

## Effect of planting density of maize on the progress and spread of northern leaf blight from *Exserohilum turcicum* infested residue source

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### Abstract

Effect of plant density (37,037, 44,444 and 55,555 plants/ha) on the increase of northern leaf blight in time and space on two maize cultivars planted at spacings of 90, 75 and 60 between rows and 30 cm within rows was investigated. *Exserohilum turcicum* infested maize residue was used as an inoculum source. Maize density did not significantly affect the disease indices, but significantly influenced the grain yield of the two cultivars. In contrast, the two cultivars differed significantly ( $P \leq 0.01$ ) in disease severity, but not grain yield. Higher disease severities and grain yields were associated with higher plant densities, whereas the apparent infection rate was lower in higher plant density. Distance from the maize residue (inoculum source) significantly influenced disease severity. The percentage leaf area blighted, area under disease progress curve and disease progress curve intercept decreased with distance from the maize residue area, but the apparent infection rate on EV8429-SR appeared to increase with distance. Disease gradients (b) were higher in closely planted maize and flattened with time in one location only.

### Introduction

Northern leaf blight (NLB), incited by the fungus *Exserohilum turcicum* (Pass) Leonard and Suggs, is a disease of major concern in Uganda. Losses as high as 60% have been recorded on susceptible cultivars [Adipala et al., 1993c].

In Uganda, it is recommended that farmers grow maize at a spacing of 90 × 30 cm. The resultant plant population and yield are, however, low. Indeed studies conducted outside Uganda have shown that closer spacing results in higher yields [Choudhary, 1981; Remison and Lucas, 1982]. In some pathosystems, however, high plant densities favour high disease severities [Adipala and Enyipu, 1994]. In contrast, higher severities of gray leaf spot (*Cercospora zae-maydis* Tehon and Daniels) were associated with low maize plant density [de Nazareno, 1992].

Generally, however, there is scarce information

on the effect of plant density on disease severity both in the temperate and tropical regions. In order to establish correct maize plant density for Uganda, it is important to ascertain the effect of maize plant density on the severity of diseases such as NLB. Such information would enhance our understanding of the NLB pathosystem and help in the development of cultural management practices. The objective of this study therefore, was to ascertain the effect of plant density on the progress and spread of NLB from a residue infested point source.

### Materials and methods

#### Field plots

Two open-pollinated maize cultivars (Kawanda Composite A (KWCA) and EV8429-SR) were

used in the study. KWCA, a Ugandan cultivar, is moderately resistant to NLB while EV8429-SR, an introduction from Centro Internacional de Mejoramiento de Maiz y Trigo (CIMMYT), is susceptible [Adipala et al., 1993b]. The plots were planted March 31, 1991 and March 13, 1992 at Namulonge and Kabanyolo, respectively. A split plot design was used with cultivars as main plots and maize densities as subplots. The subplots measured 12 × 12 m with maize planted at spacings of 90, 75 and 60 cm between rows and 30 cm within rows giving plant populations of approximately 37,037, 44,444 and 55,555 plants/ha, respectively. Three replications were used in 1991 and four in 1992. At growth stage (GS) [Ritchie and Hanway, 1982] naturally *E. turcicum* infested maize residue (4 kg, i.e., 60% soil coverage) collected from the 1990 and 1991 crops at Kabanyolo were placed at the centre of each plot covering an area of 1.5 × 1.5 m. The residue level of 4 kg was chosen because this level assured maximum disease development [Takan et al., 1994].

#### *Disease assessment*

Prior to disease assessment seven pairs of adjacent opposite plants were tagged at 0.75 m along rows on either side of the residue infested area. Percentage leaf area blighted was assessed on the whole plant basis using the scale of 0–75% [Adipala et al., 1993b]. Disease was assessed five times at each location at 7–10 day intervals beginning 76 and 65 days after planting at Namulonge and Kabanyolo, respectively. The initial assessments corresponded to approximately GS 8.0 while the final assessments were made when the maize was at GS 9.3. At maturity, plants in the residue area of each subplot were hand-harvested, sundried and their grain yield (kg/ha) determined and adjusted to 15.5% moisture content.

