Gradients of Ascochyta Blight in Saskatchewan Lentil Crops

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ABSTRACT

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Horizontal spread of Ascochyta blight was studied from 1988 to 1990 in 20 commercial lentil (*Lens culinaris*) crops planted immediately adjacent to residues of the previous year's lentil crop. The percentage of seed infected with *Ascochyta fabae* f. sp. *lentis* was determined in samples collected at harvest. In several lentil crops in which treatments to reduce disease spread were imposed on the edge of the field, incidence and severity were also assessed. Usually, the disease was observed 20 m or more from the edge of fields early in the season, and incidence, severity, and seed infection declined sharply with increasing distance from the adjacent residues. Disease severity gradients reflected the pattern of local precipitation. Gradients became shallower, and disease spread was restricted, when limited precipitation occurred, particularly in July. Seed infection occurred up to 250 m from the primary inoculum source, but gradients generally leveled off within 50 m. Although fallow, nonhost, and fungicide treatments on the edge of fields did not reduce horizontal disease spread, they eliminated high levels of seed infection close to the inoculum source.

Ascochyta blight of lentil (*Lens culinaris* Medik.), caused by *Ascochyta fabae* Speg. f. sp. *lentis* Gossen et al, causes yield losses and seed discoloration (14). The pathogen is highly host-specific and is seed- and stubble-borne (6,7). Teleomorphs of *A. f.* f. sp. *fabae* (*Didymella fabae* Jellis & Punith.) (11) and *A. f. lentis* (W. J. Kaiser, *personal communication*) were reported recently in the United Kingdom and the United States, respectively. However, a teleomorph of *A. f. lentis* has not yet been found in Saskatchewan. Thus, in Saskatchewan the pathogen is believed to be dispersed like many other pycnidial fungi, mainly by rain splash of conidia (5). Recommendations for disease control include crop rotation and disease-free seed.

In 1988 Bedi and Morrall (2) conducted a survey for Ascochyta blight in 118 commercial lentil crops in Saskatchewan; this included testing samples of seed used for planting. Although greater than 50% of the seed lots contained at least a trace of *A. f. lentis*, the disease distribution in fields suggested that seed was not the only source of inoculum. In crops in which Ascochyta blight was observed, disease severity was frequently higher on one side of the field than the other. Usually the side with higher disease severity was adjacent to residues of a 1987 lentil crop. This uneven distribution of disease was confirmed in 21 crops by isolating the pathogen from seed samples harvested in different areas of the field. It appeared that the pathogen had moved into these crops from inoculum sources in adjacent fields, but movement was sufficiently restricted so that the crops were not uniformly diseased by the end of the season. Low rates of horizontal and temporal spread are characteristic of many diseases spread by rain splash (4).

The purpose of this study was to investigate spread of Ascochyta blight in commercial lentil crops in relation to lentil residues and volunteers from the previous year in adjacent fields. A preliminary report of part of the results has been published (1).

MATERIALS AND METHODS

Pattern of seed infection in commercial crops. Experiments were conducted in Saskatchewan in 1988 and were repeated in 1990 to provide a larger data base, representative of a wider range of climatic conditions. Lentil crops planted immediately adjacent (i.e., where no road, trail, or fenceline was present) to 1-yr-old lentil residues were located at Laird (60 km north of Saskatoon), Meota, and North Battleford (170 and 140 km northwest of Saskatoon, respectively) in 1988 and at Elrose (145 km southwest of Saskatoon), Laird, and Zealandia (95 km southwest of Saskatoon) in 1990. In 1988, one lentil crop was sampled at each location; in 1990, five were sampled at Elrose, four at Laird, and two at Zealandia. The lentil crops were all of the cultivar Laird, which is moderately resistant to Ascochyta blight (14). All four major compass directions, with respect to the location of the adjacent lentil residues, were represented among the 14 crops. In each lentil crop, plant samples were collected at harvest in four transects, about 40 m apart, perpendicular to the edge of the field assumed to contain the primary source of inoculum. An exception was in 1990 at Laird 2, where there were only three transects, 20 m apart. The samples within each transect were collected at various distances from the edge of the field. At Laird in 1988 and at Laird 4, Elrose 4, and Elrose 5 in 1990, the samples were collected after the crops had been cut and placed in windrows.

After collection, plant samples were dried and threshed. Batches of 100 seeds per sample were surface-sterilized and incubated on 20% V8 juice agar or potato-dextrose agar as described previously (16).

Experiments to reduce disease spread. Experiments were conducted in crops of cv. Laird at three locations in 1989 and at two locations in 1990. Treatments to reduce disease spread into the lentil crop were established on the edge of fields, using farm machinery, and disease was monitored throughout the growing season. Rainfall data for the growing season were obtained from either Environment Canada or local farmers.

