Epidemiology of Spot-Type Net Blotch on Spring Barley in Saskatchewan

C. G. J. van den Berg and B. G. Rossnagel

Department of Crop Science and Plant Ecology, and Crop Development Centre, University of Saskatchewan, Saskatoon, Saskatchewan, Canada S7N 0W0.
Present address of first author: Department of Plant Science, University of Manitoba, Winnipeg R3T 2N2.
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ABSTRACT

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The number of airborne spores of *Pyrenophora teres* f. *maculata*, disease progress, and occurrence of conditions favorable for disease development were studied in relation to crop development and weather variables in a barley crop growing in a field with infested crop debris in 1986 and 1987. Conidia were trapped in both years, but no ascospores were detected. Daily number of airborne conidia followed a seasonal pattern. It was generally low during June, increased during July, and peaked about 1 August. The daily number of airborne conidia was correlated with the senescence of the upper leaves. Variation in daily number of airborne conidia was correlated with minimum and mean temperature on the previous and same day during June, and with maximum and mean temperature on the same day during July. No relationship was observed between daily number of airborne conidia and duration of leaf surface wetness during the growing season. The hourly number of airborne conidia followed a diurnal pattern, with a maximum at 1400 hours. The periodicity was associated with diurnal changes in temperature, relative humidity, and occurrence of leaf surface wetness. Combinations of temperature and leaf surface wetness observed on most nights during the growing season would allow infection. Consequently, progression of spot-type net blotch closely followed plant development, and each leaf was infected shortly after emergence.

Additional keywords: Hordeum vulgare, spore dispersal.

Spot-type net blotch, incited by *Pyrenophora teres* f. *maculata* Smedeg. (anamorph: *Drechslera teres* f. *maculata*), has become the most prevalent foliar disease of spring barley (*Hordeum vulgare* L.) in some areas of Saskatchewan (18,20). It has become more important than net-type net blotch, incited by *P. teres* f. *teres* Smedeg. Net-type net blotch is more important than spot-type net blotch in winter barley in Europe (6,15,16).

The disease cycle has been described for *P. t. teres* (6). Initial infections result from conidia or ascospores produced on infested crop debris (7,12) or from seed infection (9,14). Secondary spread is via conidia produced on infected leaves (6). Information on the quantity of airborne spores produced during the growing season is limited, but important for the interpretation of epidemics and the development of effective control measures.

The number of airborne conidia of *P. t. teres* and the related fungus *Cochliobolus sativus,* causal agent of spot blotch in barley and wheat, followed both a seasonal and a diurnal pattern in barley crops in eastern Canada (1,10). The daily number of conidia was small in June and increased in July with peaks in late July and August. The peaks have been related to extended periods of leaf surface wetness and high temperatures. The diurnal pattern reached a maximum at 1200 hours and has been related to diurnal changes in temperature, relative humidity, wind velocity, and leaf surface wetness.

Little information is available concerning the epidemiology of *P. t. maculata* under the semiarid conditions of Saskatchewan. The objectives of this study were to investigate the influence of environmental factors on the number of airborne conidia and the development of net blotch epidemics, and to determine the occurrence of conditions favorable for disease development.

MATERIALS AND METHODS

A field plot (0.8 ha) of the two-row spring barley cultivar Elrose, which is susceptible to spot-type net blotch, was established in 1986 and 1987 at Shellbrook, Saskatchewan. The plot had a history of spot-type net blotch on barley with a severe epidemic occurring in 1985. Seed was planted at a rate of 110 kg/ha with a row spacing of 15 cm using a double disk drill. Seeds were planted directly into standing barley stubble, which was infested with *P. t. maculata.* The plots were seeded on 23 May 1986 and 26 May 1987. Fertilizer was applied as 27-27-0 at 112 kg/ha with the seed and as 34-0-0 at 67 kg/ha on 2 June 1986 and 9 June 1987. Weeds were controlled with 3.5 L/ha Roundup (glyphosate) before seeding and a tank mix of 1.0 L/ha Buctril-M (bromoxynil and MCPA) and 3.5 L/ha Avenge 200-C (difenzoquat) on 9 June of 1986 and 1987.

Plant development and disease severity were observed at intervals of 3–11 days from 30 June 1986 onward and at intervals of 4–8 days from 10 June 1987 onward. Plant development was determined using the Zadoks scale (22). Disease severity was estimated as percent leaf area discolored using the percentage scale (keys 1.1 and 1.7 in reference 5). The percentage of leaf area discolored was assessed on all leaves of 40 primary culms that were taken at random from the plot at 4-m intervals. Progress of leaf area discoloration was analyzed for each leaf position using regression procedure REG of SAS software (SAS Institute Inc., Cary, NC) on logit-transformed data. Homogeneity of residual variances was tested with Bartlett's procedure (17). Differences between slopes were determined with the test for homogeneity of slopes (17).

