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NORTHERN LEAF BLIGHT PROGRESS AND SPREAD FROM INFESTED MAIZE RESIDUE

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ABSTRACT

Local epidemics of northern leaf blight, incited by the fungus *Exserohilum turcicum* (Pass) Leonard & Suggs, usually originate from conidia on infested maize residue. The effect of four residue levels: 0, 1, 2, and 3 kg/2.25 m^2 on the progress and spread of northern leaf blight was monitored on a susceptible maize cultivar EV8429-SR. Final percentage leaf area blighted and area under disease progress curve were significantly ($P \leq 0.05$) higher in the residue infested plots compared to the residue-free plots. Disease severity decreased with increase in distance from the maize residue area, whereas the apparent infection rate remained relatively constant. Gradients of disease spread curves were significantly ($P \leq 0.01$) influenced by levels of maize residue and ranged from 0.2 to 1.6. The gradients flattened as the season progressed. Presence of lesions in residue-free plots indicated background contamination and/or disease spread from the residue-infested plots.

Key Words: **Apparent infection rate, disease, epidemics, *Exserohilum turcicum*, gradients, inocula, Uganda**

RÉSUMÉ

Les épidémies de rouille foliaire nordique provoquées par le champignon *Exserohilum turcicum* (Pass) Leonard & Suggs proviennent habituellement des conidies sur le résidu du maïs infesté. L' effet de quatre niveaux de résidu: 1, 2, et 3 kg /2.25 m² sur la progression de la rouille foliaire nordique a été surveillée sur la variété de maïs susceptible EV 8429-SR. Le pourcentage final de la surface de la feuille atteinte de rouille et la surface au-dessous de la courbe de progression de l'infection etaient significativement (P≤0,05) plus élevés dans les parcelles à résidu infesté par rapport aux parcelles indemnes de résidu. La gravité de la maladie diminuait avec la distance croissante depuis la surface du résidu tandis que le taux d' infection, apparent demeurait relativement constant. Les pentes des courbes de progression de la maladie étaient significativement (P≤ 0,01) influencées par les niveau de résidu du maïs et variaient de 0, 2, à 1,6. Les pentes s'aplatissaient suivant la progression de la saison. La présence de lésions dans de parcelles exemptes de résidu suggérait des antécédents de contamination et/ou de progression de la maladie à patir des parcelles à résidu infesté.

Mots Clés: **Taux d'infection apparent, maladie, épidemies, *Exserohilum turcicum*, pentes, inoculums, Uganda**

INTRODUCTION

In many tropical areas, northern leaf blight caused by the fungus *Exserohilum turcicum* (Pass) Leonard and Suggs (Teleomorph: *Setosphaeria turcica* (Luttrell) Leonard and Suggs) is an important disease on maize (Adipala *et al.*, 1993a & b; Bigirwa *et al.*, 1993). There are speculations that recent country-wide epidemics in Uganda have been largely due to large amounts of infested maize residue in farmers fields (Adipala *et al.*, 1993a). However there have been no detailed studies to confirm these assumptions. In contrast, the role of residue-borne pathogens in the epidemiology of maize diseases has been extensively documented especially in the USA (Boosalis *et al.*, 1967; Littrell and Sumner, 1971; Sumner and Littrell, 1974; Lipps, 1983; de Nazareno *et al.*, 1993).

In the USA, survival of *E. turcicum* on maize residue is often instrumental in the development of northern leaf blight (Boosalis *et al.*, 1967). Indeed, Robert and Findley (1952) used *E. turcicum* infested maize leaves to induce northern leaf blight epidemics. Lipps (1983) found that *Colletotricum graminicola* (Ces.) Wilson infested maize residue was a source of inoculum for anthracnose development. Other pathogens reported to survive on maize residue include *Phyllosticta maydis* Arny and Nelson, which incites yellow maize leaf blight, *Physoderma maydis* Miyabe, which incites brown leaf spot (Shurtleff, 1980), and *Cercospora zea-maydis* Tehon and Daniels, which induces gray leaf spot (Payne and Waldron, 1983). It is generally assumed that conidia produced on residues left on the soil surface constitute primary inocula for residue-borne pathogens of maize and sporulation on mature leaf lesions serve as a source of secondary spread (Sumner *et al.*, 1981; Lipps, 1983). These literature reports indicate that infested maize residue present on soil surface could be an important factor in the epidemics of maize diseases.

