Spatial and Temporal Analysis of Spread of Late Leaf Spot of Peanut

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ABSTRACT

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Gradients of late leaf spot incidence (leaflets with lesions), severity (lesions per leaflet), and defoliation (percentage of leaflets) were established from point sources of *Cercosporidium personatum* located centrally in each of four peanut (*Arachis hypogaea*) field plots during 1986. Gradients were assessed in four directions (N, S, E, W) from inoculum sources. Velocity of spread measured from 3 to 6 wk after introduction of source plants ranged from 0.07 to 0.09 m/day for incidence, from 0.04 to 0.06 per day for severity, and from 0.03 to 0.06 per day for defoliation data. As secondary cycles developed, disease gradients became more shallow. Isopathic rates decreased with increasing isopath level. Defoliation was first observed about 2 wk after the appearance of lesions and progressed from the lowermost to the uppermost leaves, despite large numbers of lesions throughout the canopy. Disease incidence data were useful in defining a measure of the extent of disease spread within the plot. Severity data provided information on the intensity of disease across the incidence gradient.

Late leaf spot of peanut (*Arachis hypogaea* L.), caused by *Cercosporidium personatum* (Berk. & Curt.) Deighton, is a serious disease that occurs in most peanut production areas. The disease is generally first observed in mid to late season in the southeastern United States, but rapid disease progression and subsequent defoliation can reduce yields by up to 50% (2,7,18). Mild (20 C) temperatures and prolonged periods of leaf wetness, rain, or high relative humidity are especially favorable for epidemic development (17). However, few quantitative data are available concerning the primary or secondary spread of *C. personatum*.

Several approaches are available for defining an increase in disease. The temporal development of disease can be defined in terms of the increase in disease incidence or severity over time. The spatial pattern of disease can be described by using gradient models (8,10), frequency distributions (4), indices of dispersion (14), or geostatistics (5). Spatiotemporal aspects of disease increase can be defined in terms of velocity of spread (3,11-13), focus expansion models (19,20) or spatiotemporal statistics (6,16).

Several models have been used to describe disease gradients (3,8-10,12). The linearized inverse power equation, $\log(y) = \log(a) - b\log(x)$ (8), and the negative exponential equation, $\ln(y) = \ln(a) - bx$, where y is a measure of disease and x is a measure of distance (10), have been especially popular because of their simplicity in calculating slope (b) parameters. The parameter b in both equations describes gradient steepness and can be used to compare gradients (8).

These models can be corrected for maximum disease by substituting logit(y) for ln(y). Minogue and Fry (13) found that the logit(y) vs. linear(x) model described gradients of potato late blight. Berger and Luke (3) reported that a logit(y) vs. log(x) model described gradients of oat crown rust.

Minogue and Fry (12,13) described an application of a logit(y) vs. linear(x) model for calculating the velocity (v) of a disease isopath from a source. They defined the relationship $v = r/b$, where r is the apparent infection rate as defined by Vanderplank (21), representing disease increase with respect to time, and b is, as before, a gradient parameter, representing the decline of disease intensity with distance. The velocity value has been used to compare disease spread in different cultivars (3,13) or in response to different chemical treatments (13).

Pathogen dispersal gradients or velocities can be estimated by quantitative disease measurement. Disease can be measured in various ways, such as lesion number, lesion density, lesion area, percent defoliation, or percent incidence. Whether the method of disease assessment would influence the interpretation of the results of late leaf spot dispersal gradients is not known.

The objectives of this study were to describe primary and secondary dispersal gradients of late leaf spot of peanut from a point source; to determine whether isopaths of *C. personatum* move at constant velocity away from a source; to describe the spatiotemporal spread of *C. personatum* from a source; and to determine whether the definition of disease (in terms of incidence, severity, or defoliation) affects the interpretation of results.

MATERIALS AND METHODS

Field plots. A field measuring 16 × 96 m was planted with peanut (cultivar Florunner) at the Southwest Georgia Branch Experiment Station (Plains, GA) on 25 May 1986. The plot had been in a grain sorghum-soybean rotation the previous 4 yr. Seed was sown in two-bed rows 1 m apart at a rate of 100 kg/ha. Rows were oriented along a north-south axis. The field was divided into four plots measuring 16 × 24 m.

On 14 July, leaflets with late leaf spot lesions were collected from naturally infected Florunner plants at the Coastal Plain Experiment Station (Tifton, GA). Leaflets with lesions were placed in 20-mesh wire screens (50 lesions per screen) and attached to wooden stakes 30 cm long. A single screen containing 50 lesions was positioned in the center of each plot within the center row at mid-canopy 6 wk after planting.

The plots were irrigated nightly with overhead irrigation for 3 wk to promote establishment of the primary infection gradient by *C. personatum*. Nightly temperatures during this period were consistently above 21 C and below 30 C. Thus, conditions were highly favorable for leaf spot development.

A second field plot was established at the University of Georgia Plant Sciences Farm at Watkinsville, GA. Seed was sown in rows 1 m apart at a rate of 100 kg/ha. A greenhouse-grown source plant containing about 100 lesions was placed in the center of each of two adjacent 10-m^2 blocks within the field on 9 July. Disease incidence, severity, and defoliation were assessed on 6, 20, and 28 August and 5 September.

Disease assessment. Incidence was measured as the percentage of infected leaflets as follows: (leaflets with lesions × 100)/(total nodes × four leaflets per leaf). Severity was measured as number

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of lesions per leaflet, based on the number of leaflets present. For logit transformations of severity, a carrying capacity for the number of lesions per leaflet was calculated, based on the highest mean number of lesions per leaflet found in a sampling unit of four stems.

