Effects of Septoria Leaf Blotch on Soft Red Winter Wheat Milling and Baking Quality[1]

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ABSTRACT

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Septoria leaf blotch causes economic yield losses in wheat worldwide. Research on the impact of septoria leaf blotch on grain quality, however, has been limited to its effect on test weight. The objectives of this study were to determine the effect of septoria leaf blotch severity on soft red winter wheat quality in cultivars with varying levels of resistance and to assess the impact of disease pressure on selection for improved quality in breeding programs. Twelve cultivars expressing a range of genetic resistance were grown in a split-plot design with four replicates in two Missouri environments. Cultivars were considered main plots. Five experimental subplot treatments, including a noninoculated unprotected control and plots with fungicide protection as well as plots inoculated at tillering, jointing, and flag leaf, were used to establish a range of septoria leaf blotch severity. Increased disease pressure resulted in linear reductions in test weight ($r = 0.97^{**}$), milling quality ($r = 0.98^{**}$), adjusted flour yield ($r = 0.97^{**}$), and a linear increase in water absorption in the flour ($r = 0.95^{**}$). Increased disease severity also resulted in an increase in flour protein and a decrease in baking quality, however, the linear correlation coefficients were nonsignificant. The role of resistance genes for maintaining quality was important for milling quality but was negligible for baking quality. Cultivar by treatment interactions were due primarily to changes in magnitude and not in cultivar rank, which suggested that selection for milling and baking quality would be effective even when septoria leaf blotch disease pressure is high.

Septoria leaf blotch, caused by the fungus *Mycosphaerella graminicola* (Fuckel) Schroeter (anamorph: *Septoria tritici* Roberge in Desmaz) is a major disease of wheat (*Triticum aestivum* L. em. Thell) worldwide. Where environmental conditions are favorable for disease development, yield losses ranging from 20 to 43% have been reported (Cooke and Jones 1971, Caldwell 1976). Losses due to natural infection in Missouri during the 1990 crop year averaged 22% for commercially grown cultivars but were as high as 35% for Caldwell and Pioneer 2551 (McKendry and Henke 1994a).

Septoria leaf blotch can reduce the economic value of wheat by decreasing both grain yield and quality. Test weight, a function of both kernel density and random kernel packing volume (Yamazaki and Briggle 1969), and an initial indicator of grain quality, can be significantly affected by this disease; reported reductions under natural infection reached 3.7 lb/bu (Caldwell and Narvaez 1960). Soft wheat quality, however, is not based solely on test weight, but rather on a complex combination of several milling, baking, processing, and dough characteristics that determine the suitability of a cultivar for a specific end-use product. In general, low to medium protein content, low water absorption, high break flour yield, a high degree of kernel softness, and fine flour granulation are important traits for soft wheats used in cookies, cakes, crackers, and other products (Finney 1990). These traits are heritable and are important objectives in soft wheat breeding programs (Patterson and Allen 1981).

Much of the research on soft wheat quality has focused on the value of the cultivar. However, little attention has been given to the impact of diseases on milling and baking quality and to the interaction effects of disease with cultivar on quality. Finney and Sill (1963) reported that wheat streak mosaic virus and soilborne mosaic virus reduced flour yield and increased flour ash content but did not affect protein quality in hard wheats. Mathre et al (1977) found that *Cephalosporium* stripe disease reduced flour yield and test weight in hard wheats. Johnson et al (1979) evaluated the effect of powdery mildew on soft wheat quality through the use of near-isogenic lines of Chancellor wheat and found that severe powdery mildew infection lowered flour protein but did not significantly affect particle size index, flour yield, or flour ash content and had only a minor effect on baking quality.

Despite the importance of septoria leaf blotch worldwide, research on its impact on wheat milling and baking quality has been limited to reports of reductions in test weight under severe disease pressure (Caldwell and Narvaez 1960, Eyal and Ziv 1974, Mehta 1976). Our objectives in this study were to determine the effect of septoria leaf blotch severity on soft red winter wheat quality in a range of elite cultivars with different levels of resistance and to assess the impact of disease pressure on selection for improved quality in breeding programs.