For a maize residue-borne pathogen, the final disease severity would be influenced by the amount of infested maize residue on soil surface, which would be influenced by the cropping system and tillage practices. Diseases such as anthracnose, northern leaf blight, gray leaf spot and brown leaf spot are more severe under minimal tillage than in conventional tillage where maize debris is buried (Boosalis *et al.*, 1967; Sumner *et al.*, 1981; Lipps, 1983; de Nazareno, 1992; de Nazareno *et al.*, 1993). It is therefore possible that deep ploughing and crop rotation may control some of the residue borne pathogens. Under continuous maize cultivation, deep ploughing may reduce inoculum levels and the incidence of early season disease development, but this may not necessarily result into complete disease control (Sumner *et al.*, 1981; Lipps, 1983). Farmers in Uganda rarely practice deep cultivation and it is likely that infested maize residue is an important factor in the initiation of epidemics of northern leaf blight of maize. This study was undertaken to evaluate the role of *E. turcicum* - infested maize residue in the progress (increase over time) and spread (increase over distance) of northern leaf blight from an *E. turcicum* focal point under ambient conditions in Uganda. The information will be of use in designing cultural management practices for the control of northern leaf blight in tropical environments.

MATERIALS AND METHODS

Field plots. The field plots were established during the long rains of 1991 and 1992 at Namulonge and during the short rains of 1992 at Kabanyolo, Uganda. An open-pollinated susceptible maize cultivar, EV8429-SR, was used in all trials. The plots were laid on land under maize-soybean rotation which had been disc-ploughed and later disc-harrowed to achieve fine seedbed. The trial was planted on March 15, 1991 and April 1, 1992 at Namulonge and on September 10, 1992 at Kabanyolo. The experiment was arranged as a randomized complete block with three replicates, except at Namulonge where four replicates were used in 1992. Each treatment unit consisted of 12 x 12 m plots containing 17 rows of maize, planted at a spacing of 75 cm between rows and 25 cm between plants within rows. Naturally *E. turcicum* infested maize residue collected from the 1990, 1991 and 1992 long rain crops at Kabanyolo was used as a source of inocula in 1991 and 1992. The residue was kept dry in the store to protect it from rain and later weighed prior to placement in the field. At growth stage (GS) 4-5 (Ritchie and

Hanway, 1982) the residue was surface-applied at the centre of each plot covering an area of 1.5 x 1.5 m. Four residue levels: 0, 1, 2, and 3 kg /2.25 m^2 were tested, i.e., 0 would represent conventional tillage where residue is fully incorporated into the soil (control); 1 = 20% soil surface coverage; 2 = 40% surface coverage; and 3 kg a minimum tillage treatment leaving residue (>60% surface coverage) on the soil surface. Infested maize residue was placed in the fields 45 and 35 days after planting at Namulonge and Kabanyolo, respectively. The experiment was hand-weeded thrice.

Disease assessment. For each distance away from inoculum source, a pair of opposite plants spaced approximately 0.75 m apart in adjacent rows were tagged in East, West, South and North directions. A total of 28 pairs of plants were used per experimental unit. All plants in areas covered by the maize residue were also tagged. For each tagged plant, the number of lesions on the ear leaf, and above and below the ear leaf were counted independently. Percent leaf area blighted was assessed using a scale of 0–75% (Adipala *et al.*, 1993a) based on a modified scale of 0–5 established by Elliott and Jenkins (1946). Data were collected four times at 7–10 day intervals, except at Namulonge which was scored only 3 times in 1992 due to termite damage.

