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Effect of imazalil seed treatment on common root rot and grain yields of cereal cultivars

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Seed treatment trials were conducted in 1978 and 1979 with imazalil for the control of common root rot [*Cochliobolus sativus*] of cereals. In 1978, imazalil applied at 0.2 and 0.3 g a.i./kg seed resulted in a significant reduction, both at the seedling stage and at plant maturity, in the severity of root rot of four wheat and two barley cultivars at nine locations in the three Prairie Provinces. In 1979, the root rot ratings of mature plants were significantly reduced as the rate of imazalil was increased from the nontreated check through 0.05, 0.1, 0.15, and 0.2 g a.i./kg seed for the two spring wheat cultivars at two locations. A dose response was evident, particularly in 1979. The partial control of the disease was not generally reflected by higher yields. In fact, an overall yield depression was significant in 1978. However interactions occurred between cultivars, treatments, and locations; some cultivars, notably Cypress and Neepawa wheat, had slightly improved yield at some treatment rates at most locations. Lack of a uniform yield response may be a result of some phytotoxicity of the fungicide; the treatments generally depressed seedling emergence.

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On a poursuivi, en 1978 et 1979, des essais de traitement de semence à l'imazalil en vue de réprimer le piétin commun des racines de céréales (*Cochliobolus sativus*). En 1978, l'application d'amazalil à raison de 0,2 et 0,3 g m.a./kg de graines a réduit de façon significative, à la fois aux stades de jeune plant et de plante à maturité, la gravité du piétin commun des racines de quatre cultivars de blé et de deux cultivars d'orge, à neuf endroits dans les trois provinces des prairies. En 1979, il y a eu, dans le cas des deux cultivars de blé de printemps et à deux endroits, une diminution significative des indices de piétin commun des racines à la maturité des plantes suivant l'augmentation de la dose d'imazalil depuis le témoin non traité en passant par les doses de 0,05; 0,1; 0,15 et 0,2 g m.a./kg de graines. Un effet de dose s'est particulièrement manifesté en 1979. Les rendements les plus élevés n'ont généralement pas reflété la répression partielle de la maladie. En fait, il y a eu dans l'ensemble une baisse de rendement significative en 1978. Il y a eu, cependant, interaction entre cultivars, traitements et emplacements; les rendements de quelques cultivars, notamment les blés Cypress et Neepawa, ont légèrement augmenté à certaines doses du fongicide à la plupart des endroits. L'absence d'effet uniforme sur les rendements peut être le résultat d'une certaine phytotoxicité du fongicide; les traitements ont généralement ralenti la levée des jeunes plants.

Losses due to common root rot in cereals are considerable in western Canada; they have been estimated at about 10% in barley (9) and 6% in wheat (8). The disease may be caused by various fungi (1), but in the Canadian Prairies, *Cochliobolus sativus* (Ito and Kurib.) Drechsl. ex Dastur [conidial state: *Bipolaris sorokiniana* (Sacc. in Sorok.) Shoem. (Syn. *Helminthosporium sativum* P.K. and B.)] is the primary pathogen (7, 10, 11). It can attack wheat and barley plants at any time during their development, the infections arising from seed-borne or soil-borne inoculum. Protectant-type fungicides applied to seed can reduce the former (5, 6), but systemic-type fungicides seem necessary to lessen those from soil-borne pathogens in the post-seedling to mature stages. Recently Chinn (3) reported a significant reduction of common root rot in seedling and mature plants of wheat grown from seed treated with imazalil [1-(β-allyloxy-2, 4 dichlorophenethyl) imidazole] in field and greenhouse tests. The effectiveness of this compound for control of the disease in the field was investigated extensively in 1978 and 1979, and the results are presented here.

Materials and methods

In 1978 treated and nontreated seed of *Triticum aestivum* L. cvs. Cypress, Neepawa, and Glenlea; *T. durum* Desf. cv. Wascana; *Hordeum vulgare* L. cvs. Brandon strain DL-2 (hull-less) and Bonanza; and *Avena sativa* L. cv. Hudson were sown in subplots, comprising four 6-m rows, 23 cm apart with 350 seeds per row, at Melfort, Regina, Rosetown, Saskatoon, Scott, and Swift Current, Saskatchewan; Beaverlodge and Lacombe, Alberta; and Winnipeg, Manitoba. The experimental design was a four-replicate split-plot factorial with cultivars and fungicide treatments being main and subplots, respectively. Fungicide dosages were 0.2 and 0.3 g active ingredient (a.i.)/kg seed.

