Influence of Tillage and Crop Rotation on Yield, Stalk Rot, and Recovery of *Fusarium* and *Trichoderma* spp. from Corn

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ABSTRACT

Lipps, P. E., and Deep, I. W. 1991. Influence of tillage and crop rotation on yield, stalk rot, and recovery of *Fusarium* and *Trichoderma* spp. from corn. Plant Dis. 75:828-833.

An experiment was established in 1985 on a Hoytville silty clay loam soil in northwest Ohio to determine the effect of tillage (fall plowing vs. no tillage) and crop rotation (continuous corn [*Zea mays*] vs. corn-soybean [*Glycine max*]) on corn production. In 1987 and 1988, data were taken on grain yield, incidence of stalk rot, and recovery of *Fusarium* and *Trichoderma* spp. from stalk, crown, and subcrown mesocotyl tissue. During 1987 and 1988, precipitation from April through September was only 69 and 40%, respectively, of the long-time average. In both years, yield was significantly higher in corn-soybean rotation than in continuous corn. Incidence of stalk rot was not influenced by crop rotation in either year, but there was significantly higher stalk rot in fall-plowed than in no-tillage treatments in both years (1987 [$P = 0.06$] and 1988 [$P = 0.05$]). Severe stalk rot in 1987 (87.5% mean of all treatments) was caused primarily by *F. graminearum*. In 1988, stalk rot was much less severe (19.4% mean of all treatments) and was caused by *F. moniliforme*. These differences appeared to be related to different rainfall patterns. Levels of stalk-rotting *Fusarium* spp. in both years remained low in the subcrown mesocotyl but increased in crown and stalk tissues as the season progressed. *T. pseudokoningii* and *T. hamatum* were prevalent in subcrown mesocotyls, crowns, and stalks in both years at constant levels throughout the sampling period.

Corn (*Zea mays* L.) stalk rot is caused by many soilborne and residue-borne fungi (2,3,5,8,12,22) and is highly influenced by plant stress (3,5,7), especially low moisture stress (5,7,21). *Fusarium* spp. are most commonly cited as the cause of stalk rot, with *F. graminearum* Schwabe and *F. moniliforme* J. Sheld. being prevalent in moist and drier regions, respectively (3,7,8,22,29).

Reduced tillage and crop rotation influenced severity of grain sorghum (*Sorghum bicolor* (L.) Moench) stalk rot, caused by *F. moniliforme*, in a semiarid region (7). In Nebraska, a cropping system with a winter wheat-grain sorghum-fallow rotation and a minimal disturbance of crop residue and soil was developed to conserve soil moisture, reduce incidence of stalk rot, and increase sorghum yield. In Delaware, *Fusarium* spp. were isolated more frequently from rotted corn stalks taken from conventionally tilled fields than from those collected in nontilled fields (2). In rotation-tillage plots in Illinois, stalk rot was lowest in no-tillage plots with both continuous corn and corn-soybean rotation (10).

Although tillage appears to affect the severity of stalk rot, the influence of crop rotation has not been consistent. In Ohio, root and stalk rot were most severe on plants in plots planted continuously to corn for 7 yr and were least severe in plots following soybeans (*Glycine max* (L.) Merr.) (28). In New York, stalk rot in corn following corn was no more severe than when corn followed a small grain or legume (1), and in Illinois, stalk rot incidence was related to tillage but not to rotation with soybeans (10).

The lower amount of stalk rot in nontilled fields seems to be related to lack of late-season moisture stress. Apparently, reduced tillage fields maintain higher soil moisture reserves throughout the growing season than tilled fields

Manuscript 274-89.

Accepted for publication 16 February 1991 (submitted for electronic processing).

(7,25). However, in no-tillage continuous corn, the influence of greater soil moisture reserves may be masked by increased plant stress attributable to leaf blight pathogens associated with crop residues, such as *Cercospora zeae-maydis* Tehon & E. Y. Daniels (14) or *Colleotrichum graminicola* (Ces.) G. W. Wils. (15). Therefore, tillage and crop rotation may have a more complex effect on incidence of corn stalk rot than either factor alone.

