Effect of Levels of Corn Residue on the Epidemiology of Gray Leaf Spot of Corn in Ohio

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ABSTRACT

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The effect of soil-surface residue level (0, 10, 35, and 85% soil coverage) on the progress of gray leaf spot of corn, caused by *Cercospora zeae-maydis*, over time was studied in Ohio during two environmentally different growing seasons. Area under the disease progress curve (AUDPC) was calculated and analyzed with analysis of variance followed by orthogonal polynomials. In the first year, under favorable environmental conditions for disease development, the relationship between disease severity and amount of residue on the soil surface was positive, significant at $P < 0.01$, whereas in the second year, under dry conditions less favorable for disease development, the relationship was significant at $P = 0.07$. However, the linear orthogonal polynomial of residue level was significant for AUDPC in both years ($P < 0.001$ and < 0.04 for 1990 and 1991, respectively). Final severity, as measured by lesions per leaf, for the favorable and unfavorable years was 12.6–118.3 and 0.4–3.2, respectively. AUDPC for the 85% residue level was clearly higher than the other levels for the favorable weather year. Under unfavorable conditions, there was a tendency for disease severity to be similar between 0 and 10% residue levels and lower than the 35 and 85% residue levels. Our study shows that any tillage method leaving residue on the soil surface favors gray leaf spot development and that disease increases with amount of residue. Tillage systems leaving greater than 35% residue cover may result in high disease levels, especially under environmental conditions favorable for disease development.

Interest in conservation tillage systems and multiple cropping has increased in the past two decades because of the increased cost of fossil fuels, periodic world food shortage, and concern over soil erosion (16). With the advent of more selective and efficient herbicides and the development of farm machinery capable of planting seeds without the normal seedbed preparation, farmers have adopted soil conservation practices using no tillage or only a minimum amount of tillage to establish corn (*Zea mays* L.).

As a consequence of these practices, a fair amount of the previous year's crop residue is left undisturbed on the soil surface (26). The beneficial effects of buffering topsoil temperature, conserving moisture, and reducing wind and water erosion are frequently offset by the negative effects of residue as a nutrient source and shelter for survival, growth, and reproduction of plant pathogens (5,11,24).

Foliar pathogens of corn of low competitive saprophytic ability, such as the causal agents of anthracnose (*Colletotrichum graminicola* (Ces.) G.W. Wils.), eyespot (*Kabatiella zeae* Narita & Hiratsuka), and gray leaf spot (*Cercospora zeae-maydis* Tehon & Daniels), have become major pathogens in areas where conservation tillage practices are used (11–13,15–18,20,23). Adoption of no-tillage practices in Ohio began in the early 1970s, and by 1987 more than 10% of the cultivated area of the state was under this system (1,2).

Abundant moisture, adequate air temperature, and host susceptibility, in addition to the presence of a source of inoculum (i.e., infested residues) on the soil surface, are necessary for *C. zeae-maydis* to cause an epidemic (3,12,21). Although the effects of tillage on plant disease epidemiology are complex, Boosalis et al (5) stated that the degree of influence on plant diseases by residue generally relates to the amount of residue remaining after planting. They further indicated that tillage systems that leave 20% cover are less likely to influence disease development than those leaving 90% residue cover after planting.

The influence of tillage on development of gray leaf spot was experimentally demonstrated under North Carolina conditions by Payne et al (18). A comparison of no-tillage and other tillage systems leaving various residue levels on the soil surface indicated that there were more airborne conidia within no-tillage plots. Furthermore, plants had greater number of lesions per leaf in no-tillage plots than in plowed and disked treatments. Differences between no-tillage and the other methods used were more evident in the second year because of increases in inoculum associated with the no-till treatments (18). In 1984, an extensive field survey was conducted in Maryland (22) to relate soil tillage, crop rotation, and environment conduciveness for disease development with gray leaf spot intensity. A significant positive relationship between presence of overwintering corn debris and gray leaf spot was established.

In both of the previous studies relating soil tillage to gray leaf spot development, the authors did not quantify the residue cover at planting (18,22). Moreover, corn plants were subjected to one of several tillage methods that may have induced a differential effect on plant growth (e.g., corn under no-tillage is shorter than corn under plowed and disked tillage in Ohio). Our study was undertaken to determine the direct influence of different amounts of infested corn-residue covering the soil on the epidemiology of gray leaf spot of corn under Ohio conditions. These experiments were designed to be independent of the method of tillage and avoid possible interactions between crop development and tillage method.