Tests in 1989 were located at Laird (two sites), North Battleford, and Zealandia (Table 1). All crops were seeded between 8 and 10 May. Three treatments were evaluated: 1) spraying a strip of the crop on the edge next to the residues with a fungicide ("fungicide"), 2) isolat-

Table 1. Details of check and treatments to reduce spread of Ascochyta blight of lentil at six locations in Saskatchewan, 1989–1990

Year / Location	Treatment strip width (m)			
	Check	Fungicide	Nonhost	Fallow
1989				
Laird 1	0	9	8	8
Laird 2	0	...	...	9
North Battleford	0	...	16.5	16.5
Zealandia	0	9	8.5	8.5
1990				
Laird	0	11	11	...
Zealandia	0	11	11	...

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ing the crop by interposing a nonhost strip between the adjacent lentil residues and host crop ("nonhost"), and 3) isolating the crop by leaving a strip fallow ("fallow"). At each location a check was also included in which the crop was seeded adjacent to the residues.

At each site, the crop was divided into treatment sections, and each treatment was applied only once. Fallow treatments were tested at all locations, and nonhost treatments at all locations except Laird 2 (Table 1). Because of differences in farmers' seeding equipment, the width of fallow and nonhost treatments varied from 8 to 16.5 m at different locations. Nonhost treatments consisted of either barley (*Hordeum vulgare* L.) or wheat (*Triticum aestivum* L. or *T. durum* Desf.). Four subsample transects were established in each treatment section. About 20 m lay between transects within a treatment section, and 24–37 m between adjacent treatment sections. Sample sites were marked with stakes within each transect at various distances from the 1988 residues.

Fungicide treatments were included at Laird 1 and Zealandia. At both locations, a 9-m strip on the crop edge was sprayed with chlorothalonil at 1.7 kg a.i./ha in 210 L of water. Spray frequency consisted of two and three applications at Zealandia and Laird 1, respectively. The first application was made at the early bloom stage (55 days after seeding). A second application was made 18 days later at Zealandia. At Laird 1, second and third sprays were applied at 10-day intervals.

In 1990, tests were located at Laird and Zealandia. The crops were seeded on 7 and 8 May, respectively. Two treatments, nonhost and fungicide, were reevaluated, and a check was included at both locations (Table 1). The nonhost strips were seeded to wheat. In the fungicide treatment a strip on the edge of the lentil crop was sprayed with chlorothalonil at 1.7 kg a.i./ha in 180 L of water. The fungicide was first applied 24 days after seeding at Laird and 28 days after seeding at Zealandia. Subsequent applications were made at 9- to 10-day intervals until early August.

Each test in 1990 was a randomized complete block with three replicates. The treatment strips were approximately 32 m long and 11 m wide. A sample transect was established perpendicular to the edge at the center of each treatment strip, and sample sites were located within each transect at various distances from the adjacent lentil residues. Transects were separated by at least 30 m.

Disease assessment. Disease incidence was assessed on lentil seedlings 30–40 days after seeding at all sites except Laird 2 in 1989. The number of seedlings with one or more Ascochyta blight lesions within a 1-m^2 quadrat was determined and expressed as a percentage of the total number of plants. In this study, disease severity refers to the percentage of aerial plant tissue diseased, including stem and pod lesions. Disease severity was assessed in late June and in July in 1989 and in late June, July, and early August in 1990. Severity was rated in each 1-m^2 quadrat according to the Horsfall-Barratt grading system (10). Individual Horsfall-Barratt values were converted to percent disease severity values (17). Generally, plants were harvested when the lower pods were ripe. After harvest, the percent seed infection was assessed as described above.

Data analysis. The relationship of disease incidence, disease severity, and seed infection with distance from the inoculum source was examined. Two transformations to linearize the data, the inverse power law (8) and the negative exponential (12), were evaluated. One was added to values in some data sets to avoid zero readings. In all cases, the inverse power law resulted in the highest coefficients of determination when transformed data were fitted to a linear regression model. Not all values collected from each transect were used in regression analyses. "Plateau" values, values resulting from increases in disease before the start of decreasing trends, and data from the sprayed area of the fungicide treatments were excluded. Significance was evaluated at $P = 0.1$, 0.05, and 0.01 because it was recognized that data

