

## Composition of Wheat Straw Infested with *Cephalosporium gramineum* and Implications for Its Decomposition in Soil

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### ABSTRACT

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Field-grown winter wheat straw infested with *C. gramineum* contained significantly less acid-detergent fiber, more soluble components, and two to three times more nitrogen than noninfested straw. These results suggest that straw infested with *C. gramineum* should decompose faster than noninfested straw. However, earlier workers showed that infested straw decomposes at approximately the same rate as noninfested straw, and they discounted the importance of the broad-spectrum antibiotics produced by

*C. gramineum* in survival of the pathogen in straw. It is possible that antibiotics produced by *C. gramineum* in infested straw offset the nutritive advantages of higher nitrogen and soluble contents and equalize decomposition rates of infested and noninfested straw. Because substrate composition has been overlooked in previous studies of survival of *C. gramineum* in residue, a reexamination of this question is suggested.

*Additional key words:* acid-detergent fiber, *Triticum aestivum*.

*Cephalosporium gramineum* Nisikado and Ikata (= *Hymenula cerealis* Ell. and Ev.) causes Cephalosporium stripe disease of winter wheat (*Triticum aestivum* L.). This fungus infects the host through root injuries and spreads systemically by means of conidia in xylem vessels. Chlorotic striping of leaf blades and sheaths of diseased tillers is characteristic. At maturity, diseased culms are discolored, appearing dull instead of bright (2,3). Tillers die prematurely, usually after heading but before grain filling is complete.

The fungus survives between wheat crops as mycelium within straw that is parasitically colonized (4,5). The fungus does not survive in the soil apart from a host or host debris (4,5,7,18). Therefore, any factor affecting decomposition of host debris influences longevity of the fungus and the amount of inoculum present in the soil (9,12).

Bruehl et al (8) reported that *C. gramineum* produced a wide-spectrum antibiotic active at pH values lower than 6.5. In later work they showed that all fresh isolates of *C. gramineum* produced antibiotic, whereas some isolates maintained in culture for 2-5 yr had, to varying degrees, lost the ability to produce the antibiotic. Nonproducer isolates were pathogenic. Bruehl et al (9) concluded that antibiotic production is selected for in nature and is important to survival in infested host debris. The antibiotic reduces invasion of the substrate by competitors and, in so doing, the substrate is conserved (4,9). Bruehl and Lai (6) found that *C. gramineum* survived best in the pH range 3.9-5.5. Survival was reduced under highly acidic (pH 3.3) conditions or above neutrality (pH 7.6).

Hopp (11) showed that producer isolates survived better than nonproducers in the pH range 4.5-6.6. Above pH 7.2 there was no difference. Bruehl (4) concluded that survival of *C. gramineum* is dependent upon prior colonization of the host debris, continued production of small quantities of a wide-spectrum antifungal antibiotic, and sparing utilization of the substrate.

Mathre and Johnston (13) studied the effect of soil fertility, host genotype, *C. gramineum* isolate, and soil pH on the decomposition and recovery of *C. gramineum* from naturally infested wheat straw over a 2-yr period. Soil fertility (N and P concentrations) did not have a significant effect on decomposition, and infested straw usually decomposed faster than noninfested straw, although differences were significant only after 18 mo. There were significant differences among host genotypes and *C. gramineum* isolates after 2 yr. Decomposition rates were not related to host susceptibility. Straw decomposition was faster at pH 7.5 than at pH 6.4 or 5.3. Because soil pH affected decomposition of both noninfested and infested straw similarly, Mathre and Johnston concluded that the decomposition of infested straw was more dependent on microbial activity of each soil than on pH effect on *C. gramineum* antibiotic activity.

The purpose of this study was to elucidate a factor overlooked in previous studies, namely the difference in substrate composition between noninfested and infested straw.

### MATERIALS AND METHODS

This study was conducted over the 1979-1980 and 1980-1981 growing seasons. Hereafter these will be referred to as the 1979 and 1980 seasons, respectively.

Eight winter wheat cultivars (Table 1) were planted in four-row plots (1.3 × 3.0 m) on 9 September 1979 at the Plant Pathology

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farm, Pullman, WA. Plots were arranged in a randomized complete block design with four replicates. Three cultivars were selected from the 1979 experiment for inclusion in the 1980 experiment to represent the range of disease severity. Breeding line 80-112 was included because it had a low percentage of diseased tillers in preliminary experiments. In 1980, the wheats (Table 1) were planted on 12 September, and plots were arranged in a completely random design with four replicates. Fertilization and weed control were consistent with local commercial practices. Sufficient natural inoculum in 1979 eliminated the need for artificial inoculation. However, the 1980 plot required inoculum. Inoculation was accomplished by incorporating 1,143.4 kg of naturally infested chopped wheat straw per hectare within the top 15 cm of soil before planting.