On 22 August, quadrats measuring 2 × 2 m were established in a grid of eight by 12 quadrats within each of two plots. Disease assessments were made on 22 and 27 August and on 3, 10, and 17 September. Five stems were collected at random from each quadrat on each assessment date. Total nodes, leaflets remaining, leaflets with lesions, and total lesions were recorded for each stem. Samples collected on 10 and 17 September were rated only for percent defoliation, except for those quadrats extending within the same row as the source (north-south orientation) or as a single row of quadrats extending from the source across beds of peanut (east-west orientation). These samples were also rated for incidence, severity, and defoliation.

The peanut canopy was divided into three distinct layers: the upper canopy comprised the uppermost fully expanded four leaves, the middle canopy the next four lower leaves, and the lower canopy the four leaves below the middle canopy. Nodes below this point were not included because of defoliation that was not associated with late leaf spot.

Numbers of lesions on defoliated leaflets were also estimated. The change in the number of defoliated leaflets within each canopy zone between each assessment date and the next was determined. Each defoliation increment was multiplied by the number of lesions per leaflet determined on the previous assessment date. Lesions on defoliated and attached leaflets were summed across assessment dates to arrive at estimated lesion numbers within each canopy zone.

Disease gradients. Gradients were assessed weekly for 4 wk beginning 3 wk after the initial placement of source lesions. Four stems were selected at random at each of nine 15-cm intervals from 15 to 135 cm from the source in directions north, south, east, and west of the source. The total numbers of lesions, leaflets with lesions, missing leaflets, and total leaflets on each stem were recorded. Incidence, severity, and defoliation at each sampling point along each direction away from a source were expressed as the means of the values for the four stem samples. Preliminary analyses indicated that the temporal progression of disease was described by the logistic function and that the logit(y) vs. linear(x) model best fit the gradient data (1).

A gradient parameter (b) was determined for the assessment dates of 11, 18, and 22 August for each of the four field plots. Gradient slopes appeared to be reasonably stable during this span of time. Velocity of spread ($v = r/b$) was then calculated separately for each field plot.

Isopathic rate versus isopath level. Rates of disease progress in terms of incidence, severity, and defoliation were calculated as the slopes of the regression of logit disease (y) on the date of assessment (t). Equations derived for each 15-cm assessment interval from the source were used to calculate the corresponding time required to reach a given isopath level (e.g., $y = 0.10$). Each time value was then divided into its corresponding distance to yield the isopathic velocity at each distance. Velocity values, calculated at 15-cm intervals from 15 cm through 1 m, were averaged to yield an isopathic rate for a given isopath level. Additional velocity values were calculated at 3, 5, 7, and 9 m from the source by using data collected from quadrats.

RESULTS

Incidence. Disease incidence, assessed on 5, 11, 18, and 22 August, decreased sharply from the source up to 1 m (Fig. 1). Disease incidence rose sharply between 22 August and 27 August. Incidence between 1 and 9 m from the source increased from about 10% on 22 August to about 90% by 10 September. Disease incidence expressed as logits declined linearly with increasing distance from the source between 5 and 11 August (Fig. 1). On 22 August, disease was observed throughout the field plots.

Disease incidence expressed as logits increased linearly with time (Fig. 2). Gradients of disease incidence, based on the logit(y) vs. linear(x) model, were similar in all four field plots. Gradient slope was very steep on 5 August, less steep on 11, 18, and 22 August, and shallow on 27 August and 7 and 10 September (Table 1).

Rates of disease progress among the four fields ranged from 0.02 to 0.25/day (Table 2). The gradient parameter, based on the average gradient slope within each plot between 11 and 22 August, ranged from 2.49 to 2.83/m. Velocities of spread (r/b) therefore ranged between 0.07 and 0.09 m/day (Table 2).

Isopathic rates of disease incidence were greater at low (10%) incidence levels than at high (90%) levels. Rates of incidence isopaths decreased as a power function with increasing isopath level (Fig. 3).

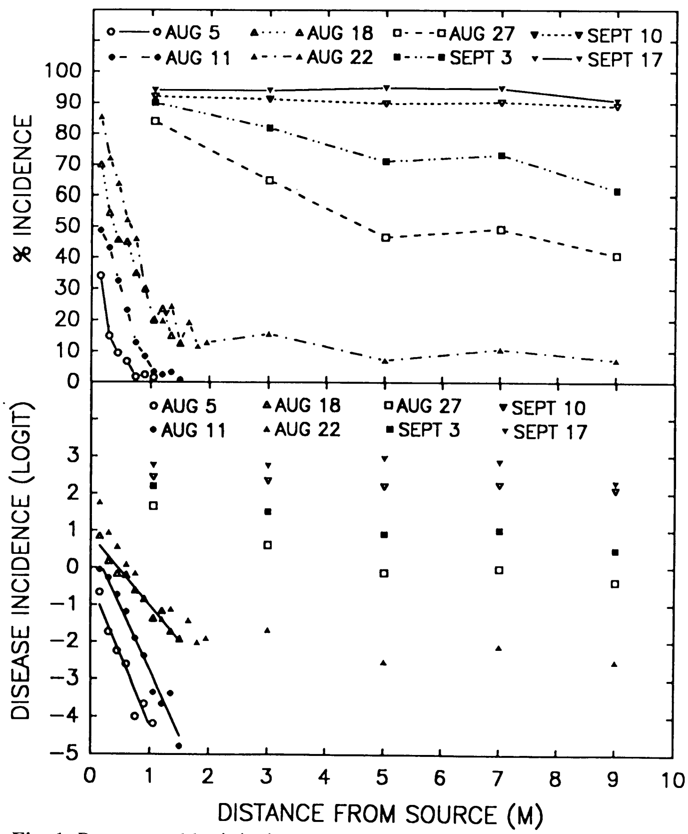

Fig. 1. Percent and logit incidence of late leaf spot of peanut with respect to distance from a point source, assessed on eight dates. Mean values from four field plots within each date are presented.