Tillage and crop rotation influence corn yield (4,9). In long-term trials in Ohio, corn yields were always influenced positively by no-tillage on a well-drained silt loam soil and negatively influenced by no-tillage on a poorly drained silty clay loam soil (4). Improved yield with no-tillage on well-drained loam soil appears related to better water retention and lack of late-season water stress (4). The mechanism responsible for lower yields with no-tillage in the poorly drained silty clay loam soil was not known (4).

Trichoderma spp. have been reported as pathogens of corn seedlings (17,24) and stalks (27), however, this association has not been consistent (30). *Trichoderma* spp. are generally considered to be secondary invaders in corn plants (3,22). *T. harzianum* Rifai has been reported to give biological control of Fusarium crown rot of tomato (23), and *T. harzianum* and *T. koningii* Oudem. have been reported to cause increased growth of corn plants (30).

This study was initiated to determine individual effects and possible interactions among yield, incidence of stalk rot, tillage, rotation, and the presence of *Fusarium* and *Trichoderma* spp. in corn tissues.

MATERIALS AND METHODS

Plots were established in 1985 at the Ohio Agricultural Research and Development Center, Northwest Branch, Custar, OH, on a Hoytville silty clay loam (21:39:40:4, sand/silt/clay/organic matter, pH 7.0) with subsurface drainage tiles on 17-m spacing. Two tillage and two rotation factors were arranged in a split-plot design with four replicated blocks. Whole plots were tillage (either no-tillage or fall plowed), and subplots were rotation sequence (continuous corn, corn planted on even years with soybean on odd years, and corn planted on odd years with soybean on even years). Experimental units were 21 × 30 m and consisted of 28 corn rows planted 75 cm apart. Data presented represent the third and fourth years of the tillage-rotation history.

Plots representing plow treatments were moldboard plowed, 20–25 cm deep, in early November of each year after broadcast applications of fertilizer (90 kg/ha of K). In the spring, plowed plots were tilled twice, 10 cm deep, with a field cultivator before planting. Additional fertilizer was applied to corn through the planter (17 kg/ha each of N, P, and K), and nitrogen (90.8 kg/ha of N) was side-dressed at early- to mid-whorl growth stage. Hybrid corn (Crows brand 444, Crows Hybrid Corn Co., Milford, IL) (79,000 seed/ha) was planted on 29 April 1987 and 26 April 1988. The soybeans (various cultivars) (432,000 seed/ha, rows 38 cm apart) were planted in early May of each year. Herbicides were applied preemergence to corn as a combination of paraquat (0.56 kg/ha), atrazine (1.68 kg/ha), cyanazine (2.8 kg/ha), and alachlor (2.24 kg/ha) and to soybean as a combination of paraquat (0.56 kg/ha), chloramben (2.0 kg/ha), metribuzin (5.6 kg/ha), metolachlor (2.24 kg/ha), and bentazon (0.8 kg/ha).

Plant stand counts (plants per 30-m row) were recorded on 17 June 1987 and 28 June 1988 from the center two rows (rows 14 and 15 of a 28-row-wide experimental unit) of each experimental unit.

Ten plants, selected randomly and located between two undisturbed adjacent plants, were dug from each 28-row experimental unit from row 5, 6, 7, or 8 in 1987 and row 9, 10, 11, or 12 in 1988 at each sampling time. Plants were dug on 7 July, 17 August, and 3 September 1987 and 6 June, 5 July, 28 July, 22 August, and 21 September 1988. After digging, the tops of plants were cut off at the second internode above the brace roots, and the root-soil mass was trimmed to within 3 cm of the crown. The intact lower stalk, crown, and subcrown mesocotyl of plants were packaged in plastic bags, transported to the laboratory, and stored at 3 C overnight. The lower stalks were split and 0.5-cm^3 tissue samples were taken with a sterile scalpel from the pith of the first internode above the brace roots and from the crown region near the origin of the first several whorls of adventitious roots. A 1- to 1.5-cm-long section of the subcrown mesocotyl of each plant was also removed, surface-disinfected in 0.5% sodium hypochlorite for 30 s, and drained on paper towels. All three tissue samples were divided in half and pressed between paper towels to remove excess moisture. One section of each tissue type was placed onto a medium selective for *Fusarium* spp. (NSA) (18) and a medium selective for *Trichoderma* spp. (TSA) (17).