MATERIALS AND METHODS

Pathogen

Fourteen single pycnidium isolates of *S. tritici* were obtained from leaf samples from a range of soft red winter wheat cultivars grown at Columbia, Portageville, and Mt. Vernon, MO. Leaves were dried and stored in a refrigerator at 5-10°C to ensure a source of material from which to reisolate if pathogenicity had become attenuated. Leaf segments 3-5 cm long were placed on microscope slides in petri dishes on moistened filter paper to create a high humidity atmosphere. Pycnidiospores were extruded from pycnidia in a cirrhus. A single cirrhus was removed from each leaf segment to ensure isolate diversity. Isolates were maintained on yeast malt agar plates, transferred to fresh plates at seven-day intervals, and increased for inoculation on a rotary shaker in liquid yeast extract medium for seven days at 21-23°C. Isolates were then combined and concentrated to 5×10^6 spores per milliliter. Three drops of Tween 20 (FisherBiotech, Fair Lawn NJ) per liter of inoculum were added as a sticker/surfactant.

Preliminary Glasshouse Seedling Screen

Sixty-two soft red winter wheats grown in the 1989 Missouri Small Grains Performance Tests (McKendry et al 1989) were screened as seedlings for resistance to septoria leaf blotch. Twenty-five seeds of each cultivar were planted in rows 5 cm apart in 27- × 27- × 6-cm plastic flats in a randomized complete block design with four replicates. The spring wheat Fortuna and the soft red winter wheat Oasis were used as the susceptible and

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resistant checks, respectively. Seedlings were inoculated at the two-leaf stage using the quantitative technique of Eyal and Scharen (1977). To ensure even coverage, each flat was rotated during spraying with 25 ml of inoculum from a hand-held atomizer. After inoculation, flats were placed into a mist chamber for 72 hr at 22–25°C and then returned to the glasshouse bench under a 16-hr photoperiod and 25°C daily temperature. Disease severity was assessed at 15 and 21 days after inoculation on the first (coleoptilar) and second leaves, respectively, using the Saari and Prescott (1975) scale adapted for assessing foliar disease severity in wheat seedlings (McKendry and Henke 1994b). The 0–9 scale reflects the second digit of the Saari and Prescott two-digit scale and quantifies the percentage leaf area necrosis in 10% increments, from no visible symptoms (0) to complete necrosis of the inoculated leaf (9). Ratings for the first and second leaves were averaged for each accession. Analysis of variance of the average scores for each accession was conducted. Mean ratings for the first and second leaves were compared using Fisher's least significant difference (LSD) ($P = 0.05$) based on the error mean square from the analysis of variance. Twelve cultivars were identified that exhibited the complete spectrum of resistance to susceptibility present in commercial soft red winter wheat cultivars available in Missouri.

Field Study

The field study was conducted during 1989-90 in two distinct Missouri environments: Mexico silt loam soil at the University of Missouri's Delta Center, Portageville, and Tiptonville silt loam soil at the Agronomy Research Center, Columbia. Cultivars were sown in six-row plots, 4.6-m long with 17.8-cm row spacing, at a constant plant density of 1,850 seeds per plot. All plots were trimmed to 3.2 m for harvest. A split-plot planting design with four replicates was used at each location. On either side of each plot, a six-row buffer plot of the more resistant Pioneer 2550 was planted to prevent disease spread among treatments. Cultivars were considered main plots. Five subplot treatments were used to produce varying levels of disease pressure: 1) fungicide protection using a systemic fungicide (Tilt, Ciba) 3.6 EC (propiconazole) applied to plots at stem extension, Zadoks growth stage (GS) 31 (Zadoks et al 1974) and at the boot stage (GS 40) at a rate of 0.126 kg a.i. ha^{-1}; 2) noninoculated, nonprotected control; 3) inoculation of the plot canopy in the fall at tillering (GS 21) and reinoculation when plants began to grow in the spring (GS 29), referred to as inoculation at tillering; 4) inoculation of the plot canopy in the spring when plants began to grow (GS 29) and again at first node detection (GS 31), referred to as inoculation at jointing; and 5) inoculation of the plot canopy at first node detection (GS 31) and again at flag leaf emergence (GS 41), referred to as inoculation at flag leaf.