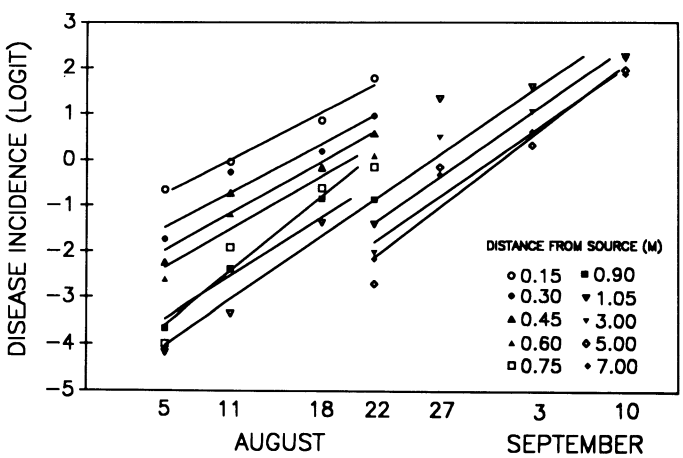

Fig 2. Disease incidence (logit) of late leaf spot of peanut with respect to time at various distances from a point source of inoculum. Mean values from four fields are presented within each distance.

Percent incidence with respect to distance from the source and time in the upper (Fig. 4A), middle (Fig. 4B), and lower (Fig 4C) canopy layers decreased with distance from the source from 22 August through 27 August, then increased gradually through 17 September.

Isopathic rates of disease incidence were greatest in the lower and least in the upper canopy (Fig. 5). Rates decreased over isopath levels from 40 to 90% incidence.

Defoliation. Defoliation decreased sharply from the source through 1 m away from the source (Fig. 6). No defoliation was observed on 5 August. Defoliation between 1 and 9 m from the source was 1–5% on 22 August and increased to 70–80% by 17 September. Defoliation expressed as logits declined linearly on 11 and 18 August. On 22 August, defoliation was observed at low levels throughout the plot (Fig. 6).

At the Watkinsville site, defoliation gradients extending beyond 0.45 cm were not detected. Therefore, gradient analyses were not conducted.

Defoliation expressed as logits increased roughly linearly with time (Fig. 7). Gradients of defoliation, based on the logit(y) vs. linear(x) model, were observed in each of the four fields at Plains. Steep gradients were observed on 11, 17, and 22 August. Gradients were shallow on 27 August and 7 and 10 September (Table 3).

Rates of disease progress among the four fields at Plains ranged from 0.11 to 0.19/day (Table 2). The average gradient parameter (b) within each plot between 11 and 22 August ranged from 2.17 to 3.51/m. Velocities of spread ranged between 0.03 and 0.06 m/day. The gradient parameter calculated for the four plots during the later stage of disease development (27 August through 10 September) ranged from 2.17 to 3.34/m; Velocity of spread ranged from 0.03 to 0.06 m/day.

Isopathic rate of defoliation was faster at the low (10%) defoliation level than at the high (90%) defoliation level (Fig. 8). Rate of defoliation isopaths decreased with increasing isopath level.

Percent defoliation, with respect to distance from the source and time in the upper (Fig. 4D), middle (Fig. 4E), and lower (Fig. 4F) canopy layers, increased from 22 August through 17 September. Defoliation was greatest (100%) in the lower canopy layer and least (30%) in the upper canopy layer.

Isopathic rates of defoliation were faster in the lower than in the upper canopy. Rates decreased over isopath levels from 10 to 90% (Fig. 9).

Severity. Lesions per leaflet on 22 August decreased sharply with distance from the source through 1 m (Fig. 10). Less than one lesion per leaflet was observed 9 m from the source. Between 1 and 9 m from the source, number of lesions per leaflet increased to about 50 by 17 September. The highest mean number of lesions per leaflet found in a sampling unit of five stems was 87, and this value was used as the carrying capacity for the calculation of logit lesions per leaflet. Lesions per leaflet expressed as logits declined linearly with increasing distance from the source between 5 and 11 August. On 22 August, lesions were observed throughout the plot (Fig. 10).

Lesions per leaflet expressed as logits increased linearly with time (Fig. 11). Gradients of severity based on the logit(y) vs. linear(x) model were similar in all four field plots (Table 4). Gradient slope was very steep on 5 August, less steep on 11, 18, and 22 August, and shallow on 27 August and 3, 10, and 17 September.

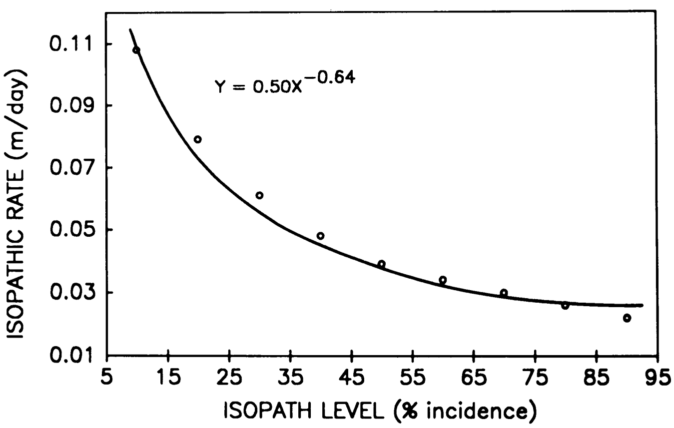

Fig. 3. Relationship between isopathic rate (rate of movement of a given level of disease) and isopath level (predefined fixed level of disease) for disease incidence of late leaf spot of peanut. Means were derived from pooled data (four directions from the source × four field plots).