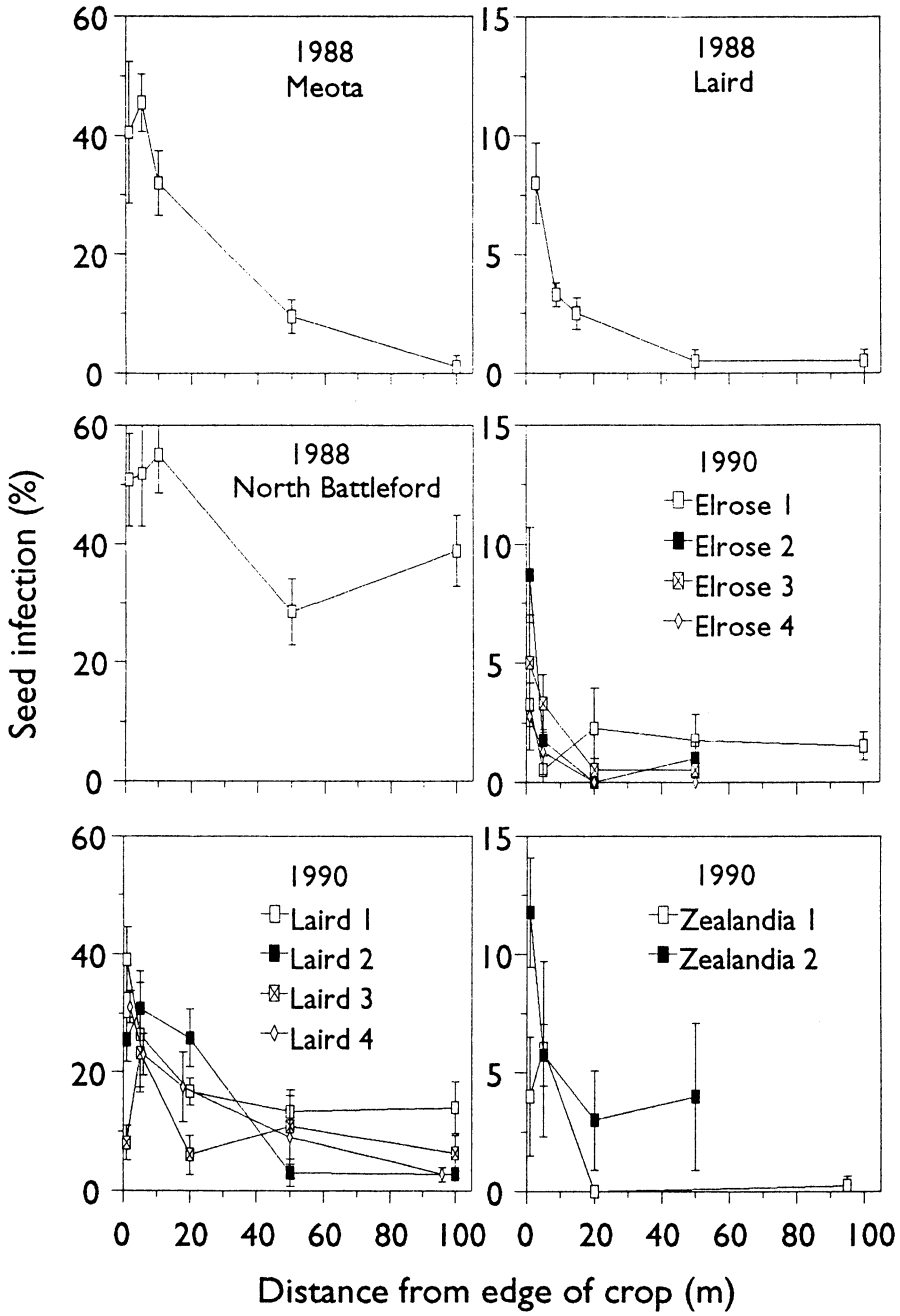

Fig. 1. Mean percent infection of seed with Ascochyta blight in relation to distance from 1-yr-old lentil residue in an adjacent field at six locations in Saskatchewan, 1988–1990. Vertical bars indicate the standard error. Note that scales in the right and left columns are different.

collected in commercial fields are highly subject to uncontrollable sources of variation.

RESULTS

Pattern of seed infection in commercial crops. The level of seed infection was highest on the edges of lentil crops adjacent to the previous year's lentil residues in 12 of the 14 crops sampled (Fig. 1). Steep gradients were evident at Meota and North Battleford in 1988 and at Laird in 1990. However, spread of disease was limited. At Meota, for example, seed infection was 41% close to the inoculum source and only 1% 100 m away. Shallow seed infection gradients were present at Laird in 1988 and at Elrose and Zealandia in 1990. At these locations seed infection was about 10% or less close to the inoculum source and declined to below 3% within 5–20 m. In one crop at Elrose no seed infection was detected.

Monthly precipitation from May to July (Table 2) was reflected by differences in gradients among locations. In 1988 at Meota and North Battleford, precipitation in May and June was more than three times that at Laird, where less disease spread occurred. Precipitation at Laird in 1988 was far below the 30-yr average each month, and spread at this location was limited to about 15 m. In 1990 the furthest spread of disease occurred at Laird, where precipitation was highest. Lower total and less frequent precipitation and less disease spread occurred at Elrose and Zealandia.

Two anomalies were observed in the data. First, in five crops there was a small increase in seed infection on the edge of the crop before the decline started (Fig. 1). Second, at North Battleford in 1988 a large increase in disease occurred between 50 and 100 m from the inoculum source.