Disease severity was evaluated by cutting one row of each plot and visually separating the tillers into healthy and diseased classes. The percentage of infected tillers was calculated. Healthy cultivars were in the hard-kernel stage at the time of disease severity evaluation (16 July 1980 and 2 July 1981). Presence of *C. gramineum* was confirmed by plating surface-sterilized nodes on acidified cornmeal agar (8).

In 1979, straw from the cultivars contained in a single randomly selected block was analyzed, but in 1980, straw from each replicate was analyzed. Infested and noninfested straws from each cultivar were selected, the leaf sheaths were removed, and the third and fourth internodes were ground in a Wiley mill to pass a 30-mesh screen.

Weight loss and modified acid-detergent fiber (MADF) were determined by the method of Clancy and Wilson (10). Lignin, cellulose, and ash were determined by the method of Van Soest and Wine (15). Triplicate determinations were conducted for each sample. Ground straw samples were dried at 65 C (72 hr), and 0.5-g samples were removed for analysis. All weight determinations were made on the same Mettler H6T analytical balance. Kjeldahl nitrogen was determined for all samples by the USDA Western Wheat Quality Laboratory, Pullman, WA.

The 1979 data were analyzed as a randomized complete block split-plot design using cultivars as blocks. This allowed the comparison of treatment effects (ie, noninfested vs. infested straw). The 1980 data were analyzed as a completely random split-plot factorial design allowing comparison of cultivars and treatments. In both years, *F* tests were used to indicate significant differences between treatment means. Fisher's (protected) least significant difference test was used to compare cultivar means.

## RESULTS

In both 1979 and 1980 a large percentage of diseased tillers occurred in all cultivars (Table 1). Significant differences between cultivars were present in both years. In 1979, Nugaines had the fewest diseased tillers (49.2%) and Selection 101 the most (89.6%). In 1980, 80-112 had the fewest diseased tillers (45.6%) and Selection 101 had the most (97.3%). In all cases, *C. gramineum* was isolated from straws visually assessed as being diseased.

Significant differences in composition existed between noninfested and infested straw (Table 2) in both 1979 and 1980. There were significant differences in straw composition among cultivars in 1980 (Table 3).

In 1979, noninfested straw had a significantly smaller percentage weight loss and ash, and a larger percentage of MADF, lignin, and cellulose than the infested straw (Table 2).

In the analysis of the 1980 data, there was a nonsignificant cultivar  $\times$  treatment interaction, and the main effects of treatment and cultivar were compared. Noninfested straw had a significantly smaller percentage weight loss and larger percentage of MADF and cellulose than infested straw. There was no significant difference in lignin and ash content (Table 2). Differences between cultivars (Table 3) were not related to disease reactions (Table 1). Nitrogen content of infested straw (Table 2) was significantly larger than noninfested straw in both 1979 and 1980. In 1979 and 1980, infested straw contained over three times and two times as much N,

respectively, as noninfested straw. There were no significant differences between cultivars with respect to nitrogen content (Table 3).

## DISCUSSION

Results obtained from the proximate analysis of noninfested and infested straw agree with the observation that *C. gramineum* causes a premature blight of diseased tillers (2). In both years, infested straw had a significantly larger percentage of soluble substances, a correspondingly smaller percentage of fiber, and two to three times greater nitrogen content than noninfested straw. Berry (1) showed

TABLE 1. Percent of tillers with *Cephalosporium stripe* in 1979 and 1980, Pullman, WA

Cultivar	Diseased tillers (%) <sup>a</sup>	
	1979	1980
Nugaines	49.2 a	81.2 b
Sprague	54.4 ab	...
Caribo	67.2 b	...
Wanser	68.6 b	...
Stephens	69.2 bc	...
Daws	82.1 cd	81.7 b
Ticonderoga	87.5 d	...
Selection 101	89.6 d	97.3 c
80-112 <sup>b</sup>	...	45.6 a

<sup>a</sup> Means within columns followed by the same letter are not significantly different according to Fisher's (protected) least significant difference (*P* = 95%).

<sup>b</sup> Breeding line 80-112 was evaluated in 1980 only.

TABLE 2. Composition of noninfested wheat straw and straw infested with *Cephalosporium gramineum*, Pullman, WA, in 1979 and 1980

Treatment	Percent of dry weight					
	Weight loss <sup>a</sup>	MADF <sup>b</sup>	Lignin	Cellulose	Ash	Nitrogen <sup>c</sup>
1979 <sup>d</sup>						
Noninfested	61.0	39.0	6.6	31.1	1.4	0.16
Infested	63.9	36.1	5.7	28.5	1.9	0.52
1980 <sup>e</sup>						
Noninfested	49.8	50.2	6.8	38.1	2.9	0.14
Infested	56.4	43.6	7.3	32.8	2.8	0.32

<sup>a</sup> Weight loss = soluble carbohydrates, starch, hemicellulose, and proteins.