After 5 days, one colony of *Trichoderma* spp. from each tissue section on TSA was transferred to malt extract agar (20 g of Difco malt extract, 20 g of Difco agar, and 1 L of water) (MEA). The single colony represented the colony type that grew from the largest area of the tissue piece. Isolates were identified to species 5–7 days later (6,20). One colony of *Fusarium* spp. from each tissue section on NSA was transferred to potato-dextrose agar (PDA) (19) in test tubes. Cultures were exposed to light from fluorescent and black light tubes, 12 hr/day, for at least 7 days for development of colony morphology and color characteristics (19). Isolates of *Fusarium* spp. were also cultured on carnation leaf agar (CLA) under the fluorescent and black lights (25 $\mu E \cdot m^{-2} \cdot s^{-1}$) for 7 days or more to enhance sporulation and aid in identification (19).

The incidence of stalk rot was determined by hand-squeezing the internode above the brace roots of 100 plants in the center two rows on 22 September 1987 and 11 October 1988. Plants that crushed were considered to be rotted (26). The center two rows were harvested for grain yield on 24–25 September 1987 and 13–14 October 1988. Grain yield was based on weight of shelled corn at 15.5% moisture. Weather data for April through September 1987 and 1988 were obtained from the Ohio Autoweather Network station located 0.3 km from the field plot.

Analysis of variance (ANOVA) was used to determine main and interaction effects of tillage (whole plots) and rotation (subplots) on plant stand, yield, and percentage of plants with stalk rot. ANOVA also was used to examine the main and interaction effect of tillage, rotation, and time of sampling (sub-subplot) on recovery of individual fungal species from the three tissue types. Correlation coefficients were calculated to examine the relationship between incidence of stalk rot and yield and the relationship between the percentage of plants yielding *Trichoderma* spp. and those yielding *Fusarium* spp.

RESULTS

Total precipitation from April through September 1987 and 1988 was 69 and 40%, respectively, of the long-time average for this location (Table 1). In 1987, early-season rain (16.3 cm in May and June) allowed normal growth, but a dry July and August (2.2 cm between 14 July and 26 August) caused severe moisture stress. Most of the moisture in August and September 1987 came in a single rain event on 26 and 27 August (4.8 cm). In 1988, there was season-long moisture stress, and leaf rolling was evident during the entire season. Rains in July and August allowed plants to develop during the latter half of the season.

Incidence of stalk rot in 1987 was much greater than in 1988 (Table 2). *F. graminearum* was recovered from stalks of 63% of the plants sampled on the last sampling date (Fig. 1H), and an average of 87.5% of the plants had stalk rot when data were taken 21 days later. *F. moniliforme*, *F. oxysporum* Schlechtend.:Fr., and *F. semitectum* Berk. & Ravenel were present on the last sampling date at levels below 10%. In 1988, *F. moniliforme* and

F. equiseti (Corda) Sacc. were recovered from 51 and 27% of stalk tissues sampled, respectively (Fig. 2H), and the average percentage of plants with stalk rot 21 days later was 19.4. *F. oxysporum* and *F. semitectum* were present at low levels in 1988 (Fig. 2B, E, and H). *F. graminearum*, although extremely prevalent in 1987, was recovered from only two plants in 1988. Other *Fusarium* spp. isolated in 1987 or 1988 included *F. subglutinans* (Wollenweb. & Reinking) P. E. Nelson, T. A. Toussoun & Marass, *F. sambucinum* Fuckel, *F. acuminatum* Ellis & Everh., and *F. solani* (Mart.) Sacc., but the percentage of plants yielding these species was below 5% in both years, and recovery was never correlated with sampling date or tissue type.