Experiments to reduce disease spread. *Patterns of spread.* Disease incidence gradients with a significant slope occurred at all locations in 1989 but at neither location in 1990 (Fig. 2). Disease incidence in the check declined sharply with increasing distance from the edge of the field, except at Laird 1 (1989), where an anomalous increase occurred at 200 m in one sampling transect. The steepest gradient occurred in 1989 at North Battleford, where mean incidence was 40% close to the inoculum source and only 0.5% 100 m away. Ascochyta blight had spread about 20 m from the primary inoculum source into all of the crops by mid-June, except at Zealandia in 1990, where it was detected only at 1 m from the adjacent residues (data not shown).

A total of 26 disease severity gradients were evaluated in 1989 and 18 in 1990, and a wide range of slope values was found (Table 3 and Fig. 3). To facilitate comparison of measurement dates, transformed data and regression lines for the check at each location are plotted in Figure 3. In 1989 slope values in the check were highly significant on both assessment dates at all locations except Laird 2. At Laird and North Battleford, the locations with the highest precipitation in June and July (Table 2), disease severity and gradient steepness in the checks remained about the same or increased from the first to second assessment date. At Zealandia, where precipitation was much lower, particularly in July, both disease severity and gradient steepness decreased from the first to the second assessment date.

In 1990, disease severity in the check at Laird increased in the first 5 m but decreased over the next 45 m (Fig. 3). Slopes for the gradients were significant on all assessment dates. Gradients be-

Table 2. Number of days with rain, total rainfall, and 30-yr average rainfall at locations of field experiments in Saskatchewan in May, June, and July 1988–1990

Year / Location	No. of days with rain			Rainfall (mm)					
				Total			30-yr av.		
	May	June	July	May	June	July	May	June	July
1988									
Laird	5	8	7	11	23	58	40	62	64
Meota[a]/N. Battleford	7	9	10	33	94	46	35	60	65
1989									
Laird	5	5	4	78	56	39	40	62	64
N. Battleford[a]	6	10	6	51	85	61	35	60	65
Zealandia	7	5	2	98	31	13	36	66	55
1990									
Elrose	5	9	9	24	54	58	...	...	...
Laird	5	8	7	58	57	93	40	62	64
Zealandia	3	7	7	17	39	68	36	66	55

[a] Data obtained from Environment Canada. All other data obtained from local farmers.

Table 3. Regression[a] of mean severity of Ascochyta blight on distance from 1-yr-old lentil residue in an adjacent field at six locations in Saskatchewan, 1989–1990

Year / Location	Date	Treatment[b]	Coefficient of determination (r^2)	Intercept (a)	Slope (b)	Probability ($b = 0$)
1989						
Laird 1	4 July	FU	0.91	0.91	−0.36	0.000
		NH	0.41	0.48	−0.22	0.361
		FA	0.87	0.83	−0.32	0.065
	24 July	FU	0.82	1.23	−0.42	0.035
		NH	0.98	1.39	−0.55	0.000
		FA	0.96	1.49	−0.53	0.004
Laird 2	24 June	FA	0.03	0.08	0.02	0.800
	14 July	FA	0.96	1.36	−0.65	0.004
N. Battleford	6 July	NH	0.75	0.55	−0.19	0.056
		FA	0.59	1.42	−0.46	0.130
	25 July	NH	0.99	1.92	−0.63	0.070
		FA	0.84	0.87	−0.20	0.085
Zealandia						
	29 June	FU	0.26	0.24	−0.05	0.250
		NH	0.83	1.42	−0.79	0.090
		FA	0.96	1.18	−0.51	0.004
	21 July	FU	0.14	0.26	−0.05	0.530
		NH	0.83	0.61	−0.32	0.090
		FA	0.96	0.92	−0.44	0.128
1990						
Laird						
	28 June	FU	0.77	0.47	−0.17	0.020
		NH	0.81	1.05	−0.58	0.040
	25 July	FU	0.31	0.44	−0.05	0.250
		NH	0.36	0.69	−0.15	0.210
	3 Aug.	FU	0.27	0.54	−0.08	0.300
		NH	0.97	1.34	−0.49	0.000
Zealandia						
	13 July	FU	1.0	0.07	0	...
		NH	1.0	0.07	0	...
	23 July	FU	0	0.11	0.01	0.940
		NH	0.54	0	0.08	0.040
	1 Aug.	FU	0.23	0.28	−0.07	0.340
		NH	0.65	1.37	−0.19	0.099

[a] $\log_{10}$ (disease severity) $= a + b \log_{10}$ (distance).
[b] FU = fungicide, NH = nonhost, FA = fallow.

came shallower from the first to the second assessment date but much steeper between the second and third dates. Precipitation at this location was about average in June and much higher than average in July (Table 2). Weather conditions were less favorable for development of Ascochyta blight at Zealandia. Precipitation in May, June, and July was low compared to Laird and far below the 30-yr average in May and June. Slopes of the disease severity gradients in the check were not significantly different from zero.