For all inoculated treatments in the field, inoculum was prepared as above, and applied in the evening using a Herbi atomizer sprayer. A cardboard barrier inserted between plots during inoculation was used to prevent drift of inoculum between treatments. Plots were covered with transparent plastic for 24 hr to increase humidity and promote infection. Disease severity was assessed as percent of canopy infected when kernels were watery-ripe (GS 70–73).

Plots were harvested with a combine at maturity using a Kincaid experimental plot combine. Test weight and moisture content were determined immediately after harvest (GAC II, Dickey-John). Grain from each plot at both locations was sent to the USDA-ARS Soft Wheat Quality Laboratory at Wooster, OH, for analyses of milling and baking quality. Dockage was removed using the Carter-Day Dockage Remover (Carter-Day Co., Minneapolis, MN). Evaluations were conducted on each sample without removing shrivelled seed. Adjusted flour yield and softness equivalent were determined according to Finney and Andrews (1986). The milling quality score was determined as the percentage deviation of adjusted flour yield from a high quality standard (the fungicide-protected Pioneer 2555 plot). Flour protein and moisture content were estimated by near-infrared reflectance spectroscopy according to Williams (1979) and Williams et al (1982). Alkaline water retention capacity (AWRC) was determined according to Yamazaki et al (1968). The USDA-ARS Soft Wheat Quality Laboratory baking quality score was determined as the percentage deviation from the nursery standard of a composite score of flour protein, AWRC, and softness equivalent, weighted according to the relative contribution of each component to baking quality.

Statistical analyses were performed on plot data using an analysis of the split-plot design outlined by Cochran and Cox (1957), in which environments and cultivars were considered fixed. For the combined analyses of variance, environments were tested against the replicate within environment mean square, while cultivar and cultivar by environment effects were tested with the whole plot error (error a). Treatment, environment by treatment, cultivar by treatment, and environment by cultivar by treatment effects were tested using the subplot error (error b). Mean separations were done using Fisher's LSD test at the $P = 0.05$ level of probability. Linear regression of the independent variable disease severity on each quality parameter was done using the combined means over replicates and environments as outlined by Gomez and Gomez (1984). Pearson product-moment correlations were calculated among quality parameters using the combined means over replicates and environments.

RESULTS AND DISCUSSION

Preliminary screening of soft red winter wheats grown in the Missouri Small Grains Performance Tests (McKendry et al 1989) indicated that the majority of the shorter statured, early maturing wheats grown in the major soft red winter wheat producing areas are susceptible to septoria leaf blotch. None of the 64 entries screened, including the check cultivar Oasis, which carries the Bulgaria 88 resistance gene, was immune to infection, and few cultivars exhibited any form of resistant reaction. Cultivars that represented the complete range of reaction type from moderately high resistance (Pioneer 2555) to susceptibility (Arthur 71) were selected for the field study (Table I). The high positive correlation of the seedling disease score with field infection identified in our laboratory ($r = 0.83^{**}$, significant at $P = 0.01$) and in other studies ($r = 0.85^{**}$) (Brokenshire 1976) was evident from assessment of disease development in the field (Table I), where, in general, disease severity was greatest in the more susceptible cultivars (seedling disease score > 5.0). The one exception was the cultivar HybriTech Pacer, which had a high seedling disease score but a proportionally lower field disease score. Results

TABLE I
Names, Seedling Disease Scores, and Mean Field Disease Severity Scores of Soft Red Winter Wheat Cultivars

Cultivar	Seedling Disease Score[a] (0–9 scale)	Field Disease Severity Score[b] (%)
Susceptible		
Arthur 71	8.5	68.0
Clark	7.4	64.4
Pike	7.2	61.9
HybriTech Pacer	6.6	54.7
Caldwell	6.2	63.9
MO 10501	6.2	62.3
Resistant		
Florida 302	5.0	46.9
Saluda	4.9	51.1
Pioneer 2551	4.8	53.9
Cardinal	4.1	53.1
Oasis	3.6	27.1
Pioneer 2555	2.6	40.6
$LSD_{(0.05)}$[c]	1.4	4.9

[a] Mean disease score of 25 seedlings based on the 0–9 rating scale ranging from no disease (0) to complete necrosis of the inoculated leaves (9) (Saari and Prescott 1975).

