CROPPING PATTERN AND SOIL MANAGEMENT INFLUENCE ON PLANT DISEASES: I. *Diplodia macrospora* leaf spot of maize[1] /

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Resumen

Se estudió el efecto de diferentes tipos de preparación del suelo y sucesiones de cultivos sobre la incidencia y la severidad de la mancha de la hoja de maíz causada por Diplodia macrospora. *Este trabajo se realizó en Turrialba, Costa Rica.*

La preparación del suelo afectó tanto la incidencia como la severidad de esta enfermedad. Siempre se afectó la mayor cantidad de tejido de maíz en los tratamientos que se dejaron con residuos de cosecha sobre la superficie del suelo. Aquellos tratamientos en los que se limpió la superficie del suelo, produjeron plantas de maíz más sanas. También la proporción de incremento diario de la enfermedad resultó mayor en aquellos tratamientos con residuos de la cosecha anterior.

El doble cultivo de maíz, en el mismo pedazo de terreno y el maíz que se cultivó después de la asociación de maíz y frijol, registró valores más altos de incidencia y severidad que aquel maíz que se cultivara en un terreno en donde había frijol común como cultivo individual.

Introduction

In Central America, maize (*Zea mays* L.) is produced mainly by small farmers. It is the most important component of a wide variety of cropping patterns managed according to the specific ecological and socio-economic conditions of the location.

In the lowland tropics, maize is cultivated as monocrop, in association with plantain, (*Musa acuminata x M. baldisiana*), cassava (*Manihot esculenta*) or taro (*Xanthosoma* sp.) or double cropped with sweet potato (*Ipomoea batatas*) legumes or with another maize crop in the same cropping season (8).

Due to high rainfall, ear rot, stalk rot and leaf spot caused by various pathogens can be limiting factors to good yields. *Diplodia macrospora* Earle is becoming increasingly important in recent years both as an ear rot and leaf spot pathogen in the Central American lowland tropics (7).

Crop sequence and seed-bed preparation frequently have been identified by small farmers as the most important management practices influencing disease development in maize (2). Small farmers practice several types of soil preparation ranging from conventional plowing and removal of crop residues to different types of minimum tillage and no-tillage.

Crop residues are a source of inoculum for numerous plant pathogens in temperate climates; however, the role of crop residues as a source of inoculum under conditions of constant temperature, high rainfall and diverse soil microflora has not been investigated sufficiently in tropical agroecosystems.

This research was conducted to study the effect of soil management and crop sequence on the leaf spot disease of maize caused by *D. macrospora*.

1 Received for publication in March 14, 1983
This information is part of a thesis submitted by the senior author to the UCR-CATIE/Costa Rica joint Graduate Program in Agricultural Sciences and Natural Resources as partial fultillment of the requirements for the M S. degree

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Material and methods

The field experiment was conduced at Turrialba, Costa Rica. Turrialba is approximately 600 m above sea level and has a mean annual precipitation of 2 700 mm, a mean annual temperature of 22°C and a mean annual solar radiation input of 154 kcal cm^{-2}.[1] According to the Holdridge classification system, Turrialba is in the Premontane Tropical Wet Forest Zone (5). The soils of the field plot area are in the Rocky Phase of the Instituto soil series, and in the Inceptisol order and Tropepts sub-order of the Seventh Approximation classification system (4).

Field data on the incidence and severity of *Diplodia* leaf spot and bean rust (9) were obtained from an experiment planted in 1976 to study three cropping patterns including maize and common beans (*Phaseolus vulgaris* L.) under four different soil management practices. In this experiment, each year from about June to November, the field was uniformly planted with maize and from December to April with common beans as sole crop; maize as sole crop and an association of maize and common beans. Figure 1 A presents average rainfall pattern for Turrialba and the rainfall conditions during experimental periods reported here and elsewhere (9). Figure 1B presents the three cropping patterns resulting from different crop sequences. Each cropping pattern was cultivated with four different soil management practices: a) conventional soil preparation (CT) – removal of crop residues plowing and roto-tilling; b) minimum tillage (MT-1) – maize stalks were pulled but left on the soil surface and covered with soil, as practiced by some small farmers; c) minimum tillage (MT-2) – maize stalks were up-rooted and left on the surface; and d) no-tillage (OT) – the new crops were planted between the maize rows of the previous crops while old stalks were still standing in the field.