The presence of airborne spores was monitored from 2 June to 8 August 1986 and from 28 May to 9 August 1987 with a battery-operated Burkard 7-day volumetric spore trap (Burkard Scientific Instruments, Rickmansworth, Herts., UK). The spore trap was inoperative between 13 and 15 June 1986. The spore trap was located in the center of the plot with the air intake orifice at 42 cm above the soil surface. Plants within 1 m of the spore trap were cut regularly to allow unimpeded air movement. Air was drawn at a rate of 10 L/min and the Melinex tape was coated with a mixture of Vaseline, paraffin wax, and toluene. To quantify the number of spores, exposed tapes were cut into 24-h sampling segments, mounted on microscope slides in lactophenol-cotton blue, and scanned under a light microscope at a magnification of 100×. The number of spores of *P. teres* was counted and recorded on an hourly basis.

Temperature, relative humidity, precipitation, and leaf surface wetness were monitored in the plot with a Campbell CR21 micrologger and accompanying sensors (Campbell Scientific Canada Inc., Edmonton, Canada). All variables were recorded at 1-h intervals between 2 June and 9 August 1986 and between 28 May and 9 August 1987. Temperature was measured with a thermistor (model 101) that was placed at 25 cm above the soil surface and shielded from direct sunlight with a white cover. Relative humidity was measured with a thermistor and PCRC-11 chip (model 201) that was placed at 30 cm above the soil surface and shielded from direct sunlight with a white cover. Precipitation was measured with a tipping bucket rain gauge (model 2501, Sierra-Misco Inc., Berkeley, CA). Leaf surface wetness was measured with two electrical impedance grids (model 231) coated with two thin coats of latex paint (4). One sensor was deployed with a rotation of 15° along the short axis and the other with a rotation of 15° along the long axis. Both sensors were placed 50 cm above ground level with the tilted top facing north. Leaves were considered to be wet when the average value of the sensors exceeded 80% of the maximum value. Daily number of airborne conidia was correlated with leaf area discoloration for each leaf position and meteorological factors observed on the same day and four preceding days using the correlation procedure CORR of SAS software. Meteorological data of preceding days were shifted using function LAG of SAS software. For days between sampling days, leaf area discoloration was calculated using linear interpolation.

In 1987, attempts were made to induce sporulation on infected plant material. Sporulation was determined on crop debris consisting of 10 5-cm-long stem pieces and the remnants of 10 leaves and on 10 leaves for each leaf position of the growing crop on each sampling day. Immediately after disease severity was recorded on each sampling day, leaves were placed in petri dishes with moist filter paper in both bottom and lid, then placed in an incubator with cool-white fluorescent light and a 12-h light/dark cycle at 19 C. After 1, 3, and 5 days of incubation, leaves were submersed in 10 ml of distilled water and washed for 15 s on a wrist-action shaker. The spore concentration of the wash water was determined with a hemacytometer. The number of spores produced was calculated as the product of the spore concentration and the volume of the wash water.

RESULTS

Growth and development of the barley crop were similar for 1986 and 1987: vegetative and early reproductive growth occurred in June and flag leaf emergence and spike development occurred in July (Figs. 1 and 2).

Spot-type net blotch was the most prevalent foliar disease observed within the barley plot in 1986 and 1987. It occurred throughout the plot and affected all leaves. Net-type symptoms of net blotch were not observed. Some scald, incited by *Rhynchosporium secalis,* and spot blotch, incited by *C. sativus,* were observed on the lower leaves, but the level of these diseases did not exceed 3% of the total leaf area. Severity of spot-type net blotch was assessed for each leaf until 90% discoloration (Figs. 1 and 2). In both years, percent leaf area discoloration increased rapidly for all leaves. The period between the first assessment and 90% discoloration ranged from 25 days for leaf 4 to 32 days for leaf 3 in 1986 and from 21 days for leaf 7 to 35 days for leaf 3 in 1987.

After logit transformation of the data for leaf area discoloration, the coefficient of determination ranged from 0.92 to 0.99 in both years (Table 1). Residual variances were homogeneous and slopes were compared. The only significant difference obtained was between the slope for leaf 2 and the slopes for leaves 5 and 7 in 1987. Thus, leaf area discoloration increased along a logistic curve for all leaf positions. The estimated slope represented the logistic infection rate.

Conidia of *P. teres* were trapped during the entire investigation period. As only spot-type symptoms were observed for net blotch, the trapped conidia were those of *P. t. maculata* and not of *P. t. teres.* Conidia of *Alternaria, Cladosporium,* and *Fusarium* spp. also were trapped along with pollen, small insects, soil particles, and mycelial fragments. No ascospores of *P. teres* were trapped.

Daily number of airborne conidia of *P. t. maculata* showed similar seasonal trends in 1986 and 1987. The daily number of conidia was smaller in June than in July (Figs. 1 and 2). It did not exceed 100 conidia per day in June of 1986 and 350 conidia per day in June of 1987. Number of airborne conidia increased after 1 July for both years. The seasonal peaks were 3,729 conidia per day on 4 August 1986 and 2,345 conidia per day on 31 July 1987.

