Fusarium Blight and Physical, Chemical, and Microbial Properties of Kentucky Bluegrass Sod

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ABSTRACT

SMILEY, R. W., M. M. CRAVEN, and J. A. BRUHN. 1980. Fusarium blight and physical, chemical, and microbial properties of Kentucky bluegrass sod. Plant Disease 64:60-62.

Kentucky bluegrass (*Poa pratensis*) may become severely damaged by Fusarium blight. When the disease occurred on a well-established plot, its dependence on the environment, a relationship that is not well understood, was studied. Factor analysis was performed to identify associations between Fusarium blight and the other variables. The disease was positively correlated with the thatch decomposition rate, negatively correlated with the plant growth variables, and not correlated with any microbial group including all species, sections, and composite numbers of *Fusarium*. Sod pH and *Fusarium* numbers were associated with thatch decomposition rates. Fusarium blight was least severe when the percentage of *Fusarium*-infected plant crowns was highest. These results are considered in relation to the possible role of phytotoxic substances that are produced during thatch decomposition and act as incitants of Fusarium blight of Kentucky bluegrass.

Fusarium blight of Kentucky bluegrass *(Poa pratensis* L.), reportedly caused by *Fusarium roseum* (Lk.) emend. Snyd. & Hans. f. sp. *cerealis* and by *F. tricinctum* (Cda.) emend. Snyd. & Hans. f. sp. *poae* (4), destroys bluegrass stands in several regions of the United States. The disease occurs on seeded bluegrass stands that are usually older than 4 yr but may occur earlier on stands established from sod.

Occurrence of Fusarium blight on mature turfgrasses is very dependent upon the environmental conditions (3,20), but these conditions remain poorly defined due to the unpredictable nature of the disease in well-controlled experiments. We investigated the long-term (3 yr) effects of fungicide applications on nontarget microbial activities and soil processes in closely monitored Kentucky bluegrass sod (14–16). Fusarium blight occurred on the plot in 1977 (18), and the disease was unexpectedly controlled by several fungicides that have been ineffective in all 1-yr studies. Several properties of sod also appeared to be associated with the incidence of Fusarium blight. An understanding of the relationships between this disease and certain characteristics of host growth and of sod and microbial numbers may allow more complete characterization of the conditions favoring or causing disease. This is especially important because several fungicides that control the disease in the field are not fungitoxic to the alleged pathogens in vitro (12,17).

This investigation was conducted as part of Hatch Project NY(C)153434.

Accepted for publication 21 March 1979.

00191-2917/80/000010$03.00/0

This report presents the results of correlative and multivariate analyses performed to identify associations between Fusarium blight of Kentucky bluegrass and certain turfgrass characteristics. Because a significant level of multicollinearity existed among variables, simple correlation coefficients could not be interpreted. Factor analysis was used to identify a set of independent patterns of association among the variables. The results of the factor analysis allowed estimation of partial correlation coefficients that provided a statistical measure of the degree of linear association between Fusarium blight and each of the variables.

MATERIALS AND METHODS

A 2-yr-old Kentucky bluegrass turf was installed as sod in 1975 at the Cornell University Turfgrass Field Laboratory, Ithaca, NY. The sod was a blend of the cultivars Merion, Fylking, and Pennstar. Fungicides were applied repeatedly from 1975 to 1977. Details of the plot's management, soil, the fungicides, and the application schedules and equipment have been described (14).

The 22 treatments, applied in three replicates of 1×5 m plot areas, included 15 individual fungicides, five combined or alternated "programs," one nematicide, and an untreated control. The installed sod had a thatch depth of 2 cm, and in November 1977 the depths among treatments ranged from 3 to 22 mm (14), which represented decomposition rates of 6 to −1 mm/yr. The composite pH of the upper 3 cm of thatch and soil varied from 5.6 to 6.4 in the treated areas (14).

Estimates of the numbers of bacteria, actinomycetes, and fungi in thatch and soil were made by dilution plate techniques (15) during April, June, and September 1977. Population estimates of total *Fusarium* species also were made, and in September 1977, we identified 1,329 isolates to the species (sensu Booth) (16). Percentages of bluegrass crowns infected with *Fusarium* varied from 4 to 41% for the eight treatments examined in September 1977. Additional measurements were made of the densities of turfgrass roots in the surface 4 cm of soil and of leaf clippings removed during mowing (R. W. Smiley and M. M. Craven, *unpublished*). The areas of grass killed by Fusarium blight on the plots in August 1977 ranged from 0 to 37% (19).