#### *Data analysis*

Disease severity for each pair of plants was averaged and used to test for differences among maize plant densities. No significant differences were found between the two directions from the residue source and as such, data for the two directions were pooled and used to compute initial ( $Y_i$ )

and final ( $Y_f$ ) leaf area blighted (%), area under the disease progress curve (AUDPC), slope or gradient parameter (b), apparent infection rate (r) and intercept (a). To determine the apparent infection rate, r [van der Plank, 1963], the linearized logistic and Gompertz models [Berger, 1981] were fitted to the pooled data for each data point. The appropriateness of each model was evaluated on the basis of coefficients of determination ( $R^2$ ) and plots of the residuals against time. Similarly, the exponential [Kiyosawa and Shiyomi, 1972] and the power models [Gregory, 1968] were fitted to the pooled disease spread data. Goodness-of-fit was tested as for disease progress data. The data obtained were subjected to analysis of variance (ANOVA) to test for differences among cultivars, population densities, time of disease assessment and distances from the residue area using the MSTAT-C statistical package (Russell D. Freed, Michigan State University, USA).

## **Results**

Effects of plant density on the level and progress of northern leaf blight and yield of the two maize cultivars are shown in Fig. 1 and Table 1. In both locations or years, cultivar × spacing interactions were not significant ( $P > 0.05$ ). Generally disease increased with time (Fig. 1) and cultivar differences were more pronounced from GS 9.1–9.3 compared to at GS 8.0. In both Namulonge and Kabanyolo cultivar differences were significant ( $P \leq 0.01$ ) for disease but not yield. As expected disease was more severe in the susceptible cultivar (EV8429-SR) than in the moderately resistant KWCA (Table 1). At both locations plant density significantly ( $P \leq 0.05$ ) affected the yield of the two cultivars. Although severity of the disease tended to be higher in closely planted maize, higher grain yields were associated with closer spacing (Table 1).

When yield was related to disease severity by regression analysis, regression coefficients were not significant for both individual cultivars and for the pooled data for the two cultivars. The coefficients of determination were generally low ( $R^2 \leq 0.27$ ) for both locations.