In 1986, daily minimum temperatures were lower throughout most of June than in 1987 (Figs. 1 and 2). Night frosts were recorded as late as 17 June 1986, whereas no night frosts were recorded in June of 1987. Daily minimum temperatures were similar during July of both years. Daily maximum temperatures were similar during the entire observation period of both years. Total precipitation during the observation period was 169 and 138 mm in 1986 and 1987, respectively. Precipitation in 1986 was recorded on 29 days. Most precipitation was recorded on the four days when it exceeded 20 mm. Precipitation in 1987 was recorded on 31 days. Its distribution was more uniform than in 1986, exceeding 20 mm only on one day.

The duration was determined for each period of leaf surface wetness. Frequency of wetness periods was similar for June and July in 1986 and 1987 (Table 2). In June, median duration of leaf surface wetness was 6–10 h in 1986, but only 1–5 h in 1987. In July, median duration was 11–20 h in 1986 but only 6–10 h in 1987. Thus, duration of the periods of leaf surface wetness was on average shorter in 1987 than in 1986. Periods of leaf surface wetness with a duration exceeding 6 h were distributed throughout June and July of both years (Figs. 1 and 2).

Diurnal trends were determined for number of airborne conidia of *P. t. maculata,* temperature, relative humidity, and leaf surface

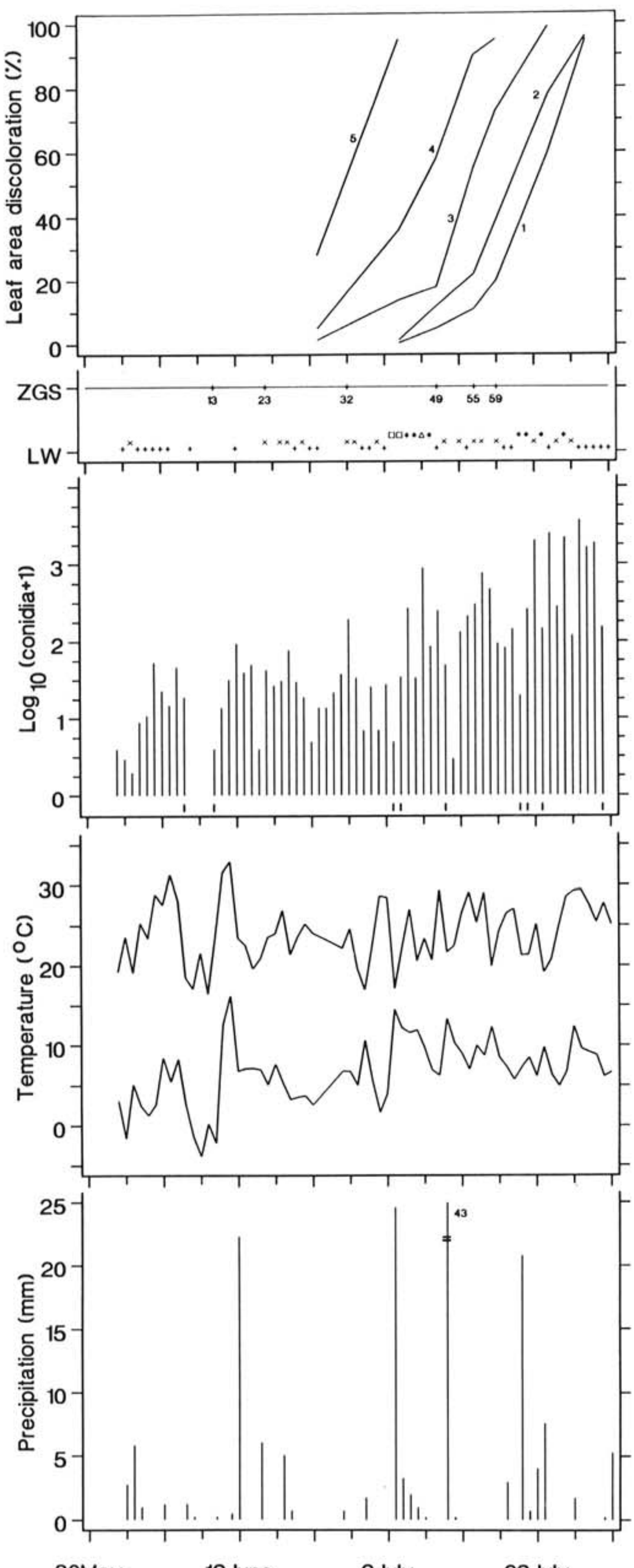

Fig. 1. Severity of spot-type net blotch on leaf positions 1–5, crop growth stage (ZGS), duration of leaf surface wetness (LW), daily number of airborne conidia of *Pyrenophora teres* f. *maculata*, minimum and maximum temperature, and precipitation in a field plot of Elrose barley at Shellbrook, Saskatchewan, between 2 June and 9 August 1986. Leaves were numbered from the flag leaf downwards. Duration of leaf surface wetness: + = 6–10 h; × = 11–15 h; * = 16–20 h; △ = 21–24 h; □□ = > 24 h. I = day with precipitation between 7 and 14 h.