Tillage-rotation effects on plant stand, yield, and stalk rot. There was no effect ($P = 0.05$) of tillage or rotation, or their interaction, on plant stand either year of the study (*data not presented*). There was a significant effect of rotation on yield in both years and a significant tillage-rotation interaction effect on yield in 1988 (Table 2). The corn-soybean rotation provided 17 and 50% higher yield in 1987 and 1988, respectively, than the continuous corn plots. Although the interaction effect was significant only in 1988, the treatment combination with the lowest yield both years was no-tillage, continuous corn. The treatment combination with the highest yield was fall-plow, corn-soybean rotation in 1987 and no-till corn-soybean rotation in 1988. The main effect of rotation on the incidence of stalk rot was not significant either year. However, the main effect of tillage was significant at $P = 0.05$ in 1988 and $P = 0.06$ in 1987. The incidence of stalk rot was correlated positively with yield in 1987 ($r = 0.73$, $P < 0.01$, $n = 16$) and not correlated with yield in 1988 ($r = -0.21$, $P = 0.06$, $n = 16$) based on data across all experimental units.

Tillage, rotation, and sample timing effects on recovery of *Fusarium* and *Trichoderma*. Tillage affected the percentage of plants yielding *Trichoderma* spp. (all species combined) from stalk tissues in 1987 and from subcrown mesocotyls, crowns, and stalks in 1988 (Table 3), with the no-tillage treatment having a higher percentage of plants yielding *Trichoderma* spp. Crop rotation influenced recovery of *Trichoderma* spp. from subcrown mesocotyls, crowns, and stalks in 1988 but not in 1987 (Table 3). *Trichoderma* spp. were recovered from more plants grown under the corn-soybean rotation than under continuous corn in 1988. Sampling time did not affect recovery of *Trichoderma* spp. in either year for any tissue type (Figs. 1C, F, and I and 2C, F, and I), but there was a significant response to sampling time for certain species depending on the tissue type examined and the year (Figs. 1A, D, and G and 2A, D, and G). The percentage of plants yielding *T. koningii* and *T. harzianum* was less than 14% at each sampling date. The level of *T. harzianum* obtained from subcrown mesocotyls (Figs. 1A and 2A) and from stalks (Figs. 1G and 2G) decreased with time both years. The effect of sampling time on recovery of *T. hamatum* (Bonord.) Bainier and *T. pseudokoningii* Rifai was generally not significant in 1987 (Fig. 1A, D, and G). In 1988, the percentage of plants yielding *T. hamatum* from subcrown mesocotyls, crowns, and stalks increased with time, and recovery of *T. pseudokoningii* from these tissues appeared to increase to a certain date then decline by the end of the growing season (Fig. 2A, D, and G).

In 1987, none of the two-way interactions (tillage × rotation, tillage × sample time, or sample time × rotation) were significant for isolation of total *Trichoderma* spp. The three-way interaction (sample time × tillage × rotation) was significant for recovery of total *Trichoderma* spp. from crowns in 1987 and stalks in 1988 (*data not presented*), but the analysis for individual species indicated that the three-way interaction was not significant for any of the individual species recovered.

The percentage of total *Fusarium* spp. from subcrown mesocotyls and crowns was statistically higher in plants from the no-tillage treatment than from plants in the fall-plowed treatment (Table 3) in 1987 but not in 1988. There was a higher recovery of *Fusarium* spp. from crowns and stalks in the continuous-corn treatment in 1988 than plants in the corn-soybean rotation treatment (Table 3). Sampling time affected the recovery of total *Fusarium* spp. from all three tissue types in both years, except for subcrown mesocotyls in 1987 (Figs. 1C, F, and I and 2C, F, and I). The percentage of

Table 1. Monthly precipitation and percentage of 30-yr average precipitation for each month at the Ohio Agricultural Research and Development Center Northwest Branch, Custar, during the 1987 and 1988 corn-growing seasons[a]

	1987		1988	
Month	**Precipitation (cm)**	**Percentage of 30-yr average**	**Precipitation (cm)**	**Percentage of 30-yr average**
April	3.8	48	4.8	57
May	7.8	92	1.2	14
June	8.5	92	0.9	10
July	4.3	44	6.1	61
August	8.1[b]	99	4.7	57
September	2.8	38	3.0	42
Total	35.3	69	20.7	40

[a]Data obtained from the Ohio Autoweather Network, the Ohio Agricultural Research and Development Center, Wooster.
[b]Sixty percent of the monthly precipitation for August 1987 fell on two consecutive days, August 26 and 27.

