The Relationship Between Epidemics of Septoria Leaf Blotch and Yield Losses in Spring Wheat

Zahir Eyal and Oded Ziv

Division of Mycology and Plant Pathology, Department of Botany, Tel-Aviv University, Israel.
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ABSTRACT

Methods for the assessment of Septoria leaf blotch progress curves in several spring wheat varieties grown at two locations in Israel were evaluated. Different amounts of disease resulted from changes in timing and number of applications of the fungicide Maneb. Disease progress curves were not satisfactorily defined when polynomic functions or logarithmic transformations were used in regression lines. Disease kinetics data were thus presented in an untransformed linear regression. The progress of Septoria leaf blotch in the dwarf variety Bet-Dagan 213, was significantly faster, and disease severity greater than that of the semi-dwarf Lakhish 221, grown under the same conditions. Disease severities of different Septoria progress curves were correlated to losses in yield and 1,000-kernal wt. Best estimates of losses were found with the linear expression of disease severities taken when the developing caryopsis had reached three-fourths its final size for four varieties at two locations. Wheat varieties showed differential vulnerability response to Septoria leaf blotch under similar epidemics caused by *Septoria tritici*.

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Septoria leaf blotch of wheat, caused by the fungus *Septoria tritici* Rob. ex Desm., is a major wheat disease in many parts of the world, particularly in the Mediterranean basin (18, 19). Severe epidemics of Septoria leaf blotch occurred in Morocco, Tunisia, and Turkey in 1969, causing substantial yield losses in regions of these countries (19).

The increase in importance of this disease is largely due to the rapid replacement of local wheat cultivars by the high-yielding, short-strawed cultivars which are susceptible to Septoria leaf blotch of wheat (19).

Caldwell and Narvaes (6) reported losses in yield of 10.5 - 44.6% with artificial infection of winter wheat with *S. tritici*, and losses in the magnitude of 10.5 - 27.6% for natural infection. Sanderson (16) in New Zealand reported losses of 8.8% in fungicide-protected wheat plots. According to Cooke and Jones (8), Septoria leaf blotch of wheat caused reductions in 1,000-kernel wt of 16.20% and 18.62% in the spring wheat cultivars Flameks and Lickti II, respectively. In the winter wheat cultivars Leonardo and Leone, losses in 1,000-kernel wt amounted to 23.71% and 24.45%, respectively.

Losses of 20% in yield were correlated with pycnidial coverage of 50% of the upper five wheat leaves when measured at early dough stage, in the spring wheat cultivar 8828-221(Yt//Nrn10/B21-1C/3/FA) grown in Israel (10). Williams and Jones (20) reported on significantly different levels in reductions in 1,000-kernel weight and in mean yield per head of three spring wheat cultivars, each responding to inoculation at different growth stages.

Studies were conducted on primary sources of inoculum (9), physiologic specialization of the pathogen (11), and chemical control (10). This paper considers the evaluation of Septoria leaf blotch epidemics and the relationship between disease severity and yield losses.

MATERIALS AND METHODS.—Septoria leaf blotch epidemics of different levels were established in fungicide-protected wheat plots at two locations in Israel. In the Lakhish Experiment Station, situated in the semi-arid southern coastal plains, two autumn-sown spring wheat cultivars were grown:the semi-dwarf cultivar (height 110-120 cm) Lakhish 221, derived from the cross Yt//Nrn10/B21-1C/3/FA, and the dwarf cultivar (height, 80-90 cm) Bet-Dagan 213 of the same cross. These crosses originated at the Volcani Center, Agriculture Research Organization, Israel. Both wheat cultivars are susceptible to Septoria leaf blotch, but possess good resistance to stem, leaf and yellow rusts. Wheat plots of 75 m^2 were sown in a paired-plot design in which the two cultivars were adjacent to one another and divided by a 3-m-wide oat buffer strip. The paired block was separated from the next wheat block in a randomized block design by an oat buffer 10 m wide. Different epidemic levels were achieved by varying the number and timing of fungicide applications among the treatments. Wheat plots were protected with tank-mixed Maneb (manganese ethylenebisdithiocarbamate). The fungicide of 80% WP formulation was applied at a rate of 250 g/dunam (one dunam = 1/10 hectare) with a low pressure, low volume, CO_2-operated knapsack sprayer to which a 4 m boom with eight nozzles (T-jet ×3, cone jet), was fitted.

