Yield Losses Caused By Fungal Foliar Wheat Pathogens in Brazil

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Accepted for publication 6 June 1984.

ABSTRACT

Luz, W. C. da. 1984. Yield losses caused by fungal foliar wheat pathogens in Brazil. Phytopathology 74:1403-1407.

In 1981–1982, field experiments were performed at the National Wheat Research Center, Passo Fundo, Rio Grande do Sul, Brazil, to estimate the yield losses due to fungal foliar diseases of wheat. Selective and broad-spectrum fungicides were applied, individually and in combinations to control one or more specific diseases. Results indicated that leaf rust and spot blotch caused the greatest economic losses in wheat. In 1982, leaf rust reduced the yield of wheat cultivars CNT 10 and Nobre by 20 and 18%, respectively. *Cochliobolus sativus* was the most prevalent leaf spot pathogen, causing yield losses of 19 and 14% in CNT 10 and Nobre, respectively. These diseases did not cause yield reductions on either cultivar in 1981. In 1981, powdery mildew reduced the yield ~8% on cultivar CNT 10 but did not reduce the yield of Nobre. In 1982, powdery mildew had no effect on yield and the combined reduction in yield due to scab and glume blotch was 8% on each of the two cultivars. In 1981, the combined reduction was 10% on cultivar CNT 10. *Leptosphaeria nodorum* caused some infection on leaves in both years of study. No other fungal leaf disease affected plants in the plots to any appreciable extent. The multiple fungal foliar diseases reduced yields about 19 and 32% in 1981 and 48 and 40% in 1982 on cultivars CNT 10 and Nobre, respectively. The total wheat loss was greater in 1982 due to higher disease severity favored by wet periods and high temperatures.

Additional key words: *Bipolaris sorokiniana, Erysiphe graminis* f. sp. *tritici, Gibberella zeae, Puccinia recondita* f. sp. *tritici*.

Several fungal foliar diseases of spring wheat (*Triticum aestivum* L.) occur in the State of Rio Grande do Sul, Brazil (14). Little is known about the yield losses caused in Brazil's wheat crop by these diseases either individually or in combinations. In the State of Rio Grande do Sul, the fungal wheat leaf disease complex has been reported to cause losses of 12, 4.9, 69, and 6.8% in 1969 (3), 1971 (11), 1972 (3), and 1973 (4), respectively. Inoculation with *Cochliobolus sativus* decreased wheat grain yield 17.1–70.2% (12). Linhares and Ignaczak (10) obtained yield increase up to 14% by controlling powdery mildew of wheat. In 1977, 50% yield reductions due to leaf rust were observed in susceptible wheat cultivar, IAS 55 (1). There has been considerable work on wheat losses due to fungal foliar diseases in other parts of the world (2,6–8,15) under either artificial inoculation or natural infection.

The objectives of this study were to determine losses in wheat yield caused by indigenous fungal foliar diseases individually and in combinations.

MATERIALS AND METHODS

Experiments were performed in 1981 and 1982 at the National Wheat Research Center area at Passo Fundo, a locale that is representative of the major wheat-growing region of the northern part of the State of Rio Grande do Sul, Brazil. Selective and polyvalent fungicides were applied separately and in combinations to control one or more specific diseases. The wheat cultivars planted were CNT 10 and Nobre, which were among the three most-cultivated wheats in this State in 1981 and 1982.