[b] Combined mean over treatments and environments expressed as percent of canopy infected.

[c] Least significant difference.

reflected the failure of HybriTech Pacer to support pycnidial development, which was manifested as less severe disease spread within the canopy under normal infection.

Above normal rainfall and cool temperatures May through July at Columbia led to significantly greater septoria leaf blotch disease pressure at Columbia compared to that at Portageville during the 1990 growing season. Heavy rainfall at Columbia resulted in standing water on a portion of one replicate of this study, which weakened plants and introduced significant variability into the replicate. As a result, that replicate was deleted from all analyses. Low levels of head scab, (*Fusarium graminearum* Schwabe) and powdery mildew, (*Blumeria graminis* DC. f. sp. *tritici* E. Marchal) were also present at Columbia but did not differentially impact either cultivars or treatments. Other diseases were negligible.

Combined analyses of variance (data not shown) indicated a highly significant environmental effect for test weight, milling quality, and adjusted flour yield. These data reflect the extent of differences in climate and soil type in these two Missouri environments in addition to the differential septoria leaf blotch disease pressure noted above, and are consistent with the data of Baenziger et al (1985), who reported a similar environmental effect on test weight and milling quality.

For test weight and milling quality traits, cultivar and treatment effects were highly significant, as were the interaction of environment with cultivar and treatment. Cultivar by treatment interactions also were significant but, with few exceptions, represented a change in the magnitude of cultivar response to treatments and not a change in the rank of cultivars.

Disease severity was significantly higher in the noninoculated control plots and in all inoculated treatments than in the fungicide-protected treatment and was highest in plots inoculated at flag leaf (Table II). On average, over all cultivars, infection did not reach the flag leaf when inoculation was done at tillering or jointing, except for the most susceptible cultivars Arthur 71 and Clark. Although significant levels of necrosis were observed on the flag leaf in other susceptible cultivars when inoculation was done at flag leaf, the more resistant cultivars had no significant flag leaf necrosis. Data from the noninoculated plots provided evidence that natural inoculum also was present in both environments.

High rainfall after physiological maturity resulted in low test weights at both locations. However, the presence of disease, even in control plots where infection was confined to the lower half of the canopy, also reduced test weight (Table II). Regression analysis over all genotypes indicated a significant linear relationship between disease severity and test weight ($r = 0.97^{**}$) with a slope of $b = -0.50$. These data for septoria leaf blotch are consistent with those of Mathre et al (1977) and Finney and Sill (1963), who reported that infection with *C. gramineum* and two wheat mosaic viruses, respectively, significantly reduced test weight.

Reductions in milling quality and adjusted flour yield associated with increased disease severity (Table II) were again linear ($r = 0.98^{**}$ and $r = 0.97^{**}$, respectively). Reductions in both milling quality and adjusted flour yield were significant for all inoculated treatments and the control, despite the absence of disease symptoms on the flag leaf. We concluded, therefore, that where septoria leaf blotch is present in the canopy, disease control is essential to maximize milling quality.

