The Effect of Fallow Periods on Common Root Rot of Wheat in Rio Grande do Sul, Brazil

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ABSTRACT

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In 1979, the incidence and intensity of common root rot of wheat in 17 fields in Rio Grande do Sul, Brazil, increased during the season from 31 and 9%, respectively, at growth stage 8–9, to 82 and 47% at growth stage 11.1–11.3. Much less disease developed in fields that were fallow for 3 or 4 yr or not previously cropped to wheat than in those cropped annually or after 1 or 2 yr fallow. Near plant maturity, the incidence and intensity averaged 68 and 25% in the former and 98 and 72% in the latter fields. The estimated yield loss in these groups of fields averaged 9.1 and 23.1%, respectively. The dominant pathogen isolated from underground parts of infected plants was *Cochliobolus sativus*. The relative abundance of its conidia in the upper 3 cm of soil sampled when wheat was maturing averaged 264 spores per gram in fields cropped annually or after 1 or 2 yr fallow, compared to 114 spores per gram in fields cropped less frequently.

Additional key words: *Bipolaris sorokiniana, Drechslera sorokiniana, Helminthosporium sativum.*

Wheat-soybean is the typical double-cropping sequence in the wheat (*Triticum aestivum* L.) growing areas of the Rio Grande do Sul and Paraná states in Brazil. Soybean (*Glycine max* L.) is cultivated in the summer (October–May) and wheat in the winter (May–November). Common root rot of wheat was shown to be an important disease in this area, mainly in places where wheat is cropped annually (1). In a small survey carried out in Rio Grande do Sul in 1979, the estimated mean loss due to this disease was 19.2% (*unpublished*). *Cochliobolus sativus* (Ito & Kurib.) Drechsl. ex Dastur, imperfect state *Helminthosporium sativum* Pam., King & Bakke syn. *Bipolaris sorokiniana* (Sacc. in Sorok.) Shoem. syn. *Drechslera sorokiniana* (Sacc.) Subram. & Jain, is the primary pathogen associated with common root rot (1). Other fungi, such as the cultivars Graminearum and Avenaceum of *Fusarium roseum* Lk. (emend. Snyd. & Hans.) f. sp. *cerealis*, are also found infecting the roots, although at low frequency. Crop rotation is not a common practice, but other crops such as beans, corn, and sorghum in summer, and barley, flax, lupines, oats, rapeseed, and rye in winter, are also cultivated. Diehl (2), in 1979, showed that root rot severity was greatly reduced in fields after 3 or more years of fallow. Although these results indicated an approach for control, it was not known if disease reductions occur under different environmental conditions.

The present work was undertaken to determine the effect of winter fallow on the level of common root rot and to estimate the damage to wheat caused by the disease in 1979. Isolations were made from the root systems of plants to validate causes of the disease, and the number of *C. sativus* conidia in fields under study was also estimated.

MATERIALS AND METHODS

Six cultivation systems were studied to determine the effect of winter fallow on common root rot of wheat. The systems studied were wheat in continuous soybean-wheat fields; wheat planted after 1, 2, 3, and 4 yr soybean-fallow; and wheat in fields that previously had not been cropped to wheat. Three fields in each system were selected within the Carazinho-Passo Fundo region, in Rio Grande do Sul. Wheat samples were collected at Feekes' scale (4) growth stages 8–9, 10.1–10.5, and 11.1–11.3 in 17 of the 18 fields.

Plants were collected as follows: a field was entered to a distance of about 30 m at one edge and then at about 5-m intervals along an oblique traverse, samples of about 10 plants were uprooted carefully to minimize damage to the roots. This was continued until 200–400 plants were obtained.

