Irrigation Management and Root and Stalk Rot of Corn

DONALD R. SUMNER, Department of Plant Pathology, and JAMES E. HOOK, Department of Agronomy,
University of Georgia, Coastal Plain Station, Tifton 31793

ABSTRACT

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Irrigation treatments did not influence populations of *Pythium* spp., *Rhizoctonia solani*, or binucleate *Rhizoctonia*-like fungi or root disease severity at pollination. Root disease severity at pollination was greater following peanut in Tifton loamy sand than in Bonifay sand, but there were very few root lesions following soybean in either soil. Rainfall and irrigation over years and soil type accounted for 30% of the variation in stalk rot severity. Stalk rot increased with decreasing rainfall during the vegetative period and with increased rainfall during the reproductive period. In 2 yr of experiments, there was significantly more stalk rot following wheat-soybean or peanut on Bonifay sand (62%) than on Tifton loamy sand (38%). In 1983, there was a significant positive linear relationship between stalk rot and yield on Bonifay sand ($R^2 = 0.48$) but not on Tifton loamy sand.

Stalk rot occurs in corn in Georgia each year and causes losses in harvestable yield when stalks lodge and ears cannot be gathered by mechanical harvesting. The most common pathogen causing cornstalk rot is *Fusarium moniliforme* Sheld., but numerous other fungi are isolated from roots and stalks of corn in Georgia (17,18). Irrigated cropland in Georgia increased from 58,500 ha in 1970 to 443,400 ha in 1982, and about 160,000 ha of corn in the coastal plain is grown with supplemental overhead irrigation (4). Research in other areas indicates that soil moisture and irrigation management may influence cornstalk rot severity (2,11,15,16). In Iowa, dry rot caused by *Diplodia zeae* was worse in years with high rainfall and temperature (10). This research was initiated to determine the influence of irrigation management on root and stalk rot of corn grown on soils in the Georgia coastal plain and to develop strategies for producing high yields of corn with good standability.

MATERIALS AND METHODS

Treatments and design. The influence of irrigation on corn production, stalk rot, and populations of *Pythium* spp., *Rhizoctonia solani* Kühn, and binucleate *Rhizoctonia*-like fungi in soil was examined in replicated field experiments for 3 yr (1981, 1982, and 1983) at the Coastal Plain Experiment Station, Tifton, GA. Four experiments were on a Bonifay sand (loamy, siliceous, Thermic, grossarenic Plinthic Paleudult) and two were on a Tifton loamy sand (fine loamy, siliceous, Thermic Plinthic Paleudult). Irrigation treatments were applied to each plot (12.2 × 12.2 m) by a solid-set system with two overlapping sprinklers. All replicates of a treatment were irrigated simultaneously. Table 1 summarizes the crop management and field design for each experiment. Plots were turned 25 cm deep with a moldboard plow and leveled. Broadcast applications of fertilizer were not incorporated. Corn was planted in 90-cm rows (60-cm in 1983) with starter fertilizer banded beside each row. In experiments 1 and 2, 2.2 kg a.i./ha of carbofuran was spread in an 18-cm band over the row to control soil insects. Within 48 hr of planting, 4.5 kg a.i./ha of butylate plus 0.84 kg/ha of cyanazine plus 0.84 kg/ha of atrazine was applied in 0.3–0.7 cm of water by sprinklers to control weeds. For experiments 3–6, 6.6 kg a.i./ha of fenamiphos was applied in 1.5 cm of water by sprinklers to control nematodes. Plots were sidedressed with NK fertilizers when corn was 0.2–0.5 m tall and fertilized with N added to irrigation water when corn was 1.2 and 1.8 m tall to total the amount of fertilization indicated in Table 1. Irrigation treatments used in this study were as follows:

On demand by tensiometers. When the average matric suction of half or more of the tensiometers in the control zone exceeded 30 kPa (0.3 bars), enough water was added to bring the soil water content of the control zone to 90% of the water-holding capacity. Control zones used for various treatments were shallow (15–30 cm), deep (45–60 cm), or variable (15–60 cm). In the 2-day delay treatment, water was applied 48 hr after tensiometers of the control zone indicated a need for irrigation. In 1983, corn was not irrigated

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for 5-wk periods during the late vegetative, pollination, or grain fill stages but was applied on demand at other times. These treatments provided additional periods of moisture stress within the growing season to more fully evaluate the influence of seasonal soil moisture patterns on yield and disease.