Historical flour yield data from the soft wheat quality laboratory ranks the cultivars Florida 302, Pioneer 2555, Cardinal, and Caldwell as the top milling wheats in this study, with cleaned wheat flour yields of 77.7, 77.5, 77.4, and 76.8%, respectively. Other cultivars included in this study have historically produced somewhat lower flour yields (ranging from 75.9% for the cultivars

TABLE II

Combined Treatment Means for Septoria Leaf Blotch Severity and Milling Quality Traits

Treatment	Septoria Leaf Blotch Severity[a] (%)	Test Weight (kg m^{-3})	Milling Quality[b] (%)	Adjusted Flour Yield[c] (%)
Fungicide protected	17.5 d	700.9 a	94.7 a	72.65 a
Noninoculated control	51.7 c	681.0 b	91.8 b	71.78 b
Septoria tritici at tillering	63.2 b	680.9 b	91.3 bc	71.59 c
At jointing	65.8 b	678.8 b	91.0 c	71.53 c
At flag leaf	71.8 a	670.3 c	89.6 d	71.07 d
$\text{LSD}_{(0.05)}$[d]	1.6	4.1	0.7	0.18

[a] Mean percent canopy infection over cultivars and environments assessed at Zadoks growth stage 70–73 (Zadoks et al 1974).

[b] Expressed as a value relative to the quality standard (Pioneer 2555 under fungicide protection).

[c] Adjusted to 14% moisture and 52% softness equivalent according to the testing procedures of the Soft Wheat Quality Laboratory, Wooster, OH.

[d] Least significant difference based on the standard error to separate differences between subplot levels according to Cochran and Cox (1957).

TABLE III

Combined Means over Environments (%) for the Milling Quality Scores of 12 Soft Red Winter Wheat Cultivars under Five Subplot Treatments

Cultivar	Fungicide Protected	*Septoria tritici* Inoculation at			Noninoculated Control
		Tillering	Jointing	Flag Leaf	
Arthur 71	93.3 cd (r)[a]	90.9 c (rs)	89.7 de (s)	89.0 de (s)	89.3 fg (s)
Clark	93.6 cd (r)	89.2 de (st)	87.8 f (t)	88.6 d–f (st)	90.9 de (s)
Pike	91.2 f (r)	88.1 e–g (s)	88.5 ef (s)	87.2 g (s)	88.8 f–h (rs)
HybriTech Pacer	92.0 ef (r)	90.0 cd (rs)	89.1 de (s)	85.1 h (t)	87.9 hi (s)
Caldwell	93.3 cd (r)	87.8 fg (s)	87.9 f (s)	87.6 fg (s)	88.6 gh (s)
MO 10501	94.3 bc (r)	90.6 c (st)	89.2 de (tu)	88.0 e–g (u)	91.8 d (s)
Florida 302	99.9 a (r)	97.6 a (rs)	97.2 a (s)	94.3 b (t)	98.6 a (rs)
Saluda	95.2 b (r)	88.9 d–f (s)	90.1 d (s)	89.7 cd (s)	89.9 ef (s)
Pioneer 2551	91.7 ef (r)	87.3 g (s)	86.3 g (st)	84.1 h (t)	86.8 i (s)
Cardinal	99.0 a (r)	93.1 b (t)	95.8 b (s)	95.1 ab (st)	96.9 b (rs)
Oasis	92.6 de (rs)	94.2 b (r)	92.6 c (rs)	90.4 c (s)	93.6 c (r)
Pioneer 2555	100.0 a (r)	97.7 a (rs)	97.6 a (rs)	95.6 a (s)	99.2 a (r)
$\text{LSD}_{(0.05)}$[b]	1.3	1.3	1.3	1.3	1.3

[a] Letters in parentheses are based on the standard error to separate differences between subplot treatments within the same cultivar ($\text{LSD}_{(0.05)} =$ 2.4%).

[b] Least significant difference based on the standard error to separate differences between two cultivars at the same or different treatment level according to Cochran and Cox (1957).

Arthur 71 and Saluda to 74.6% for the cultivar Pioneer 2551). Milling quality scores estimated for these varieties under fungicide protection (Table III) were consistent with these historical rankings.

Reductions in milling quality were linearly related to disease severity in all of the susceptible cultivars with correlation coefficients ranging from $r = 0.79^*$ (significant at $P = 0.05$) for Pacer to $r = 0.99^{**}$ for Caldwell. The benefits of genetic resistance to septoria leaf blotch, however, were clear. Losses in milling quality in Oasis containing the Bulgaria 88 resistance gene and Pioneer 2555, which has both seedling and field resistance, were significant only when inoculation was done at flag leaf.

