Effects of Crop Management Practices on Common Root Rot of Winter Wheat

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ABSTRACT

Broscious, S. C., and Frank, J. A. 1986. Effects of crop management practices on common root rot of winter wheat. Plant Disease 70:857-859.

Crop management practices were evaluated for individual and interaction effects on common root rot of wheat in Pennsylvania. Four management practices were incorporated into replicated field experiments conducted on four farms located in Centre County and Lancaster County, PA, during the 1981 and 1982 growing seasons. Management variables tested were two planting depths (2 and 4 cm), two row spacings (13 and 18 cm), three seeding rates (101, 168, and 235 kg/ha), and four spring nitrogen fertilization levels (0, 34, 67, and 101 kg/ha). The management practices did not interact consistently over the range of values tested to influence the intensity of common root rot, indicating that the effects of a management practice could be considered individually. Planting depth was the only factor that consistently influenced the intensity of common root rot. In all experiments, seed planted 4 cm deep produced plants with longer subcrown internodes with higher disease intensity than those planted 2 cm deep; however, yields were not significantly lower in the deeper planting. *Bipolaris sorokiniana* and *Fusarium* spp. were the fungal pathogens most frequently isolated from lesions on subcrown internodes. The frequency of *Pythium* spp. isolation was higher in 1981, when soil moisture was more uniform throughout the season.

Common root rot is a disease problem in many wheat-producing areas of North America caused by a complex of several soilborne pathogens (15). In Pennsylvania, the most prevalent and destructive of these organisms is *Bipolaris sorokiniana* (Sacc. in Sorok.) Shoem. (syn. *Helminthosporium sativum* Pamm., King, & Bakke; teleomorph *Cochliobolus sativus* (Ito & Kurib.) Drechs. ex Dast.) (J. A. Frank, *unpublished*).

Although symptoms of the disease are often inconspicuous, it can significantly reduce the yield and quality of wheat (2). Tinline and Ledingham (19) reported yield reductions of 2.5–5.6% depending on the cultivar, and Sallans (13) estimated that common root rot can decrease yields as much as 17.8%.

Heavy infestations of *B. sorokiniana* in the soil or on the seed may result in failure of the seedlings to emerge from the ground (23). Postemergence infection can cause stunting or blighting of seedlings and a tan discoloration of the coleoptile. Severe infection causes the entire crown and basal culm to become necrotic, and the subcrown internodes may also develop necrotic lesions (23), which can reduce the functioning of the seminal root system. Plants that survive seedling-stage infection usually mature but yield poorly because of a weakened root system and reduced tillering (22,23). Infection of plants later in the season decreases the size, number, and quality of kernels (2,10).

Crop management practices have been recognized as factors affecting common root rot. Because recovery from seedling infection requires sufficient nutrients and favorable environmental conditions (14), host nutrition can affect the severity of infection and the subsequent level of yield reduction. Simmonds (16) inoculated wheat seedlings with *H. sativum* and found that injury from infection was reduced when an adequate nitrogen supply was available to the plants. Excessive fertilization, however, could increase vegetative growth and cause rapid depletion of soil moisture through transpiration, thereby predisposing the plants to infection by *H. sativum* (23). Ledingham (8) found that nitrogen applications increased root rot incidence by 15–19%.

Manipulation of seeding depth and rate may be an effective method of reducing infection by *H. sativum*. Tinline (18) and Ledingham et al (10) observed that root rot severity increased as planting depth increased. Greaney (4) planted seeds 2.5, 5.1, 7.6, and 10.2 cm below the soil surface and found that disease severity increased with planting depth. However, planting depth did not affect the frequency with which Broadfoot (1) isolated *H. sativum* from wheat roots, but he proposed that an increase in planting depth might result in more fungal damage to the plants.

Machacek (11) made root rot surveys in Manitoba, Canada, and indicated that an increase in depth and density of the planting of wheat appeared to increase the incidence of common root rot. After increasing the density of spring wheat plots, Greaney (4) observed an increase in the severity of infection that he attributed to reduced plant vigor from greater competition. Broadfoot (1), Sallans (14), and Tinline (18) have all reported that variation in seeding rate has no significant influence on damage caused by *H. sativum*.