The diseases and causal organisms studied were leaf rust (caused by *Puccinia recondita* Rob. ex Desm.), powdery mildew (caused by *Erysiphe graminis* D.C. ex Merat f. sp. *tritici* E. Marshall), scab (caused by *Gibberella zeae* (Schw.) Peth.), spot blotch (caused by *Cochliobolus sativus* (Ito & Kurib.) Drechs. ex Dastur [anamorph = *Bipolaris sorokiniana*]), glume blotch (caused by *Leptosphaeria nodorum* Muller [anamorph = *Septoria nodorum* Berk.]), and tan spot (caused by *Pyrenophora trichostoma* (Fr.) Fck. (anamorph = [*Drechslera tritici-repentis* (Died.)= Shoem.]. Treatments and fungicide rates were as follows: i) no fungicides; ii) butyltriazol, 0.4 L/ha (no leaf rust); iii) ethirimol, 2 L/ha (no powdery mildew); iv) butyltriazol, 0.4 L/ha + ethirimol, 2 L/ha (no leaf rust or powdery mildew); v) butyltriazol, 0.4 L/ha + ethirimol, 2.0 L/ha + benomyl, 2 kg/ha (no diseases except spot blotch); and vi) butyltriazol, 0.4 L/ha + ethirimol, 2 L/ha + benomyl, 2 kg/ha + mancozeb, 2 kg/ha (no diseases). The experiment was replicated four times in a split-plot arrangement of a randomized complete-block design in which cultivars were whole plots and the treatments were subplots. Plots were 7.0 × 2.4 m (12 rows, 20 cm apart). The fungicide or fungicide combinations were selected based on their known effectiveness against one or more specific diseases. Plants were sprayed weekly from growth stage 12 (two leaves unfolded) to 90 (cariopsis hard) (16) with each fungicide mixture prepared in 200 L of water per hectare. Spraying was done with a small-plot spray rig (5) with the nozzles set as close to the foliage as possible.

Disease severity was estimated as the percentage of leaf area infected (9) at growth stages 49 (first awns visible), 69 (complete anthesis), 85 (soft dough), and 87 (hard dough). Leaves with leaf spot symptoms were collected and first examined for the presence or absence of pycnidia of *Mycosphaerella graminicola* (Fückel) Schroeter (anamorph = *Septoria tritici* Rob. ex Desm.) under a stereoscopic microscope (×40). Isolations of organisms were made from 100 lesions and from spots from the heads by plating surface-sterilized small sections (2 mm^2) on V8-juice agar. Plates were maintained under near-ultraviolet light for a photoperiod of 12 hr at 21 ± 3 C. The presence of necrotrophic organisms was recorded 5 days later.

The center eight rows of all plots were harvested by plot combine and the yields were converted to kilograms per hectare. The data were submitted to analysis of variance and the differences were determined by Duncan's multiple range test, $P = 0.05$.

RESULTS

The results of occurrence of the diseases are given in Table 1. In 1981, powdery mildew was severe at tillering and the disease eventually affected 20% of the top four leaves on CNT 10 at the anthesis stage (Table 1). A moderate infection was observed on Nobre. In 1982, the disease was not severe on either cultivar.

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Except for the moderate symptoms on the heads in plants approaching maturity, leaf spotting fungi (particularly *L. nodorum*) did not cause much damage on the foliage in 1981. Infections by *C. sativus* were infrequent. In 1982, a heavy attack of leaf spots occurred on both cultivars.

All plants of CNT 10 exhibited a high level of leaf rust resistance in 1981. On Nobre, the disease occurred late in the season and in low severity. In 1982, both cultivars were severely infected by *P. recondita*. No other leaf diseases of any consequence were noticed in the plots in 1981 and 1982. All plants in the protected plots were completely, or almost completely, free from the diseases for which they were treated, efficiently separating the diseases (Table 1).

Leaf spot diseases occurred at very low levels in 1981; *L. nodorum* was associated with 91% of the necrosis in the first four treatments listed in Table 2. *C. sativus* was noticed on about 4% of the total lesions examined from these four treatments.

In 1982, the conidial stage of *C. sativus* was observed from tillering to maturity and was consistently the most common organism isolated from leaf spots (Table 2). An average of 2 and 10% of the spots on the leaves of Nobre and CNT 10, respectively, yielded pycnidiospores of *L. nodorum* (Table 2). Other organisms, including *P. trichostoma*, were observed, but their incidence was less. *M. graminicola* was not seen during the 2-yr study. Isolations made from plots treated with benomyl + butyltriazol + ethirimol yielded mainly *C. sativus* in both 1981 and 1982 (Table 2).

