Effect of Lime and Sulfur Application to Low-pH Soil on Incidence of Cephalosporium Stripe in Winter Wheat

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ABSTRACT

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Application of lime to soil with an initial pH of 4.8 raised the pH to about 6.5 and maintained it at that level during the 2 yr of the study. Conversely, sulfur application had no effect on soil pH. In the first season after liming, Cephalosporium stripe incidence was 36.1 and 21.8% in the untreated and limed plots respectively; corresponding incidences for the second season were 30.4 and 5.7%. No corresponding yield increase was noted from Cephalosporium stripe control because of severe take-all development in the limed plots.

Cephalosporium stripe is a disease of winter wheat caused by the soilborne fungus *Cephalosporium gramineum* Nisikado & Ikata. The disease name refers to the characteristic chlorotic stripes that occur on leaves of infected plants, although stunting and premature ripening of tillers (whiteheads) are also associated with the disease (5). Yields of infected plants can be severely reduced (17) because prematurely killed heads may contain no grain or, more commonly, shriveled grain.

C. gramineum infects winter wheat via the root system during winter and early spring (2,14). After entry into the plant, it colonizes the vascular system between the tillering and physiologically mature growth stages (5). After harvest, the fungus survives as vegetative mycelium within the parasitically colonized residue, and when conditions favor sporulation, large numbers of conidia are produced from this food base (6). As the residue decomposes, *C. gramineum* dies because it is a poor saprophytic competitor in the soil environment (6,7).

Survival and sporulation of *C. gramineum* in wheat straw is influenced by pH (7,11). A wide-spectrum antibiotic is produced by the fungus and is active at pH values lower than 6.5 (8); however, the exact role of this antibiotic in affecting straw decomposition is not clearly understood (15). Nevertheless, *C. gramineum* has been reported to survive best within the pH range 3.9–5.5 (7,11). Furthermore, both uninfested straw and straw infested with *C. gramineum* decompose slower in the pH range of 5.3–6.4 than at pH 7.5 (13).

In Kansas, Cephalosporium stripe occurs in the central one-third of the state, where wheat is continuously cropped. Many of the fields in this region have a soil pH of less than 5.5 (determined in 0.01 M $CaCl_2$ [18]) in the top 15 cm of soil (3). This field study was conducted to determine if lime or sulfur application to soil within this pH range would affect the incidence of Cephalosporium stripe in subsequent years. The incidence of take-all, another soilborne disease prevalent in Kansas and known to be influenced by lime application, was also monitored.

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MATERIALS AND METHODS

A field site was selected at the Harvey County Experiment Field near Hesston, KS, that had an initial soil pH of 4.8. The field had been cropped to wheat for several consecutive years and was naturally infested with *C. gramineum*. It was fallowed during the 1979–1980 wheat season and planted to wheat again in 1980–1981. During the 1980–1981 season, Cephalosporium stripe was uniformly distributed across the field and incidence was about 5%.

During the summer of 1981, the field was divided into plots 9.2 × 25.9 m in a split-plot design with four replicates. The main plots were seeded with one of two winter wheat cultivars: Parker 76 or Newton during the 1981–1982 season and Newton or Vona during the 1982–1983 season. Subplots consisted of one of three soil treatments: no amendment, 488 kg/ha of elemental sulfur, or 5,606 kg/ha of effective calcium carbonate. Soil amendments were applied on 16 July 1981 and incorporated by disking.

Immediately before sulfur or lime application and twice per cropping season thereafter, soil samples were collected from each plot for pH determination. Fifteen random samples (about 125 g each) per plot were collected from the top 15 cm of soil with a trowel and bulked, dried, and homogenized. Two 10-g subsamples were taken from each bulked sample, suspended in 20 ml of 0.01 M $CaCl_2$ (18), and the pH determined.