Data analysis. For each distance from the residue source, the mean leaf area blighted was calculated for each data point and direction of disease assessment. When no significant differences were detected between directions, data for the four compass points were pooled for each residue treament. Data collected at different points in time were used to compute unstandardized area under disease progress curves (AUDPC) (Campbell and Madden, 1990), and the apparent infection rates, r, (van der Plank, 1963) for each distance. The apparent infection rates, depicting rate of disease increase over time, were computed by fitting the logistic model:

$$(\ln(y/0.75-y) = a+rt$$

where y = the proportion of leaf area blighted, a = the logit of the amount of disease at time zero and, r = rate of disease increase with time (t) to the logit transformed data. The logistic model was selected because of its common usage and it was comparable or better than the Gompertz model in our data presented elsewhere (Adipala *et al.*, 1994). The exponential model,

$y = a\exp(-bx)$ (Kiyosawa and Shiyomi, 1972) and power model, $y = axb$ (Gregory, 1968)

were fitted to disease gradient data. In these models y is the proportion of disease severity at x units of distance from the inoculum source and b is the slope (Fontem *et al.*, 1991). In the power and exponential models a is the disease proportion at one unit of distance from the inoculum source. The coefficients of determination (R^2) of the linearized models and the residual plots were used to test the goodness-of-fit of each model (Cornell and Berger, 1987). However, this was not done for the Namulonge 1992 data because of the few (3) data points. The r and b-values were therefore estimated by regressing the logit of leaf area blighted on time and distance, respectively (Minogue and Fry, 1983a). ANOVA was used to test for differences in the disease parameters and yield with respect to residue level, distance and time, and yield. When the F-statistics were significant, means were compared using Fisher's Protected Least Significant Differences (LSD) at $P = 0.05$.

RESULTS

Preliminary analysis of lesion number and percentage leaf area blighted data showed a similar trend for these two disease parameters. Adipala (1992) also demostrated that the lesion number and percentage leaf area blighted were appropriate parameters for describing disease progress and spread. Consequently, only the percentage leaf area blighted data are presented.

In all the three seasons there was favourable disease development (Fig. 1). Direction from residue source did not have a significant effect on the severity of northern leaf blight assessed at different distances from the source plants. Data for the four directions (North, East, South and West) were therefore pooled and used to compute AUDPC, apparent infection rates (r) and intercept