In the laboratory, the roots of the plants were washed thoroughly and the lower leaves were removed. All plants were individually categorized for disease intensity on the basis of the percentage area of the total (recovered) subterranean plant structure (roots, lower stem, crown, and subcrown internode) that had lesions. The classification categories were clean = no lesions or a few minute flecks; slight = 1–25% with lesions; moderate = 25–50% with lesions; and severe = more than 50% of the area with lesions. Numerical values of 0, 2, 5, and 10 were assigned to the four categories, respectively. Percent disease intensity ratings (DR) were calculated by using a slight modification of McKinney's formula (9):

$$\text{Intensity } (DR)\ \% = 100\ (\Sigma n_i D_i) / ND_{max} \qquad (1)$$

in which n_i is the number of plants in the i category, D_i is the numerical value of the i category, N is the total number of plants in the sample, and D_{max} is the maximum category value (ie, 10).

Isolations were made from small pieces excised from lower culms, crowns, subcrown internodes, and the primary and secondary roots of infected plants as described by Diehl (1), except that 2.75% NaOCl solution was used for disinfection and 200 μg of streptomycin was added per milliliter of water agar. Two pieces of each plant part were plated at each of two, and usually three, times of sampling for each field.

The number of *C. sativus* conidia present in soil was estimated by using a modification of the flotation method of Ledingham and Chinn (7). The original method gave 10% or less recovery of a known quantity of spores added to the oxisol soils of Rio Grande do Sul. Recovery was about 40% using a modified method (*unpublished*) developed for the soil by L. Duczek, Agriculture

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TABLE 1. Incidence and intensity of common root rot in wheat at three growth stages (GS) in fields in which wheat is cropped annually or after different periods of fallow[y]

Fallow period between 1979 and previous wheat crop	Field	Incidence (%)			Intensity (%)		
		GS 8–9	10.1–10.5	11.1–11.3	GS 8–9	10.1–10.5	11.1–11.3
A. indefinite	1	39	59	86	12	14	36
1st wheat crop	2	4	25	80	2	6	25
1979	3	8	22	22	2	5	5
Average		17 a	32 a	63 a	5 a	8 a	22 a
B. 4 yr	4	20	19	68	4	6	21
	5	12	23	49	3	8	20
	6	...[z]	49	80	...	14	29
Average		16 a	30 a	66 ab	3 a	9 a	23 a
C. 3 yr	7	6	18	64	1	5	22
	8	31	46	66	14	11	40
	9	16	26	93	4	6	31
Average		18 a	30 a	74 ab	6 a	7 a	31 a
D. 2 yr	10	40	66	100	10	14	80
	11	57	82	100	17	25	89
	12	31	86	100	9	20	73
Average		43 a	78 b	100 b	12 ab	20 b	81 c
E. 1 yr	13	81	100	100	21	41	100
	14	...	...	100	...	...	71
	15	...	...	...	...	...	...
Average		81 b	100 b	100 b	21 b	41 c	86 c
F. None	16	62	92	97	16	33	56
	17	37	66	94	13	23	58
	18	23	68	95	9	18	50
Average		44 a	75 b	95 ab	13 ab	25 b	55 b
SE of means		9.0	9.0	10.3	2.9	3.1	6.2

[y]Means in columns followed by the same letter are not significantly different ($P = 0.05$, according to Duncan's null multiple range test).
[z]... indicates that no sample was taken.

TABLE 2. Number of *Cochliobolus sativus* conidia per gram (dry weight) of soil and yield loss in wheat fields in which wheat is cropped annually or after different periods of fallow

Fallow period between 1979 and previous wheat crop	Field no.	Conidia/g soil[x]	Yield loss (%)[y]
A. indefinite;	1	108	14.1
1st wheat crop	2	56	11.0
1979	3	75	4.3
Average A		80 a	9.8
B. 4 yr	4	95	4.1
	5	133	1.2
	6	171	16.1
Average B		133 ab	7.1
C. 3 yr	7	98	7.7
	8	147	6.3
	9	141	16.8
Average C		129 ab	10.3
D. 2 yr	10	265	27.7
	11	217	19.6
	12	126	18.9
Average D		203 abc	22.1
E. 1 yr	13	211	33.6
	14	274	6.8
	15	...[z]	...
Average E		243 bc	20.2
F. None	16	192	18.8
	17	519	38.1
	18	307	20.9
Average F		339 c	25.9
SE of means		46.9	