Soil management treatment plots were 144 m^2 and crop sequence sub-treatment plots were 48 m^2. Treatments and sub-treatment were arranged in a

1 Average 34 year data, Turrialba, Costa Rica.

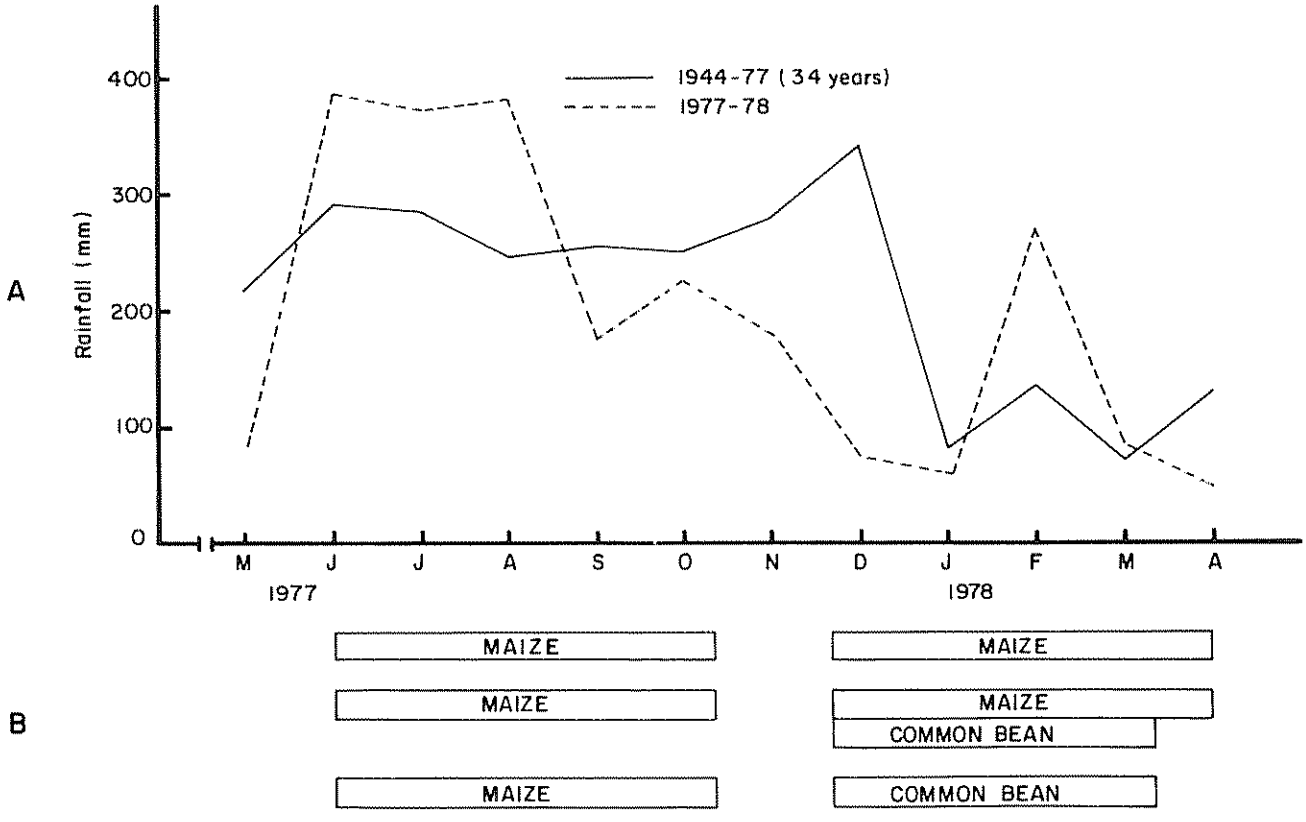

Fig 1 A) Average (34 years) rainfall and monthly average rainfall registered during the experimental period; B) Cropping patterns resulting from three crop sequences studied to determine incidence and severity of *Diplodia* leaf spot of maize. Turrialba, Costa Rica, 1978