Table 2. Main and interaction effects of tillage and crop rotation on yield and incidence of stalk rot of corn grown on Hoytville silty clay loam near Custar, OH, during 1987 and 1988

	Grain yield (kg/ha)[a]		Percent stalk rot[b]	
Effect	**1987**	**1988**	**1987**	**1988**
Main				
Tillage				
No-tillage	5,356	5,174	81.3	8.3
Fall plow	6,174	4,118	93.8	30.5
LSD[c]	NS	NS	NS[d]	5.4
Rotation				
Continuous corn	5,218	3,100	87.0	21.3
Corn-soybean	6,319	6,193	88.0	17.5
LSD[c]	924	742	NS	NS
Interaction				
Tillage × rotation				
No tillage, continuous corn	4,665	2,955	80.5	9.0
No tillage, corn-soybean	6,048	7,394	82.0	7.5
Fall plow, continuous corn	5,772	3,244	93.5	33.5
Fall plow, corn-soybean	6,589	4,992	94.0	27.5
LSD[c]	NS	1,050	NS	NS

[a]Yield based on grain weight at 15.5% moisture of two 30-m-long rows.
[b]Percent stalk rot determined by squeezing the internode above the base roots of 100 plants per experimental unit 2 days before harvesting for yield.
[c]$P = 0.05$.
[d]Main effect of tillage on incidence of stalk rot in 1987 significant at $P = 0.06$.

plants yielding *Fusarium* spp. increased with sampling time for crown and stalk tissues and was generally highest at the last sampling time. *F. graminearum* in 1987 and *F. moniliforme* in 1988 were the species most commonly isolated from crowns and stalks and were primarily responsible for the increase in percentage of plants yielding *Fusarium* spp. over time.

The only two-way interactions significant for the percentage of plants yielding *Fusarium* spp. were the interactions between sample time and tillage for crown tissue in 1987 and sample time and rotation for stalk tissue in 1988 (*data not presented*). However, most of the interaction effects appeared to relate to the main effect of tillage in 1987 and for rotation in 1988. The two-way interactions were not significant for individual *Fusarium* species, and all three-way interactions were nonsignificant.

Generally, the percentage of plants yielding *Trichoderma* spp. and *Fusarium* spp. was similar for crown and stalk tissues (Figs. 1F and I and 2F and I), and subcrown mesocotyls had a higher percentage of plants yielding *Trichoderma* spp. than *Fusarium* spp. both years (Figs. 1C and 2C). There was no statistically significant ($P = 0.05$) correlation between the percentage of plants yielding *Trichoderma* spp. and the percentage of plants yielding *Fusarium* spp. from subcrown mesocotyl, crown, or stalk tissues in either year.

DISCUSSION

The corn yields obtained for both years of this investigation were lower than normal for this site (4) and probably were the result of low precipitation during the two growing seasons (Table 1). In agreement with previous studies (4,9), corn yield was lower in plots maintained under continuous corn than under a corn-soybean rotation, but unlike other studies at this site (4), there was no significant difference in yield in tilled and no-tilled plots. It appeared that the better water retention capacity of the plots in no-tillage (7,25) lessened the moisture stress and prevented lower yields with no-tillage during the two dry years.

Results of this study indicated a great disparity in the incidence of stalk rot from 1987 (87.5%) to 1988 (19.4%). *F. graminearum* was isolated from a large percentage of stalks in 1987 (63%) when few stalks yielded *F. moniliforme* (17%). In 1988, *F. moniliforme* (51%) was more common in stalks than *F. graminearum* (1%). Kommedahl et al (13) documented the occurrence of *Fusarium* spp. in corn plants during the growing season and suggested that *F. moniliforme* was influenced by other *Fusarium* spp. because its occurrence in stalks decreased as other *Fusarium* spp. increased. This did not occur in our studies because the percentage of stalks yielding *F. moniliforme* either increased (Fig. 2H) with time or stayed the same (Fig. 1H). A similar change in frequency of isolation of *F. graminearum* and *F. moniliforme* in succeeding years has been reported in Colorado (8) where *F. graminearum* was more common in 1982 but rare in 1983 when *F. moniliforme* was common. We