The second experiment was conducted in the Ysdraelon Valley, in the northern part of the country, which is characterized by an average rainfall of 500-600 mm. Different levels of Septoria leaf blotch epidemics were established in a fungicide-protected wheat field. The semi-dwarf varieties Lakhish 212 (Yt//Nrn10/B21-1C/3/FA), and Mivhor 1177 (Penjamo Sib × Gabo 55, cross 8156 B of the Hazera Seed Co.) were grown in a 60-hectare wheat field. The epidemic levels were

TABLE 1. Regression coefficient (b) and correlation coefficients (r) for linear and polynomial regression of disease severity vs. time for untransformed and transformed data

Region	Wheat cultivar	Untransformed data				Log_3 1/(1-X)		Log_e X/(1-X)	
		b_1^a	r_1^a	r_2^b	r_3^c	b_1^a	r	b_1^a	r
Lakhish	Bet-Dagan 213	5.4134 A[d]	0.9823	0.9823	0.9831	0.0118 A	0.9705	0.0361 A	0.9612
	Lakhish 221	4.7020 B	0.9708	0.9733	0.9743	0.0096 B	0.9540	0.0472 B	0.8864
Ysdraelon	Lakhish 212	4.1100 A	0.8869	0.8869	0.9313	0.0061 A	0.8678	0.0629 A	0.9091
	Mivhor 1177	4.8859 B	0.8925	0.8933	0.9336	0.0076 B	0.8724	0.0656 B	0.9307

[a]Linear regression.
[b]Second-degree polynomial.
[c]Third-degree polynomial
[d]Values followed by the same letter are not significantly different, $P = 0.05$. Analysis was conducted separately for each region.

manipulated by varying the number, timing, and method of Maneb applications, using a Piper Pawnee 235 airplane. In each treatment block, which was replicated twice, ten 100 m^2 plots per cultivar were randomly selected for disease evaluation throughout the season and later for yield and 1,000-kernel wt assessments.

The disease in each plot of the two experiments was studied 7 - 11 times during the growing season at 10- to 14-day intervals. The disease development throughout the season was assayed on randomly selected wheat plants according to the following parameters:

(i) the percentage of green leaf area affected with pycnidia of *S. tritici* (disease severity);

(ii) the maximal height (cm) at which pycnidia of *S. tritici* could be found on green plant tissue (leaves, sheath, peduncles, glumes or awns), from ground level, regardless of pycnidial coverage of the measured plant part; and

(iii) the height of the wheat plant (cm) at the time of recording and its developmental stage.

The progress of the disease epidemics in each of the two cultivars as a function of time was calculated for untransformed cumulative disease severities. Appropriate F-tests were applied to the regression coefficients (b) in the linear equation $Y = a + bX$, where Y = cumulative leaf area affected by *S. tritici,* and X = time in days of Septoria leaf blotch recording from seedling emergence.

Regression coefficients of the vertical progress of Septoria leaf blotch in relation to plant development were calculated by the linear relation $Y = a + bX$, where Y = the maximal height of pycnidia (cm) from the ground at the recording time, and X = the corresponding plant height (cm) at the same recording time. Analysis of co-variance was used on the regression coefficients (b) of disease development regression lines in relation to time, and also on disease progress in relation to plant development.

RESULTS.—*Evaluation of Septoria leaf blotch epidemics.*—The initiation of Septoria leaf blotch epidemics in the two cultivars at the Lakhish experiment station had started at the end of December 1971, or 35 days after emergence. The data relating to the progress of the disease as a function of time was expressed in untransformed linear equations. Polynomial regressions of disease severity resulted in lower correlation coefficients (r) than that of the linear equation. Logarithmic transformations of the data in the form of $\log_3$ 1/(1-X) or $\log_3$ X/(1-X), where X = the proportion of foliage affected by Septoria leaf blotch, had also resulted in lower correlation coefficients (r) than that of the untransformed data used in the linear equation (Table 1).