TABLE 1. Slope (b), intercept (a), and coefficient of determination (r^2) of regression of logit disease incidence on distance from the source for late leaf spot of peanut in field plots[a]

Assessment date	Field plot I b[b]	I a	I r^2	II b	II a	II r^2	III b	III a	III r^2	IV b	IV a	IV r^2
05 August	4.08	−0.49	0.78	4.48	−3.33	0.90	4.46	−0.09	0.91	4.30	0.07	0.93
11 August	3.32	0.42	0.92	3.24	0.55	0.89	3.08	0.34	0.88	3.95	1.22	0.97
18 August	2.35	1.25	0.98	2.25	1.06	0.97	1.97	0.61	0.95	2.18	1.07	0.94
22 August	2.80	1.48	0.95	2.73	0.82	0.99	2.41	1.21	0.92	2.24	1.35	0.93
27 August	···	···	···	···	···	···	0.52	2.42	0.79	0.37	2.28	0.86
03 September	···	···	···	···	···	···	0.43	2.38	0.72	0.27	2.42	0.86
10 September	···	···	···	···	···	···	0.14	2.40	0.24	0.39	2.04	0.80

[a]Values were derived from four gradients (N, S, E, W) for each of four field plots at each assessment date.
[b]Based on gradients extending to 1–2 m on 5–22 August and to 5 m on 27 August–10 September.

TABLE 2. Apparent infection rate (r), gradient parameter (b), and velocity of spread (v) of late leaf spot of peanut, calculated using incidence, severity, and defoliation data of 11, 18, and 22 August

Assessment variable	Field plot I r[a]	I b[b]	I v[c]	II r	II b	II v	III r	III b	III v	IV r	IV b	IV v
Percent incidence	0.25	2.83	0.09	0.23	2.74	0.09	0.20	2.49	0.08	0.20	2.79	0.07
Lesions/leaflet	0.18	3.11	0.06	0.15	3.74	0.04	0.19	3.98	0.05	0.14	3.79	0.04
Percent defoliation	0.11	2.17	0.05	0.12	3.51	0.03	0.19	3.34	0.06	0.19	2.90	0.06

[a]Expressed in units of day^{-1}.
[b]Expressed in units of m^{-1}.
[c]Expressed in units of $m^{-1} \cdot day^{-1}$.

