Quantifying Cephalosporium Stripe Disease Severity on Winter Wheat

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ABSTRACT

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Four methods and times of quantifying Cephalosporium stripe disease severity were compared utilizing four winter wheat (*Triticum aestivum*) cultivars each inoculated at five different levels. Of the four disease-rating systems, only percentage of infected tillers or a disease severity scale based upon degree of systemic symptom expression caused by *Cephalosporium gramineum* were highly correlated with yield losses due to stripe. Both types of rating systems gave reliable estimates of yield loss only if taken at growth stages 10.0 or 10.5 on the Feekes' scale. Percentage of infection/yield loss curves were linear, but could not be used to directly compare data between years since the slope of the line changed from year to year. Disease severity/yield loss curves also were linear, but the slope of the line did not change significantly between years.

Cephalosporium stripe disease of winter wheat (*Triticum aestivum* L.) has been reported in many areas of the United States (1,3,5,11,14,18) and causes severe losses in parts of Kansas each year (13). Stripe is caused by the soilborne, systemic, fungal pathogen *Cephalosporium gramineum* Nisikado & Ikata (=*Hymenula cerealis* Ell. & Ev.). The fungus enters the roots and colonizes the vascular system as the plant develops. Under a continuous wheat cropping system, the fungus builds up to high levels in the soil (2,16) and can cause 50% yield loss (4).

Richardson and Rennie (12) reported yield of an individual infected tiller to be approximately 30% that of a healthy tiller. However, much of this yield consisted of shriveled grain, making the useful yield about 10–15%. Based upon this, a yield loss estimate was established utilizing the percentage of infected tillers to calculate loss (12).

Other estimates of yield loss due to stripe have been reported and, in one test (8), visual estimation (scale of 0–3) of the number of tillers with symptoms correlated highly with percentage of yield reduction. In another test (7), the number of infected tillers per meter of row did not correlate well with percentage of yield reduction. Similarly, the number of whiteheads per 1.2 m of row and a visual score (0–5), involving an estimate of the percentage of whiteheads and degree of stunting, produced very low r^2 values (7). However, using another scale (0–5) of the visual estimation of percentage of whiteheads, higher r^2 values were obtained (8). There are other reports (10,15,17) utilizing different methods to assess disease severity, although in these cases yield loss due to *C. gramineum* was not determined. Thus, many different systems have been used to determine stripe severity with varying levels of success.

This study was undertaken to compare several methods and times of rating Cephalosporium stripe severity as an indirect assessment of wheat yield loss due to Cephalosporium stripe in the field.

MATERIALS AND METHODS

Four hard red winter wheat cultivars (Eagle, Newton, Parker 76, and Triumph 64) were selected for their commercial importance in Kansas and their diverse pedigrees. They were grown in 1.2- by 7.6-m plots in a field that had not been cultivated to wheat for 4 yr and was not infested with *C. gramineum*. Artificial inoculation was accomplished by mixing oat kernels infested with *C. gramineum* (7) with the wheat seed prior to planting. All plots were seeded with 63 g of wheat seed and 200 g of oat kernels with 0, 10, 25, 50, or 100% of the kernels infested with *C. gramineum*. The four cultivars, inoculated at each of the five rates, were arranged in the field in a randomized complete block design with four replications, and the experiment was repeated the following season.

Disease assessment. Four different methods of rating Cephalosporium stripe severity were used: (i) percentage of whiteheads at growth stage 11.1 (milky ripe) on the Feekes' scale (6); (ii) percentage of flag leaves showing characteristic yellow stripes at growth stage 10.5.2 (flowering complete to top of ear); (iii) percentage of infected tillers (leaves showing stripes) at growth stages 9 (ligule of last leaf visible), 10 (sheath of last leaf grown out), 10.5 (all ears out of sheath), and 11.1; and (iv) disease severity based upon the degree of systemic symptom expression caused by the pathogen in the wheat plant at growth stages 9, 10, 10.5, and 11.1. In the latter system, the flag leaf was assigned a value of 4, the leaf immediately below it a value of 3, the second leaf below the flag leaf a value of 2, and the third leaf below the flag leaf a value of 1. An individual tiller was rated as either 0 (no stripes on the top four leaves), 1, 2, 3, or 4 based upon the highest leaf on the tiller showing a characteristic yellow stripe. An average disease severity (DS) rating for each plot was calculated by using the formula:

$$DS = \frac{1(A) + 2(B) + 3(C) + 4(D)}{\text{Total number of tillers examined}}$$

in which A = number of tillers rated 1, B = number of tillers rated 2, C = number of tillers rated 3, and D = number of tillers rated 4. At least 50 randomly selected tillers were rated in situ for each assessment method for each plot.