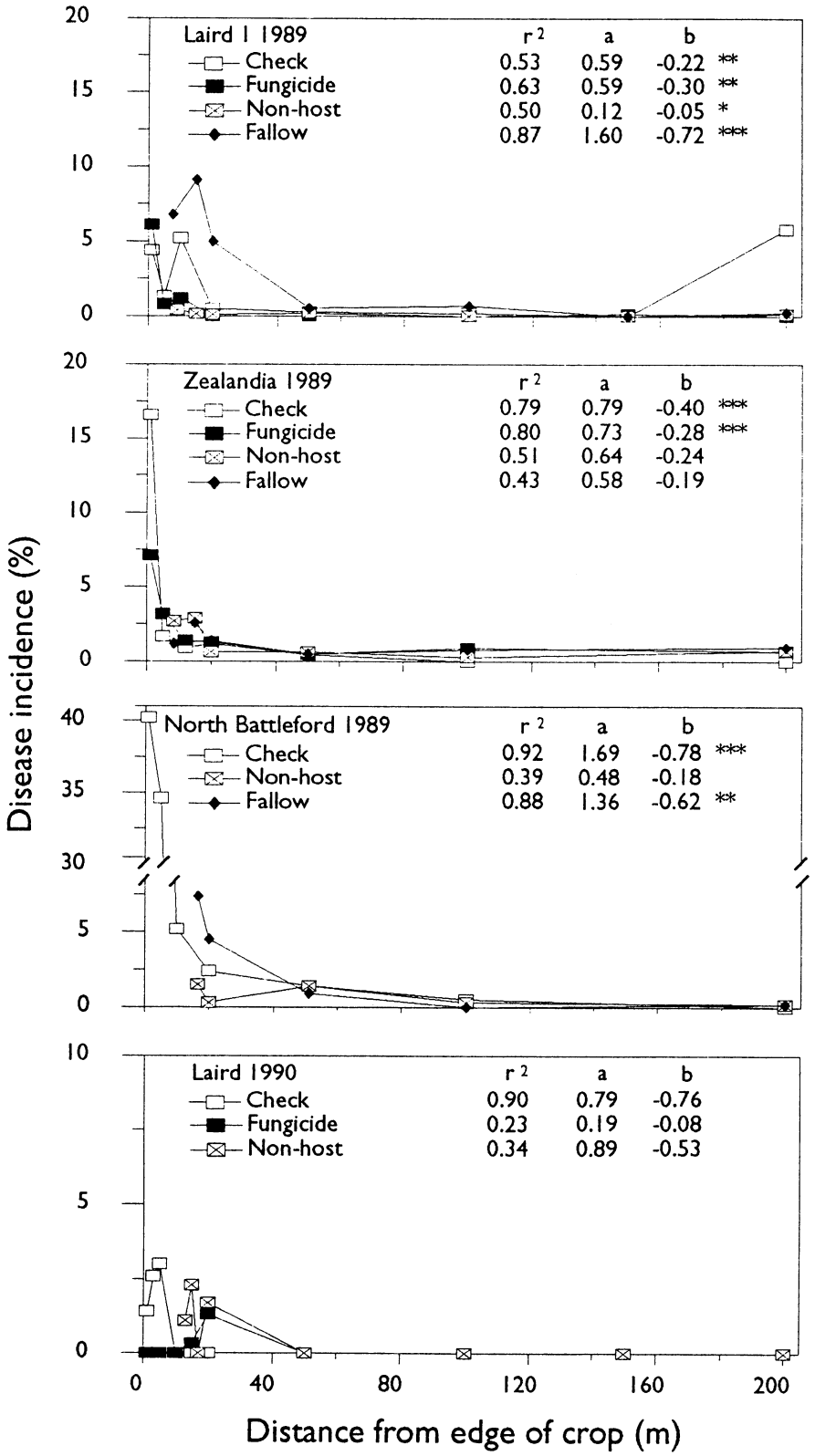

Fig. 2. Mean incidence of Ascochyta blight on lentil seedlings in relation to distance from 1-yr-old lentil residue in an adjacent field at four locations in Saskatchewan, 1989–1990. Regression parameters are based on the equation $\log_{10}$ (disease incidence + 1) = $a + b \log_{10}$ (distance). Single, double, and triple asterisks indicate slope significant at $P = 0.10$, 0.05, and 0.01, respectively. Note that scales are different at different locations.

The level of seed infection was higher on the edge of the lentil crop adjacent to lentil residues in both years at all locations (Fig. 4). Regression analysis confirmed that there was a negative relationship between seed infection and distance from the inoculum source in nine of 13 gradients in 1989 and three of six gradients in 1990. A wide range of slope values was obtained.

