square-root transformation was most effective in reducing the relationship between cultivar means and their variances. Because of this, analysis of variance was carried out on square-root transformed data and cultivar means were compared using Tukey's ω-procedure (19). The data were presented as back-transformed means for percentage of black point incidence.

Evaluation of spot blotch. Plants were grown in a growth cabinet at 21 C with a 16-hr photoperiod and a light intensity of 200 $\mu E \cdot m^{-2} \cdot s^{-1}$. Plants were grown in rootrainer books consisting of five ganged cavities ($2.5 \times 2.5 \times 10.8$ cm per cavity). Ten kernels of a specific cultivar were seeded per plot. Treatments were replicated six times in a randomized complete-block design and the experiment was repeated once. At the five-leaf growth stage, inoculum was sprayed on plant leaves until runoff. Plants were then placed in a moist chamber and left in the dark for 24 hr. Seven days after inoculation, the plants were rated for extent of leaf necrosis and chlorosis using the system described by Adlakha et al (1). Plants were rated individually on a scale ranging from 0 (no leaf chlorosis or necrosis) to 5 (necrosis and chlorosis covering more than 60% of the leaf surface). An analysis of variance was carried out on the spot blotch data. Cultivar means were compared using Tukey's ω-procedure.

Evaluation of root rot. Experiments were carried out in a greenhouse maintained at 21 ± 4 C under natural light supplemented with fluorescent light to ensure a 16-hr photoperiod and light intensity of 200 $\mu E \cdot m^{-2} \cdot s^{-1}$. The wheat cultivars were tested for root rot resistance using the procedure described by McKenzie and Atkinson (15). Tests were conducted in two greenhouse beds (264×145 cm each) filled with soil to a depth of 12.7 cm. The soil came from a location where susceptible wheat had been grown continuously for at least 6 yr and root rot was known to be quite severe. Prior to seeding, the top 8 cm of soil was removed, screened, and mixed to ensure a uniform distribution of inoculum throughout the two beds. The beds were then refilled to a depth 6 cm below the

Table 1. Cultivar means for root rot and spot blotch severity and black point incidence (%) in different tests

Cultivar	Class of wheat[w]	Root rot severity (%)		Spot blotch[x]		Black point[y] incidence (%)	
		Test 1	Test 2	Test 1	Test 2	Test 1	Test 2
Rescue	HR	100.0 a[z]	92.7 a	3.2 ab	3.9 a	47.1 a	76.9 a
Cypress	HR	88.9 ab	92.4 a	3.0 ab	3.8 ab	24.4 abc	66.2 ab
83-A-10	SW	69.0 bc	34.7 bc	2.4 bcde	2.3 e	14.7 abc	73.8 a
Cadet	HR	42.8 cd	29.3 bcde	3.4 a	3.9 a	8.1 c	21.2 c
Dirkwin	SW	39.6 cd	31.8 bcd	2.2 de	2.2 e	33.9 abc	85.5 a
Bliss	SW	38.1 d	38.0 b	2.6 abcde	2.9 bcde	7.7 c	53.2 ab
Lemhi 62	SW	38.1 d	29.2 bcde	2.5 abcde	2.3 e	37.3 ab	87.2 a
HY320	PS	37.8 d	17.5 def	2.3 bcde	3.2 abcd	23.3 abc	55.2 ab
Glenlea	U	34.3 d	25.0 bcde	2.4 bcde	3.4 abc	10.6 bc	35.5 bc
SWS12	SW	32.6 d	18.9 cdef	2.5 abcde	3.0 abcde	43.4 a	67.5 ab
SWS21	SW	32.5 d	31.6 bcd	2.3 bcde	3.0 abcde	15.6 abc	69.8 a
SWS15	SW	32.0 d	22.3 bcdef	2.7 abcde	3.8 ab	10.5 bc	59.5 ab
Fielder	SW	26.8 d	22.6 bcdef	1.8 e	2.2 e	14.2 abc	66.3 ab
Sinton	HR	26.3 d	12.5 f	3.1 abc	3.9 a	11.5 bc	56.0 ab
Springfield	SW	23.1 d	24.7 bcdef	2.3 bcde	2.4 de	33.8 abc	81.7 a
Neepawa	HR	19.8 d	15.5 def	3.1 abc	3.3 abc	15.1 abc	49.5 ab
7825-J3D	HR	16.3 d	10.5 f	2.6 abcde	2.5 cde	29.3 abc	58.4 ab
Owens	SW	14.6 d	13.9 ef	1.9 e	2.4 de	26.9 abc	78.8 a