[x]Means followed by the same letter are not significantly different ($P = 0.05$ according to Duncan's null multiple range test).
[y]Losses in fields 1, 3, 10, and 13 were calculated by projection; in fields 11, 12, 14 partly by a modified individual plant method and partly by projection; and in all others by the individual plant method.
[z]... indicates that no sample was taken.

Canada Research Station, Saskatoon, Saskatchewan, and presented here with his permission. Five milliliters of mineral oil were added to 10 g of soil in a 25 × 200-mm screw-capped test tube. A 5% tetrasodium pyrophosphate solution was added until the contents were about 50 mm from the tube top. The tubes were shaken by hand for 4 min. As the layers began to separate (30–60 min) the oil emulsion was stirred gently with a spatula for about 10 sec to assist clearing. The layer was stirred again for 10 sec after an additional 30–60 min. An aliquot was removed from the oil-emulsion layer with a pipette and four drops (0.1 ml) were individually placed on microscope slides, spread, and the conidia were counted under a microscope at about ×60.

Soil samples for counting conidia were collected when plants were taken at growth stage 11.1–11.3. Each sample was a composite of subsamples from the top 3 cm of soil at five to ten sites in a field. Before use, the samples were sieved three times to ensure thorough mixing of subsamples and to remove large particles and plant debris. The number of spores per gram (dry weight) of soil was calculated by multiplying the average number of spores per drop of oil × the number of drops per milliliter × 0.5 (milliliters of oil per gram of soil extracted) × the dry weight correction factor.

The percent loss from common root rot was estimated for each of the 17 fields sampled. For 10 fields percent loss was calculated by using the individual plant methods (8) as follows:

$$\text{Loss (\%)} = 100 - 100\ Y_t / N y_h \qquad (2)$$

in which Y_t is the total weight of grain from sampled plants, N is the number of plants in the sample, and Y_h is the average weight of grain per healthy plant in the sample.

Other methods of loss calculation were used for the seven remaining fields. This was necessary due to the destruction of grain by frost in three fields, to the harvest of grain just prior to final sampling in another field, and to the absence of any healthy plants in the remaining three fields. The calculations were as follows:

1. The percent yield reduction per plant in the slight (Sl), moderate

(Mo), and severe (Sv) categories was determined for each of the above 10 fields and then averaged over the fields. For example, for a field the percent yield reduction per slightly affected plant is

$$(SL) = 100 - 100 y_{sl}/y_h \quad (3)$$

in which y_{sl} is the average yield per slightly affected plant and y_h is the average yield per healthy plant. The 10-field average percent reduction for each disease severity category was separately determined.

2. Loss for a field devoid of grain (total of four fields) was wholly projected:

$$\text{Loss (\%)} = (Sl \cdot L + Mo \cdot M + Sv \cdot S)/100 \quad (4)$$

in which L, M, and S are the percentages of slightly, moderately, and severely affected plants, respectively; and Sl, Mo, and Sv are the 10-field average percent yield reductions calculated for slightly, moderately, and severely affected plants, respectively.

3. Loss for the other fields (total of three), the plants of which produced grain but none or very few were in the clean category, was derived partly by modification of the individual plant method and partly by projection. Loss (%) = $(100 - 100\ Y_t/Ny_{sl})$ (least projected loss) in which Y_t and N are total yield and number of plants as in Eq. 2, y_{sl} is the average weight of grain from plants in the least-affected category, and the least projected loss is the loss projected for the plants in the least-affected category as in Eq. 4.