Lambert model. Water was applied when indicated by the meteorological-based irrigation scheduling and forecasting program of Lambert et al (9). The Lambert model uses temperature, solar radiation, plant age, and calculated soil moisture to predict evapotranspiration and adjust soil moisture. If the predicted soil moisture declines below a preset depletion limit (50–70% of total available water), irrigation is recommended.

Calculated risk model. Water was applied when indicated by an economics-based irrigation scheduling model. This model predicted evapotranspiration from temperature, solar radiation, plant height, and calculated soil moisture. It then predicted the yield, assuming normal rainfall but no irrigation. If the potential profits lost by not irrigating exceeded the cost of irrigating, the model recommended irrigation. Inappropriate economic input led to application of only half as much water as with shallow tensiometers.

Wilting. Water was applied when some leaf rolling was visible on more than half the corn plants by 1000 hours Eastern Standard Time.

Fixed irrigation. Soil water was fully replenished just before tassel emergence and 1 wk after pollination was complete; otherwise, no water was added.

Sampling and procedures. Soil water pressure was measured daily with mercury manometer tensiometers at depths of 10, 20, 30, 45, 60, 75, 90, and 120 cm and gypsum blocks at depths of 20, 30, 45, 60, and 75 cm. These were located in the centers of at least two replicates of each treatment.

The number of "days with dry soil," as used in this text, was calculated from the tensiometer observations and refers to the number of days when soil water pressure fell below −30 kPa for each tensiometer depth. The number of days with dry soil was summed for the 42 days before pollination (vegetative stage) and for the 35 days after pollination (reproductive stage). For these periods, there were continuous daily observations of soil water pressure in each experiment.

Soil water content was observed by gravimetric sampling at 2- to 4-wk intervals in Lambert model-treated plots as required for model reinitiation. Air temperatures, solar radiation, relative humidity, and wind run were measured continuously throughout each experiment; pan evaporation and rainfall were recorded daily.

Grain yield samples were taken by hand harvesting 1.8 × 6.1 m/plot at high moisture (30–40%) 1 wk before the combine harvest. Ears were dried, shelled, and weighed. Grain yields were expressed as weight of shelled grain adjusted to 15.5% moisture content.

Soil was sampled for analysis of background populations of soilborne pathogens in each plot of each experiment in April or May before irrigation treatments were begun. Additionally, soil was sampled in each plot during November 1982 for experiments 3–5. These plots were fallow from harvest until sampling. In 1983, soil was sampled at harvest for experiments 6 and 7. In 1981 and 1982, selected plots in experiments 1–5 were sampled during the season just before and 5–48 hr after irrigating to assess short-term changes in *Pythium* populations. For each sampling, a soil tube was used to take 10 cores (2.5 ×15 cm) in the row in the central area of each plot. After mixing, soil from each plot was assayed on PARP medium for *Pythium* spp. (7), and multiple-pellet samples were assayed on tannic acid-benomyl medium for *R. solani* and binucleate *Rhizoctonia*-like fungi (17). *F. moniliforme* is ubiquitous in cornfield soil in southern Georgia (D. R. Sumner, *unpublished*), and no attempt was made to measure populations of *F. moniliforme* or other *Fusarium* spp. in soil.

Cornstalk rot was determined empirically in experiments 2–7 by hand squeezing the second internode above the ground within 1 wk of harvest. A stalk was considered rotted if the rind and pith were soft and could be collapsed by hand. Twenty-five adjacent stalks in each of two rows in the central area of each plot were sampled and the percentage of stalk rot was calculated. Lodging counts were taken on the same stalks. A stalk was considered lodged if it had fallen or broken over and the plant was touching the ground. Lodging was caused primarily by stalk rot, but insect and wind damage were also contributing factors.

Root disease severity was determined at midsilk in experiment 6 and 2 wk after midsilk in experiment 7 in 1983. Ten plants were dug with a shovel, and roots 20–25 cm deep were rated in each plot on a scale of 1–5, where 1 = <2, 2 = 2–10, 3 = 11–50, and 4 = >50% discoloration and decay; 5 = dead plant. Brace and crown roots were counted, and the number of brace and crown roots with lesions 0–5, 5–10, or >10 cm below the ground was recorded. Root growth was estimated for comparisons within experiments on an empirical scale of 1–5, where 1 = very poor, 2 = poor, 3 = fair, 4 = good, 5 = excellent growth.