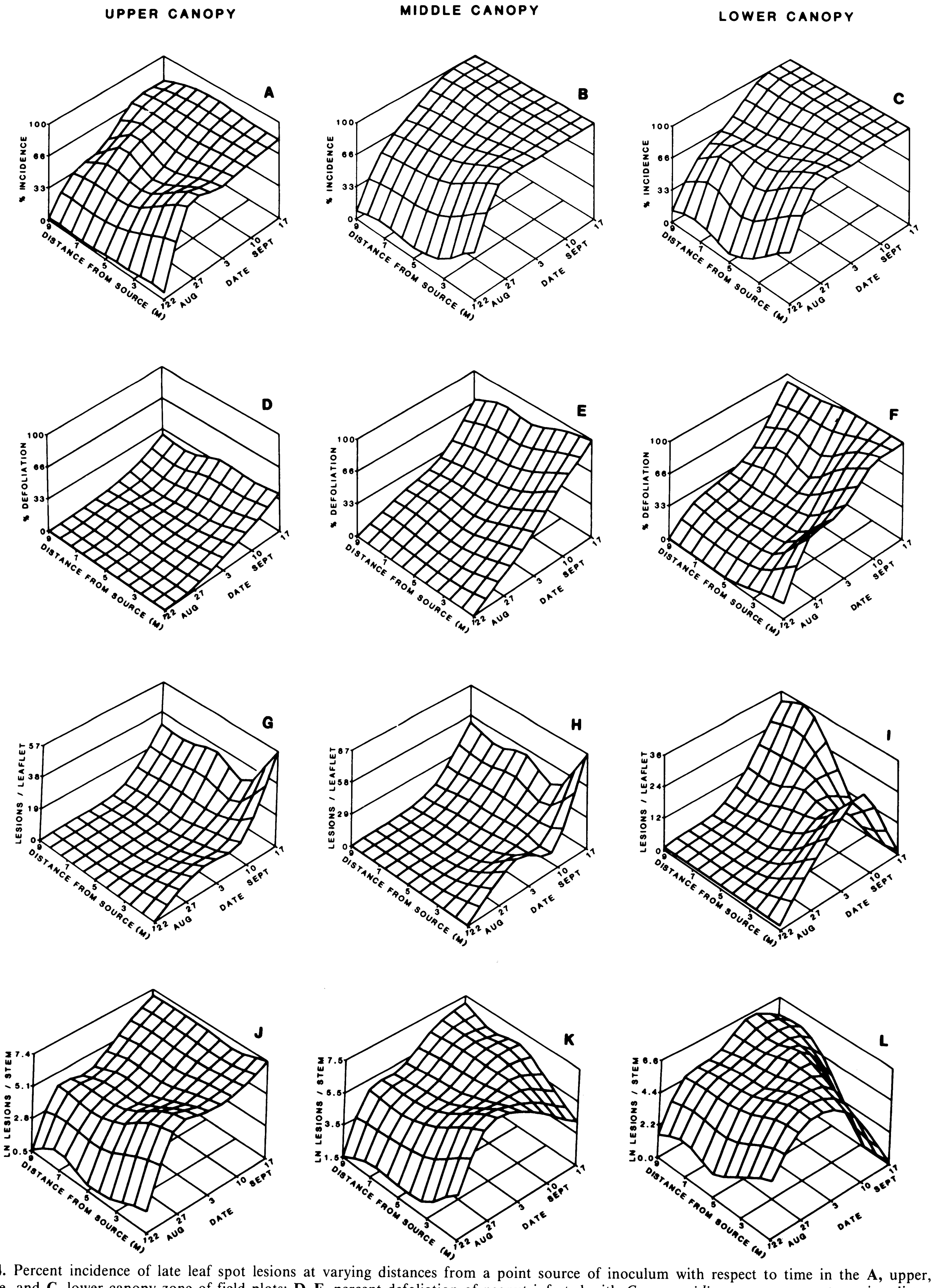

Fig. 4. Percent incidence of late leaf spot lesions at varying distances from a point source of inoculum with respect to time in the **A,** upper, **B,** middle, and **C,** lower canopy zone of field plots; **D–F,** percent defoliation of peanut infected with *Cercosporidium personatum* at varying distances from a point source with respect to time; **G–I,** late leaf spot lesions per peanut leaflet at varying distances from a point source with respect to time; **J–L,** natural lagarithm of late leaf spot lesions per stem at varying distances from a point source with respect to time.

Rate of disease progress among the four field plots ranged from 0.14 to 0.19/day (Table 2). The mean gradient parameter between 11 and 22 August ranged from 3.11 to 3.98/m. Velocity of spread ranged between 0.04 and 0.06 m/day.

Isopathic rate of disease severity was faster at the low (one lesion/leaflet) severity level than at the high (seven lesions/leaflet) level (Fig. 12). Rate of severity isopaths decreased with increasing isopath level.

Lesions per leaflet in the upper (Fig. 4G) and middle (Fig. 4H) canopy layers increased rapidly from 22 August through 17 September. In the lower canopy (Fig. 4I), a similar increase was observed at 9 m from the source. However, at 1 m from the source, lesions per leaflet increased from 22 August through 10 September, then declined sharply. Lesions per leaflet in the upper canopy at 1 and 9 m from the source increased to 0.13 and 0.02, respectively, by 17 September. On 10 September, severity levels were 14–16 lesions per leaflet at 3–9 m from the source. By 17 September, the gradient slope shifted from negative to positive, with no lesions observed at 1 or 3 m from the source, because of complete defoliation of leaflets with lesions.

The natural logarithm of lesions per stem varied with respect to time, distance, and canopy layer. In the upper (Fig. 4J), middle (Fig. 4K), and lower (Fig. 4L) canopy, lesion number increased quickly between 22 and 27 August. In the upper canopy, lesions increased gradually between 27 August and 17 September.

Total lesion numbers (summed over the lower, middle, and upper canopy zones) on 17 September at 1, 3, 5, 7, and 9 m from the source were 580, 331, 534, and 658, respectively.

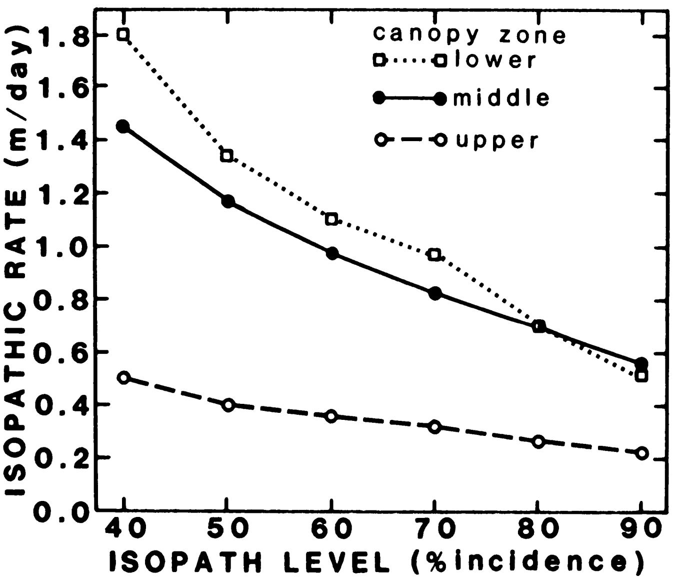

Fig. 5. Relationship between isopathic rate (rate of movement of a given level of disease) and isopath level (predefined fixed level of disease) for percent incidence of late leaf spot of peanut within the lower, middle, and upper canopy zones of field plots.