Factor analysis was used to aid in identifying the relationships among Fusarium blight severity, thatch decomposition rate, sod pH, clipping densities in May and August, root density, and the numbers of fusaria, fungi, actinomycetes, and bacteria. A total of 66 observations, representing three replicates of the 22 fungicide and nematicide treatments, were used to estimate the correlation matrix for the 10 variables. The SPSS factor analysis procedure (6) was used to perform an "R" type of factor analysis with the verimax method of orthogonal factor matrix rotation. A variable was considered an important element of a factor if the factor loading (correlation coefficient) exceeded the significant value of the simple correlation coefficient evaluated at $P = 0.01$ ($r = 0.325$).

Factor analysis is a multivariate statistical technique used to determine the structure of the linear dependences among a set of variables. The technique considers the variability within the data to be the result of interdependence among the variables (communality) and the result of innate variability unique to each variable. Communality (h^2) is further partitioned into a set of orthogonal factors that represent hypothetical determinants of the correlations among the variables. Factor analysis provides an estimate of the correlation between each variable and each factor (factor loading). This information is presented in the form of a factor matrix and can be used to group the original set of variables according to their importance in each factor. Then the most important variables can be grouped into independent subsets. Partial correlation coefficients can then be used to examine the interdependence among the variables in each subset (8).

Table 1. Correlation matrix for Fusarium blight and some properties of Kentucky bluegrass[a]

	Bacterium numbers	Actinomycete numbers	Fungus numbers	*Fusarium* numbers	Root densities	Leaf clippings May	Leaf clippings Aug.	Soil pH	Thatch decomposition
Fusarium blight (% of area)	0.20	0.12	0.00	0.37**	−0.41**	−0.51**	−0.46**	0.435**	0.70**
Thatch decomposition (mm/yr)	−0.16	−0.16	0.11	0.47**	−0.29*	−0.35**	−0.25*	0.60**	
Sod pH (0-3 cm) (in 0.01 M $CaCl_2$)	−0.18	−0.05	0.21	0.29*	−0.04	−0.31*	0.15		
Leaf clippings (Aug.) (g/m^2)	0.30*	0.27*	0.21	−0.28*	−0.00	0.60**			
Leaf clippings (May) (g/m^2)	0.24	0.17	0.14	−0.38**	0.31*				
Root densities (0–4 cm) (mg/cm^3)	−0.15	−0.06	−0.06	0.03					
Fusarium numbers (prop/g of soil)	−0.11	−0.16	0.09						
Fungus numbers (prop/g of soil)	−0.06	0.16							
Actinomycete numbers (prop/g of soil)	0.49**								
Bacterium numbers (no./g of soil)									

[a]Significance of coefficients is indicated at $P = 0.05$ (*) and at $P = 0.01$ (**).

RESULTS

Correlation coefficients between Fusarium blight and each of the other variables (Table 1) were significant for numbers of *Fusarium* propagules, densities of roots and leaf clippings, sod pH, and thatch decomposition rates. The interdependence among these variables prevented an interpretation of these associations.

The factor matrix (Table 2) indicated that Fusarium blight was an important element of three factors (1, 2, and 4). Factor 1 suggested a common positive association between the disease, thatch decomposition, sod pH, and numbers of *Fusarium* propagules. Factor 2 suggested a negative association between the disease and the production of leaf tissue. Factor 4 indicated a negative association between the disease and root density and suggested that root density was unrelated to leaf growth. Factors 2 and 5 had only minor influences on Fusarium blight and indicated that numbers of bacteria and actinomycetes, although associated with each other, were unrelated to disease, and that the numbers of fungi were not related to any other variable. The relatively low communality value (0.669) for Fusarium blight was probably caused by the direct effects of some fungicides on the disease, but this could not be verified. On the other hand, nearly all of the variation in thatch decomposition rates, as judged by the high communality (0.997), was associated with the variables that we measured.