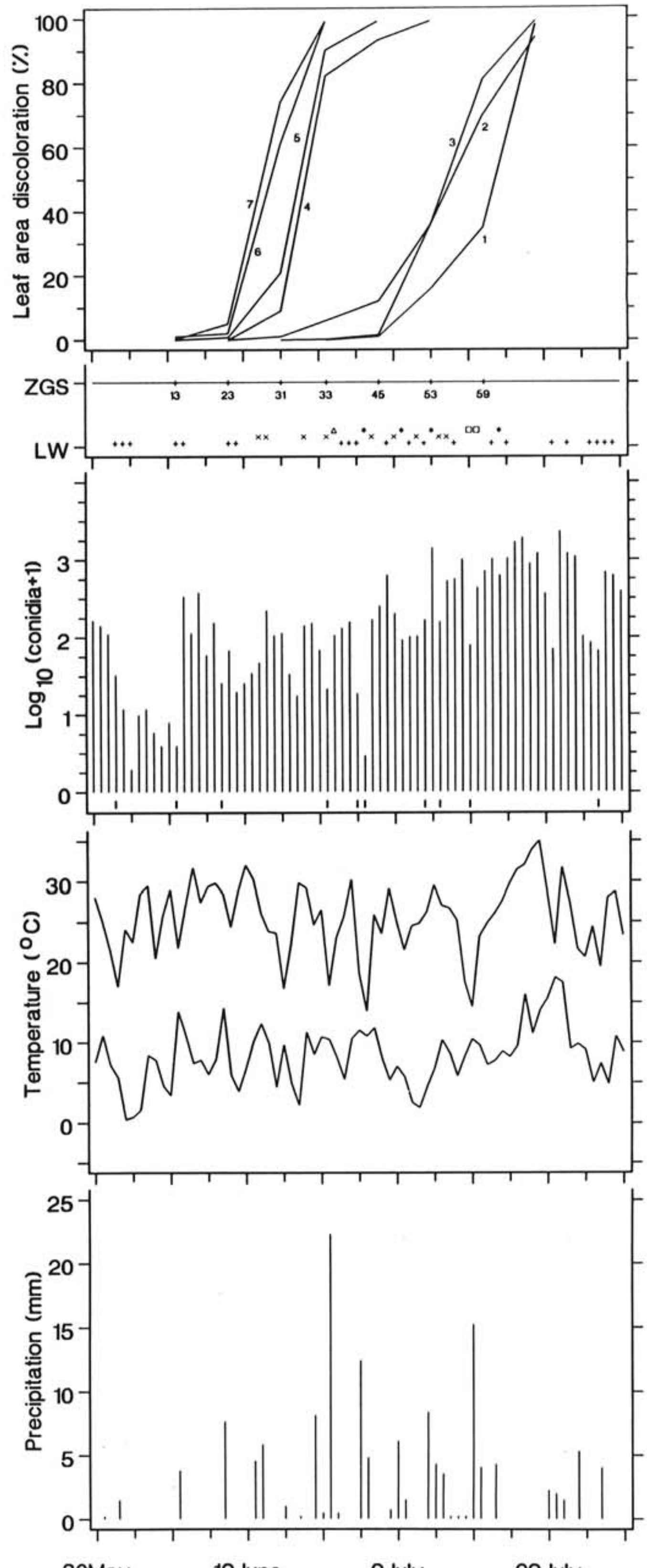

Fig. 2. Severity of spot-type net blotch on leaf positions 1–7, crop growth stage (ZGS), duration of leaf surface wetness (LW), daily number of airborne conidia of *Pyrenophora teres* f. *maculata*, minimum and maximum temperature, and precipitation in a field plot of Elrose barley at Shellbrook, Saskatchewan, between 30 May and 9 August 1987. Leaves were numbered from the flag leaf downwards. Duration of leaf surface wetness: + = 6–10 h; × = 11–15 h; * = 16–20 h; △ = 21–24 h; □□ = > 24 h. I = day with precipitation between 7 and 14 h.

wetness over the entire observation period of 69 and 71 days for 1986 and 1987, respectively (Figs. 3 and 4). Number of airborne conidia, and values for temperature and relative humidity, were averaged for each hour of the day. Hourly leaf surface wetness was expressed as the percentage of the number of days that the presence of leaf surface wetness was recorded. The number of conidia was small during the night from 2000 to 0600 hours with a minimum at 0400 hours in both years. Then, it increased and reached a maximum at 1400 hours in both years. Solar noon was reached around 1310 hours during June and July. During the night and early morning the number of conidia was small, while temperature was low and relative humidity and occurrence of leaf surface wetness high. The increase in number of conidia was accompanied by increasing temperature, decreasing relative humidity, and decreasing occurrence of leaf surface wetness.