<sup>b</sup> MADF = modified acid-detergent fiber.

<sup>c</sup> Kjeldahl nitrogen.

<sup>d</sup> All means within columns are significantly different based on *F* tests.

<sup>e</sup> All means within columns except lignin and ash are significantly different based on *F* tests. Means represent the average of four cultivars.

TABLE 3. Average composition of noninfested straw and straw infested with *Cephalosporium gramineum* of four winter wheat cultivars, Pullman, WA, in 1980

Cultivar	Percent of dry weight <sup>a,b</sup>					
	Weight loss <sup>c</sup>	MADF <sup>d</sup>	Lignin	Cellulose	Ash	Nitrogen <sup>e</sup>
Daws	55.8 a	44.2 b	7.7 a	33.6 c	2.2 b	0.24 a
Nugaines	47.9 b	52.1 a	5.0 b	39.5 a	2.7 ab	0.20 a
Selection 101	57.5 a	42.5 b	7.3 a	31.9 c	3.2 a	0.28 a
80-112	51.2 b	48.8 a	8.1 a	36.9 b	3.4 a	0.19 a

<sup>a</sup> Means within columns followed by the same letter are not significantly different according to Fisher's (protected) least significant difference (*P* = 95%).

<sup>b</sup> Means represent the average of infested and noninfested straw analyzed separately.

<sup>c</sup> Weight loss = soluble carbohydrates, starch, hemicellulose, and proteins.

<sup>d</sup> MADF = modified acid-detergent fiber.

<sup>e</sup> Kjeldahl nitrogen.

that with increasing age, percent crude protein decreased and the percent fiber increased in oat straw. Waksman and Tenney (16) followed the composition of winter rye plants over the season and found a gradual decrease in nitrogen and ash, and an increase in lignin and cellulose (fiber) with increasing age. The *C. gramineum*-infested straw, therefore, has characteristics of immature straw.

Waksman and Tenney (17) also studied the decomposition in soil of several different types of plants of different ages and concluded that less mature plant tissue decomposed more rapidly. More rapid decomposition was attributed to increased nitrogen and decreased lignin and cellulose in the immature tissue.

Smith and Douglas (14) studied the influence of nitrogen content and straw application rate on rate of straw decomposition in soil. Straw with higher nitrogen content decomposed faster in soils that could not supply nitrogen to the straw for decomposition. In soils with residual nitrogen able to supply nitrogen for decomposition, there was no effect of straw nitrogen content.

Based on the study of Smith and Douglas (14) and the results of this study, *C. gramineum*-infested straw should decompose faster than noninfested straw. The fact that it decomposed only slightly faster than noninfested straw and only significantly so after 18–24 mo as reported (13) is important. The conditions under which the previous study was conducted (ie, low nitrogen) would tend to maximize the difference in rate of decomposition between noninfested and infested straw. The infested high-nitrogen straw should decompose faster and immobilize less nitrogen than the noninfested low-nitrogen straw. The fact that infested straw decomposes at the same rate as noninfested straw supports the hypothesis that the antibiotics produced by *C. gramineum* inhibit competing soil microflora and in doing so slows decomposition of infested straw.

It is difficult to speculate about the results of Bruehl and Lai (6), since they did not report the nitrogen content of the soils with which they worked. However, they used a single soil sample and adjusted aliquots of that sample to different pH values. In naturally colonized straw, *C. gramineum* survived best in the range of pH 4.4–7.4; poorest survival occurred at pH 8.2–8.8. These results are consistent with the hypothesis that antibiotic production under acidic conditions is important to survival.

In the study of Mathre and Johnston (13), the relationship between decomposition and pH appears to be confounded by increasing nitrogen content of the soils from pH 5.5 (4 ppm NO<sub>3</sub>-N) to pH 7.5 (15 ppm NO<sub>3</sub>-N). This could explain the increased decomposition of both noninfested and infested straw at the elevated pH.

In the previous studies of survival and decomposition of *C. gramineum*-infested straw (6,7,9,12,13), the effect of substrate composition was overlooked. Studies on survival of *C. gramineum* in artificially colonized sterilized straws (13) have been justifiably criticized. This technique exaggerates the degree of possession by allowing the pathogen to thoroughly colonize the substrate before burial in soil. However, the use of naturally infested vs. noninfested straw does not take into consideration differences in substrate composition, making the evaluation of the role of antibiotics on survival of *C. gramineum* difficult.

In light of these results, and of the importance of *C. gramineum*

as a pathogen of wheat, a reexamination of the question of *C. gramineum* survival and decomposition of infested residue in the soil is warranted with attention to factors such as substrate composition, soil fertility, and soil pH.

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