The factors identify subsets of the variables according to the degree of association among the variables. Because independent factors were constructed, partial correlation coefficients could be computed from the simple correlation coefficients associated with the important variables in each factor. These partial correlation coefficients represent the degree of linear association between a pair of variables after correcting for interdependence with other variables (13), and can be used to evaluate the importance of the associations between Fusarium blight and the other variables. Significance levels at $P = 0.10$, $P = 0.05$, and $P = 0.01$ were 0.211, 0.250, and 0.325, respectively.

Table 2. Factor matrix for 10 measured properties of Kentucky bluegrass sod

Variable	Factor 1	2	3	4	5	Communality (h^2)
Fusarium blight (% area)	0.61[a]	−0.40	−0.11	−0.34	−0.02	0.669
Thatch decomposition (mm/yr)	0.97	−0.06	−0.11	−0.22	0.01	0.997
Sod pH (0-3 cm) (in 0.01 M $CaCl_2$)	0.61	−0.17	−0.06	0.09	0.28	0.497
Leaf clippings (Aug.) (g/m^2)	−0.20	0.67	0.24	−0.03	0.24	0.604
Leaf clippings (May) (g/m^2)	−0.27	0.77	0.11	0.21	0.06	0.730
Root densities (0–4 cm) (mg/cm^3)	−0.08	0.10	−0.11	0.93	−0.03	0.892
Fusarium numbers (prop/g of soil)	0.46	−0.28	−0.07	0.07	0.03	0.297
Fungus numbers (prop/g of soil)	0.12	0.14	0.64	−0.03	0.59	0.382
Actinomycete numbers (prop/g of soil)	−0.10	0.08	0.65	−0.02	0.22	0.487
Bacterium numbers (no./g of soil)	−0.08	0.20	0.77	−0.09	−0.18	0.678

[a]Factor loading (correlation between the variable and the factor).

For Factor 1, the partial correlation coefficient between Fusarium blight and thatch decomposition, when *Fusarium* numbers and sod pH were held constant, was 0.566. This was a highly significant ($P = 0.01$) relationship. The corresponding correlations between disease and pH (0.026) and between disease and *Fusarium* numbers (0.065), with the other two variables held constant, were insignificant. Correlations between thatch decomposition and pH (0.438) or *Fusarium* numbers (0.282), with the other variables in Factor 1 held constant, were significant. The thatch decomposition rate was clearly the variable most closely associated with Fusarium blight, and the sod pH and numbers of *Fusarium* species were significantly correlated with the decomposition process.

Coefficients among variables in Factor 2 indicated that the effects of leaf growth rates on disease were roughly similar and that both are negatively correlated. The coefficient between disease and leaf growth in August, with growth in May held constant, was −0.224 ($P = 0.10$). The corresponding relationship for leaf growth in May was −0.329 ($P = 0.01$). Within Factor 4 there were only two variables, and therefore the partial correlation between the disease and root density (−0.410; $P = 0.01$) was the same as the simple correlation coefficient.

Fusarium blight was mostly associated

with three of our measured variables: the rates of thatch decomposition, bluegrass leaf growth, and root density. We recognize that correlations do not suggest cause-and-effect relationships, but they do imply patterns that can be considered in terms of known biological principles.

Fusarium blight severity was not correlated ($P = 0.10$) with the total number of *Fusarium* propagules, any one of the 19 species identified (sensu Booth) and enumerated in these plots (16), any one of the nine sections the species are grouped into, or either of the groups *F. roseum* or *F. tricinctum* (sensu Snyder and Hansen). The latter two groups are the alleged causal agents of Fusarium blight. Moreover, the relationship between the percentages of *Fusarium*-infected plant crowns (16) and of blighted grass (19) indicated that the disease was least severe where the infection percentages were highest (Fig. 1).

DISCUSSION

Kentucky bluegrass often becomes dormant during the summer when production of leaves and roots is minimal (2). Bluegrass maintained at low levels of fertility with little or no supplemental watering is more apt to become dormant than frequently fertilized and watered bluegrass, and Fusarium blight is more likely to occur under the latter conditions. Our results suggest that when management intensity is moderate, the severity of disease is negatively associated with the growth rate of the bluegrass.