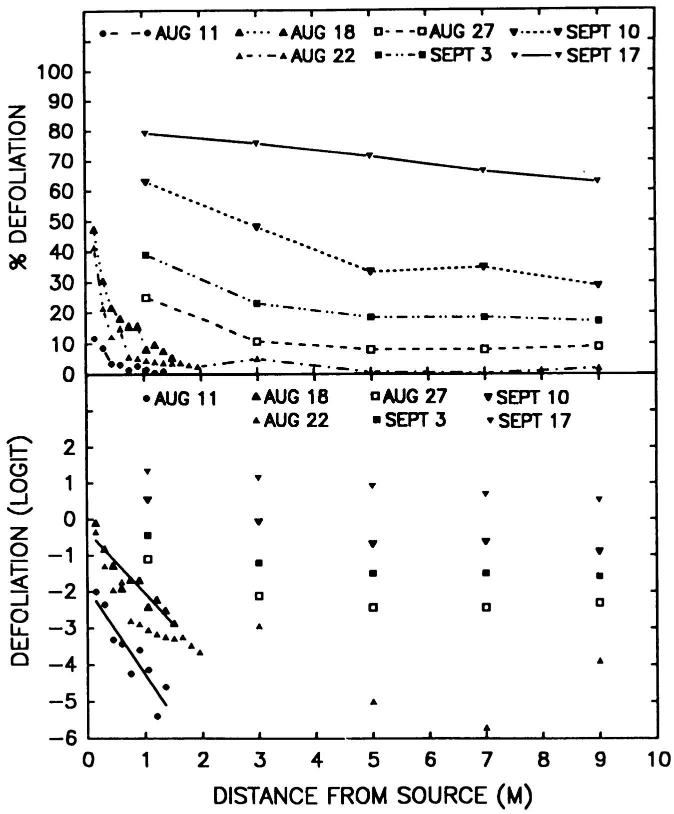

Fig. 6. Percent and logit defoliation of peanut with respect to distance from a point source of *Cercosporidium personatum,* assessed on eight dates. Mean values from four field plots within each date are graphed.

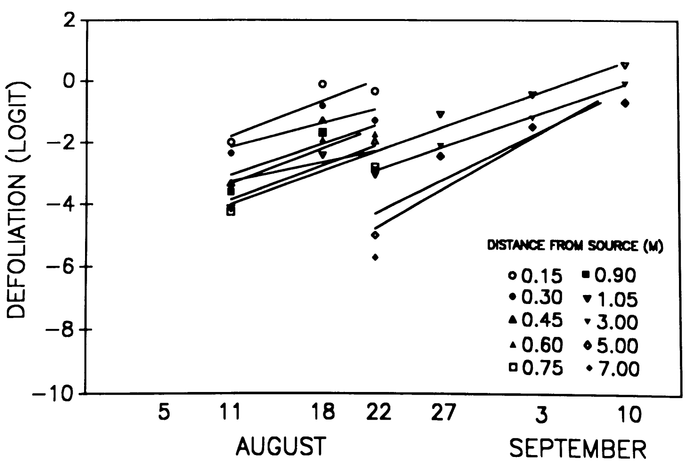

Fig. 7. Defoliation (logit) with respect to time at various distances from a point source of inoculum. Mean values from four fields are presented within each distance.

TABLE 3. Slope (b), intercept (a), and coefficient of determination (r^2) of regression of logit defoliation on distance from the source of infection for late leaf spot of peanut[a]

	Field plot											
	I			II			III			IV		
Assessment date	b[b]	a	r^2	b	a	r^2	b	a	r^2	b	a	r^2
11 August	2.57	−1.04	0.89	3.81	−1.41	0.76	4.07	−1.22	0.97	3.75	−1.82	0.75
18 August	2.10	0.07	0.92	2.86	0.13	0.81	1.71	−0.56	0.96	2.71	−2.56	0.82
22 August	1.84	−0.41	0.87	4.50	−0.14	0.94	4.23	−0.22	0.86	2.24	−0.63	0.53
27 August	···	···	···	···	···	···	0.46	−0.74	0.78	0.27	−1.04	0.99
03 September	···	···	···	···	···	···	0.13	−0.99	0.84	0.15	−0.20	0.73
10 September	···	···	···	···	···	···	0.17	−0.01	0.92	0.25	1.27	0.86
17 September	···	···	···	···	···	···	0.01	1.12	0.92	0.22	1.81	0.98

[a]Values were derived from four gradients (N, S, E, W) for each of the four field plots at each assessment date.
[b]Based on gradients extending 1–2 m on 11–22 August and to 5 m on 27 August–10 September.

Cumulative lesion numbers on 17 September at 1, 3, 5, 7, and 9 m from the source, including estimates of lesions on defoliated leaflets, were 1,139, 682, 884, 781, and 912, respectively.

At the Watkinsville site, gradients of disease severity extending beyond 0.90 m were not observed before 5 September. Gradients developing beyond 0.45 cm were observed only south of the source on 5 September. Gradients were described by a logit(y) vs. ln(x) model ($r^2 = 0.85$–0.88).

DISCUSSION

Late leaf spot of peanut occurs annually throughout the U.S. peanut production region. In 1986 dry conditions during much of the summer delayed development of the disease. The consistently warm temperatures and application of irrigation at Plains provided highly favorable conditions for late leaf spot development, giving us the opportunity to study late leaf spot gradients with little interference from outside inoculum.

At the Southwest Branch Station at Plains, the initial gradient arising from source lesions was evident on 5 August. Nightly irrigation may have contributed to additional lesion development away from the source by 11 August. Disease was less severe near the source on 11 and 18 August than on 5 August, perhaps because of an increase in defoliation between these dates and a decline in the proportion of leaves with lesions as a result of new growth. Sporulating lesions were observed on 5 August. Lesion number rose sharply on 18 August and on 3 September, suggesting that the latent period of *C. personatum* is 2–3 wk.