The following results are based on graphical evaluation of the data. During June of both years, the diurnal periodicity for number of airborne conidia was evident on days with large numbers of airborne conidia (> 50 conidia per day), but not on days with small numbers of airborne conidia. Large numbers of airborne conidia were observed on days without precipitation between 0700 and 1400 hours and minimum temperatures above 3 C. During July of both years, the diurnal periodicity was evident on all days, except those with precipitation between 0700 and 1400 hours. Very large numbers of airborne conidia (> 1,000 conidia per day) were observed in late July during the senescence of the upper leaves. Daily number of airborne conidia was not related to the duration of leaf surface wetness on the preceding night in June or July.

Number of airborne conidia was correlated with leaf area discoloration during July, but not during June (Table 3). In June, daily number of airborne conidia was correlated with mean and minimum temperature on the same and preceding day for both years. In July, number of airborne conidia was correlated with mean temperature, maximum temperature, difference between maximum and minimum temperature, and daily amount of precipitation on the same day. When days with precipitation between 0700 and 1400 hours were omitted from the analysis, no correlation was apparent between the number of airborne conidia and amount of precipitation. Correlations of daily number of airborne conidia with mean temperature and amount of precipitation for 6- and 8-h intervals indicated similar associations (data not shown).

The ability of *P. t. maculata* to sporulate on infected plant tissue was investigated in 1987. Throughout the growing season, *P. t. maculata* produced three harvests of conidia during the incubation period on the pieces of stem debris. On the pieces of leaf debris, *P. t. maculata* produced two harvests of conidia during the incubation period. These leaves were completely shriveled and measured only a few square centimeters each. They disintegrated after 3 days and were discarded. The number of conidia collected ranged from 200 to 400 per centimeter of stem per wash and from 700 to 900 per leaf per wash. Pseudotheciumlike bodies were observed on the stem pieces, but no ascospores were recovered.

No spores were produced on any leaf of the growing crop after 3 days of incubation before 30 June 1987. Conidia were produced on the chlorotic leaf area, but not on the dark brown necrotic lesions. On completely senesced leaves, conidia were produced on the entire leaf surface. Conidia were produced on the lower

TABLE 1. Estimated parameters for regression lines for increase in leaf area discoloration over time after logit transformation for five leaf positions in 1986 and seven leaf positions in 1987

Leaf position[x]	N[y]	Intercept	Slope[z]	r^2
1986				
Leaf 5	2	−64.9	0.354 a	...
4	5	−47.6	0.245**a	0.98
3	5	−64.9	0.324**a	0.93
2	5	−53.3	0.259**a	0.98
1	5	−60.1	0.288**a	0.96
1987				
Leaf 7	4	−93.8	0.543**a	0.99
6	4	−81.8	0.473* ab	0.92
5	4	−86.5	0.487**a	0.99
4	4	−57.9	0.322* ab	0.92
3	6	−48.6	0.250**b	0.96
2	4	−63.3	0.318**ab	0.96
1	4	−75.9	0.379**ab	0.94

[x]Leaves were numbered from the flag leaf downwards.
[y]Number of observation days.
[z]*, **, Significance of slope at the 0.05 and 0.01 probability level, respectively. Slopes within the same year followed by the same letter are not significantly different from each other at the 0.05 probability level according to the test for homogeneity of slopes.

TABLE 2. Frequency of the duration of leaf surface wetness periods at Shellbrook, Saskatchewan, in June and July of 1986 and 1987

	1986		1987	
Duration (h)	June	July	June	July
1–5	4	4	10	6
6–10	11	7	7	10
11–15	4	9	4	5
16–20	1	7	0	4
21–24	0	1	0	1
>24	0	1	0	1
Total	20	29	21	27