Plots were seeded around the first week in October, and standard fertilizer and herbicide programs for winter wheat production in Kansas were applied. Reduced tillage was practiced between growing seasons. This involved relatively shallow tillage with a V-plow or disk and a field cultivator. At maturity, grain yield was determined by harvesting a 1.8-m swath from the center of each plot with a combine and adjusting weights to 12.5% moisture.

During both cropping seasons, incidence of Cephalosporium stripe was determined at the fully headed growth stage. About 25 tillers were randomly collected from around each of four sites per plot and bulked (100 tillers per plot). Incidence was calculated by dividing the number of tillers showing characteristic yellow stripes on the leaves with associated dark vascular bundles (5) by the total number of tillers collected.

In previous years, the field site had shown some take-all disease caused by the soilborne fungus *Gaeumannomyces graminis* (Sacc.) von Arx and Olivier var. *tritici* Walker. Take-all is affected by lime application (16), so the incidence of this disease was also quantified. Because several diseases and injuries resemble take-all on field-collected plants, an indirect baiting assay was used to quantify take-all incidence. Twenty-five randomly selected plants per plot were dug during April for each year of the study. Soil was washed from the roots, plant parts above the crown were removed and discarded, and the roots were placed 1.5 cm below three Newton wheat seeds in vermiculite in plastic tubes (2.5 × 12.5 cm) (4). The tubes were watered and fertilized as needed for 4 wk, then the roots of the seedling plants were washed free of vermiculite and rated under a dissecting microscope for the presence of take-all lesions (19). Incidence of *G. graminis* var. *tritici* was estimated by the percentage of tubes with seedling "trap" plants showing lesions.

RESULTS AND DISCUSSION

Application of lime raised the pH of those plots an average of 1.5 units within 4 mo (Table 1). There was also about a 2.0 unit difference between this treatment and the check or sulfur treatments throughout most of the experimental period (Table 1). Since pH was measured in 0.01 M $CaCl_2$, the values reported here are about 0.5 units lower than values determined in H_2O but are a more accurate representation of the pH roots encounter (18).

Elemental sulfur was applied in an attempt to increase acidity and determine the effect of more acid conditions on the incidence of Cephalosporium stripe. However, sulfur application had no significant effect on soil pH during the study. Intact sulfur granules were still visible within soil clods as late as summer 1983 despite the fact that they had been thoroughly incorporated into the soil 2 yr earlier. Perhaps a dust formulation, rather than granules, would have been more effective in lowering the pH.

During both years of the study, there was significant Cephalosporium stripe development (Table 2). In the 1981–1982 season, the lime treatments sustained the least amount of stripe, although the difference was not significant within a cultivar. However, combining the data from both cultivars produced the following incidences: check, 36.1%; sulfur, 36.4%; and lime, 21.8%, with an LSD ($P = 0.05$) of 10.3. Furthermore, by the 1982–1983 season, the lime treatments sustained significantly less Cephalosporium stripe than the check or sulfur treatments when comparing data within a single cultivar. Although the effect may take more than 1 yr to become pronounced, lime application to low-pH soil, to produce a more neutral condition, appears to substantially reduce the incidence of Cephalosporium stripe. Although pH is assumed to play the most important role in the decline in incidence, the roles of added calcium or changes in nutrient availability cannot be ruled out. The high incidence of take-all in the limed plots may also have played a role in reducing stripe; however, take-all incidence was essentially identical in both

Table 1. Effect of sulfur and lime application on soil pH

Soil treatment	Soil pH[w] Summer 1981	Fall 1981	Spring 1982	Fall 1982	Summer 1983
Check	4.8 a[x]	4.8 a	4.6 a	4.6 a	4.6 a
Sulfur[y]	4.8 a	4.8 a	4.7 a	4.6 a	4.5 a
Lime[z]	4.8 a	6.3 b	6.6 b	6.6 b	6.5 b

[w]Determined in 0.01 M $CaCl_2$.
[x]Values within a column followed by a common letter are not significantly different ($P = 0.05$) according to Duncan's multiple range test.
[y]Elemental sulfur (488 kg/ha) applied 16 July 1981.
[z]Effective calcium carbonate (5,606 kg/ha) applied 16 July 1981.