For example, if a field contained slightly to severely diseased plants its loss (%) was = $(100 - 100\ Y_t/Ny_{sl}) + (Sl \cdot L/100)$.

RESULTS AND DISCUSSION

Incidence and intensity of common root rot increased with advancing plant age in almost all fields (Table 1). Between cultivation systems, marked differences in both attributes were observed. Root rot was less frequent and severe, often significantly so, in fields that previously had not been cropped to wheat or were fallowed for 3 or 4 yr than in those that carried wheat every 3 yr or more often (Fig. 1).

It is noteworthy that the disease was present at about the same levels in the fields not previously cropped to wheat as in those that had been fallowed for 3 or 4 yr. This suggests that native grasses and/or weeds in the soybean crop on land not cropped previously to wheat may serve as reservoirs of *C. sativus* and further, that 3 and 4 yr fallow provides a sufficiently long period for inoculum in the soil to decline to low levels. An alternative hypothesis is that inoculum is extremely low after 3 or 4 yr fallow and in soil not previously cropped to wheat and that the wheat seed sown in these fields carried sufficient inoculum to induce considerable disease. Black point (smudge) due to *C. sativus* is prevalent on seed, and seed treatment with fungicides is rarely used by farmers. However, since the incidence and intensity of disease increased with time, many infections in the post-seedling stages probably originated from spores in the soil rather than from those carried on the seed.

The relative number of *C. sativus* conidia in the upper 3 cm of soil appeared to be associated with the frequency of wheat crops in the fields (Table 2). Soil not previously cropped to wheat contained the least (average of 80 spores per gram) and soil cropped annually the most (average of 339 spores per gram). There was a general relationship between high disease incidence or intensity (Table 1) and high spore numbers (Table 2). However, since the spore population densities were assessed when the wheat was near maturity it is unknown if they were the cause or partly the result of the different disease levels. The incidence of disease in fields cropped to wheat every 3 yr or more often and in fields cropped less frequently increased with time in rather parallel fashion. The average incidence in the former group of fields was 46, 80, and 98% as compared to 15, 32, and 68% in the latter at the three stages of

Fig. 1. Wheat plants typifying those in different cultivation systems. Common root rot was severe (note extensive lesion development) on wheat in fields cropped to wheat annually or after 1 or 2 yr fallow (three plants at left) and slight on wheat in fields cropped to wheat less frequently (three plants at right).

TABLE 3. Species of fungi isolated from lower culms and subterranean plant parts of wheat plated on potato-dextrose agar as a percentage of total isolates

Fallow period between 1979 and previous wheat crop	Isolates (no.)	*Cochliobolus sativus* (%)	*Fusarium oxysporum* (%)	*Fusarium graminearum* (%)	*Fusarium acuminatum* (%)	*Fusarium equiseti* (%)	*Curvularia* sp. (%)	*Pythium* sp. (%)	Others[a] (%)
Indefinite; 1st in wheat, 1979	46	28	26	9	0	0	4	0	33
4 yr	50	36	22	4	0	2	0	0	36
3 yr	44	32	27	7	5	7	0	4	18
2 yr	43	33	16	2	14	5	0	0	30
1 yr	27	22	22	0	8	8	0	0	40
none	51	43	17	4	10	10	0	0	16
Wheat sampled at growth stage:									
8–9	51	47	27	4	6	10	0	0	6
10.1–10.5	102	28	19	7	9	5	1	2	29
11.1–11.3	108	31	22	3	3	3	1	0	37

[a] *Alternaria* spp., *Rhizoctonia solani, Fusarium* spp., *Acremonium strictum, Epicoccum purpurascens, Colletotrichum graminicola,* and *Penicillium* spp.

sampling, respectively. This suggests that numbers of conidia in the two groups of fields did indeed differ initially and that those differences were maintained throughout the season. Information on spore population densities in soil from the time of seeding of wheat to its maturity is needed to validate this point.