Yield determination. All plots were harvested the same day after the latest-maturing cultivar was ripe. A combine (Kinkade Equipment Manufacturing, Haven, KS 67543) was used to harvest each plot and yields were adjusted to 12% grain moisture. Yield loss was calculated by subtracting the yield of a given cultivar-inoculum level treatment from the appropriate uninoculated yield.

Average head yield. In early spring 1979 a grower's field showing symptoms of stripe was selected. Twelve 1-m lengths of drill row were staked out in a 200 m^2 area. Lengths of drill rows showing almost no stripe infection (0–5%) were selected as well as lengths showing light (6–20%), moderate (21–40%), or heavy (41–60%) infection levels. Disease severity, using rating system (iv), was determined at growth stage 10.5. Upon maturity, each 1-m length of drill row was harvested, the number of heads counted, and the grain yield determined.

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RESULTS

Percentage of whiteheads and percentage of flag leaves with stripes were poorly correlated with yield loss (Table 1). Good correlations with yield loss (high r values) were obtained when either percentage of infection or disease severity (based on degree of systemic symptom expression) determined at growth stages 10.0 or 10.5 were used (Table 1, Fig. 1 and 2A). Disease severity and yield per head also correlated highly in the naturally infested field (Fig. 2B). Estimates of percentage infection or disease severity at growth stage 9 produced variable results and low r values (Table 1). Similarly, at growth stage 11.1 many of the leaves were senescing, which introduced variability into the rating systems (Table 1). Yield losses at the highest inoculation level were: Newton = 54%, Eagle = 59%, Parker 76 = 63%, and Triumph 64 = 70%. Under conditions of this study, yield loss differences exceeding 12% between treatments were predictable ($P = 0.05$) by the disease severity rating system

TABLE 1. Correlations of yield loss with Cephalosporium stripe disease severity values obtained using different disease rating systems performed at various growth stages of winter wheat

Disease rating system	Growth stage[a]	Correlation coefficient[b] 1979	1980
Percentage of whiteheads[c]	11.1	0.38	···
Percentage of flag leaves with stripes[d]	10.5.2	0.27	···
Percentage of infected tillers[e]	9.0	0.30	···
Percentage of infected tillers	10.0	0.87	0.88
Percentage of infected tillers	10.5	0.80	0.80
Percentage of infected tillers	11.1	0.41	···
Disease severity[f]	9.0	0.28	···
Disease severity	10.0	0.90	0.81
Disease severity	10.5	0.79	0.84
Disease severity	11.1	0.46	···

[a] Determined by the Feekes' scale.

[b] Values determined by correlating grain yield loss due to Cephalosporium stripe with disease ratings from four winter wheat cultivars. Yield loss calculated using the yield of each cultivar inoculated with each of four different levels of *Cephalosporium gramineum* inoculum compared to the yield of the uninoculated control. Minimum of 200 randomly selected tillers rated per cultivar-inoculum level treatment. Correlation coefficient values greater than 0.50 are significant at $P = 0.05$ and those greater than 0.62 are significant at $P = 0.01$.

[c] Tillers rated for premature ripening.

[d] Flag leaves rated for presence of characteristic yellow stripes caused by *C. gramineum*.

[e] Tillers rated for presence of stripes on the leaves caused by *C. gramineum*.

[f] Disease severity = $1(A) + 2(B) + 3(C) + 4(D)$ divided by the total number of tillers examined, in which A = number of tillers with the top three leaves symptomless but the fourth leaf showing stripes, B = number of tillers with the top two leaves symptomless but the third leaf showing stripes, C = number of tillers with the top leaf symptomless but the second leaf showing stripes, and D = number of tillers with the top leaf showing stripes.