In 1982, root disease severity was determined at maturity on 10 plants per plot in one or two plots from each of three irrigation treatments (shallow tensiometers, deep tensiometers, and Lambert model) and unirrigated plots in experiment 5. Fungi were isolated from roots and vascular bundles of four plants in each of two irrigated plots of experiment 3 and five plants from each of three treatments in experiment 7 (irrigated full season, full season except weeks 6–10, and unirrigated). These treatments represented a wide range of soil moisture conditions.

Data were analyzed by least-square analysis of variance, general linear models, linear correlation, linear regression, and stepwise multiple-regression statistical procedures. Arc sine, square root, and logarithmic transformations were used for analysis where appropriate, but only the nontransformed means are presented in the tables.

RESULTS

Populations of soilborne pathogens. *Pythium irregulare* Buis. predominated in soil in April, May, June, and November and *P. aphanidermatum* (Edson) Fitzp. and other unidentified *Pythium* spp. predominated in July. Populations of *Pythium* spp. did not change significantly 24 hr after irrigation, and irrigation management did not influence populations of *Pythium* spp. in soil at harvest or in November (4 mo after harvest). Populations ranged from 0 to 73 colony-forming units (cfu) per gram of soil among treatments, and most soil samples had 2–30 cfu per gram. Populations were similar to those observed in soil with corn in other years but were lower than populations

Table 1. Crop management and experimental design for irrigation experiments

Exp.	Year	Soil	Corn hybrid	Dates			Population at harvest (plants/ha)	Fertilizer (kg/ha)						Exp. design[a]	No. of replicates
				Planting	Pollination	Harvest		N	P	K	Mg	S	Zn		
1	1981	Bonifay	Funks G4507A	11 Mar.	28 May	14 July	53,740	274	60	225	86	129	6	RCBD	4
2	1981	Bonifay	Funks G4507A	14 Apr.	16 June	4 Aug.	72,233	257	59	216	66	107	6	RCBD	4
3	1982	Bonifay	DeKalb XL71	10 Mar.	27 May	13 July	81,982	315	58	202	43	113	6	RCBD	4
4	1982	Bonifay	DeKalb XL71	10 Mar.	27 May	13 July	82,935	315	58	202	43	113	6	RCBD	4
5	1982	Tifton	DeKalb XL71	10 Mar.	28 May	14 July	86,075	315	25	202	43	113	6	RCBD	4
6	1983	Bonifay	DeKalb XL71	23 Mar.	15 June	26 July	91,094	290	58	163	38	47	6	CRD	5
7	1983	Tifton	DeKalb XL71	23 Mar.	15 June	20 July	93,585	320	0	186	0	0	1	CRD	5

[a] CRD = completely random design, RCBD = randomized complete block.

observed in legumes.

Populations of *R. solani* and *Rhizoctonia*-like fungi were low and variable (0–30 cfu/100 g) and were not influenced by irrigation management. The predominant basidiomycetes were *R. solani* AG-4 (a pathogen on numerous crops other than corn), AG-2 type 1, and AG-2 type 2 (the crown and brace root pathogen of corn); binucleate *Rhizoctonia*-like CAG-2 and CAG-5; *R. zeae* Voorhees; and *Laetisaria arvalis* Burdsall.

Root diseases. On Bonifay sand, plants with stalk rot that were examined in 1982 at harvest usually had severe root rot. Crown and brace roots were pink to red and frequently hollow, and secondary and tertiary fibrous roots were often completely disintegrated. Plants without stalk rot had moderate to severe root rot. In other experiments, root discoloration and decay were found on roots in soil cores taken as deep as 90 cm, but roots deeper than 25 cm were not evaluated in these experiments.

In 1983, root disease severity at midsilk or 2 wk after midsilk was negligible and not influenced by irrigation treatment (Table 2). In experiment 6 on Bonifay sand, root growth and plant height were greater in all irrigated treatments than in unirrigated plots, and full-season irrigation treatments were superior to several of the treatments with discontinuous irrigation (Table 2). In contrast, in experiment 7 on Tifton loamy sand, there were no differences in root growth and plant height among treatments. On Bonifay sand, the number of white crown and brace roots per plant was greatest with full-season irrigation and was correlated with height and grain yield ($r = 0.71$ and 0.52, respectively, $P = 0.01$). The number of white crown and brace roots per plant in Tifton loamy sand also correlated with height and grain yield ($r = 0.41$ and 0.40, respectively, $P = 0.01$) but was not related to irrigation treatments.