Cultivar by treatment interaction effects were detected for milling quality, but with few exceptions, were due to a change in magnitude and not in rank of the cultivar response to increased disease severity. We concluded, therefore, that although septoria leaf blotch significantly decreased milling quality, selection for improved milling quality would be reasonably effective even under moderate to severe levels of disease pressure.

Finally, though it has been a long-held assumption that low test weight is associated with low flour yield, the correlation between test weight and milling quality ($r = 0.29^*$) and between test weight and adjusted flour yield ($r = 0.29^*$) suggests that this association was not strong in these genotypes.

Environmental effects were nonsignificant for flour protein, AWRC, and softness equivalent, but were significant for the overall baking quality score (data not shown). Cultivar and treatment effects were significant for all baking quality traits estimated, as were the interactions of environment with both cultivars and treatments. Cultivar by treatment interactions were significant for flour protein, AWRC, and softness equivalent but were nonsignificant for the overall baking quality score. We concluded, therefore, that selection for improved baking quality in these genotypes would be effective despite high levels of septoria leaf blotch disease.

Across all cultivars, increased disease pressure resulted in a significant increase in both flour protein and AWRC (Table IV). This result is consistent with the loss of photosynthetic leaf area and, therefore, of carbohydrate availability to the developing kernel, which occurs under severe disease pressure from foliar pathogens. Flour produced from grain grown under these conditions would tend to have both higher protein content and higher water absorption. These results agree with reports for *C. stripe* (Mathre et al 1977) and wheat mosaic virus (Finney and Sill 1963) infections in which protein and AWRC increased with increased disease severity but differ from the reduction in flour protein reported for leaf rust (Caldwell et al 1934) and powdery mildew (Johnson et al 1979) infections.

Softness equivalent, a measure of kernel hardness and endosperm friability, was less affected by increased disease severity than either flour protein or AWRC. Under severe disease pressure resulting from inoculation at flag leaf, however, the softness equivalent was significantly reduced. This was probably due to increases in both number of shrivelled kernels and flour protein associated with this treatment. For all cultivars, fungicide protection also resulted in a significant reduction in the softness equivalent when compared to other treatments. These data suggested that the increase in kernel density due to more complete endosperm development had a detrimental effect on the degree of kernel hardness. Although reasons for this association are not clear, the negative correlations in this study between softness equivalent and test weight ($r = -0.49^{**}$) and flour protein ($r = -0.55^{**}$) were highly significant.

The baking quality score across all cultivars was also significantly reduced with increased disease severity (Table IV). However, the linear correlation coefficient between these two parameters was not significant. We concluded, therefore, that severe septoria leaf blotch disease pressure had a greater impact on

TABLE IV

Combined Treatment Means (%) for Septoria Leaf Blotch Severity and Baking Quality Traits

Treatment	Septoria Leaf Blotch Severity[a]	Flour Protein	AWRC[b]	Softness Equivalent	Baking Quality[c]
Fungicide protected	17.5 d	10.78 c	56.7 c	56.21 b	89.2 a
Noninoculated control	51.7 c	11.07 b	57.1 b	57.93 a	88.5 ab
Septoria tritici at tillering	63.2 b	11.16 b	57.2 b	58.21 a	88.3 ab
At jointing	65.8 b	11.17 b	57.4 b	58.06 a	87.6 b
At flag leaf	71.8 a	11.83 a	57.6 a	56.51 b	85.0 c
$LSD_{(0.05)}$[d]	1.6	0.12	0.2	0.31	1.3

[a] Mean percent canopy infection over cultivars and environments assessed at Zadoks growth stage 70–73 (Zadoks et al 1974).

[b] Alkaline water retention capacity.

[c] Expressed as a value relative to the quality standard (Pioneer 2555 under fungicide protection).

[d] Least significant difference based on the standard error to separate differences between subplot levels according to Cochran and Cox (1957).