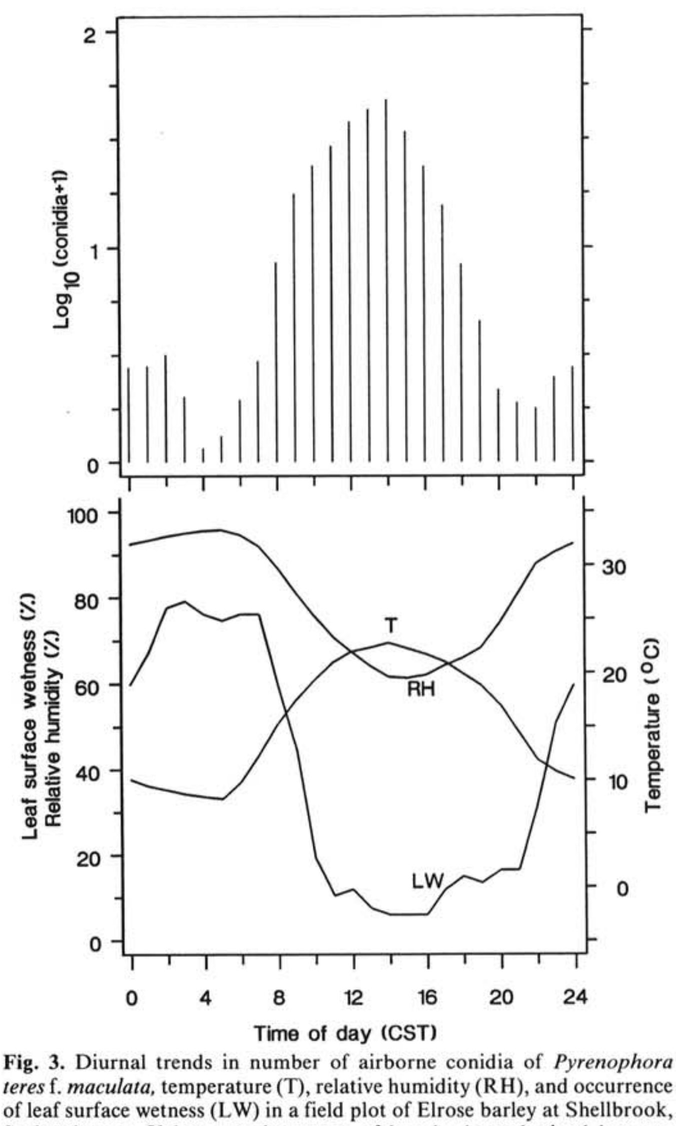

Fig. 3. Diurnal trends in number of airborne conidia of *Pyrenophora teres* f. *maculata*, temperature (T), relative humidity (RH), and occurrence of leaf surface wetness (LW) in a field plot of Elrose barley at Shellbrook, Saskatchewan. Values are the means of hourly data obtained between 2 June and 8 August 1986.

leaves (4–7) when more than 90% of the leaf area was discolored. Conidia were obtained after 1, 3, and 5 days of incubation, with the exception of 7 July 1987, when the leaves disintegrated after 3 days (Table 4). Conidia were produced on the upper leaves (1–3) once 15–40% of the leaf area was discolored. On several occasions, conidia were not produced during the first 24 h of the incubation period. The number of conidia increased with the length of the incubation period.

The latent period was calculated as the period between the first appearance of symptoms and the first observation of sporulation in vitro. The latent period decreased from 21 days for leaf 7 to 14 days for leaf 1.

DISCUSSION

The daily number of airborne conidia of *P. t. maculata* increased during the growing season and peaked about 1 August in both years. Seasonal increases in daily number of airborne conidia have been reported for *P. t. teres* (10,11), *P. tritici-repentis* (21), and *C. sativus* (1). During June, the daily number of airborne conidia was generally small, as conidia were only produced on crop debris. During July, the daily number of airborne conidia increased. Correlation between number of airborne conidia and leaf area discoloration indicates that infection and senescence of leaves during the growing season increased the area available for conidium production. In addition, conidia produced on leaves of the growing crop are more easily dispersed by the wind and are closer to the orifice of the spore trap than conidia produced on the crop debris. Similarly, daily number of airborne conidia for *P. t. teres, P. tritici-repentis,* and *C. sativus* was related to disease and crop development (1,10,21).

During June, variations in daily number of airborne conidia were correlated with minimum and mean temperature on the preceding day, indicating that temperature limited production and dispersal of conidia. During July, correlation of daily number of airborne conidia with maximum temperature and difference in temperature on the same day indicates that high temperatures enhanced the production of conidia. In vitro, many conidia were produced within 24 h at constant 12 and 18 C, but none at 6 and 25 C (13). In this study, temperature ranged from 1 to 35 C during July of both years and many conidia were produced daily. Correlation of daily number of airborne conidia with temperature factors suggests that the requirements for conidium production are very different in the field, where temperature follows a diurnal periodicity. The number of airborne conidia