Cornstalk rot. Disease severity varied greatly among tests and among years. In 1981, stalk rot severity was light to moderate (7–22%), but in 1982 and 1983, stalk rot was moderate to severe in all treatments (Tables 3 and 4). Rainfall and irrigation over years and soil type accounted for 30% of the variation in stalk rot severity. Stalk rot increased with decreasing rainfall during the vegetative period and with increased rainfall during the reproductive period. In the experiments on Bonifay soil, this relationship to rainfall was supported by soil moisture observations. Stalk rot increased as the number of days with dry subsoil during the reproductive stage decreased ($R^2 = 0.24$–0.30). On Tifton loamy sand, there was an interaction between years and soil moisture; therefore, there was no overall relationship between stalk rot and observed soil moisture.

There was no relationship between stalk rot and days with rainfall or evaporative demand (potential evapotranspiration × crop factor) (6) on either soil. Since evaporative demand integrates the effects of temperature and solar radiation, no separate comparison was made between stalk rot and solar radiation (or cloudiness).

In 1982 and 1983, stalk rot increased on Bonifay sand as the number of days with topsoil and subsoil dryness decreased, especially during reproduction ($R^2 = 0.21$–0.23). In 1983, there was a significant positive linear relationship between stalk rot and yield on Bonifay sand ($R^2 = 0.48$) (Table 3). Isolations were made from rotted stalk tissues and pink, rotted roots of selected plants in irrigated treatments in 1982. *R. solani, R. zeae, F. moniliforme*, and *Helminthosporium* spp. were isolated from stalks and *R. solani, F. moniliforme*, and *P. irregulare* from roots.

On Tifton loamy sand, stalk rot increased as the number of days with soil dryness during reproduction decreased in 1982 ($R^2 = 0.41$), but in 1983, stalk rot increased as the number of days with soil dryness during reproduction increased ($R^2 = 0.33$). The difference may be related to the influence of environmental conditions on different stalk rot fungi. In 1983, *Macrophomina phaseolina* (Tassi)

Table 2. Irrigation scheduling and root disease severity, plant height, and root growth in 1983

	Experiment 6 (Bonifay sand)					Experiment 7 (Tifton loamy sand)				
		Crown and brace roots					Crown and brace roots			
Irrigation treatments	RDS[x]	White	With lesions	Height (cm)	Root growth[y]	RDS	White	With lesions	Height (cm)	Root growth
Tensiometer										
15–60 cm	1.0	209 a[z]	1	230 ab	5.0 a	1.3	143	31	229	4.4
15–60 cm, 2-day delay	1.0	186 bc	1	221 abc	4.8 ab	1.2	145	26	240	4.4
15–60 cm, except late vegetative	1.0	168 c	2	155 ef	4.0 cd	1.1	157	10	252	4.6
15–60 cm, except pollination	1.0	182 c	1	180 bcd	4.6 abc	1.3	134	28	245	4.2
15–60 cm, except grain fill	1.0	184 bc	1	208 de	4.6 abc	1.3	143	30	236	5.0
15–30 cm, 2/3 replacement	1.0	220 a	2	241 a	5.0 a	1.1	168	9	258	4.4
45–60 cm, 2/3 replacement	1.0	191 bc	1	191 cd	4.4 abc	1.1	166	10	264	4.4
Two irrigations: pretassel, late pollination	1.0	193 bc	5	205 bcd	4.2 bc	1.2	151	17	254	4.2
No irrigation	1.0	134 d	1	140 f	3.4 d	1.2	160	18	233	4.2

[v] Average of 10 plants per plot at midsilk in experiment 6 and 2 wk past midsilk in experiment 7. Roots were removed 20–25 cm deep by hand with a shovel.

[w] Total for 10 plants.

[x] Root disease severity on a scale of 1–5, where 1 = <2, 2 = 2–10, 3 = 11–50, and 4 = >50% discoloration and decay; 5 = dead plant.

[y] Empirical scale of 1–5, where 1 = very poor, 2 = poor, 3 = fair, 4 = good, and 5 = excellent root growth.

[z] Numbers followed by the same letter are not significantly different ($P = 0.05$) according to Duncan's multiple range test. No letters indicates no significant differences.