Although seed treatments are somewhat effective in reducing the severity of infection by seedborne *B. sorokiniana*, manipulation of crop management practices could complement the effectiveness of fungicides by reducing the effects of soilborne *B. sorokiniana*. In addition, such control methods could be adopted by growers at little or no cost.

Specific wheat management practices have been reported to affect common root rot; however, the individual practices were not evaluated in combinations with other practices for possible interactions in relation to disease development. Also, most of the work has been conducted in Canada with little or no experimental evidence as to the applicability of those results to other environments. The purpose of this study was to evaluate the influence of row spacing, seeding depth, seeding rate, and spring nitrogen fertilization and their interactions on the severity of common root rot of wheat grown in the northeastern United States.

MATERIALS AND METHODS

Field experiments were conducted during 1981 and 1982 on farms in Centre and Lancaster counties, in central and southeastern Pennsylvania, respectively. Because the winters in Lancaster County are shorter and milder than those in Centre County, the influence of gross climatic differences or treatment effects could be observed. Experiments in Centre County were planted from 25 September to 1 October, whereas those in Lancaster County were planted between 6 and 9 October. Henceforth, experiments will be referred to by the following codes: C81 (Centre County, 1981), C82 (Centre County, 1982), L81 (Lancaster County, 1981), and L82 (Lancaster County, 1982).

The factors and their levels evaluated in this study were two planting depths (2 and 4 cm), two row spacings (13 and 18 cm), three seeding rates (101, 168, and 235

Contribution 1530, Department of Plant Pathology, Pennsylvania State Agricultural Experiment Station. Approved for publication as Journal Series Paper 7256.

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Accepted for publication 29 January 1986.

kg/ha), and four spring nitrogen fertilization levels (0, 34, 67, and 101 kg/ha). A factorial treatment arrangement was used within a randomized complete block design replicated three times.

Wheat was the previous crop in all fields to ensure the presence of soilborne and debrisborne inoculum, and all fields were tilled in late summer with a moldboard plow. Twenty-two kilograms of actual nitrogen was applied per hectare in the fall and incorporated during secondary tillage operations. Individual fields also received limestone, phosphorus, and potassium according to soil test recommendations before planting. The soft red winter wheat (*Triticum aestivum* L.) cultivar Roland (CI 17716) was planted in all experiments with a tractor-mounted drill (H&N Equipment, Colwich, KS) that was custom-built to permit row-spacing adjustment and to give precise control of seeding rate and depth. Individual plots were 1.5 m wide and 14.6 m long with seven rows in the wide-row plots and nine rows in the narrow-row plots. At the earliest opportunity in the spring, nitrogen in the form of ammonium nitrate was applied to individual plots with a 1.5-m-wide hand-pulled spreader.

The severity and extent of lesions observed on the subcrown internode (SCI) of plants was the basis for assessing common root rot. At growth stage 9 (last leaf visible) of the Feekes scale (7), all plants in a single 30-cm-long section of row were sampled from each plot (about 15–48 plants, depending on location and year). Plants were removed from the soil with a shovel, with care taken to preserve the integrity of the SCI and roots. Plants with adhering soil were placed in plastic bags and taken to the laboratory, where the soil was removed from the root system by washing under a stream of water. SCI were examined and classified using a method similar to that described by Ledingham (9). On the basis of the area of the SCI that was covered with lesions, plants were assigned to one of the following four categories: 0 = clean (Cl), 0% of SCI area covered with lesions; 1 = slight (Sl), >0–25%; 2 = moderate (Mo), >25–50%; and 4 = severe (Se), >50% of SCI area covered with lesions. The number of plants and percentage of total plants for each category were determined. The disease intensity for each plot was calculated using the formula: $[(\%Sl \times 1) + (\%Mo \times 2) + (\%Se \times 4)]/400$. Disease intensity values range from 0 (no lesions on any SCI) to 1 (all SCI covered with >50% lesions).