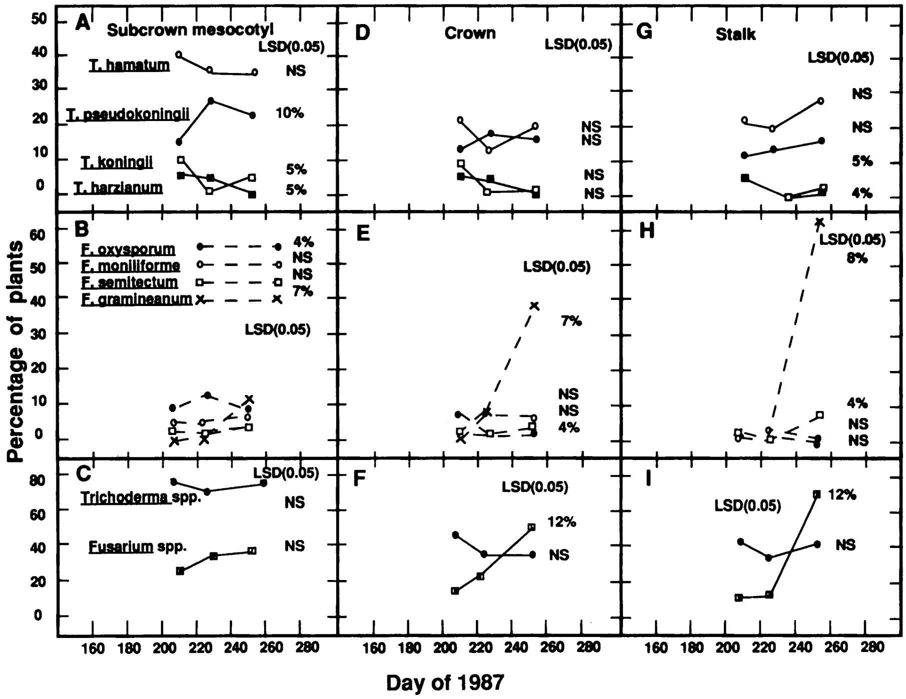

Fig. 1. Main effect of sampling time on percentage of plants yielding **(A, D, G)** *Trichoderma hamatum*, *T. pseudokoningii*, *T. koningii*, and *T. harzianum*; **(B, E, H)** *Fusarium oxysporum*, *F. moniliforme*, *F. semitectum*, and *F. graminearum*; and **(C, F, I)** total *Trichoderma* spp. and *Fusarium* spp. from **(A–C)** subcrown mesocotyl, **(D–F)** crown, and **(G–I)** stalk tissues of corn grown under no-tillage or fall-plowing in combination with continuous corn or a corn-soybean rotation in 1987. Fisher's least significant difference (LSD) values presented for comparison of data points across sampling dates and within fungal species.