Table 3. Irrigation scheduling and cornstalk rot in 1981–1982

	Experiment 2 (1981)		Experiment 3 (1982)			Experiment 4 (1982)			Experiment 5 (1982)		
Irrigation treatment	Stalk rot (%)	Yield (t/ha)	Stalk rot (%)	Yield (t/ha)	Moisture stress[x]	Stalk rot (%)	Yield (t/ha)	Moisture stress	Stalk rot (%)	Yield (t/ha)	Moisture stress
Lambert model	10	9.2 ab[y]	44 b	12.6	N	66	12.1 a	N	39 a	12.3 a	N
Tensiometer											
15–30 cm[z]	12	9.8 a	74 a	13.4	N	72	11.6 a	Sl	40 a	12.5 a	Sl
15–30 cm, 2-day delay	...	...	...	...	...	...	...	...	30 a	12.2 a	N
45–60 cm	10	7.9 b	42 b	12.8	M	54	11.6 a	M	38 a	11.6 a	Sl
15–60 cm	...	...	74 a	12.0	N	...	...	...	...	...	...
Visible wilt	22	9.2 ab	...	...	...	...	...	...	...	...	...
Calculated risk model	7	5.7 c	...	...	...	...	...	...	...	...	...
No irrigation	...	...	...	...	...	44	6.6 b	Sev	14 b	7.5 b	Sev

[x] Based on tensiometer readings, relative amount of stress for the entire season; N = none, Sl = slight, M = moderate, Sev = severe.

[y] Numbers followed by the same letter are not significantly different ($P = 0.05$) according to Duncan's multiple range test. No letters indicates no significant difference.

[z] Irrigated when the average matric suction of two depths exceeded 30 kPa.

Goid. (73%) was the fungus isolated most frequently from stalks from unirrigated plots, whereas *Helminthosporium* spp. (47%), *Fusarium* spp. (40%), *F. moniliforme* (20%), and *R. zeae* (13%) were isolated most frequently from stalks in plots irrigated full season. Charcoal rot (caused by *M. phaseolina*) appeared to be the primary stalk rot in unirrigated plots, but it was rarely observed in irrigated plots.

In 1982 and 1983, there was significantly more stalk rot in plots following wheat, soybean, or peanut on Bonifay sand (62%) than on Tifton loamy sand (34%). In 1983 on Tifton loamy sand, there was significantly more stalk rot in plots following peanut (38%) and wheat-soybean (33%) than following corn (19%). Root disease severity was greater following peanut on Tifton loamy sand than on Bonifay sand, but there were only occasional lesions on roots following soybeans on both soils (Table 5).

DISCUSSION

Root rot precedes stalk rot in corn (19), and stalk rot usually does not occur until senescence of pith and rind tissues as plants mature (12–14). Any factor that increases plant stress may lead to early senescence and increased stalk rot (2). In other research (2), abundant moisture in the vegetative stage that promoted ear development and high kernel numbers followed by lack of moisture during pollination and grain fill favored stalk rot, whereas drought during the vegetative stage followed by adequate rain was unfavorable for stalk rot, and avoiding water stress during grain fill reduced stalk rot. Researchers in California found that mild water stress (indicated by plant measurements) during the pretassel or postpollination stages caused more stalk rot than mild water stress during the grain-fill stage. They suggested that predisposition by mild early-season water stress permanently increases the probability of chronic water stress later in the season, thus leading to earlier senescence and increased susceptibility to stalk rot (15). In contrast to their hypothesis, we sometimes observed significantly more stalk rot when soil moisture was not limiting than when soil moisture was limiting early in the corn season, with no differences in yield.

Because of rainfall variability, each season's soil-water regime varies. Rainfall patterns often make up for weaknesses in scheduling techniques, turning a dry period (that would have occurred with a scheduled weakness) into an adequate period. Our studies varied with year and soil type, but stalk rot was associated with increased soil dryness in the vegetative period and with decreased soil dryness during the reproductive period on Bonifay sand. On Tifton loamy sand, the same trend occurred in 1982, but the opposite was true in 1983, when charcoal rot was abundant in treatments with drought stress during grain fill. Our results on Bonifay sand corroborate research in Nebraska on sandy and silty clay loamy soils, where stalk rot was greater in irrigation treatments that kept soil moisture near or above field capacity (matric suction <30 kPa) than in unirrigated treatments or treatments with intermediate levels of irrigation (16).