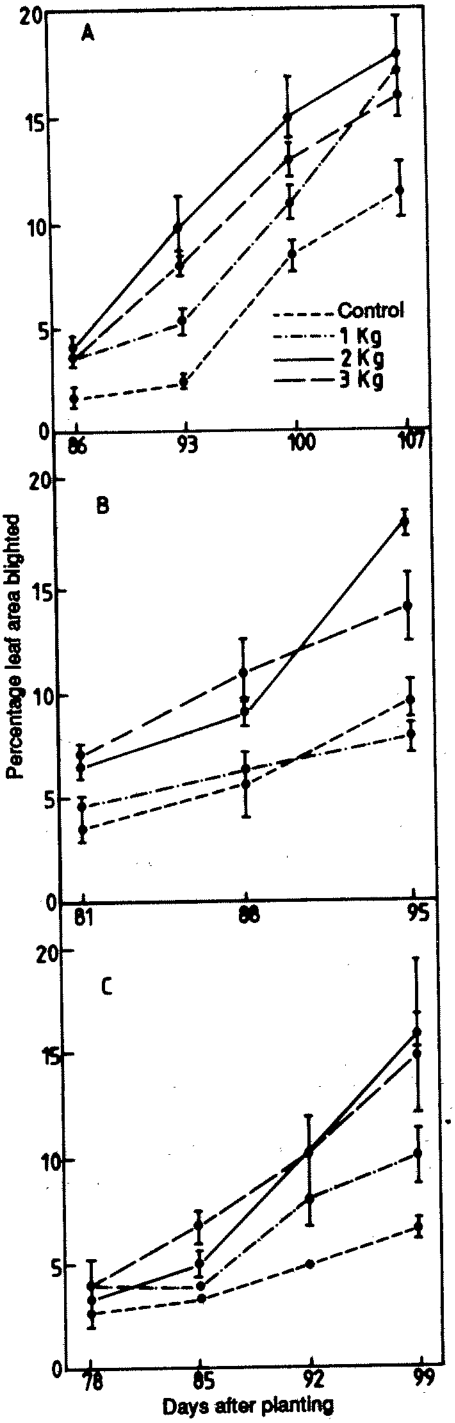

Figure 1. Effect of level of *Exserohilum turcicum* infested maize residue on progress of northern leaf blight on the maize cultivar EV8429-SR at Namulonge in 1991 (A) and 1992 (B), and at Kabanyolo in 1992 (C). Bars indicate standard errors.

TABLE 1. Effect of level of *Exserohilum turcicum* infested maize residue on initial (Y_i), and final leaf area blighted (Y_f), and area under disease progress curve (AUDPC) of northern leaf blight on the maize cultivar EV 8429-SR

Residue (kg/2.25 m^2)	Y_i	Y_f	AUDPC
Namulonge 1991			
0.0	1.7	11.5	384
1.0	3.5	17.4	370
2.0	3.5	17.9	593
3.0	4.1	16.3	509
Mean	3.3	15.8	464
$LSD_{0.05}$	NS	NS	NS
Namulonge 1992[c]			
0.0	–	–	225
1.0	–	–	211
2.0	–	–	393
3.0	–	–	382
Mean	5.3	11.9	303
$LSD_{0.05}$	NS	5.6	136
Kabanyolo 1992			
0.0	2.7	6.9	193
1.0	4.1	10.5	269
2.0	3.4	16.5	336
3.0	4.1	15.0	386
Mean	3.6	12.2	296
$LSD_{0.05}$	NS	NS	172

[a]Initial and final percentage leaf area blighted assessed at GS 9.0 and 9.3, respectively, obtained from residue infested plants.
[b]Unstandardized AUDPC calculated as described by Campbell and Madden (1990).
[c]Yi and Yf values not calculated because of few (3) data points

(a) for every data point.

The differences among maize residue levels were significant (P = 0.036) only for AUDPC at Namulonge in 1992. Generally plots infested with maize residue had higher disease levels (leaf area blighted and AUDPC) relative to the control plots without residue. However, by the last disease ratings, disease levels were highest in plots infested with 2 kg of residue (Table 1). At Kabanyolo, amount of residue did not significantly affect the initial (Yi) (P = 0.064) and final (Yf) leaf area blighted (P = 0.058) but the difference between the AUDPC values for the different levels were again significant (P = 0.043).

Percent leaf area blighted and AUDPC for each data point from the inoculum source showed