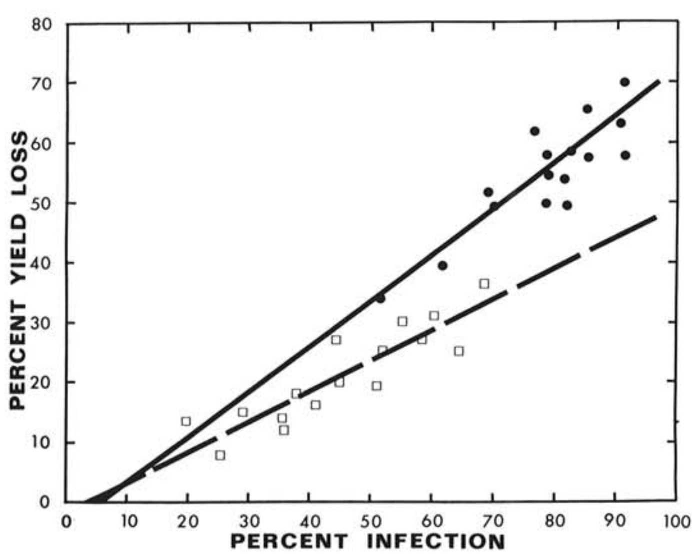

Fig. 1. Correlation of percent yield loss in winter wheat due to Cephalosporium stripe with percent stripe infection at growth stage 10.0 on the Feekes' scale. Percent yield loss determined by subtracting the yield of four winter wheat cultivars each inoculated with each of four different levels of *Cephalosporium gramineum* inoculum from the yield of the uninoculated control. Each point represents one of the cultivar-inoculum level treatments and is the mean of four replications (1979 = circles, 1980 = squares) ($r = 0.87$, $m = 0.75$, $b = -4.4$ [1979]; $r = 0.88$, $m = 0.51$, $b = -2.0$ [1980]).