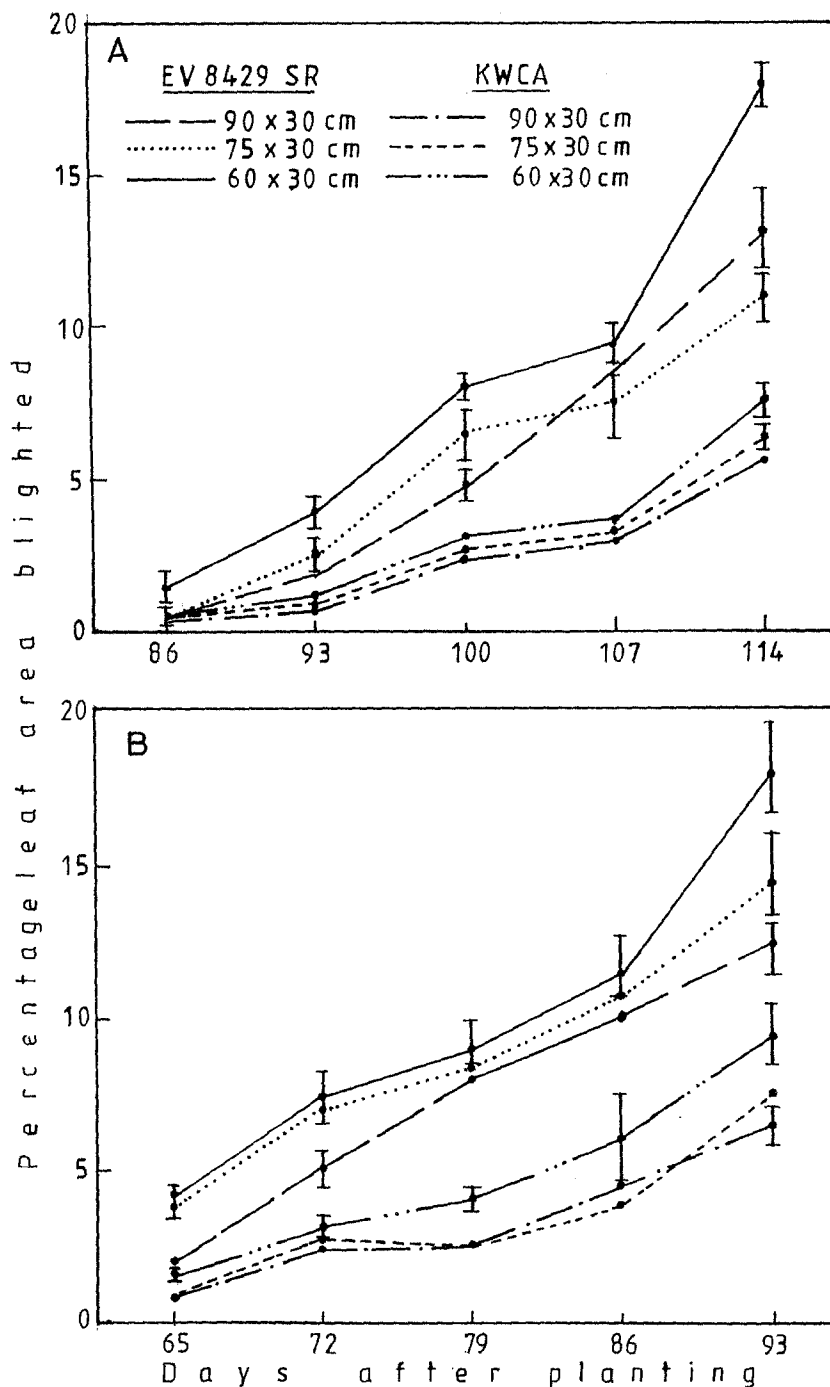


Fig. 1. Effect of maize population densities on disease progress curves of northern leaf blight on two maize cultivars grown in Uganda at Namulonge in 1991 (A) and Kabanyolo in 1992 (B). Bars indicate standard errors.

#### Disease progress

For each location, the logistic and Gompertz models were fitted to pooled data for the two

directions. Disease progress was adequately described by both the logistic and Gompertz models. However, the logistic model was chosen because of its common usage [Berger, 1981;

Table 1. Initial ( $Y_i$ ) and final percentage leaf area blighted ( $Y_f$ ) and area under disease progress curve (AUDPC) of northern leaf blight and grain yield of two maize cultivars grown at three densities in two locations of Uganda in 1991 and 1992<sup>a</sup>

Cultivar & Spacing (cm)	Namulonge				Kabanyolo			
	$Y_i^b$	$Y_f^b$	AUDPC <sup>c</sup>	Yield (kg/ha)	$Y_i$	$Y_f$	AUDPC	Yield (kg/ha)
<i>KWCA</i> :								
90 × 30	0.4	6.8	2.8	6416	0.8	3.3	6.0	2846
75 × 30	0.5	6.2	2.6	6746	1.0	5.9	6.1	3169
60 × 30	0.9	7.8	3.1	8105	1.2	9.4	8.4	5436
<i>EV8492-SR</i> :								
90 × 30	0.5	11.5	5.9	6586	2.0	10.9	16.0	2671
75 × 30	0.6	13.6	5.8	7525	3.9	13.6	16.1	2995
60 × 30	1.4	18.3	7.8	8375	4.2	16.7	19.7	4527
Mean	0.7	10.7	4.7	7292	2.2	9.9	12.2	3607
LSD <sub>0.05</sub>	NS	7.4	2.6	1822	NS	6.2	8.5	1892
CV (%)	22.8	18.5	27.1	20.1	14.7	21.3	16.7	24.8

<sup>a</sup> Data are means of three and four replicates for Namulonge and Kabanyolo, respectively, and only for residue infested areas.

<sup>b</sup> AUDPC calculated as described by Campbell and Madden [1990] and standardised by dividing by the number of days from the first to the last assessment date.