The relationship between stalk rot and yield is controversial. Increased stalk rot was associated with decreased yield in Illinois (5,8), Kansas (3), and Minnesota (20) but with increased yield in California (15) and with both increased (16) and decreased (21) yield in Nebraska. The greatest stalk rot in our experiments frequently occurred in irrigation treatments that were favorable for high yields. Stalk rot has been associated with translocation of sugars from stalk tissues to kernels (1), and it is possible that the same soil moisture regimes that promote good growth and high yields may also promote early senescence of stalk tissue and increased stalk rot. We attempted to find methods of irrigation management that would produce high yields without concurrent increased stalk rot and lodging, but we were not successful. In one year (experiment 3), frequent shallow irrigation caused more stalk rot than infrequent deep irrigation, with a comparable yield. The next year (experiment 6), frequent shallow irrigation produced a greater yield than infrequent deep irrigation, but stalk rot was comparable. Other factors that could

Table 4. Irrigation scheduling and cornstalk rot in 1983

	Experiment 6				Experiment 7		
Irrigation treatment	Stalk rot (%)	Lodging (%)	Yield (t/ha)	Moisture stress[y]	Stalk rot (%)	Yield (t/ha)	Moisture stress
Tensiometers							
15–60 cm	81 ab[z]	30 abc	7.0 a	N	14 c	8.7 abc	Sl
15–60 cm, 2-day delay	82 ab	40 ab	7.0 a	N	28 abc	10.4 a	Sl
15–60 cm, except late vegetative	61 c	13 cd	5.7 d	Sl	11 c	9.6 ab	M
15–60 cm, except pollination	36 d	2 d	3.3 c	M	24 bc	7.3 c	Sev
15–60 cm, except grain fill	27 d	1 d	2.4 c	Sev	43 a	8.4 bc	Sev
15–30 cm, 2/3 replacement	82 a	24 bcd	7.4 a	N	26 abc	9.4 ab	Sl
45–60 cm, 2/3 replacement	82 ab	49 a	5.7 b	N	29 abc	8.0 bc	Sl
Two irrigations: pretassel, late pollination	63 b	16 cd	5.4 b	Sl	39 abc	9.3 ab	Sl
No irrigation	58 c	5 cd	2.7 c	Sev	46 a	7.1 c	Sev

[y] Based on tensiometer readings, relative amount of stress for the entire season; N = none, Sl = slight, M = moderate, Sev = severe.

[z] Numbers followed by the same letter are not significantly different ($P = 0.05$) according to Duncan's multiple range test. No letters indicates no significant differences.

Table 5. Root disease severity, stalk rot, growth, and yield in corn following different crops[v]

				Crown and brace roots[x]							
					With lesions (depth, cm)						
Previous crop	Soil	No. of plots	RDS[w]	White	0–5	5–10	10	Height (cm)	Root growth[y]	Stalk rot (%)	Yield (t/ha)
Peanut	Tifton loamy sand	13	1.2 a[z]	155 b	2	11 a	9 a	265 a	4.6	38 b	9.2 a
	Bonifay sand	16	1.0 b	182 a	0	1 b	1 b	192 b	4.6	61 a	5.1 b
Soybean	Tifton loamy sand	13	1.0	169 b	0	2	4	247 a	4.5	34 b	9.2 a
	Bonifay sand	29	1.0	187 a	0	0	2	199 b	4.4	65 a	5.2 b

[v] Average of 10 plants per plot at midsilk in experiment 6 and 2 wk past midsilk in experiment 7. Root were removed 20–25 cm deep by hand with a shovel.

[w] Root disease severity on a scale of 1–5, where 1 = <2, 2 = 2–10, 3 = 11–50, and 4 = >50% discoloration and decay; 5 = dead plant.

[x] Total for 10 plants.

[y] Empirical scale of 1–5, where 1 = very poor, 2 = poor, 3 = fair, 4 = good, and 5 = excellent root growth.

[z] Numbers within crops followed by different letters are significantly different ($P = 0.05$) according to a t test. No letters indicates no significant differences.

have caused year-to-yield variability include plant density, hybrid differences, temperature, solar radiation, humidity, and soil fertility.

Some of the conflicting results in cornstalk and root rot research may be related to the numerous fungi involved. Even though *F. moniliforme, D. zeae, Gibberella zeae, M. phaseolina, Helminthosporium* spp., and *R. zeae* may be primarily saprophytes that enter senescent tissues, they may differ in their ability to colonize root and stalk tissues at different stages in the senescing process, and they may react differently to environmental variables.

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