The estimated loss in grain yield in the fields ranged from 1.2 to 38.1% (Table 2) and averaged 15.6%. There was an obvious general relationship between disease intensity and loss; fields that had low levels of disease incurred less reduction in yield than those with high levels. Wheat on soil not previously cropped to it or on 3 or 4 yr fallow sustained an average yield loss of 9.1% whereas that on land cropped annually or after 1 or 2 yr fallow had an average loss of 23.1%. The latter value is only slightly higher than the 19.2% loss estimated in 12 random survey fields in 1979 (*unpublished*). Since soybean-wheat crops are produced annually in many fields, the closeness of the two values is not surprising.

Maximal use was made of actual yield data from plants in the categories for the estimation of losses. Category and yield limitations of this approach, however, necessitated the adoption of the individual plant method, a projection method, and a combination of the two. The individual plant method is considered the most and the projection method the least reliable. The 10-field average yield reductions per plant in the slight, moderate, and severe categories were 9.9, 18.6, and 33.6%, respectively. These values indicate a relationship between disease severity and yield loss, and they were used in calculating the losses by projection. Ledingham et al (6) discussed a conversion factor that also might be used to project losses in fields where the disease intensities are known. The factor is simply derived by dividing the calculated loss for a group of fields by their average disease intensity. A conversion factor of 0.4 was obtained over the 10 fields in the present study. Losses projected from its use for the four fields lacking grain, namely fields 1, 3, 10, and 13, were 14.4, 2.0, 32.0, and 40.0%, respectively. That these values parallel those computed by the more detailed projection method (Table 2) provides support for their acceptance.

Isolations from plant parts showed *C. sativus* to be the dominant pathogen in all the cultivation systems and at all three growth stages (Table 3). It comprised 35% of the total isolates. *Fusarium oxysporum* (Schlecht.) Snyd. & Hans. occurred frequently (22% of the isolates), *F. graminearum, F. acuminatum,* and *F. equiseti* 4 to 6% each, *Curvularia* and *Pythium* spp. less than 1%, and various other fungi including species of *Alternaria, Colletotrichum, Epicoccum, Rhizoctonia*, and unidentified isolates, a total of 27%. This ranking of fungi is similar to that reported by Diehl (1).

The results of the present work confirm previous findings that the absence of wheat for several years is a means of reducing the incidence and intensity of, and damage from, common root rot. Diehl (2) in 1979 reported a decrease in root rot severity in wheat grown on land fallowed for 3 or 4 yr. Ledingham (5) also found a reduction in disease with long-term rotation in Canada. Results of surveys in southern Brazil in 1980 indicated, however, that occasional fields of wheat, even after 4 yr fallow, had considerable disease. The reason for this is as yet unknown, but some speculative causes are differing survival of conidia of *C. sativus* in soils, the occurrence of grass hosts, and the movement of infested soil via water erosion.

In 1979, rainfall in the area of the study was some 1,800 mm, with over 1,000 mm during May to September, the period of wheat production. Generally, common root rot has been considered to be a major disease in rather arid, temperate regions. The high disease intensity and damage in Rio Grande do Sul in 1979, and also in 1978 (1), indicate that it also may be very important in moist, semitropical regions.

It is significant that in southern Brazil common root rot often affects all the subterranean plant parts; lesions in the secondary and primary roots are conspicuous (Fig. 1). For this reason, the total underground system recovered when plants were pulled up was rated. In other places, such as the north central plains in North America, the disease is chiefly a foot rot with relatively little root infection distal from the crown, and lesions on the subcrown internode frequently are used as the index of the disease (10). Whether the difference in amount of root infection between these areas is associated with depth distribution of spores of *C. sativus* in the soil is unknown. Deep cultivation is practiced in southern Brazil whereas shallow cultivation to maintain a trash cover is usual in north central North America. Duczek (3) found that in Canada spores were far more numerous in the tilled than in the undisturbed layers of the soil.

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