In 1979 treated and nontreated seed of *T. aestivum* L. cvs. Cypress and Neepawa were sown in plots, comparable to the subplots in 1978, at Saskatoon and Scott, Saskatchewan. Test design was a randomized complete block with four replications. Treatment rates were 0.05, 0.1, 0.15, and 0.2 g a.i./kg seed.

Seeds were treated with an aqueous solution of imazalil and tumbled for 1 h in a glass jar. The liquid/seed volume ratio was kept constant such that 20 mL of diluted stock solution gave the desired rate of fungicide when mixed with 1 kg of seed.

Naturally occurring soil-borne inoculum of *C. sativus* was relied upon for infection. From other research studies adequate levels of inoculum were known to occur routinely at most test locations. Further, most grain fields in Saskatchewan contain in excess of 100 spores/g soil (2). This is considered sufficient to cause a high level of disease.

In 1978, 100 plants were randomly pulled from the two outer rows of each subplot at the seedling stage (2-digit code 25) and again at maturity (2-digit code 87) (16). In 1979, however, 100 plants from the two outer rows of a plot were taken only at maturity. The plants were transported to the laboratory, washed free of soil and stored in a cold room at 0°C until rated. Based on the extent of typical common root rot lesions on the subcrown internodes, the plants were individually categorized into clean, slight, moderate, and severe disease categories, and the disease intensity, expressed as "percentage disease rating", was calculated for each subplot or plot (12).

Emergence counts on the two outside rows of each subplot at Saskatoon, Scott, and Rosetown in 1978, and of each plot at Saskatoon and Scott in

Table 1. Mean plant emergence, percentage disease ratings, and grain yield in seven cereal cultivars grown from imazalil-treated and nontreated seed at nine locations in 1978

Cultivar	Treatment rate (g a.i./kg seed)	Plant emergence§	Percentage disease ratings		Grain yield‡ (quintal/ha)
			Seedling†	Maturity‡	
Common wheat					
Cypress	0.0	100	26	48	24.9
	0.2	98	15	36	25.6
	0.3	90	12	33	24.5
Glenlea	0.0	100	14	31	34.6
	0.2	92	5	21	34.3
	0.3	91	4	19	34.8
Neepawa	0.0	100	15	31	31.4
	0.2	93	5	19	31.1
	0.3	95	4	17	31.1
Durum wheat					
Wascana	0.0	100	17	41	30.4
	0.2	90	6	29	29.2
	0.3	92	6	30	29.7
Barley					
Bonanza	0.0	100	18	42	35.3
	0.2	80	10	36	33.7
	0.3	72	10	36	34.0
Hull-Less	0.0	100	17	48	30.5
	0.2	65	8	39	27.5
	0.3	60	7	38	26.0
Oat					
Hudson	0.0	100	13	27	33.3
	0.2	94	10	24	32.6
	0.3	89	9	26	32.7
Mean	0.0	100	17	38	31.5
	0.2	89	8	29	30.6
	0.3	86	8	28	30.4
SE of cultivar means		2.35	0.35	0.69	0.52
SE of imazalil rate means		1.54	0.23	0.45	0.20
SE of cultivar X rate means		4.08	0.61	1.20	0.53
Significance of cultivar effects		**	**	**	**
Significance of treatment effects		**	**	**	**
Cultivar X treatment interaction		**	**	**	*
Cultivar X treatment X location interaction		N.S.	**	*	N.S.

§Averaged over 3 locations, emergence expressed as percentage of check = 100.
†, ‡ Averaged over 8 and 7 locations respectively, due to incomplete data in some tests.
*$P < 0.05$; **$P < 0.01$.

1979, were made about 3 weeks after seeding. At maturity, grain was harvested from the two center rows using a Hege plot combine. Due to misadventure complete data were not obtained at some locations.