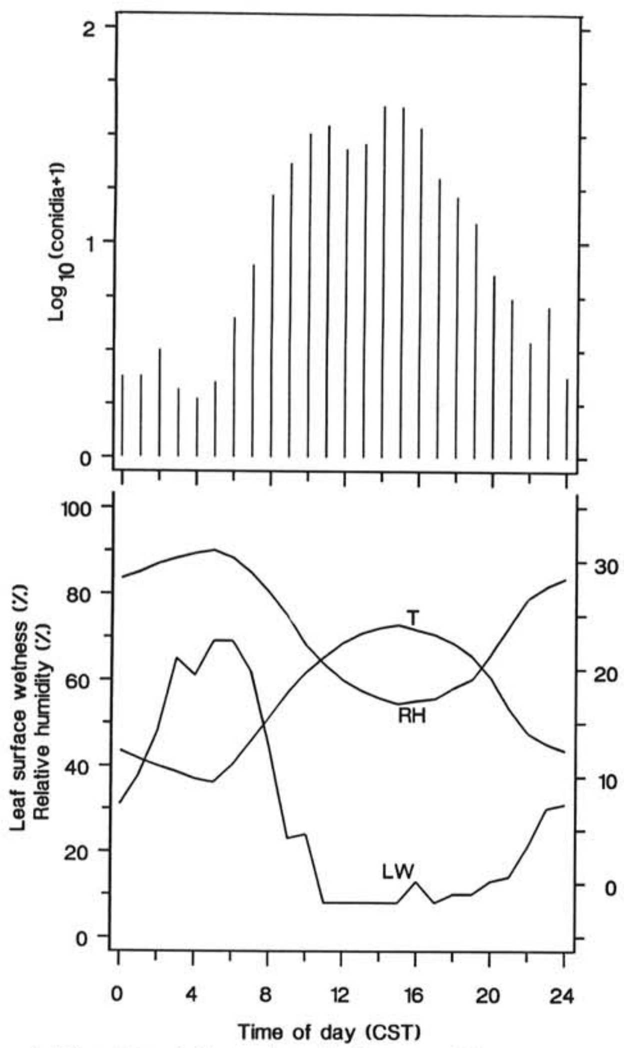

Fig. 4. Diurnal trends in number of airborne conidia of *Pyrenophora teres* f. *maculata,* temperature (T), relative humidity (RH), and occurrence of leaf surface wetness (LW) in a field plot of Elrose barley at Shellbrook, Saskatchewan. Values are the means of hourly data obtained between 30 May and 9 August 1987.

TABLE 3. Correlation of $\log_{10}$ (conidia + 1) with leaf area discoloration and meteorological factors observed on the same and four preceding days for the periods 30 May to 30 June and 1 July to 9 August in 1986 and 1987 at Shellbrook, Saskatchewan

	30 May–30 June		1 July–9 August	
Variable	1986	1987	1986	1987
Leaf area discoloration[v]				
Leaf 7[w]	...	−0.01	...	...
6	...	−0.02	...	...
5	−0.18	−0.01	...	...
4	...	0.31	0.55*[x]	...
3	...	...	0.57**	0.75**
2	...	...	0.58**	0.74**
1	...	...	0.53**	0.66**
Mean temperature				
Same day	0.37+	0.35+	0.37*	0.59**
Day −1	0.60**	0.54**	0.28+	0.34*
Day −2	0.53**	0.48**	0.36*	0.15
Day −3	0.34	0.33+	0.45**	0.08
Day −4	−0.26	0.09	0.19	−0.02
Minimum temperature				
Same day	0.39+	0.39*	−0.06	0.14
Day −1	0.52**	0.55**	0.20	0.13
Day −2	0.49**	0.29	0.30+	0.21
Day −3	0.28	0.24	0.23	0.15
Day −4	−0.24	0.11	0.04	−0.16
Maximum temperature				
Same day	0.26	0.11	0.42*	0.70**
Day −1	0.52**	0.23	0.13	0.35*
Day −2	0.43*	0.39*	0.14	0.04
Day −3	0.33	0.23	0.28	−0.01
Day −4	−0.21	0.01	0.17	0.09
Temperature difference[y]				
Same day	−0.14	−0.16	0.32+	0.52**
Day −1	0.01	−0.20	−0.02	0.23
Day −2	−0.09	0.09	−0.07	−0.10
Day −3	0.01	0.01	0.06	−0.11
Day −4	0.06	−0.07	0.08	0.18
Precipitation (entire period)				
Same day	0.13	−0.07	−0.35*	−0.39*
Day −1	0.18	0.28	−0.19	−0.27
Day −2	0.21	0.05	0.21	−0.03
Day −3	−0.36+	0.23	0.05	0.03
Day −4	0.14	0.08	0.32+	−0.12
Precipitation (restricted period)[z]				
Same day	0.12	0.13	−0.02	0.06

[v] Leaves are listed under the period in which leaf area discoloration reached 80%.
[w] Leaves were numbered from the flag leaf downwards.
[x] +, *, **, Significant at the 0.10, 0.05, and 0.01 probability level, respectively.
[y] Difference between maximum and minimum temperature on each day.
[z] Days are excluded when precipitation occurred between 0700 and 1400 h.

was small on days with precipitation in the morning because the conidia are scrubbed from the air by rain (2). Contrary to previous studies, no relationship was observed between daily number of airborne conidia and duration of leaf surface wetness. This may be due to differences in local weather conditions, although a very large number of airborne conidia of *C. sativus* were not related to the duration of leaf surface wetness for several dates presented in the data of Couture and Sutton (1).

The hourly number of airborne conidia had a diurnal periodicity for *P. t. maculata* on barley with a maximum at 1400 hours. This agrees with the previously reported pattern for *P. t. teres* with a maximum at 1200 hours (10). The diurnal periodicity in number of airborne conidia was associated with diurnal changes in temperature, leaf surface wetness, and relative humidity. Diurnal periodicity also has been observed for wind speed and turbulence (3,10). The periodicity coincides with the reported requirements for production and liberation of conidia for *P. t. teres.* Leaf surface wetness or high relative humidity is required for the production of conidia (13). At Shellbrook, these conditions generally are found only during the night. As number of conidia peaked at 1400 hours, most conidia were probably passively liberated during the day. Passive liberation of conidia by air movement was demonstrated by Kenneth (8) and may be inferred when the largest number of airborne conidia is reached slightly after midday (3).