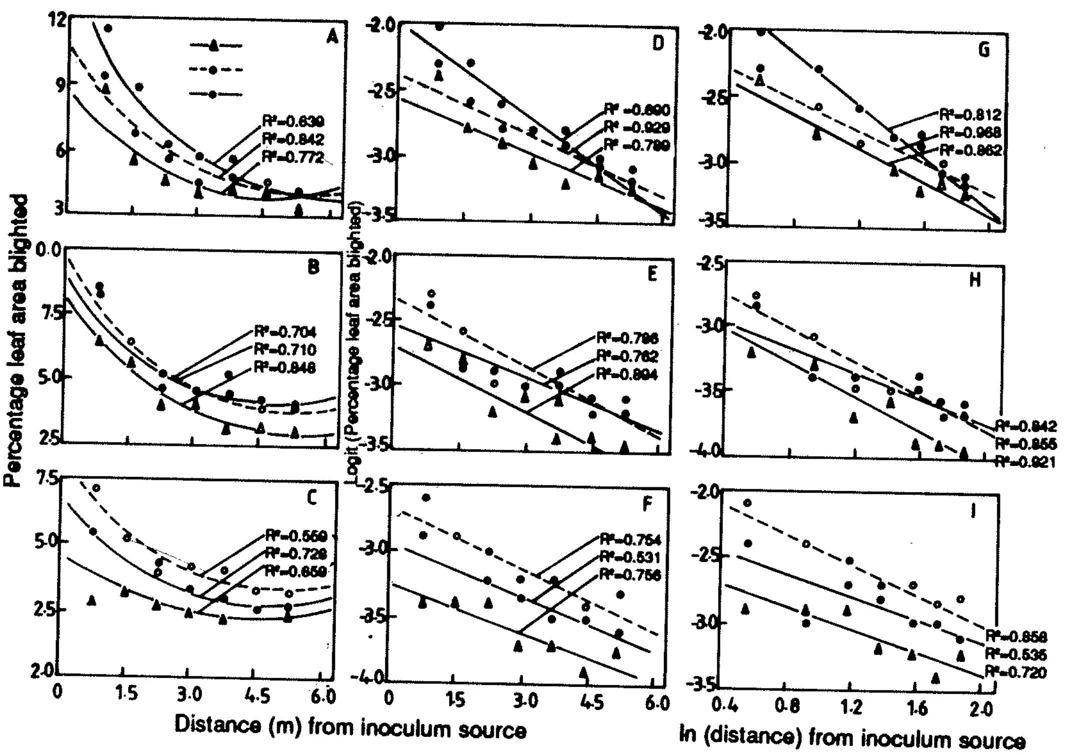

Figure 2. Northern leaf blight gradients (A, B, and C) for different maize residue levels and environments in Uganda fitted to the linearized exponential (D, E, and F) and power models (G, H, and I). Namulonge 1991 (A, D, and G); Namulonge 1992 (B, E, and H); and Kabanyolo 1992 (C, F, and I).

a similar trend and as such only AUDPC values are presented (Table 2). For all residue levels and the control, AUDPC decreased with distance from the inoculum (residue) source. However, significant residue level x distance (m) interactions for AUDPC were obtained at Kabanyolo and Namulonge in 1992. The interactive effect of residue level and distance was not significant for the apparent infection rate (r), and intercept (a). However, unlike AUDPC, r was relatively constant over distance from the inoculum source. The intercept (a), indicating the initial amount of disease for each data point from the source, showed considerable variation (Table 2).

A number of models have been used to represent plant disease gradients (Gregory, 1968; Kiyosawa and Shiyomi, 1972; Minogue and Fry, 1983a; Campbell and Madden, 1990). In this study the exponential and power model were examined on the basis of R^2-values and residual plots. The power model provided a better fit for all the three seasons, although the b-values were higher (due to the different transformation) than those obtained from the exponential model. To indicate the appropriateness of the power model, the data set for each season is presented in both the non-linear and linear forms (Fig. 2). The power model was superior to the exponential model in 60% of the comparisons in 1991, 78% in 1992 at Namulonge, and 75% in 1992 at Kabanyolo. For other cases the exponential model was better. The power model was therefore chosen to represent the spread of northern leaf blight.

With the exception of 1991, disease gradients (b) were significantly ($P = 0.001$) influenced by maize residue level. However, gradients between residue level 2 and 3 kg were not significantly different. The residue level of 2 kg had the highest b-values (Table 3). The gradients ranged from 0.2 to -1.2, from 0.2 to -1.4, and from 0.1 to -1.6 at

TABLE 2. Interaction effects between residue level and distance (x) from inocula foci on progress of northern leaf blight on the maize cultivar EV8429-SR at one location in Uganda in 1991 and two in 1992[a]