The progress of epidemics caused by the *S. tritici* in the dwarf variety Bet-Dagan 213 proceeded significantly faster than that of the taller semi-dwarf cultivar Lakhish 221 (Fig. 1). The disease coverage level by pycnidia had reached a maximal coverage of 75% of the overall wheat foliage area, on both cultivars. The disease progress in relation to plant development has shown marked differences in the vertical spread of Septoria leaf blotch on the phenotypically different wheat cultivars. In the dwarf cultivar Bet-Dagan 213 the disease had a rapid vertical development and each green leaf emerging from the sheath was readily affected by the fungus. The regression coefficient calculated from the ratio between disease progress to plant development in this cultivar was $b = 1.1677$ ($r = 0.9523$). Regression coefficient ratios approaching $b \geqslant 1.0$, reflect a rapid vertical development of the disease, while $b < 1.0$ reflects that pycnidia are concd on lower plant parts.

On the taller cultivar Lakhish 221, the disease progressed significantly slower (Fig. 1), and had not reached the upper plant portions as in the case of the dwarf variety. The calculated regression coefficient (b) for the ratio between disease progress to plant development was 0.8043 ($r = 0.9534$), significantly different ($P = 0.05$) from that of the dwarf cultivar.

In the Ysdraelon Valley the first Septoria leaf blotch foci were detected in mid-February 1972 (three months after sowing). The lower leaves had a low pycnidia density, yet sufficient to provide inoculum later in season, resulting in high pycnidia coverage of the upper three leaves. The total plant leaf area covered by pycnidia was lower, amounting to pycnidia coverage of 40% of the overall wheat leaf area (Fig. 2). The two cultivars, though susceptible to Septoria leaf blotch, differed significantly in the amount of area affected by pycnidia, with higher severities on Mivhor 1177. The progress of the disease in

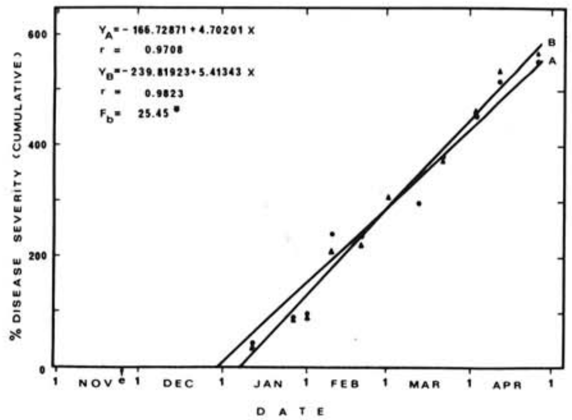

Fig. 1. The progress of Septoria leaf blotch epidemics on the dwarf wheat variety Bet-Dagan 213 (A), and the semi-dwarf variety Lakhish 221 (B) at the Lakhish Experiment Station. F-test was applied to the regression coefficients (b) in the linear equation Y = a + bX, where Y = cumulative area affected by *Septoria tritici* and X = time in days from seedling emergence (e). The symbol * indicates significant differences at $P = 0.05$.

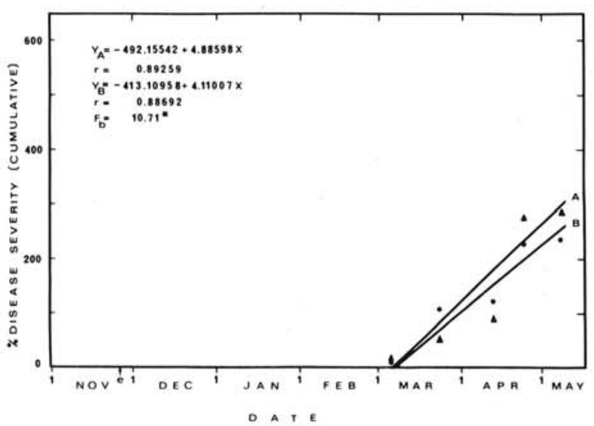

Fig. 2. The progress of Septoria leaf blotch epidemics on the semi-dwarf wheat cultivars, Mivhor 1177 (A) and Lakhish 212 (B), at the Ysdraelon Valley. F-test was applied to the regression coefficients (b) in the linear equation Y = a + bX, where Y = cumulative leaf area affected by *Septoria tritici* and X = time in days from seedling emergence (e). The symbol * indicates significant differences at $P = 0.05$.

relation to plant development had shown no differences between the two cultivars, both of similar susceptibility and phenotypic characteristics.