Thatch is almost always present on highly maintained, mature bluegrass stands and on harvested sods, but the depth of thatch is not always related to the severity of Fusarium blight (14,20). The rate of thatch decomposition has been shown here to be important to disease incidence. Decomposition is most rapid in turf that is well aerated, somewhat moist, warm, and not excessively acidic (2); similar conditions are necessary for Fusarium blight to occur.

Thatch decomposition and the sporulation of facultatively pathogenic fungi, including *Fusarium*, are also greater when bluegrass is watered occasionally rather than frequently or not at all (5). The relationship between *Fusarium* and thatch decomposition is to be expected since *Fusarium* species have important cellulolytic capabilities. Inoculum density is not important for this disease; however, *Fusarium* species are the dominant epiphytic fungi on turfgrass during the summer (1) and are likely to be the pioneer colonists of senescing tissue at that time. Rarely, other facultative pathogens, such as *Drechslera*, *Curvularia*, or *Rhizoctonia* species, have appeared to be the incitants of symptoms visually identical to those of Fusarium blight.

Smiley et al (18) demonstrated that, in New York, Fusarium blight always occurred after major rain storms, that the thatch became nearly anaerobic on sunny days after major storms, and that the disease was less severe in plots where cores were removed to improve soil aeration. On the area described in this report, the disease was most severe in plots where the redox potential was lowest on sunny days after a rain (R. W. Smiley, *unpublished data*). Reddy and Patrick (10) showed that decomposition of litter is accelerated as the number of alternating aerobic and anaerobic periods is increased. The accumulation of phytotoxins is also maximum when decomposition occurs under anaerobic conditions (7,9). Toxins can injure plant roots and reduce plant growth directly or may predispose plants to attack by pathogens (11).

The major influence of thatch on this disease was related to its decomposition and not to its modification of the soil physical environment. Decomposition processes could favor the disease by increasing availability of nutrients, leading to an increase in the pathogen inoculum density, or by releasing phytotoxins deleterious to root health. The potential for such toxins to occur is greatest in summer when bluegrasses are also weakest due to their tendency to become dormant.

This discussion suggests that the cause of Fusarium blight of Kentucky bluegrass may be abiotic. The possibility that phytotoxic substances from decomposing thatch are responsible for the disease must be studied.

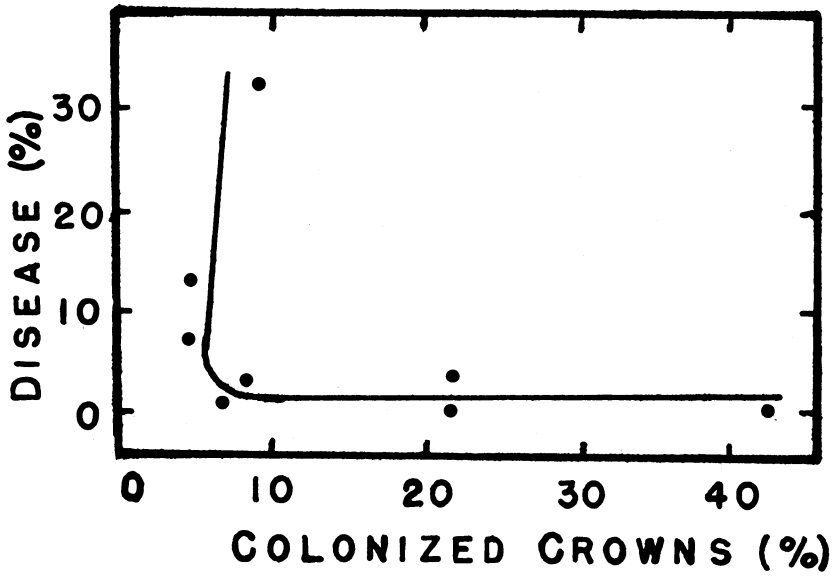

Fig. 1. Fusarium blight and the percentage of Kentucky bluegrass crowns colonized by *F. roseum* on fungicide-treated plots.

ACKNOWLEDGMENT

The support of the U.S. Golf Association-Green Section, the fungicide manufacturers, and several New York turfgrass associations is appreciated.

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