Table 2. Apparent infection rate ( $r$ ) and intercept ( $a$ ) and coefficients of determination ( $R^2$ ) of northern leaf blight severity on two maize cultivars grown at three densities at Namulonge and Kabanyolo in 1991 and 1992, respectively

Cultivar/spacing (cm)	Namulonge			Kabanyolo		
	$r$	$a$	$R^2$	$r$	$a$	$R^2$
<i>KWCA</i>						
90 × 30	0.079	-12.2	94.3	0.041	-6.7	92.5
75 × 30	0.075	-12.1	98.0	0.035	-6.2	94.9
60 × 30	0.073	-11.2	90.5	0.036	-6.6	96.2
<i>EV8429-SR</i>						
90 × 30	0.080	-11.0	97.4	0.058	-7.5	91.0
75 × 30	0.074	-10.5	93.2	0.050	-6.9	98.4
60 × 30	0.068	-9.6	96.7	0.044	-6.2	95.8
Mean	0.075	-11.1	-	0.041	-6.7	-
LSD <sub>0.05</sub>	NS	NS	-	0.010	-0.7	-

<sup>a</sup> Values were computed using pooled data for the two directions (North-South).

<sup>b</sup> Pooled data fitted to linearized logistic model  $\ln(Y/1 - Y) = a + rt$ , where  $Y$  = percentage leaf area blighted assessed at GS 8.0, 9.0, 9.1, 9.2 and 9.3,  $a$  = logit of the initial disease,  $r$  = rate of disease increase per day,  $t$  = time in days.

Campbell and Madden, 1990]. The main effects of plant density on the intercept ( $a$ ) and apparent infection rate ( $r$ ) were not significant for both locations. However, cultivar × plant density interactions were significant for  $r$  ( $P \leq 0.01$ ) and  $a$ -values ( $P \leq 0.05$ ) at Kabanyolo. At Kabanyolo the  $r$  were higher for EV8429-SR than for KWCA at medium

and wide spacings and  $a$ -values lower (Table 2).

Disease severity and rate of disease increase ( $r$ ) on the individual cultivars were not significantly affected by the plant density and direction from residue source. Consequently, data for the two directions (N-S) of disease assessment were pooled for each distance. Percentage leaf area