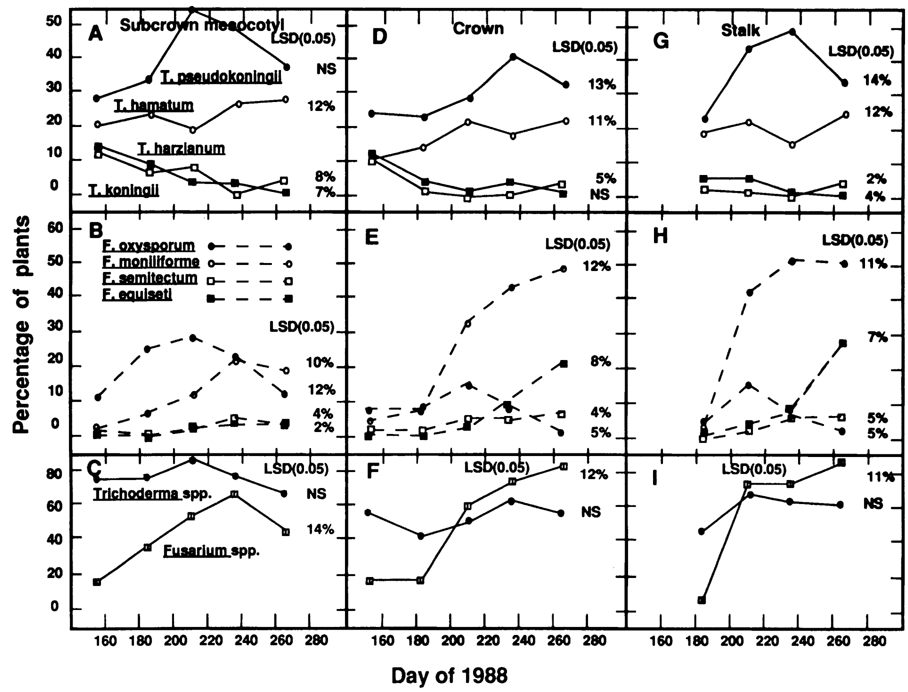

Fig. 2. Main effect of sampling time on percentage of plants yielding **(A, D, G)** *Trichoderma hamatum*, *T. pseudokoningii*, *T. koningii*, and *T. harzianum*; **(B, E, H)** *Fusarium oxysporum*, *F. moniliforme*, *F. semitectum*, and *F. equiseti*; and **(C, F, I)** total *Trichoderma* spp. and *Fusarium* spp. from **(A–C)** subcrown mesocotyl, **(D–F)** crown, and **(G–I)** stalk tissues of corn grown under no-tillage or fall-plowing in combination with continuous corn or a corn-soybean rotation in 1988. Fisher's least significant difference (LSD) values presented for comparison of data points across sampling dates and within fungal species.

suggest that the overall prevalence of these species in corn stalks was influenced by seasonal precipitation.

In the U.S. corn belt, *F. graminearum* is more prevalent in the humid eastern areas than in the drier western regions (3,5). *F. graminearum* and *F. moniliforme* appear omnipresent, and the occurrence of these fungi as stalk rot pathogens is primarily related to the influence of weather on host predisposition (5) rather than to the availability of inoculum. Moisture levels in 1987 were near normal until July when plants were pollinating. The dry conditions that prevailed during the latter half of the growing season predisposed plants to stalk rot by *F. graminearum*. In 1988, severe moisture stress persisted throughout the growing season and, under conditions similar to the western corn-growing areas, *F. moniliforme* was prevalent in stalks. The difference in the levels of stalk rot between the 2 yr could result from *F. graminearum* being significantly more virulent than *F. moniliforme* (3,8) and, thus, cause a greater percentage of the stalks to rot.

Although rotation with soybeans led to significantly higher corn yields, there was no influence on the level of stalk rot in either year (Table 2). The level of stalk rot in fall-plowed plots was higher than in no-tilled plots in both years. A study in Illinois (10) also found lower levels of stalk rot in no-tilled than in conventionally tilled fields, and in Delaware (2), *Fusarium* spp. were isolated more frequently from rotted stalks taken from conventionally tilled than from nontilled fields. These results indicate that tillage had a greater effect on incidence of stalk rot than crop rotation.

Research has shown that corn ears from plants with stalk rot weigh less than ears from plants with healthy stalks (3,11), indicating that stalk rot reduces yield. In our study, the relation between stalk rot and yield was not consistent. There was a significantly positive correlation between stalk rot and yield in 1987 ($r = 0.73$, $P < 0.01$) but the correlation coefficient in 1988 was low and negative ($r = -0.21$, $P = 0.06$). This indicated considerable variation in the relationship between the level of stalk rot and grain yield. The no-tillage, corn-soybean rotation treatment in 1988 had the highest yield (7,394 kg/ha) and a low incidence of stalk rot (7.5%). The no-tillage, continuous corn treatment had the lowest yield (2,955 kg/ha) and a low incidence of stalk rot (9.0%). The low yield was likely attributable to the greater number of barren plants in this tillage-rotation combination, and without the carbohydrate sink attributed to grain filling, plants were not affected by stalk rot (5). These inconsistencies made it highly improbable that a direct correlation existed between stalk rot incidence and yield. We suggest that the soil physical factors associated with the heavy clay soil type had a much greater effect on yield than stalk rot (4,25).