SCI that showed lesions were sampled at random from plants and surface-sterilized for 2 min in 1% NaOCl. After rinsing in distilled water, internodes were placed on acidified 1.5% water agar in petri plates. Plates were incubated at 20 C for 10–15 days and fungal colonies identified to genus. The percent frequency of isolation was calculated for each of the fungal genera pathogenic to wheat.

Data for disease intensity were subjected to analysis of variance, with sums of squares for main and interaction effects partitioned into single degree of freedom contrasts.

Yield and yield components were measured in these experiments by other researchers (3,12). References to their results are made in the Discussion section to point out associations between disease intensity and yield.

Table 1. Influence of crop management practices on common root rot disease intensity on wheat

Treatments	Common root rot disease intensity[a] at				
	L81[b]	C81	L82	C82	$\bar{x}$
Row spacing (cm)					
13	0.439	0.440	0.462	0.483*[c]	0.456
18	0.400	0.447	0.416	0.414	0.419
Seeding depth (cm)					
2	0.318**	0.362**	0.344**	0.345**	0.342
4	0.522	0.526	0.537	0.552	0.534
Seeding rate (kg/ha)					
101	0.393	0.425	0.490	0.455	0.441
168	0.452	0.436	0.387	0.450	0.406
235	0.413	0.471	0.440	0.441	0.441
Spring nitrogen level (kg/ha)					
0	0.408	0.478	0.384	0.388	0.414
34	0.427	0.429	0.472	0.474	0.451
67	0.418	0.444	0.470	0.446	0.445
101	0.426	0.425	0.428	0.485	0.441

[a] Disease assessment at growth stage 9 (Feekes scale) based on the method of Ledingham (9). Values are means over all treatment combinations and replicates, where 0 = no lesions on any subcrown internodes and 1 = all subcrown internodes with >50% of surface covered with lesions.
[b] Location code: L = Lancaster County, C = Centre County, 81 = 1981, and 82 = 1982.
[c] Contrast between treatment means significant: * = $P = 0.05$ and ** = $P = 0.01$.

Table 2. Frequency (%) of fungal pathogens of winter wheat isolated from subcrown internodes

Location[a]	Internodes sampled (no.)	Frequency of isolation (%)			
		Bipolaris spp.	*Fusarium* spp.	*Rhizoctonia* spp.	*Pythium* spp.
L81	170	38	20	22	34
L82	168	28	17	11	5
C81	120	32	18	7	15
C82	236	28	13	6	4

[a] Location code: L = Lancaster County, C = Centre County, 81 = 1981, and 82 = 1982. Samples collected at growth stage 9 (Feekes scale). Subcrown internodes showing lesions were rinsed in water, surface-sterilized for 2 min in 1% NaOCl, and placed on acidified 1.5% water agar.

RESULTS

Row spacing significantly influenced SCI disease intensity only at C82, where disease intensity was 0.483 when rows were spaced 13 cm apart compared with 0.414 at the wider spacing. A similar trend was observed in both Lancaster County experiments, but differences were not statistically significant (Table 1).

SCI disease intensity was higher when seed was planted 4 cm deep than when planted 2 cm at all locations in 1981 and in 1982 (Table 1). Disease intensity increases of 45–60% were highly significant in all experiments.

Seeding rate and spring nitrogen fertilization level were not significant factors with respect to SCI disease intensity, and no general trends were observed.

The only significant interaction of factors influencing disease intensity on SCI occurred at C82, where the increase in disease intensity with deep planting was much greater when plants were seeded at 101 kg/ha than at the two higher rates. The intensity ratings at the 2-cm depth of planting were 0.312, 0.376, and 0.372 for the 101-, 168-, and 235-kg/ha seeding rates, respectively. At the 4-cm depth, the ratings were 0.611, 0.552, and 0.540 for these same rates.