The seasonal and diurnal pattern of airborne conidia and sporulation of *P. t. maculata* on host tissue suggest that production of conidia requires leaf surface wetness, high relative humidity, and appropriate temperature regimes, and that it occurs only on senescent or dead host tissue. Further studies are required to describe the effects of diurnal regimes for temperature, leaf surface wetness, relative humidity, and the effect of the age of host tissue on the production of conidia in more detail.

Airborne conidia may be deposited on healthy tissue and subsequently cause infection. Conidia require leaf surface wetness and temperatures above 2 C for germination and infection (13). The duration of leaf surface wetness required for infection ranged from 3 to 8.5 h at temperatures between 8 and 20 C (13,19). The duration of leaf surface wetness frequently exceeded 6 h in

TABLE 4. Number of conidia per leaf obtained for each leaf position after 1, 3, and 5 days of incubation for six sampling dates in 1987

Leaf position[y]	Observation day	Sampling date[z]					
		30 June	7 July	14 July	21 July	28 July	4 Aug
7	1	2,110	···	···	···	···	···
	3	4,830					
	5	7,130					
6	1	950	1,445	···	···	···	···
	3	3,990	1,840				
	5	10,585	-				
5	1	···	2,890	3,440	···	···	···
	3		21,890	3,000			
	5		-	2,890			
4	1	···	1,720	2,560	2,780	···	···
	3		19,055	8,170	7,000		
	5		-	11,000	11,280		
3	1	···	···	1,000	6,560	5,330	0
	3			8,780	16,390	2,890	2,555
	5			17,000	20,610	3,335	2,165
2	1	···	···	0	0	8,000	0
	3			1,890	6,220	6,725	5,670
	5			8,330	14,450	8,275	8,830
1	1	···	···	0	0	0	0
	3			4,670	7,890	8,000	7,670
	5			19,220	21,670	8,890	9,890

[y]Leaves were numbered from the flag leaf downwards.
[z]Ten leaves were sampled on each date; values represent the average number of conidia observed on each observation day; — = number of conidia was not determined; ··· = leaves were not sampled.

both years and the minimum temperature was in the range of 5 to 10 C on most nights at Shellbrook. Thus, infection could occur during most nights. As airborne conidia are abundant and the conditions are frequently favorable for infection throughout the growing season, the progression of spot-type net blotch closely followed plant development and each leaf was infected shortly after emergence.

P. t. maculata produced conidia on crop debris and the growing crop. Conidia produced on the infested stubble alone were responsible for the infection of the lower leaves. Conidia produced on both the stubble and the lower leaves caused most of the infections on the upper leaves. Thus, *P. t. maculata* completed only one infection cycle (as defined in 23) on most leaf positions. On a whole plant basis, the number of infection cycles completed during the growing season in Saskatchewan appears to be limited: one cycle on the lower leaves, as the latent period equals the life span of the lower leaves, and two cycles on the upper leaves, as the latent period equals one half of the life span of the upper leaves. The number of infection cycles for *P. t. teres* is much larger in England, where several infection cycles are possible on a single leaf position as the leaf life span would be 50–60 days and the latent period 8–10 days (13).

The progression of leaf area discoloration followed a logistic curve. The average apparent infection rate on the upper leaves was 0.290 and 0.316 in 1986 and 1987, respectively. Although the progression increased logistically, only one infection cycle was completed on most leaf positions, and spot-type net blotch behaves mainly as a monocyclic disease. The logistic shape of the curve may be attributed to repeated infection of the leaves and lesion expansion. Repeated production of conidia by *P. t. maculata* during incubation on infested crop debris and infected leaves was observed in this study. This indicates that infested crop debris acted as an inoculum reservoir for the lower leaves and that infested crop debris and the lower leaves acted as an inoculum reservoir for the upper leaves. Shaw (13) observed that individual lesions may expand to an area of several square centimeters.

Control of spot-type net blotch will require a reduction of the quantity of inoculum produced on the crop debris through crop rotation, soil tillage, and other practices. In England, virtually all primary inoculum is removed by plowing (7). Due to the risk of soil erosion in Saskatchewan, the soil is prepared with a cultivator or tandem disk. These operations leave large amounts of crop debris on the soil surface and hence large amounts of primary inoculum. The amount of primary inoculum may be reduced with adequate crop rotation. If a hundredfold decrease in primary inoculum were achieved and the infection rate remained approximately 0.300, then the epidemic on the lower leaves would be delayed by about 15 days. As infested crop debris serves as a reservoir, the delay may be larger and adequately control spot-type net blotch.

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