[w] HR = Hard red spring wheat, PS = Canada prairie spring wheat, U = utility wheat, SW = soft white spring wheat.
[x] Measured on a 0–5 scale where 0 = no infection and 5 = necrosis and chlorosis covering more than 60% of the leaf surface.
[y] Back-transformed data.
[z] Means within columns followed by the same letter are not significantly different ($P = 0.05$) according to Tukey's ω-procedure.

original soil surface. Each soil bed was divided lengthwise into three ranges and 20 kernels of a specific cultivar were seeded per plot. Each plot consisted of one 40-cm row; plots were spaced 9.5 cm apart. Two border rows of the root rot-susceptible cultivar Cypress were seeded around the edge of each soil bed. The seed was placed on the soil surface and then covered with the remaining 6 cm of soil so that the soil beds were restored to their original soil depth. Deep seeding was used to promote long subcrown internode development and natural inoculum was relied on for infection. Treatments were replicated six times and arranged in a randomized complete-block design. The experiment was repeated once.

The plants were removed from the soil 7 wk after seeding. Subcrown internodes were examined and rated for root rot damage according to the extent of lesions present. Root damage was categorized according to the system described by Ledingham et al (13) in which 1 = nil (no lesions), 2 = slight (few small lesions), 5 = moderate (extensive lesions covering up to half of the subcrown internode), and 10 = severe (very extensive lesions covering most of the subcrown internode). Data on the number of plants in each category were summarized as percentage root rot (%RR) according to the following formula described by Burrage and Tinline (3): %RR = (Number of plants in category × root rot rating) × 10/Total number of plants. An analysis of variance was carried out on the root rot data and cultivar means were compared using Tukey's ω-procedure.

Comparison of disease reactions. The results of different tests in the same experiment were combined and analyzed to determine whether there was a significant test × cultivar interaction. The relationship between the severity ratings for root rot and spot blotch and incidence of black point was examined by studying the correlation among cultivar means in the different experiments. Spearman's rank correlation test (18) was used to compare the rankings of the cultivars against the three diseases in the different tests.

RESULTS

A wide range in disease severity was observed among cultivars in each test (Table 1). The only relationship among host reactions to black point, spot blotch, and common root rot was the significant ($P = 0.05$) correlation between the spot blotch ratings in tests 1 and 2 and the incidence of black point in test 2 (Tables 2 and 3). High levels of resistance were identified in certain cultivars for each disease. No cultivar was highly resistant to all three diseases, but Rescue was universally susceptible.

An analysis of variance of the combined results of different tests for the same disease demonstrated a significant ($P = 0.05$) test × cultivar interaction for each disease. Consequently, the results of each test were reported separately (Table 1). Comparisons of test results for each disease by correlation (Table 2) or ranking (Table 3) of cultivar means showed reasonably good agreement between test results.

Root rot ratings. High levels of root rot resistance were identified in cultivars of both hard red spring wheat and soft white spring wheat. The cultivars Owens, Neepawa, Sinton, and 7825-J3D were consistently rated among the most resistant entries (Table 1). Rescue and Cypress were significantly more susceptible to root rot than most of the other cultivars. The other cultivars had root rot ratings that ranged between the most resistant and the susceptible group.

Spot blotch ratings. As a group, the hard red spring wheats were highly susceptible to spot blotch. The utility wheat Glenlea and the prairie spring wheat HY320 were also rated as having severe spot blotch. Only the soft white spring wheat cultivars SWS12, SWS15, and SWS21 had spot blotch ratings similar to those for the hard red spring wheats. The cultivars Fielder, Owens, and Dirkwin consistently had the lowest spot blotch ratings. The other soft white spring wheat cultivars had spot blotch severity ratings that shifted from intermediate to low depending on the test.