In 1989 the steepest seed infection gradients occurred at Laird 1 and North Battleford (Fig. 4). This was a reflection of favorable moisture conditions throughout the season at both locations (Table 2). Although seed infection was highest on the side of the crop adjacent to lentil residues at Laird 2, seed infection did not exceed 7%. At Zealandia seed infection was below 2% throughout the crop. Moisture conditions at this location were poor after early June. Thus, an initially high disease incidence at the edge of the crop did not translate into corresponding levels of disease severity and seed infection.

In 1990 the highest seed infection occurred at Laird, the location with the highest amount and frequency of precipitation (Table 2). At Zealandia a seed infection gradient with a significant slope was observed in the check (Fig. 4), but horizontal movement of disease was less than 10 m. Limited disease development and spread at this location can be attributed to unfavorable moisture conditions until July and a low level of primary inoculum resulting from dry conditions in the late summer of 1989.

Efficacy of isolation barriers. In 1989 the slopes of disease incidence gradients in the checks were steeper than in the treatments at North Battleford and Zealandia (Fig. 2). The fallow treatment resulted in the steepest slope at Laird 1 but a nonsignificant slope at Zealandia. No significant gradients occurred in the nonhost treatment. In the fungicide treatment, gradients were significant at Laird 1 and Zealandia. The slope for the fungicide treatment was steeper than in the check at Laird 1, but the opposite was true at Zealandia. In 1990, by mid-June disease was not detected in the nonhost treatment at Zealandia and was found only very close to the inoculum source in the fungicide treatment (data not shown). In 1989 disease incidence was measured before fungicide application, whereas in 1990 it was measured on the third of eight application dates. Since the fungicide treatment had been ineffective in preventing disease spread in 1989, applications were started earlier in 1990.

In 1989 a substantial increase in the steepness of the disease severity gradients between the first and second assessment dates occurred in the nonhost and fallow treatments at Laird 1, the nonhost treat-

ment at North Battleford, and the fallow treatment at Laird 2 (Table 3). By the second date, these treatments had slopes steeper than the check (Fig. 3). However, decreases in disease severity and gradient steepness were observed in the nonhost and fallow treatments at Zealandia and in the fallow treatment at North Battleford. The first disease severity assessment in the fungicide treatment was conducted before fungicide was applied, and only one application was made between the first and second dates at both locations. On the first assessment date, the slope in the fungicide treatment at Laird 1 (Table 3) was similar to that of the check (Fig. 3). By the second date, disease severity was reduced in the sprayed area but not in the nonsprayed area. Fungicide treatment at Zealandia had no effect, because of limited disease development.

The pattern of gradient development in the nonhost treatment (Table 3) in 1990 was similar to that in the check (Fig. 3), excluding the initial increasing trend. In 1990 application of fungicide at 9- to 10-day intervals effectively suppressed disease development. In the sprayed area, disease severity remained below 4% throughout the season. A gradient with a significant slope was detected in the nonsprayed part of the treatment on 28 June. However, slope values were near zero on all other assessment dates. At Zealandia, the slope of disease severity gradients in most treatments remained near zero throughout the season.

Seed infection and the slope of seed infection gradients at Laird 1 and Laird 2 in 1989 were higher and steeper, respectively, in the fallow treatment than in the check (Fig. 4). This was not true at North Battleford, where the level of seed infection in the fallow treatment was 13% at 20 m from the primary inoculum source compared to 32% in the check. However, at 50 m from the inoculum source the level was 25% in the fallow treatment, compared to only 11% in the check. Seed infection gradients in the nonhost treatments at Laird 1 and North Battleford were steeper than in the check. Fungicide application effectively controlled seed infection in the sprayed strip at Laird 1. However, in the nonsprayed area of this treatment there was little difference in seed infection from the check. No significant gradients occurred in the treatments at Zealandia.

In 1990 a seed infection gradient with a significant slope occurred in the nonhost treatment at Laird (Fig. 4), and seed infection was higher than in the check at most distances from the inoculum source. The fungicide treatment was very effective in reducing seed infection in the sprayed area, but outside of the sprayed area seed infection was similar to that in the check. Horizontal movement of disease was not sufficient to test the nonhost and fungicide barriers at Zealandia.

DISCUSSION

In this study, gradients of Ascochyta blight developed in commercial lentil crops from inoculum on 1-yr-old residues and volunteers in adjacent fields. The gradients were not affected by the compass direction of the inoculum source, remained relatively steep throughout the growing season, and leveled off at about 50 m from the source. Such gradients are indicative of splash-dispersed pathogens (8). The horizontal spread of Ascochyta blight in lentil was different from that observed in winter faba bean in the United Kingdom (3), where a relatively shallow disease gradient developed in a crop planted adjacent to 1-yr-old faba bean residues. The disease spread at least 200 m from the inoculum source by May with little indication of leveling off. Jellis and Punithalingam (11) suggested that this pattern of spread was better explained by wind-dispersed ascospores than by splash-dispersed conidia.