Losses associated with levels of Septoria leaf blotch.—Assessment of the average disease severity of the upper three wheat leaves (flag leaf, flag minus one, and flag minus two) was related to losses in yield (kg/dunam) and 1,000-kernel wt at three growth stages. Correlation coefficients between losses and disease severity were calculated for the three growth stages at which the developing caryopsis had attained three-fourths of its final stage, early dough, and hard dough. The highest correlation coefficients (r) were obtained between losses in yield and 1,000-kernel wt and disease severity at three

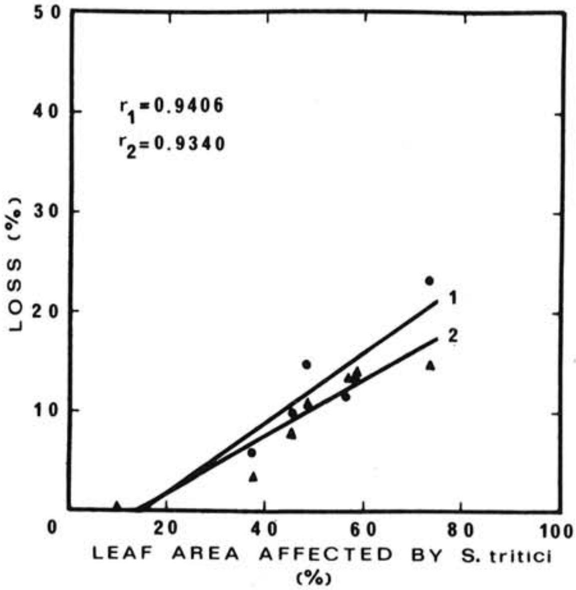

Fig. 3. The relationship between leaf area (upper three leaves) affected by pycnidia of *Septoria tritici* measured at three-quarter kernel development and losses in yield (kg/dunam) (1) and 1,000-kernel wt (2) of the wheat variety Lakhish 221 grown at the Lakhish Experiment Station. Correlation coefficients (r) of the regression line are expressed for yield parameters 1 and 2.

fourths kernel developmental stage at both locations in all cultivars tested.

In the cultivar Lakhish 221 losses in yield of 22.98% could be related to pycnidia coverage of 80% of the upper three leaves, while the same area affected by *S. tritici* could be correlated with 14.6% loss in 1,000-kernel wt (Fig. 3). In the cultivar Bet-Dagan 213, similar pycnidia coverage resulted in 1,000-kernel wt losses of 16.5%.

In the Ysdraelon Valley experiment, disease incidences reached 60-80% coverage in the two wheat cultivars. This disease level caused losses of 20.08% in yield and 11.18% in 1,000-kernel wt in the cultivar Lakhish 212 (Fig. 4-A). In the cultivar Mivhor 1177, similar disease incidences were associated with losses of 40.40% in yield and 28.27% in 1,000-kernel wt (Fig. 4-B). In the cultivar Mivhor 1177, which is characterized by grains with relatively low 1,000-kernel wt, grains from the untreated control plots were shriveled and unfit for milling.

DISCUSSION.—The initial establishment of Septoria leaf blotch on the lower plant parts depends mainly on the presence of infested plant refuse in the wheat field at the beginning of the rainy season (1, 9, 10, 12). The increase of the disease with time is closely associated with frequent rains combined with favorable temperatures. The occurrence of prolonged intervals in rainfall during the wheat-growing season in the Mediterranean basin are thus reflected in disease progress curves of polynomic functions. As in the case of potato late blight (13), arrays of mathematical functions with high correlation coefficients (r) fitted the data. The selected linear regression of the untransformed data showed a higher correlation coefficient (r) than the other transformed (logarithmic) linear regressions (Table 1). The disease