Results

Plant emergence. In 1978 treatment with imazalil reduced seedling emergence in all cultivars over the three locations (Table 1). This effect of fungicide varied in magnitude among cultivars, and reduction was especially pronounced in hull-less and Bonanza barleys. The overall reduction was significant ($P < 0.01$). Since the adverse effect on emergence in 1978 was most apparent at the 0.3 g a.i. rate, the highest rate used in 1979 was 0.2 g a.i./kg seed. There was no significant decrease in emergence in 1979 (Table 2).

Percentage disease ratings. In both 1978 and 1979, imazalil seed treatment reduced disease ratings significantly (Tables 1, 2). The response was most pronounced at the seedling stage (Table 1). Generally a dosage response was quite apparent; the degree of disease suppression increased with treatment rate (Table 2).

In 1978, both at seedling and plant maturity stages, the percentage disease ratings of plants of all cultivars grown from imazalil-treated seeds at the rate of 0.2 and 0.3 g a.i./kg seed were significantly lower than those in the nontreated checks (Table 1). The overall disease reduction, however, was much higher at the seedling stage than at plant maturity. Disease was reduced to a greater degree in wheat than in barley or oats. Although the treatments significantly reduced overall disease ratings, the degree of reduction varied widely among locations and cultivars. For example, the percentage reduction in disease intensity, generally, was greater in Neepawa than in Cypress (Table 3). A significant 3-way interaction (cultivar X imazalil rate X loca-

Table 3. Percentage reduction in common root rot in mature Cypress and Neepawa wheat grown from seed treated at 0.2 g a.i./kg seed relative to disease in the nontreated check

Location	Year	Cypress	Neepawa
Beaverlodge	1978	20	0
Lacombe	1978	13	26
Melfort	1978	23	47
Regina	1978	25	35
Rosetown	1978	31	48
Saskatoon	1978	22	33
	1979	55	41
Scott	1978	38	59
	1979	19	36
Winnipeg	1978	46	59
Mean	1978	27	44
	1979	37	39

Table 2. Mean plant emergence, percentage disease ratings, and grain yield in two wheat cultivars grown from imazalil-treated and nontreated seed at Saskatoon and Scott, 1979

Cultivar	Treatment rate (g a.i./kg seed)	Plant emergence§	Percentage disease ratings	Grain yield (quintal/ha)
Cypress	0.0	100	80	24.7
	0.05	106	72	24.6
	0.1	101	67	25.2
	0.15	95	58	25.4
	0.2	96	51	22.8
Neepawa	0.0	100	49	32.2
	0.05	95	45	30.7
	0.1	91	37	30.5
	0.15	94	33	28.5
	0.2	83	30	30.0
Mean	0.0	100	65	28.4
	0.05	101	58	27.7
	0.1	96	52	27.8
	0.15	94	45	26.9
	0.2	89	41	26.4
SE of cultivar means		3.54	0.58	0.47
SE of imazalil rate means		5.60	0.92	0.74
SE of cultivar X rate means		7.93	1.30	1.05
Significance of cultivar effects		**	**	**
Significance of treatment effects		N.S.	**	N.S.
Cultivar X treatment interaction		N.S.	**	N.S.
Cultivar X treatment X location interaction		N.S.	**	N.S.

§Emergence expressed as percentage of check = 100.
**$P < 0.01$.

tion) was obtained (Table 1). For example, at the seedling stage the percentage disease rating for nontreated Cypress was highest (49.1) at Swift Current and lowest (14.2) at Lacombe; however, the 0.3 g a.i. treatment rate reduced the disease most at Winnipeg (80%) and least at Swift Current (32%). Such differences were also apparent among other cultivars and locations.

In 1979 the overall mature plant disease ratings, from the highest to the lowest, were: check, 0.05, 0.1, 0.15, and 0.2 g a.i./kg seed (Table 2). The disease ratings of the check differed significantly from those of the other treatments for both cultivars at each location. The efficacy of control again varied among cultivars. For example in 1978 the percentage reduction in disease with the 0.2 g rate at most locations was considerably higher in Neepawa than in Cypress (Table 3). In 1979, however, the overall mean level of percent disease reduction for these two cultivars was almost the same (Table 3).