MATERIALS AND METHODS

Field plots. Experimental plots were installed in 1990 and 1991 at the Ohio Agricultural Research and Development Center near Wooster. Gray leaf spot epidemics had not occurred in this area. The soil was plowed in the fall and disked in the spring prior to planting. Seeds of a susceptible hybrid, Pioneer Brand 3569, were planted with a John Deere No. 71 Flex planter on 1 May in both years. The final plant population averaged 71,600 plants per hectare. Experimental units consisted of five 3.7-m rows, 0.8 m apart, oriented in a north-south direction. Each experimental unit was surrounded by three and eight rows of a more resistant hybrid, Pioneer Brand 3233, in 1990 and 1991, respectively. Plots were arranged in a randomized block design with four replicates. Time of disease assessment was considered as a temporally repeated measure (6).

During the last week of April, corn residue infested with the pathogen was collected from a no-tillage field where severe gray leaf spot had occurred for

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several growing seasons (14). The residue resulted from the previous year's crop. The air-dried residue was stored inside a nonheated barn until used. The residue was weighed and distributed on both sides of the center row on 20 June 1990 and 18 June 1991, when plants were between growth stages 2 and 3 (10). Equivalent dry weights of residue were used both years. Residue application rates were 0% soil surface coverage, representing a conventional tillage system with complete burial of residues; 10 and 35% soil coverage, simulating gradations of minimum tillage; and 85%, simulating no-tillage (1,2,26). Because of the drought, three supplemental overhead irrigations were provided (25–38 mm equivalent of rain) every 2 wk, beginning at the end of flowering only in 1991.

Data collection. Eight randomly selected plants in the center row of each experimental unit were tagged for disease assessments. The number of lesions on the third leaf above and below the ear leaf and the ear leaf were used to estimate disease severity. Disease severity based on the average number of lesions on the three leaves per plant was estimated. The mean value for each experimental unit was used in data analysis (7). Disease assessments (five in 1990 and seven in 1991) were made at weekly intervals beginning on 3 August 1990 and 8 August 1991, as lesions appeared on the assessed leaves. In commercial fields, lesions are first noticed in Ohio in early August.

Weather data were obtained from a standard automated weather station located approximately 2 km from the plots and maintained by the Ohio Agricultural Research and Development Center. Average daily maximum and minimum air temperature, relative humidity (RH), and precipitation were used for comparison between years. Weather data were recorded from the time residues were applied until the last disease assessment was made.

Data analysis. The area under the disease progress curve (AUDPC) was estimated by the midpoint rule method (6). Values were standardized by dividing AUDPC values by the duration in days of the epidemic. Effect of residue level on AUDPC values was determined by analysis of variance (ANOVA). Prior to ANOVA, the Taylor power law was used to transform AUDPC data to stabilize variances (6). Orthogonal polynomials also were calculated when residue level was significant to determine linear, quadratic, and cubic changes in AUDPC as residue level increased. All analyses were performed with the Minitab (version 7.1; Minitab Inc., State College, PA 16802) statistical analysis software.

RESULTS

Environmental conditions were more favorable for gray leaf spot development in 1990 than in 1991. During the epidemic in 1990, maximum and minimum daily air temperatures ranged from 17 to 34 C and from 8 to 24 C, respectively. In 1991, high and low daily temperature ranges were 14–37 C and 0–24 C, respectively. RH was generally lower in 1991 than in 1990. The average daily minimum RH was below 50% for one-third of the days during the epidemic in 1990 and for more than two-thirds of the days in 1991. The ranges of minimum daily RH were 34–90% and 12–67% for 1990 and 1991, respectively.

Total precipitation and number of days with measurable precipitation were greater in 1990 than in 1991. From the time of residue placement in the field to the end of the epidemic, cumulative rainfall was 301 and 165 mm for 1990 and 1991, respectively. Thus, the 1991 experimental period was warmer and drier than that of 1990. Lesions appeared 7 days later relative to the date of residue placement in 1991 than in 1990.

Gray leaf spot severity increased over the experimental period during both 1990 and 1991, but the number of lesions per leaf differed greatly between years (Fig. 1). Final severity was about 10–50 times higher in 1990 than in 1991. The average numbers of lesions per leaf at the end of the epidemic for 0, 10, 35, and 85% residue level treatments were 12.6, 36.6, 42.4, and 119.4 for 1990 and 0.3, 0.7, 3.2, and 1.8 for 1991 (Fig. 1). The epidemic lasted longer in 1991 because irrigation retained green leaves until the first killing frost. As expected from the individual time data, the standardized AUDPC values were considerably higher in 1990 than in 1991 (Table 1).