Most of the glume discoloration in 1982 was caused by *C. sativus*; *L. nodorum* made up about 12 and 18% of the fungi present on the heads of CNT 10 and Nobre, respectively (Table 2).

Table 3 shows that significant differences in yields existed among treatments. The percent yield losses were calculated from the Table 3 data and the results are summarized in Table 4. The percent yield losses caused by glume blotch + scab, spot blotch and

TABLE 1. Severity of various fungal foliar diseases on two wheat cultivars[a] at Passo Fundo, Rio Grande do Sul, Brazil

		Disease severity									
	Growth stages[b] and	Powdery mildew		Leaf spots		Leaf rust		Leaf spots (heads)		Scab (heads)	
Treatments	cultivars	81	82	81	82	81	82	81	82	81	82
No fungicides											
	49 CNT 10	12	1	5	1	0	13				
	Nobre	8	1	0	2	0	8				
	69 CNT 10	20	0	7	28	0	20				
	Nobre	9	0	1	18	0	23				
	85 CNT 10	7	0	8	46	0	32				
	Nobre	5	0	6	33	1	34				
	87 CNT 10							20	42	16	17
	Nobre							21	25	22	20
Butyltriazol											
	49 CNT 10	12	1	6	1	0	0				
	Nobre	8	1	0	1	0	0				
	69 CNT 10	20	0	8	31	0	0				
	Nobre	8	1	1	20	0	0				
	85 CNT 10	7	0	8	49	0	0				
	Nobre	4	0	7	39	0	0				
	87 CNT 10							19	35	17	19
	Nobre							19	21	25	18
Ethirimol											
	49 CNT 10	0	0	6	2	0	11				
	Nobre	0	0	0	2	0	8				
	69 CNT 10	0	0	8	29	0	25				
	Nobre	0	0	1	22	0	28				
	85 CNT 10	0	0	9	45	0	30				
	Nobre	0	0	9	35	4	37				
	87 CNT 10							19	32	16	19
	Nobre							18	25	26	21
Butyltriazol + ethirimol	49 CNT 10	0	0	6	1	0	0				
	Nobre	0	0	1	2	0	0				
	69 CNT 10	0	0	8	31	0	0				
	Nobre	0	0	1	19	0	0				
	85 CNT 10	0	0	10	46	0	0				
	Nobre	0	0	9	35	0	0				
	87 CNT 10							20	32	14	16
	Nobre							17	24	25	20

(continued)

TABLE 1 (continued). Severity of various fungal foliar diseases on two wheat cultivars[a] at Passo Fundo, Rio Grande do Sul, Brazil

Treatments	Growth stages[b] and cultivars	Disease severity									
		Powdery mildew		Leaf spots		Leaf rust		Leaf spots (heads)		Scab (heads)	
		81	82	81	82	81	82	81	82	81	82
Butyltriazol + ethirimol + benomyl	49 CNT 10	0	0	0	4	0	0				
	Nobre	0	0	0	3	0	0				
	69 CNT 10	0	0	0	26	0	0				
	Nobre	0	0	1	16	0	0				
	85 CNT 10	0	0	0	44	0	0				
	Nobre	0	0	2	25	0	0				
	87 CNT 10							5	23	0	0
	Nobre							8	18	0	0
Butyltriazol + ethirimol +benomyl +mancozeb	49 CNT 10	0	0	0	0	0	0				
	Nobre	0	0	0	0	0	0				
	69 CNT 10	0	0	0	2	0	0				
	Nobre	0	0	0	2	0	0				
	87 CNT 10							0	0	0	0
	Nobre							1	1	0	0

[a] Percentage of infected area according to James (9). Observations done on four top leaves except in growth stage 85 (disease severity rated on flag leaf) and growth stage 87 (disease severity rated on heads).
[b] According to the scale of Zadoks et al (16): 49 = first awns visible, 69 = complete anthesis, 85 = soft dough, and 87 = hard dough.