Assessment of disease incidence on lentil seedlings in the present study indicated that the pathogen often moved 20 m or more into the crop from the inoculum source early in the season. In some "isolation" treatments, incidence gradients had a significant negative slope by June, indicating that inoculum had already been dispersed past the treatment barriers. This observation is inconsistent with typical splash dispersal, in which spores move at most a few meters during each episode of dispersal (9), and suggests that other mechanisms are involved. Adjacent residues may have been dragged into the fields during cultivation or blown in during the fall and spring. Also, wind-dispersed aerosols (5), ascospores, and plant debris (e.g., abscised leaflets) cannot be ruled out.

The Horsfall-Barratt grading system is subjective, but it can be used rapidly. Thus, it was possible to make several measurements of disease severity and to examine effects of weather on disease development and spread. Development of disease severity gradients at each location reflected the pattern of precipitation. Gradients became shallower, and disease spread was restricted, when precipitation was low, particularly in July. This was most evident in the check at Zealandia in 1989 (Fig. 3), in which the slope decreased from −0.52 on 29 June to −0.16 on 21 July. Total precipitation at Zealandia in June was less than half

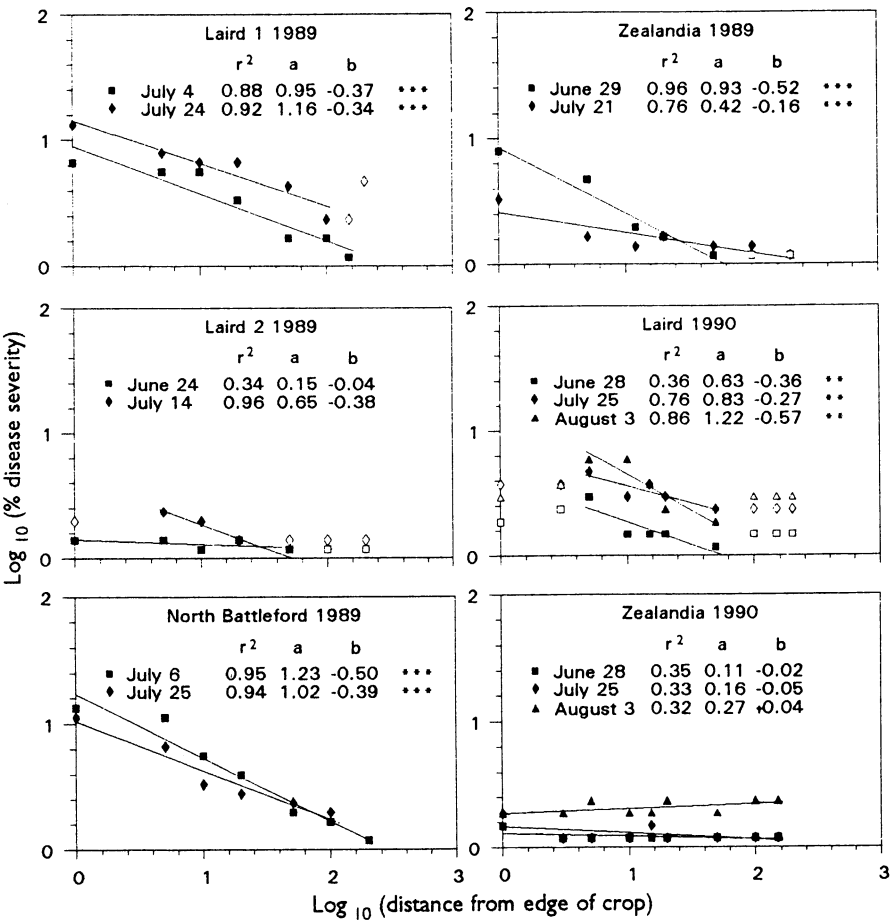

Fig. 3. Relationship of mean disease severity to distance from 1-yr-old lentil residue in an adjacent field in the check in June and July at four locations in Saskatchewan in 1989 and in June, July, and August at two locations in Saskatchewan in 1990. The regression equation was $\log_{10}$ (disease severity) = $a + b \log_{10}$ (distance). Open symbols indicate data excluded from regression analysis. Single, double, and triple asterisks indicate slope significant at $P = 0.10$, 0.05, and 0.01, respectively.

of the 30-yr average. A similar reduction in gradient steepness was observed from 28 June to 25 July in the check at Laird in 1990. The observed reduction in disease severity resulted from host growth without additional disease progress, which was due to low precipitation and premature abscission of diseased leaflets. The lack of disease development and spread at Laird 2 in 1989 was probably due to a weak source of primary inoculum, because weather conditions were conducive to a blight epidemic.