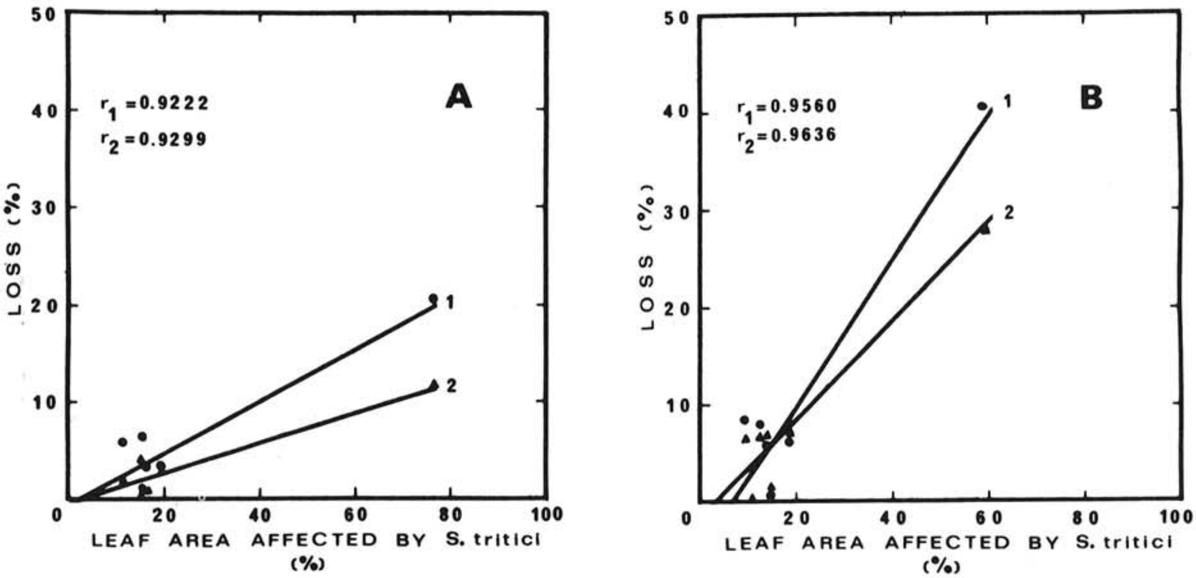

Fig. 4-(A,B). The relationship between leaf area (upper three leaves) affected by pycnidia of *Septoria tritici* and losses in yield (kg/dunam) (1) and 1,000-kernel wt (2), at the Ysdraelon Valley. **A**) Wheat cultivar Lakhish 212. **B**) Wheat cultivar Mivhor 1177. Correlation coefficients (r) of the regression line are expressed for yield parameters 1 and 2.

progress curve was significantly steeper for the dwarf cultivar Bet-Dagan 213 than that of the semi-dwarf Lakhish 221 (Fig. 1). Brönnimann et al. (3) reported that short forms of the cultivar Zenith were attacked earlier and more severely by *S. nodorum* than tall ones (3). The compactness of the internodes in the dwarf varieties increases the probability of high Septoria blotch severities on upper plant parts even under conditions of moderate disease. The disease progress curves of the two susceptible semi-dwarf cultivars, Mivhor 1177 and Lakhish 212, grown in the Ysdraelon Valley, were significantly different, with Mivhor 1177 showing faster progress and higher rate of infection (Fig. 2).

The differential response of wheat cultivars to Septoria leaf blotch is further accentuated by evaluating the relationship between disease progress and plant development. This relationship enables us to obtain quantitative information concerning Septoria leaf blotch epidemics at any chosen date (or) dates during the growing season. It therefore can be used in studies of cultivar performance in disease nurseries or yield test if proper check cultivars (susceptible dwarfs and semi-dwarfs) are included. High regression coefficients are expected in the dwarf cultivars where the disease progresses fast in relation to plant ht as compared to semi-dwarfs of equal susceptibility, especially so under low or medium levels of *Septoria* epidemics; this may differ under severe *Septoria* epidemic levels.

The varieties Lakhish 212 and Lakhish 221, both sib selections of the same cross (Yt//Nrn 10/B21-1C/3/FA), though grown in different locations and under different Septoria blotch progress curves, showed similar severity-loss (in yield and 1,000-kernel wt) relationship (Figs. 3 and 4). The highest correlation coefficients (r) for this relationship were recorded at Septoria blotch severities of the three upper leaves at three-fourths kernel stage (5, 14, 15). Our findings show that the determination of a specific critical stage, which equates loss to disease severity at a particular growth-stage, is of lesser importance, since high correlation also existed between losses and severity at later development stages than that of 3/4 kernel stage.

Lakhish 221 has already shown similar losses under corresponding Septoria blotch epidemics (10), suggesting stability in the Septoria blotch severity/yield loss relationship.

Differential responses in severity-loss relationship were recorded for Lakhish 212 and Mivhor 1177 (Figs. 4-A and 4-B). The cultivar Mivhor 1177 of the Mexican cross 8156B, was particularly vulnerable to Septoria leaf blotch. Differential response in yield of wheat cultivars to *Septoria nodorum* and *S. tritici* were reported also by other investigators, who showed that some wheat cultivars manifested tolerance, while others showed different degrees of vulnerability (2, 4, 7, 8, 17).

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