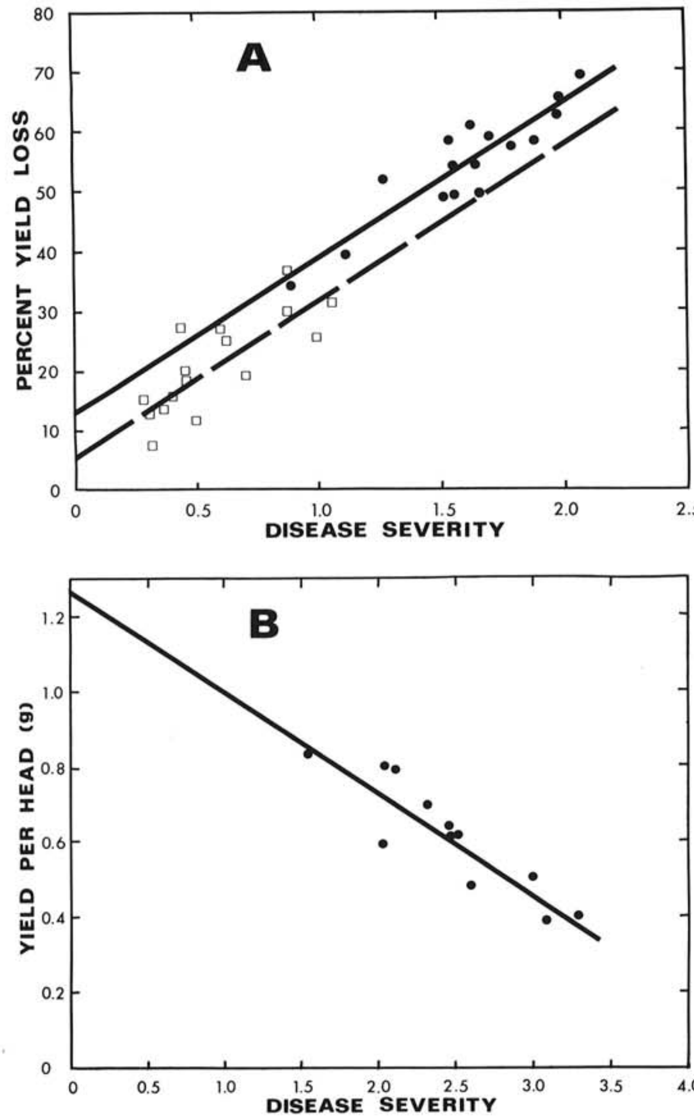

Fig. 2. Correlation of **A,** percent yield loss in winter wheat due to Cephalosporium stripe or **B,** yield per head with disease severity rated at growth stage 10.0 (A) or 10.5 (B) on the Feekes' scale. Disease severity = $1(A) + 2(B) + 3(C) + 4(D)$ divided by the total number of tillers examined, in which A = number of tillers with the top three leaves symptomless, but the fourth leaf showing stripes, B = number of tillers with the top two leaves symptomless but the third leaf showing stripes, C = number of tillers with the top leaf symptomless but the second leaf showing stripes and D = number of tillers with the top leaf showing stripes. Percent yield loss (A) determined by subtracting the yield of four winter wheat cultivars, each inoculated with each of four different levels of *Cephalosporium gramineum* inoculum, from the yield of the uninoculated control. Each point represents one of the cultivar-inoculum level treatments and is the mean of four replications (1979 = circles, 1980 = squares). Yield per head was determined by harvesting 1-m lengths of drill row in a naturally infested field and dividing grain yield by the number of tillers (59–107) harvested ($r = 0.90$, $m = 25.6$, $b = 13.2$ [A, 1979]; $r = 0.81$, $m = 25.7$, $b = 6.2$ [A, 1980]; $r = 0.90$, $m = -0.27$, $b = 1.27$ [B]).

when plots were rated at growth stages 10.0 or 10.5. Similar data were obtained when the experiment was repeated the subsequent year, but the slope of the percentage infection/yield loss curve was about 0.5 the second year instead of 0.75 (Fig. 1). Conversely, the disease severity ratings obtained the second year fell on approximately the same line as those of the first-year data (Fig. 2A).

DISCUSSION

A useful disease assessment method for Cephalosporium stripe should correlate well with yield loss from the disease and be applicable to different wheat cultivars. Percentage of infection and disease severity (based upon the degree of systemic symptom expression) fulfilled both criteria. Past results (7,8) with other disease rating systems have been inconsistent. Small sample size, small plot size, and different sampling times increased the variability and, thus, decreased the disease estimate/yield loss correlation.

The percentage of infection and disease severity rating systems used here, if performed at growth stages 10.0 or 10.5, will give reliable yield loss estimates when comparing data from a given year. These rating systems also enable the separation of cultivars (Newton = 54% yield loss and Triumph 64 = 70% loss) having only slightly different reaction to *C. gramineum*. Under the conditions of this experiment, Newton sustained the least yield loss of the four cultivars, but it should be considered only a moderately susceptible cultivar because it is damaged by stripe disease.

As expected, disease estimate/yield loss curves were linearly related because infected tillers produce no grain, less grain than uninfected tillers, or shriveled grain (8,12). The yield per head from the naturally infested field indicates that plant growth from neighboring healthy tillers probably does not have time to compensate for such losses. However, the slope of the percentage of infection/yield loss curve changes from year to year, so percentage of infection data from several years cannot be used to compare yield loss estimates between years. The slope deviations between years may reflect environmental differences that affect the amount of plant damage caused by *C. gramineum*. Evidence presented here suggests that the disease severity system was better than percentage of infection when directly comparing data between years since the slope of the disease severity/yield loss curve did not change significantly. The degree of systemic symptom expression appears to be a good indicator of the amount of yield loss even when comparing wheat grown under different environmental conditions.

Currently no popular commercial wheat cultivars are grown in Kansas that have a high level of Cephalosporium stripe resistance (W. W. Bockus, *unpublished*). However, two types of resistance to *C. gramineum* have been reported (9,10). The first results in fewer plants becoming infected, while the second type restricts systemic spread of the pathogen once it has successfully entered the wheat plant. Thus, the use of percentage of infection does not provide a valid estimate of yield loss for wheat lines with the latter type of resistance. However, the disease severity rating system described here incorporates both the percentage of infection and the degree of systemic colonization by the pathogen, so it should provide a more useful yield loss estimator for field experiments involving wheat lines that express a lower rate and severity of disease development.

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