Seed infection is an objective measure of the final level of disease at harvest. The pattern of seed infection in 20 commercial crops, including those in which treatments were imposed, indicated that spread of Ascochyta blight was limited. Although disease was observed up to 250 m from the inoculum source, it usually declined to a uniformly low level within the first 50 m. The high seed infection (10–20%) that occurred further into the crop at Laird 1 and North Battleford in 1989 and at Laird in 1990 was probably a result of seedborne inoculum (2). The levels of infection in seed planted in these three fields ranged from 0.5 to 1.75% (S. Bedi and E. A. Pedersen, *unpublished*).

At several locations, disease increased on the edge of the crop before the start of the decreasing trend. The reason for this is unclear, but it may have been an edge effect resulting from a net loss of inoculum generated on infected plants. This would be similar to the phenomenon observed in small plots (13).

None of the treatments reduced horizontal spread of Ascochyta blight into the lentil crop. In 1990 fungicide spraying was started 31 days earlier than in 1989, but it was still ineffective. The percentages of seed infection in the nonhost treatment and nonsprayed area of the fungicide treatment were similar to those in the checks. In the fallow treatment, seed infection was actually higher than in the check. However, in many other cases the maximum level of disease was less than in the check. This was because the highest level of disease occurred close to the adjacent residues where the nonhost plants or fungicide-sprayed plants were located. Thus, the treatments were beneficial in reducing contamination and downgrading of seed, which may occur when good quality seed from the main part of a lentil crop is mixed with highly infected and discolored seed from the edge of the field. Nonetheless, farmers could achieve the same benefit by harvesting and handling seed from the edge of a crop separately.

Variability of the data in the present study resulted largely from conducting experiments in commercial crops, in which control over the variables of interest is difficult. The strength and distribution of primary inoculum were not uniform, and its precise location was unknown. There was no control over infection of the seed used to plant the crops. Moreover, observers had to move through the crops to measure disease, which disturbed the plant canopies and increased the risk of mechanical inoculum spread. In an attempt to solve these problems, future studies on the spread of Ascochyta blight will be conducted using an experimental design with long narrow plots separated by strips of nonhost plants (15). This design will allow greater control over the source of primary inoculum and permit disease assessments to be made from outside plot boundaries.

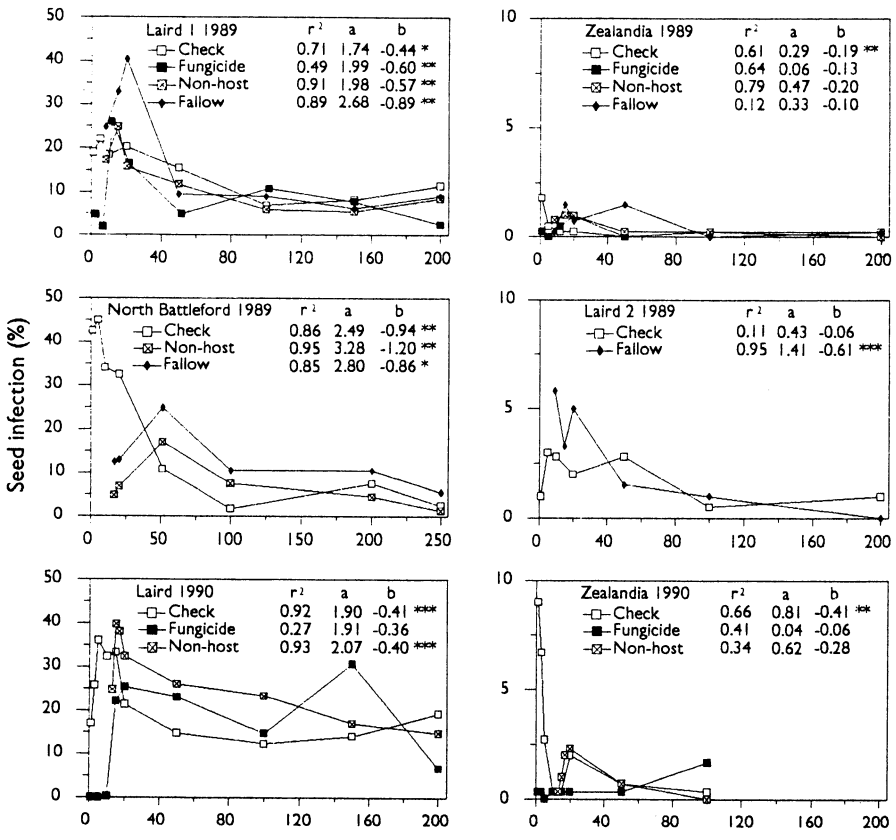

Fig. 4. Relationship of the mean percentage of lentil seed infected with *Ascochyta fabae* f. sp. *lentis* to distance from 1-yr-old lentil residue in an adjacent field at six locations in Saskatchewan, 1989–1990. Regression equation was $\log_{10}$ (seed infection + 1) = $a + b \log_{10}$ (distance). Single, double, and triple asterisks indicate slope significant at $P = 0.10$, 0.05, and 0.01, respectively. Note that scales in the right and left columns are different.

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