Grain yield. In 1978 overall yield data showed a significant decrease associated with seed treatment ($P < 0.01$) but there was a significant interaction between cultivars and rates of fungicide (Table 1). Hull-less barley exhibited the largest decrease in yield, possibly due to a high sensitivity to phytotoxic effects of the fungicide, as evident from the emergence data. Yields varied considerably among locations. Overall yield was highest at Beaverlodge and lowest at Swift Current. The 0.2 g a.i. treatment rate, however, gave a slight, but nonsignificant, increase in yield of Cypress at 7 and of Neepawa at 6 of the 9 locations. The increases ranged from 0.5 to 8.6% in Cypress and 1.3 to 9.7% in Neepawa.

In 1979 seed treatments did not result in significant yield differences. Slight overall yield increases occurred with Cypress at the 0.1 and 0.15 g a.i. rates. All other treatments resulted in yield reductions (Table 2). As in 1978, yields varied greatly between locations.

Discussion

Results reported here confirm the preliminary findings of Chinn (2) regarding efficacy of imazalil in reducing root rot of cereals. In our study imazalil seed treatment at rates of 0.05, 0.1, 0.15, 0.2, and 0.3 g a.i./kg seed significantly reduced the intensity of common root rot of wheat and barley, and to a lesser extent, of oats as evident from disease ratings based on subcrown internode lesions.

Success in controlling a soil-borne disease like common root rot of cereals depends not only on preventing seedling infection, but also on providing continued protection against omnipresent soil-borne inoculum during the entire life of the plant. Results of our experiments showing a significant reduction in common root rot at the seedling-and also at the mature stage of plant development strongly indicate that imazalil is a systemic fungicide having long lasting effectiveness.

Yield is the most important factor in assessing the efficacy of a seed treatment chemical. Generally a beneficial effect of imazalil on yield was not found. Imazalil applied at the rate of 0.2 and 0.3 g a.i./kg seed in 1978, resulted in an overall significant reduction in plant emergence and in grain yield, indicating that these rates were probably phytotoxic. This was also evidenced by the chlorotic and somewhat retarded appearance of some plots grown from imazalil-treated seeds, especially at the 0.3 g rate. However a significant 3-way interaction between cultivars, imazalil rate, and location both for percentage disease ratings and grain yield suggests that the efficacy of fungicide varied amongst cultivars and locations. Slight yield increases were obtained in 1978 in Cypress and Neepawa wheat treated at the 0.2 g a.i. rate at most locations, in 1979 in Cypress treated at 0.2 and 0.15 g a.i. rates at both Saskatoon and Scott, and in 1980 in Cypress, Glenlea, Neepawa, and Wascana wheats treated at 0.2 and 0.3 g. a.i. rates at two locations, where plot stands had been equated (15). These positive trends prompt the speculation that an enhanced yield would result from disease reduction associated with the imazalil seed treatment if the treatment was devoid of phytotoxicity. Interestingly Cypress, which most consistently showed a positive yield response, is the most susceptible to common root rot of the wheat cultivars included in this work. Further investigation to ascertain the most appropriate rate of imazalil that will maximize both disease control and yield response seems warranted.

The effect of imazalil on common root rot in the present work was assessed entirely by scoring the disease on the subcrown internode only. Whether this accurately reflects the overall effectiveness of the fungicide in other parts of the plant is unknown. The usefulness of the subcrown internode lesions as indices of common root rot in nontreated plants has been well demonstrated previously (8-11, 13, 14), but variable suppression of disease in the lower stem, crown, and roots as distinct from that of the subcrown internode should be explored.

Preliminary studies (Verma, unpublished data) showed that the number of *C. sativus* conidia produced on subcrown internodes, crowns, and stems of plants grown from imazalil-treated seed was significantly lower than that on nontreated plants. In the present studies, since plants from treated seed had less disease than those from nontreated seed, a significantly lower spore population on plants grown from treated seed was not surprising. It would be interesting to determine whether the viability of the spores produced on the plants grown from imazalil-treated seed is affected.

Imazalil seed-treatment increases the diameter of subcrown internodes (3), reduces their length, and stimulates formation of coleoptile-node-tillers (CNTs) (4) in cereals. Whether these thicker and shorter internodes were any aid in reducing severity of common root rot, or whether plants with CNTs have a better chance of escaping root rot infection as compared to those with no CNTs was not clarified in the present work.

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