TABLE V

Combined Means Over Environments (%) for the Baking Quality Scores of 12 Soft Red Winter Wheat Cultivars under Five Subplot Treatments

Cultivar	Fungicide Protected	*Septoria tritici* Inoculation at			Noninoculated Control
		Tillering	Jointing	Flag Leaf	
Arthur 71	89.4 cd (r)[a]	86.1 ef (rs)	84.2 f (st)	80.4 g (t)	85.2 e (rs)
Clark	88.2 c–e (r)	85.7 f (r)	85.4 f (r)	84.1 ef (r)	87.0 de (r)
Pike	86.8 e (r)	88.5 de (r)	85.7 ef (r)	86.2 de (r)	89.1 cd (r)
HybriTech Pacer	92.4 b (r)	89.7 cd (rs)	89.5 cd (rs)	85.3 e (s)	91.6 bc (r)
Caldwell	92.7 b (r)	92.6 b (r)	90.5 c (r)	89.6 bc (r)	91.4 bc (r)
MO 10501	88.4 c–e (r)	85.0 f (rs)	84.9 f (rs)	82.5 fg (s)	87.6 de (r)
Florida 302	93.6 b (r)	93.7 b (r)	95.9 b (r)	92.0 b (r)	93.9 b (r)
Saluda	87.0 de (r)	79.8 g (s)	78.4 g (s)	78.0 h (s)	80.5 f (s)
Pioneer 2551	78.0 g (r)	76.2 h (rs)	77.0 g (r)	72.2 i (s)	73.9 g (rs)
Cardinal	90.5 c (r)	91.7 bc (r)	91.3 c (r)	88.7 cd (r)	91.6 b (r)
Oasis	83.3 f (s)	88.3 de (r)	88.2 de (r)	81.1 g (s)	88.5 d (r)
Pioneer 2555	100.0 a (r)	102.2 a (r)	100.2 a (r)	99.5 a (r)	101.5 a (r)
$LSD_{(0.05)}$[b]	2.5	2.5	2.5	2.5	2.5

[a] Letters in parentheses are based on the standard error to separate differences between subplot treatments within the same cultivar ($LSD_{(0.05)}$ = 4.4%).

[b] Least significant difference based on the standard error to separate differences between two cultivars at the same or different treatment level according to Cochran and Cox (1957).

milling quality than on baking quality.

Genetic variability for baking quality was observed at all treatment levels but, as noted earlier, a cultivar by treatment interaction was not detected. The reduced effect of disease pressure on baking quality compared to milling quality was evident from individual cultivar data (Table V) and was consistent with data of Johnson et al (1979), who concluded that disease pressure due to powdery mildew affected milling quality more than baking quality. The level of cultivar resistance to septoria leaf blotch did not seem to affect the relative reductions observed in baking quality with increased disease. There was no significant reduction in baking quality with increased disease pressure for any of the cultivars (Clark, Pike, Caldwell, Florida 302, Cardinal, or Pioneer 2555), yet they ranged from being very susceptible (Clark) to moderately resistant (Pioneer 2555) to septoria leaf blotch. These results emphasize the different effects of disease development on milling and baking traits identified in the combined cultivar analyses and suggest that resistance genes are less important than background genotype in determining baking quality under conditions of septoria leaf blotch disease pressure.

In summary, economic losses in soft red winter wheat due to septoria leaf blotch infections can result from losses in both grain yield and quality. With increased disease severity, reductions in test weight and in milling and baking quality traits occurred. However, the effect was more pronounced on milling quality and adjusted flour yield than on any of the baking quality traits evaluated. The importance of resistance genes in maintaining milling quality was clearly evident. In the genotypes studied, the impact of resistance genes on baking quality was negligible compared to the value of the background genotype.

Cultivar by treatment interaction effects were greatest for test weight, milling quality, and adjusted flour yield, but were also significant for flour protein and AWRC. Those interaction effects, however, were not significant for the overall baking quality score. In all cases, interactions were due primarily to a change in magnitude and not in the rank of cultivars. Our conclusion is that selection within breeding programs for milling and baking quality would not be hindered in years when there is significant disease due to septoria leaf blotch.

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