Plaut and Berger (15) reported rates of disease progress of 0.32–0.53/day for total disease, 0.39–0.55/day for defoliation, and 0.28–0.36/day for visible disease caused by *C. personatum*. In the case of late leaf spot, the time interval used in calculating rates could influence the rate value, especially considering a long latent period of 2–3 wk. Using the rate (slope) of the logistically

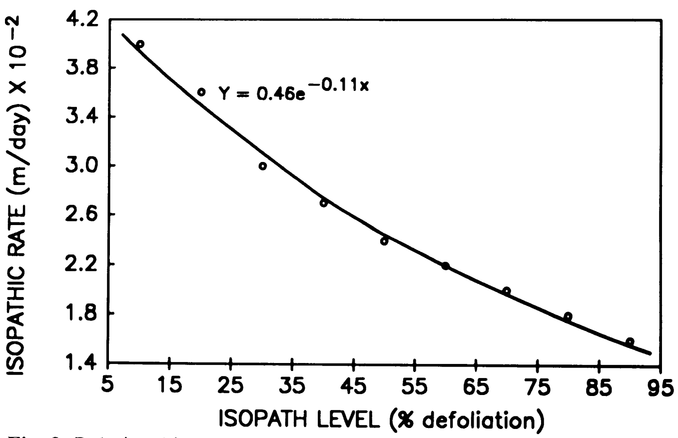

Fig. 8. Relationship between isopathic rate (rate of movement of a given level of disease) and isopath level (predefined fixed level of disease) of percent defoliation of peanut in plots with point sources of *Cercosporidium personatum*. Means were derived from pooled data for each distance from the source (four directions × four field plots).

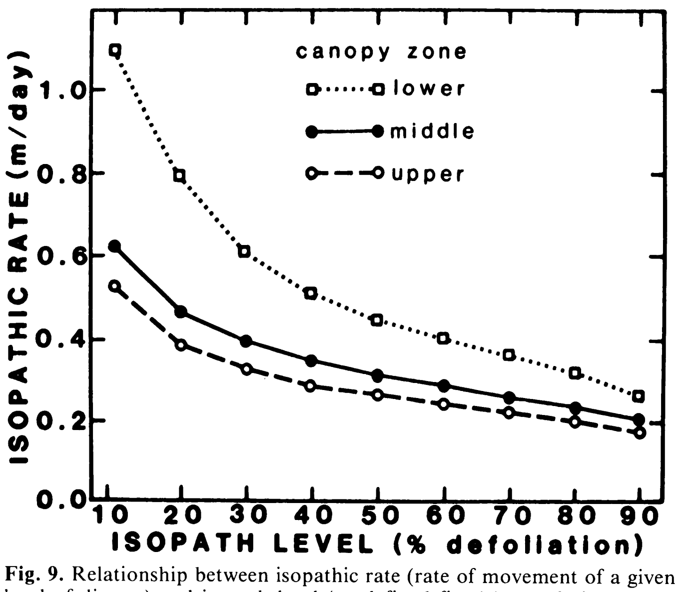

Fig. 9. Relationship between isopathic rate (rate of movement of a given level of disease) and isopath level (predefined fixed level of disease) for percent defoliation of peanut infected by *Cercosporidium personatum* for the lower, middle, and upper canopy zones of field plots, each containing a point source of inoculum.

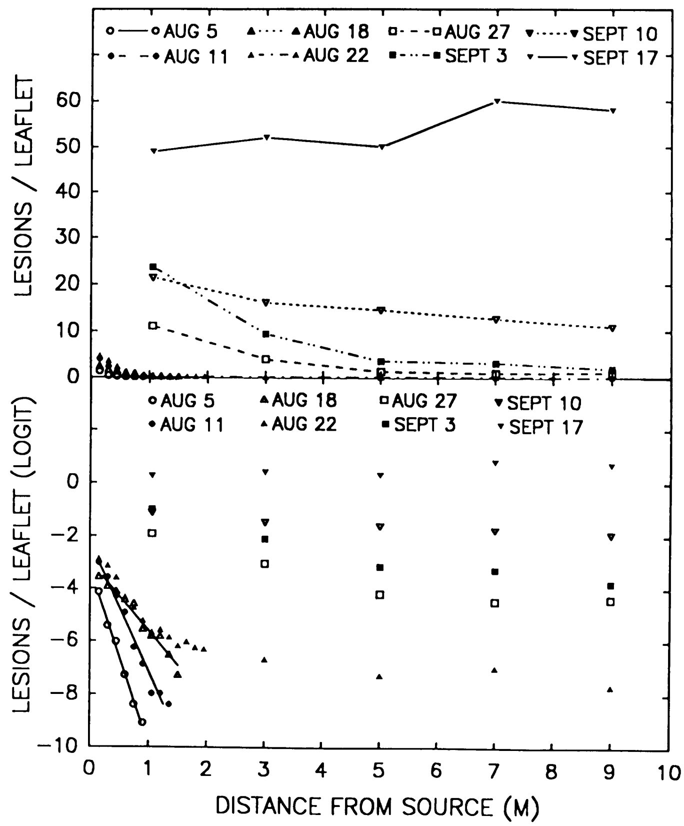

Fig. 10. Late leaf spot lesions and logit lesions per peanut leaflet with respect to distance from a point source of inoculum, assessed on eight dates. Mean values from four field plots within each date are graphed. A carrying capacity of 87 lesions per leaflet was used for logit determination.

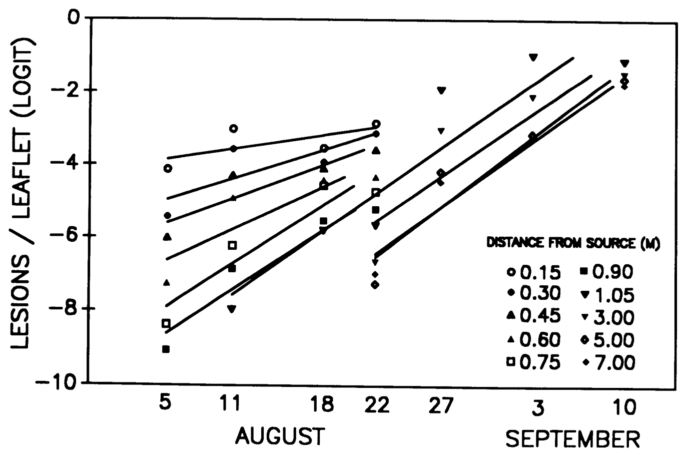

Fig. 11. Lesions per leaflet (logit) with respect to time at various distances from a point source of inoculum. Mean values from four field plots are presented within each distance. A carrying capacity of 87 lesions per leaflet was used for logit determination.