The incidence of *Fusarium* spp. in crowns and stalks increased with time during the growing season. On the last sampling date, the most common *Fusarium* spp. in these tissues were the stalk rot pathogens, *F. graminearum* in 1987 and *F. moniliforme* in 1988. Kommedahl et al (13) reported that the incidence of *Fusarium* spp. in corn roots and stalks increased with time during the growing season, particularly after tasseling. Our results confirmed this report and also agreed with the later study by Windels and Kommedahl that indicated the major stalk rot pathogens colonize corn tissues near the end of the growing season (29).

The role of *Trichoderma* spp. in stalk and root disease of corn is relatively unknown, but most researchers consider *Trichoderma* spp. to be secondary invaders (22,30). Whitney and Mortimore (27) considered *Trichoderma* spp. to be the cause of stalk rot in Ontario. Studies by McFadden and Sutton (17) indicated that *T. koningii*, *T. harzianum*, and *T. hamatum* could cause first-internode lesions on corn seedlings and that populations of *Trichoderma* spp. were higher in soil amended with corn residue than nonamended soil. In our field experiments, the incidence of plants yielding *Trichoderma* spp. from subcrown mesocotyls, crowns, and stalks was fairly high and did not differ significantly across sampling dates. In 1987, tillage and rotation basically had no effect on the percentage of plants yielding *Trichoderma* spp. from plant tissues, but in 1988, significantly more plants yielded *Trichoderma* spp. from the no-tillage treatment than the fall-plowed treatment and the corn-soybean rotation treatment than the continuous-corn treatment. Because of these results, we are inclined to agree with Whitney and Mortimore's conclusion (27) that *Trichoderma* populations increase under tillage systems where corn residues accumulate, but the effect of rotation on these population levels remains unclear. Because the percentage of plants yielding *Trichoderma* spp. was relatively high and remained constant over time, the association of *Trichoderma* spp. in tissues may indicate some type of parasitic relationship with corn, but if this were a pathogenic relationship, we would have expected to detect an increase in the percentage of infected plants during the season.

Fusarium and *Trichoderma* spp. were isolated from the same plant tissues, indicating that these two fungi coexist within the corn plant. However, correlation analysis indicated no significant relationship between the percentage of plants yielding *Fusarium* and *Trichoderma* spp. In each tissue type examined, the incidence of *Trichoderma* spp. remained constant, whereas the incidence of *Fusarium* spp. generally increased over time. In studies where *Trichoderma* spp. have been shown to parasitize pathogenic fungi, the populations of *Trichoderma* spp. increased and the pathogen populations decreased (16). In our study, these fungi appeared to occur independently within corn tissues, and the *Trichoderma* spp. did not appear

Table 3. Main effect of tillage and crop rotation on percentage of corn plants yielding *Trichoderma* and *Fusarium* spp. from subcrown mesocotyl, crown, and stalk tissues collected from Hoytville silty clay loam near Custar during 1987 and 1988

	Subcrown mesocotyl		Crown		Stalk	
Year and main effect	***Trichoderma* spp.**	***Fusarium* spp.**	***Trichoderma* spp.**	***Fusarium* spp.**	***Trichoderma* spp.**	***Fusarium* spp.**
1987						
Tillage						
No tillage	72[a]	43	47	40	45	30
Fall plow	73	21	35	23	38	33
LSD[b]	NS	6	NS	7	6	NS
Rotation						
Continuous corn	75	33	44	33	43	31
Corn-soybean	69	31	38	30	40	31
LSD[b]	NS	NS	NS	NS	NS	NS
1988						
Tillage						
No tillage	82	41	56	48	60	55
Fall plow	69	45	37	56	41	65
LSD[b]	5	NS	15	NS	13	NS
Rotation						
Continuous corn	70	44	43	57	45	67
Corn-soybean	81	43	50	46	57	53
LSD[b]	9	NS	7	10	12	8

[a] Mean percentage based on isolations from 10 plants per experimental unit with three sample times in 1987 and five sample times (four sample times for stalks) in 1988 of a split-plot design with four replication blocks.
[b] $P = 0.05$.

to have any inhibitory activity against the *Fusarium* spp. that cause stalk rot.

ACKNOWLEDGMENTS

Salaries and research support were provided by state and federal funds appropriated to the Ohio Agricultural Research and Development Center and The Ohio State University. We thank Paul Houdashelt, Audrey Johnston, John Nixon, and Brent Lehman for technical assistance.

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