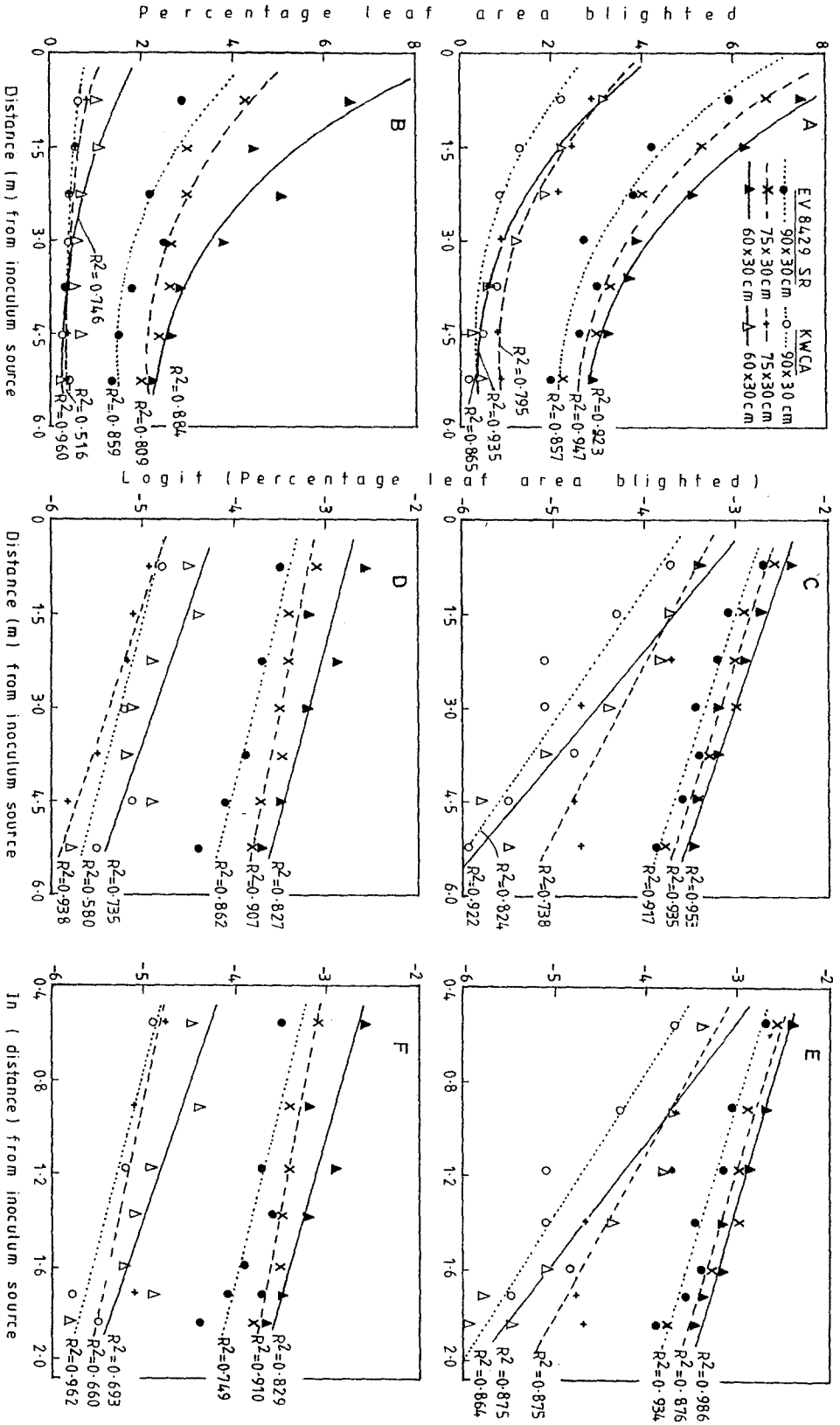


Fig. 2. Effect of maize spacing on disease gradients (A and B) of northern leaf blight on two maize cultivars fitted to the exponential (C and D) and power (E and F) models at two locations of Uganda. Namulonge, 1991 (A, C and E); Kabanyolo, 1992 (B, D and F). Pooled data for four directions of disease assessment on 10 June 1991 and 18 June 1992.

blighted (Fig. 2) and AUDPC showed a similar trend and as such only AUDPC values are presented (Table 3). At both locations, AUDPC values generally decreased with distance from the residue source but no significant effects of cultivars and distance were detected at Namulonge. Cultivar  $\times$  distance interactions were significant for AUDPC ( $P \leq 0.05$ ),  $a$  ( $P \leq 0.01$ ) and  $r$  ( $P \leq 0.01$ ) at Kabanyolo. Apparent infection rates tended to vary with distance from the maize residue area for the two cultivars while the intercepts generally decreased (Table 3).

### Disease spread

Exponential [Kiyosawa and Shiyomi, 1972] and power models [Gregory, 1968] were fitted to the disease spread data. Both models adequately depicted the spread of NLB (Fig. 2). However, the power model was chosen to represent the disease spread because of its common usage [Gregory, 1968; Campbell and Madden, 1990].

The effect of maize density on the disease gradients ( $b$ ) was not significant ( $P > 0.05$ ) at either location, but  $b$ -values tended to be higher in absolute value in higher maize densities (Table 4). They were significantly ( $P \leq 0.05$ ) higher on EV8429-SR than on KWCA at Namulonge. The gradients ranged from  $-0.1$  to  $-1.4$  at Namulonge and from  $-0.1$  to  $-1.0$  at Kabanyolo. Gradients at Kabanyolo significantly varied with time of disease assessment and the  $b$ -values were rather low (Tables 4 and 5).