TABLE 4. Slope (b), intercept (a), and coefficient of determination (r^2) of regression of lesions per leaflet on distance from the source of infection for late leaf spot of peanut[a]

Assessment date	Field plot I			Field plot II			Field plot III			Field plot IV		
	b[b]	a	r^2	b	a	r^2	b	a	r^2	b	a	r^2
05 August	7.98	−3.79	0.92	7.40	−3.42	0.96	5.78	−3.64	0.98	4.51	3.16	0.58
11 August	4.78	−2.78	0.94	5.92	−1.69	0.96	4.93	−2.46	0.99	5.06	−1.87	0.96
18 August	2.06	−3.31	0.85	2.36	−3.28	0.92	4.57	−1.07	0.64	3.14	−2.55	0.94
22 August	2.48	−2.65	0.94	2.94	−3.01	0.90	2.44	−2.73	0.94	3.17	−1.88	0.96
27 August	···	···	···	···	···	···	0.30	−2.37	0.88	0.43	−1.50	0.88
03 September	···	···	···	···	···	···	0.30	−1.17	0.90	0.36	−0.85	0.88
10 September	···	···	···	···	···	···	0.13	−0.79	0.49	0.85	−0.14	0.92
17 September	···	···	···	···	···	···	0.08	−0.27	0.31	0.64	−0.14	0.53

[a]Values were derived from four gradients (N, S, E, W) for each of the four field plots at each assessment date.
[b]Based on gradients extending to 1–2 m on 5–22 August and to 5 m on 27 August–10 September.

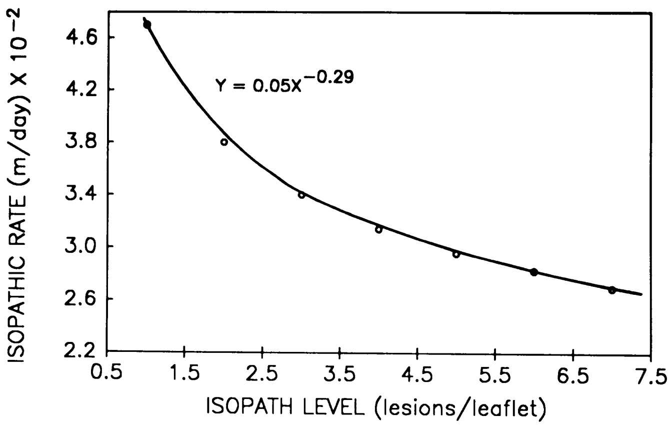

Fig. 12. Relationship between isopathic rate (rate of movement of a given level of disease) and isopath level (predefined fixed level of disease) for late leaf spot severity on peanut. Means were derived from pooled data for each distance (four directions × four field plots).

transformed disease progress curves, we found rates of 0.20–0.25/day for disease incidence and 0.11–0.19/day for defoliation.

In the studies of Minogue and Fry (13) and Berger and Luke (3), the rate of disease progress of potato late blight and oat crown rust, respectively, remained essentially constant at varying distances from the source. We also observed a relatively constant rate of disease progress of peanut late leaf spot at each distance from the source.

Velocities of spread of 0.2–1.2, 3–4, and 0.3 m/day have been reported for *Puccinia coronata* (3), *Phytophthora infestans* (13), and *Septoria nodorum* (9), respectively. We observed that velocity of spread of late leaf spot varied depending on method of assessment. In addition, velocity values for primary gradients may not reflect the velocity of spread at later stages of disease development in polycyclic diseases. Minogue and Fry (13) and van den Bosch et al (19) found that it takes a few generations for velocity to stabilize before becoming constant. Stable velocities were not observed for peanut late leaf spot; gradient slopes continued to become more shallow with time.

Isopathic rates, with respect to isopath level, have been characterized as increasing, remaining constant, or decreasing (12). We observed that isopathic rate (velocity) decreased with increasing isopathic level, perhaps because more time is required to reach a high isopath level as the saturation level is approached. High isopath levels appear to spread at slower rates than low levels.

The monitoring of disease development within canopy zones showed that disease incidence progressed rapidly throughout the canopy. Defoliation, however, progressed from lowermost to uppermost leaves, despite large numbers of lesions in the middle and upper canopies. This suggests that late leaf spot may accelerate the natural progression of defoliation, which occurs from the lowermost to the uppermost leaves.

Disease severity, measured as the number of lesions per leaf, varied with distance from the source and time. Severities were higher near the source during the early stages of disease and lower during the later stages. However, cumulative lesions remained relatively constant across the gradient.

Disease incidence data provided estimates of pathogen movement away from the source. Severity data provided an estimate of pathogen intensity as disease progressed from the source. However, calculation of logit values of lesions per leaflet requires a value for the carrying capacity. The carrying capacity of peanut is not clearly defined and may vary among cultivars of varying levels of resistance. Although incidence and severity data were well suited for defining the early stages of disease spread, defoliation data may be more useful in identifying gradients during the later stages of disease development.

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