TABLE 2. Frequency of isolation of various fungi from spots on leaves and heads of two wheat cultivars, Passo Fundo, Rio Grande do Sul, Brazil

Cultivars and treatments	Fungi isolated (%)											
	Cochliobolus sativus			*Leptosphaeria nodorum*			Others[a]			No organisms		
		1982			1982			1982			1982	
	1981	Leaves	Heads	1981	Leaves	Heads	1981	Leaves	Heads	1981	Leaves	Heads
CNT 10												
No fungicides	3[b]	83	90	92	12	12	6	8	8	2	8	2
Butyltriazol	5	81	86	90	10	13	5	6	4	1	7	4
Ethirimol	2	81	86	89	9	11	4	6	4	1	6	2
Butyltriazol + ethirimol	4	79	87	92	10	12	7	5	8	2	4	4
Butyltriazol + ethirimol + benomyl	92	86	96	0	0	1	8[c]	5	5	1	6	5
Butyltriazol + ethirimol + benomyl +mancozeb	1	0	0	0	0	0	4	4	3	94	96	97
NOBRE												
No fungicides	4	85	88	93	2	17	7	7	5	0	13	4
Butyltriazol	5	81	81	92	3	20	3	9	3	1	8	5
Ethirimol	5	86	87	90	2	17	6	8	7	0	13	4
Butyltriazol + ethirimol	6	81	88	92	1	19	5	9	8	1	12	9
Butyltriazol + ethirimol + benomyl	94	90	98	0	0	2	6[c]	6	7[c]	0	10	5
Butyltriazol + ethirimol + benomyl + mancozeb	0	2	0	0	0	0	0	8[c]	2[c]	0	90	98

[a] Included *Alternaria tenuis, Epicoccum nigrum, Fusarium* spp., *Nigrospora* sp., *Phoma* spp., *Pyrenophora trichostoma*, and nonsporulating fungi.
[b] Data collected from 100 lesions, five replicates except: treatment vi (see Table 3) in 1982 (50 lesions in one replicate from leaves and 25 lesions in one replicate from heads) and in 1981 (100 lesions in average of two replicates from leaves and heads).
[c] Mostly *Alternaria tenuis*.

TABLE 3. Effect of various selective or grouped fungicides on grain yield (kg/ha) of two wheat cultivars at Passo Fundo, Rio Grande do Sul, Brazil

Treatments and disease occurrence	Rates/ha	Cultivar and year			
		CNT 10		Nobre	
		1981	1982	1981	1982
i) No fungicides		2,999[y]c[z]	1,426 d	2,112 b	1,388 d
ii) Butyltriazol (no leaf rust)	0.4 L	2,765 c	1,774 c	2,002 b	1,692 d
iii) Ethirimol (no powdery mildew)	2 L	3,272 b	1,480 d	2,247 b	1,432 d
iv) Butyltriazol + ethirimol (no leaf rust and no powdery mildew)	0.4 L + 2 L	3,268 b	1,787 c	2,281 b	2,694 c
v) Butyltriazol + ethirimol + benomyl (no diseases except spot blotch)	0.4 L + 2 L +2 kg	3,686 a	1,994 b	3,092 a	1,885 b
vi) Butyltriazol + ethirimol + benomyl +mancozeb (no disease)	0.4 L + 2 L + 2 + 2 kg	3,692 a	2,741 a	3,100 a	2,324 a

[y] Yield in kilograms per hectare. Average of four replicates. Coefficients of variation (%): 1981-plot = 6.2, subplot = 6.1; 1982-plot = 5.6, subplot = 7.4.
[z] Yields followed by the same letter do not differ significantly according to Duncan's multiple range test, $P = 0.05$.

leaf spots + scab were obtained by subtraction from percent yield losses from other treatments.

Leaf rust reduced the yield of CNT 10 by 20% in 1982 (Table 4). In 1981, the yield was not significantly affected by this disease. In 1981, CNT 10 was resistant to the prevalent races of *P. recondita*. On Nobre, slight symptoms of leaf rust were observed late in the season of 1981. In 1982, however, an average yield loss of 18% due to leaf rust was observed on Nobre. In 1981, all chemical treatments applied increased yield on cultivar Nobre. The treatments designed to control all diseases except spot blotch and the complete fungicide treatment designed to control all diseases resulted in the highest yields. On cultivar CNT 10, those were the only two treatments which significantly increased yield in 1981. In 1982, all fungicide treatments increased yield on both wheat cultivars. The complete fungicide treatment had the highest yield increase (Table 3).