split-plot, complete block design with four replications. For the sole crops and the association the same planting density of 4 and 10 pl m^2 for maize and beans respectively were used. When beans and maize were associated, two rows of beans (33 cm apart) were grown between rows of maize (1 m apart). The varieties used were Tuxpeño Planta Baja C-7 for maize and CATIE-1 for beans. Maize as sole crop received 105.0; 35.4 and 11.8 kg ha^{-1} of N, P_2O_5 and K_2O respectively. Beans were fertilized with 97.5; 105.0; 38.0 and 15.0 kg ha^{-1} of N, P_2O_5, K_2O and MgO respectively when grown in association with maize. In soil management treatment CT, this was supplied through commercial fertilizers but in treatments MT-1, MT-2 and OT it was supplied through commercial fertilizers, and the nutrient content of the amount of biomass left as mulch, according to chemical analysis of the tissue.

Weeds were controlled with Gramoxone (Paraquat 0.5 kg ha^{-} a.i.) in soil treatments MT-1, MT-2 and OT and manually controlled in treatment CT.

Field data on the incidence and severity of *Diplodia* leaf spot were obtained from June to October 1977. Incidence (I) is the number of infected units and severity (S) is the affected area. The concepts of incidence and severity have been previously discussed by James and Shih (6).

Incidence and severity were recorded weekly from the same six plants randomly selected from the center of each 48 m^2 plot of sole maize. Evaluations were made from 14 days until 102 days after maize emergence. Total number of leaves per plant, number of infected leaves and area affected in each leaf were recorded at each sampling.

A scale from 1-5 was established, based on leaf area infected (Figure 2). Total severity was calculated by multiplying percentage leaf area affected by its frequency (3).

Results and discussion

In all treatments, onset of the epidemic and further development of the disease were closely associated with both amount and frequency of rainfall. Amplitude and frequency of deviations from mean temperature (21.9° C) for the experimental period were also positively and significantly correlated with the number of infected leaves, although they were not correlated with increase in lesion size. Temperatures above 21.9C apparently favor production, liberation, dissemination and penetration of the inoculum.

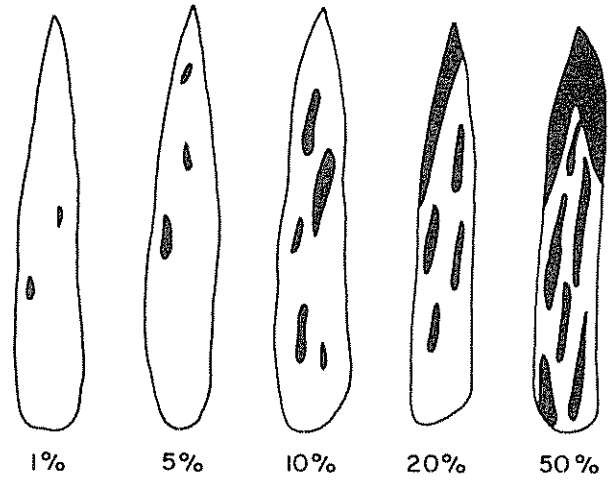

Fig 2. Diagrammatic representation of different percentages of leaf infection by *Diplodia macrospora* in maize leaves. Turrialba, Costa Rica

There was a positive and significant correlation between incidence and severity for all treatments (R = 0.87). Average incidence values increased steadily up to 35 days after emergence of the maize plants. During this first stage, daily rate of increase on incidence was 0.184 (r = 0.184)[1]. In a second stage, from 35 to 102 days, it was 0.065 (r = 0.065). Three different stages can be differentiated in the daily rate of increase in severity: a first stage, which lasted for 43 days with an average of r = 0.139; a second stage, from 43 to 75 days after emergence where only a slight increase of the severity values was registered between sampling periods, suggesting that total leaf area of the maize plant increased nearly as fast as the increase in lesion size; a third stage, from 75 to 102 days after emergence, where disease increased at a daily rate of r = 0.025 (Table 1).