Black point ratings. Black point incidence in the cultivars Rescue, SWS12, and Lemhi 62 was high in both tests, while only Cadet and Glenlea had disease incidences that were significantly lower than those of the most susceptible cultivars. The other cultivars had black point levels that ranged from intermediate to high and usually were not significantly different from those of the cultivars at either extreme.

DISCUSSION

This study clearly shows that resistance to *C. sativus* in one part of a wheat plant provides no indication of that cultivar's resistance at other sites in the plant. It appears that resistance to *C. sativus* in the roots and subcrown internode involves different defense mechanisms than those controlling black point incidence in the developing kernel or lesion formation on the leaves.

The significant negative correlation between black point and spot blotch was mainly due to the difference in disease reactions between the soft white and hard red spring wheat cultivars. Cultivars such as Dirkwin, Owens, and Springfield had low levels of spot blotch but were susceptible to black point. The reverse was true for the hard red spring wheats Cadet, Neepawa, and Sinton. This relationship should be further examined with additional cultivars to determine whether screening for resistance to one disease indirectly selects for susceptibility to the other disease. Such information would be useful because testing for spot blotch reaction takes only one-fourth to one-third of the time required to screen for black point resistance.

The results of this study support the findings of a previous study by Conner and Whelan (7), which found no consistent difference in black point incidence between the root rot-susceptible and moderately resistant cultivars. Similar studies in barley also failed to demonstrate any relationship between cultivar

Table 2. Correlation coefficients for ratings of cultivars in different tests against root rot, spot blotch, and black point

Test	Root rot 2	Spot blotch 1	Spot blotch 2	Black point 1	Black point 2
Root rot 1	0.93***[a]	0.41 ns[b]	0.38 ns	0.23 ns	0.41 ns
Root rot 2	···	0.39 ns	0.37 ns	0.27 ns	0.19 ns
Spot blotch 1	···	···	0.80***	−0.15 ns	−0.49*
Spot blotch 2	···	···	···	−0.30 ns	−0.56*
Black point 1	···	···	···	···	0.67**

[a] * = Significant at $P = 0.05$; ** = significant at $P = 0.01$; *** = significant at $P = 0.001$.
[b] ns = Not significant.

Table 3. Spearman rank correlations of cultivar means in different tests against root rot, spot blotch, and black point

Test	Root rot 2	Spot blotch 1	Spot blotch 2	Black point 1	Black point 2
Root rot 1	0.86***[a]	0.28 ns[b]	0.19 ns	0.03 ns	0.08 ns
Root rot 2	···	0.11 ns	0.01 ns	0.01 ns	0.24 ns
Spot blotch 1	···	···	0.79***	−0.15 ns	−0.49*
Spot blotch 2	···	···	···	−0.30 ns	−0.56*
Black point 1	···	···	···	···	0.72***

[a] * = Significant at $P = 0.05$; ** = significant at $P = 0.01$, *** = significant at $P = 0.001$.
[b] ns = Not significant.

reactions to spot blotch, root rot, and head blight (4). In crosses of *Hordeum vulgare* L. with *H. leporinum* Link, Clark reported that all progeny were susceptible to leaf spotting caused by *C. sativus* (4). While certain lines were resistant to root rot or head blight, none of the lines were resistant to both diseases. In the current study, however, wheat cultivars were identified that carried resistance to more than one disease. For example, Owens had low disease ratings for both root rot and spot blotch. Cadet and Glenlea had low incidences of black point and intermediate ratings for common root rot. Fielder, Springfield, and Dirkwin had low ratings for spot blotch and intermediate to low ratings for root rot. The results of this study indicate that resistance to common root rot, black point, and spot blotch are independently inherited and likely could be incorporated into a cultivar.

This is the first report of high levels of spot blotch resistance in the soft white spring wheat cultivars Fielder, Owens, and Dirkwin. An examination of the pedigrees of these three cultivars (6) shows that they share Norin 10 and Brevor as parents. This suggests that resistance to spot blotch in the most resistant soft white spring wheat cultivar may have originated from either Norin 10 or Brevor.

Resistance to common root rot in Neepawa and Sinton has been previously reported (9,10). Similarly, earlier reports of black point resistance in Glenlea (5) and Cadet (7) were confirmed in this study.