Powdery mildew decreased yield in 1981 by 8% on the cultivar CNT 10 but did not decrease the yield of Nobre. In 1982, the disease did not affect yield of either cultivar.

The reduction in yield due to combined infection of heads by *G. zeae* and *L. nodorum* in both years probably was caused mainly by *G. zeae*, because in 1981 *L. nodorum* moderately infected the glumes very late in the season and glume blotch was not severe in 1982. Due to difficulty in selectively controlling these two head diseases by fungicides, the yield reduction caused by each disease alone could not be measured.

In 1982, *C. sativus* caused yield decreases of 20 and 14% in CNT 10 and Nobre, respectively. The results in 1981 indicated that losses due to foliar diseases were higher on the cultivar Nobre than on CNT 10, and that most of this loss was due to scab which occurred in a considerable proportion of the wheat crop and was particularly severe on Nobre.

In 1982, wheat treated with a complete fungicide schedule had the highest yield. Losses of about 48 and 40% were caused by all diseases on CNT 10 and Nobre, respectively.

TABLE 4. Yield losses caused on spring wheat cultivars CNT 10 and Nobre by fungal foliar diseases of wheat at Passo Fundo, Rio Grande do Sul, Brazil

Disease	Yield loss (%)			
	1981		1982	
	CNT 10	Nobre	CNT 10	Nobre
Leaf rust	NS[a]	NS	20	18
Powdery mildew	8	NS	NS	NS
Leaf rust + powdery mildew	NE[a]	NS	20	18
Leaf rust + powdery mildew + glume blotch + scab	19[b]	32	28	26
Glume blotch + scab[y]	10	NE	8	8
Spot blotch[y]	NS	NS	20	14
Leaf spots + scab[y]	10	NE	28	22
Leaf rust + powdery mildew + leaf spot + scab	19[c]	32	48	40

[a] NS = not significant, and NE = not evaluated due to difficulty in the comparison of treatments for calculation of these losses or due to absence of one disease in this particular year.
[b] The data were obtained by subtraction from other treatments.
[c] Leaf rust did not occur on this cultivar in 1981.

DISCUSSION

Leaf rust and spot blotch were the most important wheat diseases in 1982. The high incidence of spot blotch was probably a consequence of frequent and prolonged rainy periods, combined with warm temperatures (13).

Powdery mildew was an important wheat disease in Rio Grande do Sul only in 1981. In 1982, however, due to frequent and prolonged rains, the disease was not severe. Scab was clearly an important wheat disease in Rio Grande do Sul in the 2 yr this study was conducted.

The occurrence of pathogenic leaf spotting fungi did not explain the total amount of necrosis, particularly in 1982. A very low amount of necrosis due to thermic-hydric conditions, wind, or infection by *P. recondita* at crop maturity and by nonsporulating fungi was possibly included in the estimated amount of leaf spot diseases. The total loss was greater in 1982 than 1981 due to a higher disease severity favored by frequent and prolonged rains during 1982. Losses up to 69% were recorded in 1972 (3) under similar weather conditions.

The lack of yield difference when the fungicides were used with little or no disease indicated that neither ethirimol nor butyltriazol had any physiological effect on yield.

The lack of yield increase in 1981 with the application of mancozeb compared to the treatment without mancozeb showed that no measurable nutritional or physiological effects were caused by that fungicide. Yield reductions in this present study seem to be a result of the death of a significant amount of plant tissue caused by wheat pathogens.

The severity of diseases in the trials was representative of the severity seen in commercial wheat crops in Rio Grande do Sul, in both years and similar total yield loss was observed.