The fungal pathogens of winter wheat that were isolated from SCI are listed in Table 2 along with their relative frequencies. In all experiments, *B. sorokiniana* was observed most frequently, with *Fusarium* spp. generally the second most frequent. *Rhizoctonia* spp. and *Pythium* spp. were also observed consistently. In both 1982 experiments, the occurrence of *Pythium* spp. was reduced compared with the levels observed in 1981.

DISCUSSION

The predominant pathogens implicated in causing common root rot in this study were *B. sorokiniana* and *Fusarium* spp., with the former consistently isolated with greatest frequency. This confirms our previous observations that *B. sorokiniana* is the most prevalent pathogen associated with common root rot in Pennsylvania. In addition, the isolation results indicate that species of *Rhizoctonia* and *Pythium* also may be involved in the root rot complex. The lower level of *Pythium* spp. isolated in 1982 compared with 1981 was probably attributable to differences in soil moisture. Root rots caused by *Pythium* spp. are favored by wet soil conditions (23). In 1982, the distribution of rainfall was not uniform. Plants were sampled in early June after an extended period of low rainfall from April to late May that probably restricted infection by *Pythium* spp. These results suggest that environmental influences can significantly change the relative contributions of the various fungi involved in the root rot complex of winter wheat.

Interactions between crop management practices tested did not consistently influence common root rot disease intensity. The lack of significant interactions indicates that the effects of any single management practice on disease can be evaluated individually.

Spring nitrogen level, row spacing, and seeding rate had no effect on common root rot in our tests. Previous research on these factors has demonstrated their effects to be quite variable. Two reports indicate that root rot severity increases with higher seeding rates (4,11), whereas others show no such responses (1,14,18). Likewise, beneficial (16) and detrimental (8) effects of nitrogen have been reported. Edaphic and other environmental differences may explain these contradictions.

Increasing planting depth of wheat seed definitely increased the amount of disease caused by root-rotting pathogens. Our conclusion supports most previous reports concerning the effects of planting depth on the severity of common root rot (2,4,10,11,18). This report confirms the relationship between these factors as reported by Canadian workers, despite differences in environment and crop management practices.

The reasons for higher disease intensity on more deeply seeded plants could not be determined directly from our experiments. Plants from seeds placed 4 cm deep were observed to develop longer SCI than those planted 2 cm deep. The higher infection levels observed on deep-seeded plants may have resulted from an increase in total SCI surface area available for infection. Another possibility is that additional elongation by the SCI may cause physical or physiological alterations that render it more susceptible to infection and colonization by soilborne organisms. Finally, higher moisture levels found deeper in the soil may increase the number or efficiency of fungal propagules, thereby enhancing the probability of successful infection.

Regardless of higher SCI disease intensity, deep planting increased grain yields at L82 and had no significant effect at the other three locations (12). Deep planting significantly reduced the number of tillers per square meter, but this was compensated by an increase in the number of kernels per tiller (3). The implication is that the increases in SCI disease intensity observed in our study are independent of yield. Other researchers working with barley found that root rot on SCI did not necessarily relate to yield loss (5,6). This disagrees with other researchers (10,19,21), who used a similar disease rating system to support the generalization that grain yield decreases with increasing disease intensity.

Infection by common root rot fungi occurs throughout the season (20). The fact that we sampled plants only once during the season and could not determine when the infections took place could account for the lack of association between disease increase and yield. Simmonds and Sallans (17), using root amputation techniques, found that damage to the seminal root system was most deleterious to yield if it occurred between the seedling stage of growth and midseason. After this period, the nodal roots become the primary organs of absorption. If most of the infections we observed had occurred just before sampling, damage to the plants may have been mild enough to preclude significant effects on yield. Plants with common root rot occur scattered throughout fields along with healthy plants. Uninfected plants have the ability to compensate for the reduced yield of infected plants (6), and the distribution of diseased plants in the field would influence the degree of yield compensation (15). The effects of yield compensation and time of infection in relation to disease tolerance must be studied in more detail before the relationship between common root rot and yield is completely understood.

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