Level	x[b]	Namulonge 1991 AUDPC	Namulonge 1991 r[d]	Namulonge 1991 a	Namulonge 1992[e] AUDPC	Kabanyolo 1992 AUDPC	Kabanyolo 1992 r	Kabanyolo 1992 a
0	0.75	262	0.079	-10.2	143	160	0.041	-6.9
	1.50	199	0.080	-10.7	181	171	0.034	-5.2
	2.25	245	0.119	-14.8	154	192	0.065	-8.9
	3.00	264	0.066	-9.2	162	148	0.034	-6.5
	3.75	295	0.068	-9.6	177	159	0.052	-7.9
	4.50	203	0.107	-13.3	186	141	0.002	-4.6
	5.25	208	0.060	-14.2	162	125	0.051	-7.8
1	0.75	332	0.095	-11.9	315	239	0.066	-8.7
	1.50	332	0.095	-11.9	204	155	0.045	-7.0
	2.25	250	0.110	-13.7	214	190	0.049	-7.1
	3.00	234	0.096	-12.4	166	172	0.072	-9.6
	3.75	203	0.096	-12.6	146	145	0.036	-6.5
	4.50	158	0.103	-13.5	158	11	0.064	-9.4
	5.25	155	0.088	-12.0	122	125	0.028	-5.6
2	0.75	490	0.077	-9.6	409	378	0.060	-7.7
	1.50	343	0.067	-9.1	315	233	0.062	-8.4
	2.25	269	0.056	-8.2	248	204	0.042	-6.7
	3.00	245	0.094	-12.1	228	170	0.099	-12.2
	3.75	232	0.045	-7.7	211	141	0.044	-7.2
	4.50	191	0.066	-9.8	136	133	0.051	-8.0
	5.25	146	0.079	-11.3	142	108	0.030	-6.4
3	0.75	443	0.114	-13.6	399	386	0.014	-7.9
	1.50	335	0.093	-11.7	249	222	0.047	-7.1
	2.25	267	0.079	-10.6	204	200	0.060	-8.4
	3.00	226	0.074	-10.3	187	186	0.065	-9.0
	3.75	249	0.081	-10.9	165	220	0.049	-7.3
	4.50	207	0.072	-10.1	177	167	0.049	-7.6
	5.25	172	0.061	-13.2	166	148	0.020	-5.0
	Mean	253	0.082	-11.3	204	183	0.048	-7.5
	$LSD_{0.05}$	NS	NS	NS	77	77	NS	NS

[a]Data are means of three and four replicates for Namulonge 1991 and Kabanyolo 1992, and Namulonge 1992, respectively.
[b]Distance (m) from the maize residue area (inoculum source) rounded to the nearest units.
[c]Unstandardised AUDPC computed as described by Campbell and Madden (1990).
[d]Data fitted to linearized logistic model ln(y/0.75-y) = a + b x time where y = severity %, a = ln (y/0.75-y) at time 0, b = rate of disease increase per day.
[e]r and a values not calculated because of few (3) data points.

Kabanyolo in 1992. The b-values were not significantly influenced by time of disease assessment although the slopes later flattened (Table 4). Similarly, differences between gradients for the different seasons, locations and years were not significant ($P = 0.079$).

DISCUSSION

Lesions of northern leaf blight were first observed on plants in the maize residue area and higher disease levels developed in the plots containing maize residue than in the controls. This is an indication that maize residue was the source of inoculum. The importance of the amount of surface maize residue on epidemics of northern leaf blight is reflected in the increased disease intensity at higher residue levels. Thus, the amount of residue infested with *E. turcicum* at time of planting and thereafter may be an important factor in the epidemic of northern leaf blight. Studies by Sumner and Littrell (1974), Sumner *et al*., (1981),

TABLE 3. Slopes (b), intercepts (a), and coefficients of determination of the northern leaf blight linearized gradients at three levels of *Exserohilum turcicum* infested maize residue on the maize cultivar EV8429-SR, grown at one location of Uganda in 1991 and two in 1992[a]

Residue (kg/2.25 m^2)	b	a	R^2
Namulonge 1991			
1.0	-0.684	-3.324	96.8
2.0	-0.852	-1.688	98.5
3.0	-0.649	-2.167	94.9
Mean	-0.650	-2.164	–
$LDS_{0.05}$	NS	NS	–
Namulonge 1992			
1.0	-0.529	-2.468	85.7
2.0	-0.874	-1.662	89.4
3.0	-0.716	-1.925	85.0
Mean	-0.556	-2.198	–
$LSD_{0.05}$	-0.279	-0.544	–
Kabanyolo 1992			
1.0	-0.474	-2.755	72.8
2.0	-0.943	-2.054	95.8
3.0	-0.618	-2.290	72.9
Mean	-0.540	-2.575	–
$LSD_{0.05}$	-0.313	-0.655	–

[a]Pooled data for the four different directions (N, E, S, and W) fitted to power model $Y = ax^b$, where Y = leaf area blighted (%) assessed at GS 9.0, 9.1, 9.2 and 9.3, a = logit initial disease 1 m from the inoculum source, b = rate of disease decrease per metre.