The ratings of cultivars shown to be either resistant or susceptible to a particular disease were quite consistent among tests. However, the ratings of cultivars with intermediate levels of disease resistance tended to shift and resulted in the slight inconsistencies among test results. Other studies (8,17) have noted that the ratings of cultivars with moderate root rot resistance are more strongly influenced by the environment than those of resistant or susceptible cultivars.

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LITERATURE CITED

1. Adlakha, K. L., Wilcoxson, R. D., and Raychaudhuri, S. P. 1984. Resistance of wheat to leaf spot caused by *Bipolaris sorokiniana*. Plant Dis. 68:320-321.
2. Boodley, J. W., and Sheldrake, R. 1973. Cornell Peat-lite mixes for commercial plant growing. Cornell Univ. Inf. Bull. 43. 8 pp.
3. Burrage, R. H., and Tinline, R. D. 1960. Common root rot and plant development following treatment of wheat with aldrin, gamma BHC, and heptaclor, with and without mercury fungicides. Can. J. Plant Sci. 40:672-679.
4. Clark, R. V. 1966. The reaction of barley lines to root rot, leaf spot and headblight. Can. J. Plant Sci. 46:603-609.
5. Conner, R. L., and Davidson, J. G. N. 1988. Resistance in wheat to black point caused by *Alternaria alternata* and *Cochliobolus sativus*. Can. J. Plant Sci. 68:351-359.
6. Conner, R. L., and Thomas, J. B. 1985. Genetic variation and screening techniques for resistance to black point in soft white spring wheat. Can. J. Plant Pathol. 7:402-407.
7. Conner, R. L., and Whelan, E. D. P. 1989. Role of chromosome 5B in controlling black point incidence in hard red spring wheat. Can. J. Plant Sci. 69:675-679.
8. Conner, R. L., Whelan, E. D. P., and MacDonald, M. D. 1989. Identification of sources of resistance to common root rot in wheat-alien amphiploid and chromosome substitution lines. Crop Sci. 29:916-919.
9. Harding, H. 1972. Reaction to common root rot of 14 *Triticum* species and the incidence of *Bipolaris sorokiniana* and *Fusarium* spp. in subcrown internode tissue. Can. J. Bot. 50:1805-1810.
10. Hurd, E. A., and Patterson, L. A. 1976. Sinton hard red spring wheat. Can. J. Plant Sci. 56:399-400.
11. Johnston, H. W. 1969. Diseases of cereals in the Maritime provinces in 1969. Can. Plant Dis. Surv. 49:122-125.
12. Larson, R. I., and Atkinson, T. G. 1970. A cytogenetic analysis of reaction to root rot in some hard red spring wheats. Can. J. Bot. 48:2059-2067.
13. Ledingham, R. J., Atkinson, T. G., Horricks, J. S., Mills, J. T., Piening, L. J., and Tinline, R. D. 1973. Wheat losses due to common root rot in the prairie provinces of Canada 1969-1971. Can. Plant Dis. Surv. 53:113-122.
14. Machacek, J. E., and Greaney, F. J. 1938. The "black-point" or "kernel smudge" disease of cereals. Can. J. Res. Sec. C 16:84-113.
15. McKenzie, H., and Atkinson, T. G. 1968. Inheritance of Thatcher-type resistance to common root rot in spring wheat. Can. J. Plant Sci. 48:479-486.
16. Russell, R. C. 1943. The relative importance from the pathological standpoint of two types of smudge on wheat kernels. Sci. Agric. Ottawa 23:365-375.
17. Sallans, B. J., and Tinline, R. D. 1965. Resistance in wheat to *Cochliobolus sativus*, a cause of common root rot. Can. J. Plant Sci. 45:343-351.
18. Snedecor, G. W., and Cochran, W. C. 1976. Statistical Methods. Iowa State University Press, Ames. 593 pp.
19. Steel, R. G. D., and Torrie, J. H. 1960. Principles and Procedures of Statistics. McGraw-Hill, New York. 481 pp.
20. Wiese, M. V., ed. 1987. Compendium of Wheat Diseases. 2nd ed. American Phytopathological Society, St. Paul, MN. 112 pp.