LITERATURE CITED

1. Barcellos, A. L., and Ignaczak, J. C. 1978. Efeito da ferrugem da folha em diferentes estadios de desenvolvimento do trigo. Pages 212-219 in:

Proc. 10th Reunião Anual Conjunta de Pesquisa de Trigo. Vol. 2. 3–7 April. Empresa Brasileira de Pesquisa Agropecuaria Centro Nacional de Pesquisa de Trigo, Porto Alegre, Brazil.
2. Bronnimann, A. 1968. Zur kenntnis von *Septoria nodorum* Berk. dem Erreger der Spelzenbraune und einer Blattdurre des Weizens. Phytopathol. Z. 61:101-146.
3. Caetano, V. da R. 1972. Estudo sobre o Virus do Nanismo Amarelo da Cevada, em trigo, no Rio Grande do Sul. Tese Doutorado. Escola Superior de Agricultura Luiz de Queiroz, Pyracicaba, Brazil. 75 pp.
4. Caetano, V. R., Caetano, V. R., Castro, C., Diehl, J. A., and Santiago, J. C. 1973. Efeito dos problemas fitossanitarios na produção do trigo Lagoa Vermelha, sob condições controladas de campo, no ano de 1972. Relatorio apresentado na 5th Reuniao Anual Conjunta de Pesquisa de Trigo. 4–8 August, Pelotas, Brazil. 16 pp.
5. Fernandes, J. M. C., and Nardi, C. A. 1980. Multipulverizador para experimentos com defensivos. Pages 113-115 in: Proc. 11th Reunião Nacional de Pesquisa de Trigo. 4–8 August, Porto Alegre, Brazil.
6. Hampton, J. G., and Close, R. C. 1976. Effect of septoria leaf spot in spring wheat. N.Z. J. Exp. Agric. 4:89-92.
7. Hagborg, W. A. F., Chiko, A. W., Gleischmann, G., Gill, C. C., Green, G. J., Martens, J. W., Nielsen, J. J., and Samborski, D. J. 1972. Losses from cereal diseases in Manitoba in 1971. Can. Plant Dis. Surv. 52:113-118.
8. Hosford, R. M., Jr., and Busch, R. H. 1974. Losses in wheat caused by *Pyrenophora trichostoma* and *Leptosphaeria avenaria* f. sp. *triticea*. Phytopathology 64:184-187.
9. James, W. C. 1971. An illustrated series of assessment keys for plant diseases, their preparation and usage. Can. Plant Dis. Surv. 51:39-65.
10. Linhares, W. I., and Ignaczak, J. C. 1978. Determinação de perdas e danos causados pelo mildio—1976–1977. Pages 238-252 in: Proc. 10th Reunião Anual Conjunta de Pesquisa de Trigo. Vol. 2. 3–7 April, Porto Alegre, Brazil.
11. Luz, N. K. 1974. Efeito sobre o trigo do Virus do Nanismo Amarelo da Cevada e de molestias fungicas, em experimentos de campo, em Julio de Castilhos. Agron. Sulriograndense 10:325-340.
12. Luz, W. C. da. 1977. Avaliação da influencia de *Drechslera sorokiniana* (Sacc.) Subram & Jain no produto economico de cultivares de trigo. Pages 138-142 in: Proc. 9th Reunião Anual Conjunta de Pesquisa de Trigo. 28 March–1 April, Londrina, Brazil.
13. Luz, W. C. da. 1982. Influencia do periodo de umidificação pos-inoculação no reação de cultivares de trigo a mancha foliar (*Cochliobolus sativus*). Fitopatol. Bras. 7:111-115.
14. Luzzardi, G. C., and Pierobom, C. R. 1970. Molestias de trigo na Região Sul do Brazil. Circular Instituto de Pesquisa Agropecuaria do Sul. 42. 24 pp.
15. Roelfs, A. P. 1978. Estimated losses caused by rust in small grain cereals in the United States—1918–1976. U.S. Dep. Agric. Misc. Publ. 1363. 85 pp.
16. Zadoks, J. C., Chang, T. T., and Konzak, C. F. 1974. A decimal code for growth stages of cereals. Weed Res. 14:415-421.