### Discussion

The epidemiology of northern leaf blight is governed mainly by weather variables [Shurtleff, 1980; Levy and Cohen, 1983; Hennessy et al., 1990] and cultivar susceptibility [Pataky, 1992]. Plant density has, however, been shown to modify microclimate under field conditions [Rotem, 1978]. It is therefore probable that the high sever-

Table 3. Effect of two maize cultivars, moderately resistant (KWCA) and susceptible (EV8429-SR), on the spread of northern leaf blight from an inoculum source at Namulonge and Kabanyolo in 1991 and 1992, respectively

Cultivar/Distance (m)	Namulonge			Kabanyolo		
	AUDPC <sup>a</sup>	$r^b$	$a^b$	AUDPC <sup>a</sup>	$r^b$	$a^b$
<b>KWCA</b>						
0.75	2.9	0.086	-9.2	3.6	0.044	-6.6
1.50	2.3	0.074	-9.8	2.9	0.040	-6.5
2.25	2.5	0.071	-9.5	1.8	0.031	-6.2
3.00	2.3	0.072	-9.9	1.8	0.039	-6.8
3.75	1.9	0.083	-11.0	1.0	0.036	-6.6
4.50	2.0	0.074	-9.8	1.5	0.041	-7.1
5.25	1.8	0.068	-13.6	0.8	0.031	-7.5
<b>EV4829-SR</b>						
0.75	9.0	0.068	-12.6	8.5	0.043	-5.5
1.50	7.3	0.071	-11.6	6.3	0.049	-6.5
2.25	6.0	0.066	-11.4	5.3	0.049	-6.7
3.00	5.5	0.068	-11.6	4.7	0.050	-6.9
3.75	5.5	0.080	-12.7	4.4	0.045	-6.5
4.50	5.3	0.097	-11.7	3.7	0.053	-7.1
5.25	4.8	0.100	-11.2	3.5	0.063	-8.5
Mean	4.2	0.075	-11.1	3.6	0.044	-6.7
LSD <sub>0.05</sub>	NS	NS	NS	1.0	0.012	-1.1

<sup>a</sup> Computed as described by Campbell and Madden [1990] and standardized by dividing by the number of days from the first to last assessment date.

<sup>b</sup> Pooled data fitted to logistic model  $\ln(Y/1 - Y) = a + rt$  where  $Y$  = leaf area blighted assessed at GS. 8.0, 9.0, 9.1, 9.2 and 9.3,  $a$  = logit initial disease,  $r$  = rate of disease increase per day and  $t$  = time in days.

Table 4. Gradients (b), intercepts (a) and coefficients of determination ( $R^2$ ) of northern leaf blight on two maize cultivars grown at three spacings in two locations of Uganda in 1991 and 1992

Location/spacing (cm)	KWCA			EV8429-SR		
	b	a	$R^2$	b	a	$R^2$
<i>Namulonge 1991</i>						
90 × 30	-0.210	-4.0	43.9	-0.516	-2.4	82.9
75 × 30	-0.426	-3.9	52.7	-0.551	-2.6	83.1
60 × 30	-0.366	-3.8	65.3	-0.660	-2.2	81.3
Mean	-0.334	-2.0	-	-0.576	-2.3	-
<i>Kabanyolo 1992</i>						
90 × 30	-0.683	-2.7	82.6	-0.592	-2.0	89.7
75 × 30	-0.559	-3.0	75.9	-0.662	-2.2	97.2
60 × 30	-0.703	-2.6	92.9	-0.755	-1.9	94.7
Mean	-0.661	-2.8	-	-0.656	-2.0	-

Cultivar × spacing interaction not significant.

Table 5. Time × cultivar interaction\* on slope (b), intercept (a) and coefficient of determination ( $R^2$ ) of northern leaf blight on two maize cultivars grown at two locations of Uganda in 1991 and 1992

	KWCA			EV8429-SR		
	b	a	$R^2$	b	a	$R^2$
<i>Namulonge 1991</i>						
3 June	-0.319	-5.1	23.7	-0.723	-3.0	81.1
10 June	-0.221	-4.5	22.8	-0.597	-3.2	88.5
18 June	-0.339	-3.8	84.1	-0.473	-2.2	58.8
25 June	-0.223	-3.5	12.3	-0.416	-1.9	39.7
2 July	-0.503	-2.6	52.5	-0.648	-1.5	88.3
Mean	-0.334	-3.9	-	-0.576	-2.4	-
<i>Kabanyolo 1992</i>						
4 June	-0.376	-3.3	90.5	-0.650	-2.8	85.9
11 June	-0.824	-2.8	95.9	-0.850	-2.1	98.9
18 June	-0.850	-2.7	86.4	-0.799	-1.8	95.5
25 June	-0.618	-2.6	72.5	-0.517	-1.8	65.5
2 July	-0.637	-2.3	78.5	-0.468	-1.6	94.9
Mean	-0.656	-2.8	-	-0.661	-2.0	-