The variance of AUDPC increased with the mean. Therefore prior to ANOVA, AUDPC was transformed to AUDPC* = AUDPC$^{(1-b/2)}$, in which b is the slope for Taylor's power relation

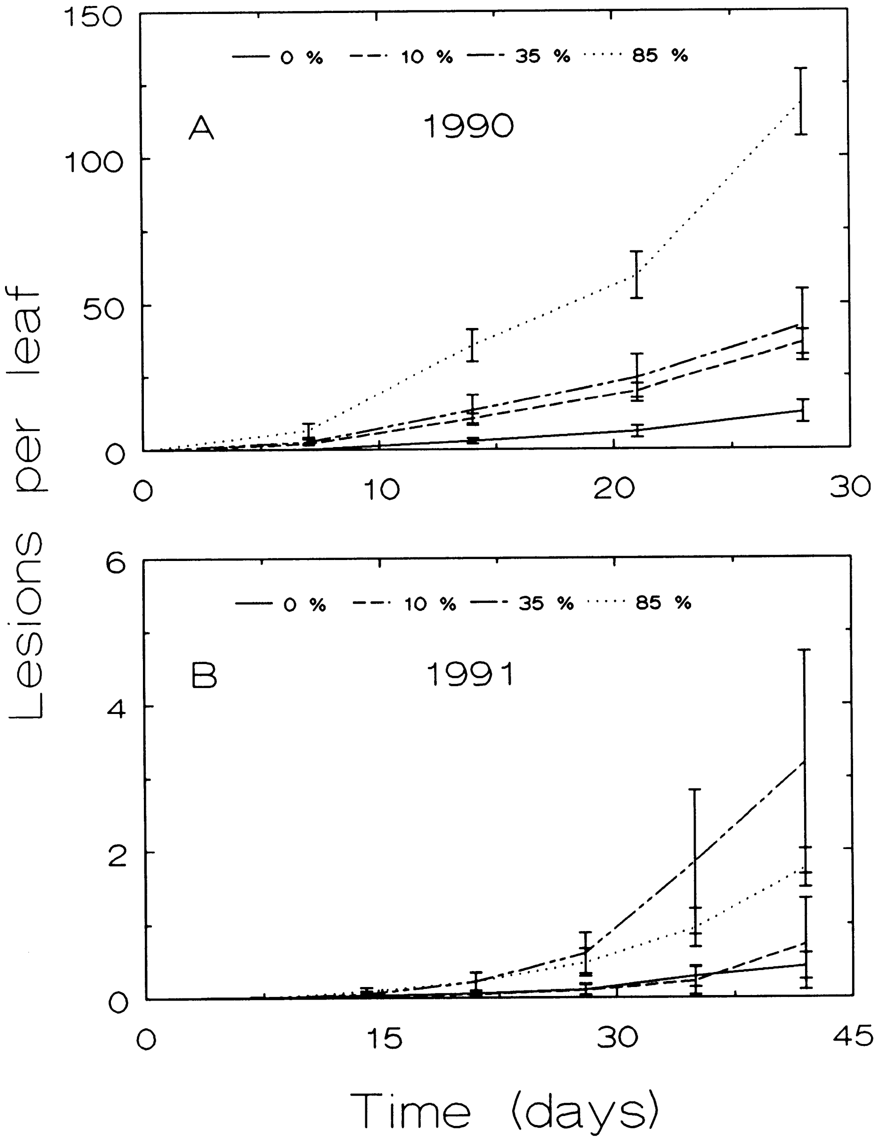

Fig. 1. Effect of different levels of infested corn residue on development of gray leaf spot, caused by *Cercospora zeae-maydis*, on Pioneer Brand 3569 planted in plots with 0, 10, 35, and 85% soil surface coverage in **(A)** 1990 and **(B)** 1991. Points represent means of four replicates; bars are standard errors.

between the log(variance) and log(mean). For 1990, $b = 2.16$; therefore, the ln(AUDPC) transformation was used, because the logarithm is the limit as b approaches 2 (6).

In 1990, the effect of residue level was highly significant ($P < 0.01$) for AUDPC*. AUDPC increased with residue level, as indicated by a significant ($P < 0.001$) linear orthogonal polynomial. However, the 10 and 35% residue levels had very similar values for the three variables (Table 1).

In 1991, disease severity was much lower but variability was higher, denoted by the standard errors (relative to the means), than in 1990 (Fig. 1B, Table 1). Taylor's b for AUDPC was 1.49. The effect of different levels of residue on the soil surface on disease severity and progress was less clear. ANOVA for AUDPC* indicated that residue level was significant at $P = 0.07$. Generally, disease severity (as measured by AUDPC) in plots with 0 and 10% residue levels were similar but lower than in plots with 35 and 85% residue levels. The linear orthogonal polynomial was found to be significant ($P < 0.04$).