TABLE 4. Effect of time of disease assessment on the slopes (b) of the northern leaf blight linearized gradients on the maize cultivar EV8429-SR at one location of Uganda in 1991 and two in 1992[a]

Location/ time	b	a	R^2
Namulonge 1991			
3 June	-1.178	-3.159	74.0
10 June	-0.706	-2.322	93.4
17 June	-0.468	-1.786	99.4
24 June	-0.707	-1.389	94.7
Mean	-0.650	-2.164	–
$LSD_{0.05}$	NS	-0.501	–
Namulonge 1992			
20 June	-0.460	-2.702	93.7
27 June	-0.665	-2.056	96.6
4 July	-0.542	-2.837	92.3
Mean	-0.556	-2.198	–
$LSD_{0.05}$	NS	-0.492	–
Kabanyolo 1992			
4 December	-0.703	-3.072	58.9
11 December	-0.517	-3.011	75.4
18 December	-0.392	-2.464	73.7
25 December	-0.550	-1.752	94.6
Mean	-0.540	-2.575	–
$LSD_{0.05}$	NS	-0.606	–

[a]Values computed using pooled data for the four directions (N, E, S and W) fitted to the power model $Y = ax^b$, where Y = leaf area blighted (%), a = logit initial disease at 1 m from the residue area, b = rate of the disease decrease per metre.

Lipps (1983, 1988), de Nazareno (1992) and de Nazareno *et al.* (1993) have shown that minimal tillage practices leaving residues on the surface compared to conventional tillage result in greater probabilities for the development of epidemics in reduced tillage due to higher inoculum levels. Other studies (Robert and Findley, 1952; Boosalis *et al.*, 1967; Fullerton and Fletcher, 1974). conducted in the USA and New Zealand have also shown that maize residue is an important factor for the survival of *E. turcicum* and in the development of northern leaf blight epidemics. Thus, tillage practices should aim at minimizing the amount of maize residue on soil surface but without destroying soil physical properties. The fact that only residue levels of 2 and 3 kg were markedly different from the control suggest that in order to minimize destruction of the physical properties of the soil by deep tillage, limited tillage leaving some residue on surface would provide a workable compromise. The apparent infection rates were relatively constant with increase in distance from the maize residue area. This is in agreement with observations in other pathosystems (Berger and Luke, 1979; Minogue and Fry, 1983b; Alderman *et al.*, 1989).

The presence of disease in the control plots was attributed to background contamination from nearby maize fields. Thus although lesions were first observed mostly on the maize residue infested area, a few lesions were also observed at the edge of the untreated plots. This indicated the presence of incoming inoculum from sources other than the infested maize residue, probably due to long distance spread of the pathogen from neighbouring fields. According to Gregory (1968) gradient values near zero are an indication of secondary spread and background contamination or proximity to a large area source. Indeed Patterson *et al.* (1963) noted that northern leaf blight epidemics were characterised by sudden onset, suggesting that large volumes of inoculum are imported on air currents to the host. This indicates that although infested maize residue provides initial source of inoculum, under conducive conditions, air current may be a significant factor in secondary spread of northern leaf blight.

Pataky *et al.* (1986) concluded that the spread of northern leaf blight in both susceptible and resistant cultivars is limited to neighbouring plants. Our results clearly show that considerable disease spread occurred with rapid gradient flattening as indicated by the low gradient values which ranged from 0 to -1.6. The gradients also decreased with time in agreement with previous observations on maize (Adipala, 1992; Nazareno, 1992) and in other pathosystems (Cammack, 1958; Minogue and Fry, 1983b; Alderman *et al.*, 1989).

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