\* Time × cultivar interactions were not significant at both locations.

ities of northern leaf blight observed at high plant densities are due to relatively favourable microclimate. Although de Nazareno [1992] in agreement with our data did not find significant differences in disease severity, he obtained contradictory data with gray leaf spot, which had higher severity at lower plant densities. The high severity of gray leaf spot was attributed to enhanced spread of gray leaf spot at lower maize densities which more than compensated

for the favourable conditions at higher densities. The low disease level at low plant density could also have been due to the fewer leaves to infect with the same inoculum level. It is therefore probable that the effect of plant density on disease epidemiology may vary from one pathosystem to another.

The decline in the AUDPC with distance from the residue area emphasizes the role of *E. turcicum* infested residue in initiating epidemics of northern

leaf blight [Boosalis et al., 1967; Takan et al., 1994]. Thus, management practices that remove infested maize residue would probably reduce yield losses due to NLB.

Although percentage leaf area blighted and AUDPC decreased with distance from the inoculum source, apparent infection rates in some cases increased with distance from residue (inoculum) source. This is in agreement with Minogue and Fry [1983a, b], but contrary to Alderman et al. [1989] and Berger and Luke [1979] who observed constant apparent infection rates with increase in distance from inoculum foci, or Adipala [1992] and de Nazareno [1992] who observed a decrease in apparent infection rates. According to Minogue and Fry [1983] the rapid flattening of the gradient that occurs in the initial stages of the epidemic implies that, until a steady state is reached, the apparent infection rate increases with distance from the focal centre. At the steady state apparent infection rate is constant. This indicates that the influence of plant density on disease incidence and severity is governed partly by the stage of the epidemic at the time of disease assessment and probably by the pathosystem in question.

The gradients were rather low (ranged from -0.1 to -1.4) compared to those reported in other pathosystems [Rowe and Powelson, 1973; Lipps, 1988; Alderman et al., 1989] but higher than values reported by de Nazareno [1992] and Minogue and Fry [1983b]. According to Gregory [1968], secondary spread, background contamination, or proximity to a large area source cause flattening of the primary gradient. Disease gradients also vary depending on the method of assessment and time at which the assessments are made [Cammack, 1958]. This study was conducted in an area where northern leaf blight is endemic [Adipala et al., 1993a]. It was therefore not uncommon to obtain lesions on the plants distant from the residue area before any lesions developed on the plants within the residue area. Generally, the gradients flattened with time which supports earlier observations [Cammack, 1958; Rowe and Powelson, 1973; Minogue and Fry, 1983; Lipps, 1988; Alderman et al., 1989; de Nazareno, 1992; Adipala, 1992]. This flattening has been attributed to secondary spread in polycyclic diseases such as this pathosystem. The flattening effect may have

been further accentuated by background contamination which probably arose from other fields near the vicinity of the study area.

This study indicated that maize density did not have a significant effect on disease indices, but significantly influenced grain yield. Higher severities (leaf area blighted and AUDPC), slopes (b), intercepts (a) and grain yields were associated with higher plant densities, but the apparent infection rate was not.

The higher yields obtained at higher plant density probably imply that the high levels of northern leaf blight associated with the high density did not result in proportionally high yield reduction. This is supported by the lack of a significant relationship (regression coefficients) between severity of northern leaf blight and the maize yield. Therefore, higher levels of NLB are required to cause significant yield reductions in the two open-pollinated maize cultivars. It is also likely that higher yield associated with the higher plant density compensated for the loss attributed to northern leaf blight. This study clearly indicates that farmers in Uganda should plant maize at higher populations (60 × 30 cm) than the current recommended rate of 90 × 30 cm.

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