Table 1. Impact of different levels of infested corn residue on development of gray leaf spot, caused by *Cercospora zeae-maydis*, on corn hybrid Pioneer Brand 3569 as measured by the area under the disease progress curve (AUDPC)[a]

Residue level[b] (%)	1990			1991		
	AUDPC	SE	AUDPC*[c]	AUDPC	SE	AUDPC*
0	3.83	1.22	1.20	0.12	0.05	0.54
10	12.71	1.54	2.52	0.13	0.11	0.39
35	15.42	5.07	2.54	0.72	0.36	0.80
85	39.67	5.80	3.66	0.44	0.11	0.80
			SED 0.43			SED 0.16

[a] Analysis based on four replications, with means presented. AUDPC values were standardized by dividing calculated values by duration of epidemic in each year (6).

[b] Percentage of soil surface covered; residue distribution on plots was determined by weight.

[c] Mean of transformed AUDPC values, with transformation based on Taylor's power law (6). SED = standard error of difference of two means.

DISCUSSION

C. zeae-maydis survives through the winter in infested corn tissue remaining on the soil surface from the previous season (8,19,25). Sporulation from lesions on the residues is the primary source of inoculum initiating new epidemics. Presence of infested residue on the soil surface has been associated with the increased severity of gray leaf spot in certain regions of the United States since the early 1970s (20). Therefore, the threat of gray leaf spot to corn production in areas with reduced tillage has been emphasized (4,20). For instance, Roane et al (20) warned that gray leaf spot had the potential to jeopardize the usefulness of no-tillage as a residue management practice where corn is grown year after year.

The main objective of this study was to determine whether, under field conditions in Ohio, increased amounts of infested residue on the soil affected gray leaf spot disease development over time. Our results indicated that there was a significant and positive association between disease severity and amount of residue on the soil surface, although the environment had a major effect on the level of disease variability. For instance, the effect of residue level was less pronounced under very dry conditions (1991) than under wetter conditions (1990). This agrees with research conducted in North Carolina (18), where in a dry environment, the number of lesions per leaf of gray leaf spot was very low at the end of the season and differences between tillage systems were not significant. From our results we predict that under normal conditions in Ohio, when corn is planted by the no-tillage method in a field with infected residue from the previous crop, gray leaf spot will progress faster and reach higher final severity levels than when corn is planted under any form of reduced or conventional tillage. Because long-term accurate weather forecasting is not feasible, the safest control option is to avoid no-tillage practices in situations where corn follows corn.

Contrary to our findings, Payne et al (18) reported that the gray leaf spot disease epidemic started 2 wk earlier in no-tillage plots than in plowed plots. They postulated that this was due to the higher inoculum density in no-tillage plots. We observed that in our simulated no-tillage plots (85% residue level), the gray leaf spot disease epidemic started at about the same time as in all other plots, regardless of residue level (0, 10, or 35%) (Fig. 1). This was expected, because our experiments were initiated in residue-free areas and the inoculum was introduced only when plants were 50 cm tall. Handling of infested residue may have reduced inoculum efficiency by damage to plant tissue and disruption of conidiophores. Certainly, infested residue in no-tillage and reduced-tillage fields remains relatively undisturbed throughout the year on the soil surface. Because inoculum could be produced and liberated earlier when the residue is not disturbed, the gray leaf spot epidemic may start earlier in no-tillage fields than in fields managed with other tillage methods.

Gray leaf spot control via tillage practices is more difficult in areas of intensive corn production, especially where farmland containing infested debris is contiguous. *C. zeae-maydis* is disseminated as airborne inoculum. Spores have been collected in air currents above no-tillage fields (18). Recent studies of gray leaf spot spread from soil-surface residue sources of inoculum in Ohio (9) have shown relatively shallow gradients, ranging from 0.15 to 0.56/m in 1990. This infers that the pathogen is readily dispersed from residue on the ground within the corn canopy. This also explains the levels of disease observed in 1990 and 1991 in the plots without residue because this location was far from where the pathogen is endemic (14) and this level of background contamination was not originally expected.

This study also indicated that 10% residue coverage provided enough inoculum under favorable environmental conditions (1990) to create an epidemic similar to that supported by a 35% residue cover (Fig. 1A). The 10% residue treatment was present to simulate the conditions of conventional tillage with incomplete burial of residue, a practice that is not uncommon in Ohio cornfields. Therefore, if the intent of conventional tillage is to decrease the inoculum level, fields must be plowed and cultivated subsequently in a manner that ensures complete burial of the infested residue.

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