Table 2. Effect of lime and sulfur application to low-pH soil on incidence of Cephalosporium stripe and take-all diseases and grain yield in winter wheat

Cultivar	Soil treatment	Cephalosporium stripe incidence (%) 1982	1983	Take-all incidence (%) 1982	1983	Yield (kg/ha) 1982	1983
Parker 76	Check	44.5 b[x]	···	8.3 a	···	1,548 b	···
	Sulfur[y]	40.3 b	···	8.4 a	···	1,144 a	···
	Lime[z]	28.6 ab	···	56.8 b	···	854 a	···
Newton	Check	27.7 ab	19.8 b	10.2 a	6.8 a	3,176 d	2,063 a
	Sulfur	32.5 ab	17.5 b	6.4 a	11.8 a	2,274 c	1,747 a
	Lime	15.0 a	0.7 a	51.1 b	56.1 b	2,167 c	1,505 a
Vona	Check	···	41.0 c	···	0.3 a	···	1,660 a
	Sulfur	···	49.0 c	···	12.0 a	···	1,975 a
	Lime	···	10.6 ab	···	62.8 b	···	1,458 a

[x]Values represent the means of four replicates, and if followed by common letters, are not significantly different ($P = 0.05$) within a column according to Duncan's multiple range test.
[y]Elemental sulfur (488 kg/ha) applied 16 July 1981.
[z]Effective calcium carbonate (5,606 kg/ha) applied 16 July 1981.

1982 and 1983, yet Cephalosporium stripe in the limed treatments was significantly lower in 1983 than in 1982.

The cultivar Newton sustained less stripe disease in 1983 than in 1982 (Table 2), even though continuous wheat cultivation normally produces increasing incidence. Environmental conditions between the two years were different; 1983 was not as conducive as 1982 for stripe development, which may account for the decrease in incidence from 1982 to 1983. Nevertheless, Vona (highly susceptible to stripe) had a high incidence in 1983.

Cephalosporium stripe was first reported in Kansas in 1972 (20) and has since increased in distribution and severity to become a major yield-reducing factor in some areas of the state. One of the factors contributing to the relatively recent introduction and spread of this disease in Kansas may be related to soil pH. During the last several decades, large amounts of nitrogen fertilizer have been applied to agricultural soils (1), resulting in a slowly falling pH in the top 30 cm of soil (3). According to our findings, this may have produced a more conducive environment for the disease.

Take-all of wheat has long been known to be more severe when soil is limed (9,10,12) because of elevated pH and reduced trace-nutrient availability (16). Our results (Table 2) also show greatly increased incidence of take-all following liming of low-pH soil. This effect negated the yield response attributable to control of Cephalosporium stripe associated with this practice such that yields of limed plots were the lowest of the three treatments and significantly lower than the check during the 1981–1982 season (Table 2). Thus, to realize a yield increase from controlling Cephalosporium stripe by application of lime, take-all may have to be controlled.

Yields of Parker 76 were significantly less than those of Newton (Table 2) because the 1981–1982 season was conducive to wheat soilborne mosaic, to which Parker 76 is susceptible but Newton is highly resistant. Conversely, the 1982–1983 season was very mild with respect to wheat soilborne mosaic, hence Vona (susceptible) yielded similar to Newton (resistant). There was no effect of lime or sulfur application on wheat soilborne mosaic noted in this study (W. W. Bockus, *unpublished*).

The sulfur treatment produced significantly less grain than the check during the 1981–1982 season (Table 2), but the reason for this is not known. Further research will be necessary to determine whether a pH range where Cephalosporium stripe and take-all are both significantly reduced can be found. Such a finding would allow continuous cropping of winter wheat without severe losses from these two diseases.

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