INFLUENCE OF SOIL MANAGEMENT

Both incidence and severity of *Diplodia* leaf spot were affected by soil management treatments (Table 2). Mulching always resulted in more diseased tissue than did treatments that included plowing and removal of crop residues. At 20, 28, 66 and 75 days after emergence of maize, the incidence values were significantly different under different soil managements. On the average, soil management treatments MT-1, MT-2 and OT had more leaves infected by *Diplodia* sp. than did treatment CT (LSD test 0.05). Severity values were significantly different between soil management practices at 20, 43, 57, 84, 95 and 102 days after emergence of maize plants. Soil

1 Units per day according to Van der Plank (10)

management treatments MT-1, MT-2 and OT had average severity values higher than treatment CT. Disease severity for each treatment, in decreasing order, was MT-1 > OT > MT-2 > CT.

Table 1. Average daily rate of increase of incidence and severity of *Diplodia* leaf spot of maize in different stages of development of the epidemic. Turrialba, Costa Rica.

Days after maize emergence	Incidence		Severity	
	Stage	r value[1]	Stage	r value[1]
35	1	0.184		
43			1	0.139
75			2	0.009
102	2	0.065	3	0.025

1 $r = \frac{2.3}{t_2 - t_1} \left(\log \frac{X_2}{1 - X_2} - \log \frac{X_1}{1 - X_1}\right)$

$t_2 - t_1$ = days between stages.

X_1 and X_2 = number of infections or leaf area affected at times t_1 and t_2 respectively according to Van der Plank (10).

No significant differences in daily rate of increase for incidence or for severity values were registered, but an LSD (0.05) test showed higher rates for treatments including mulching than for treatment CT.

The removal of crop residues and plowing delayed the epidemic development by approximately five days. Maximum values for severity were always registered at the end of the maize life cycle for all soil treatments.

INFLUENCE ON CROP SEQUENCE

No statistically significant differences for incidence and severity values of *Diplodia* leaf spot among crop sequences were found. Only during the sampling at 35 days after maize emerged, was severity higher for the maize after maize sequence than for the other sequences (Table 3). Maize after maize (M → M) and maize after the association of maize and common beans (M + B → M) resulted in incidence and severity values higher than the sequence of maize after common bean monoculture (B → M). This suggests that less primary inoculum is available to infect maize after a bean monoculture than after sequences of crops including maize. The B → M sequence showed severity values lower than the rest of the crop sequences in 12 out of 13 samplings.

Table 2. Average values for incidence and severity of *Diplodia* leaf spot of maize as affected by four soil management practices. Turrialba, Costa Rica.

Days after emergence of maize [o]	Incidence (%)					Severity (%)				
	CT	MT-1	MT-2	OT	Mean Square	CT	MT-1	MT-2	OT	Mean Square
12	14.89	34.89	26.00	31.11	234.62 [ns]	0.42	1.00	0.79	0.86	4.90 [ns]
16	25.33	35.50	27.17	27.17	49.65 [ns]	0.62	1.13	0.69	0.85	3.00 [ns]
20	41.07 [b]	53.07 [a]	54.93 [a]	58.53 [a][2]	117.93 [**][3]	3.12 [b]	4.78 [ab]	4.68 [ab]	5.67 [a]	12.19 [*]
28	80.21 [b]	89.68 [ab]	84.23 [ab]	92.42 [a]	326.21 [**]	6.41	8.41	7.15	10.32	35.45 [ns]
35	83.91	89.67	87.22	91.15	18.29 [ns]	9.74 [b]	13.87 [ab]	12.07 [ab]	15.60 [a]	56.17 [**]
43	82.85	85.66	84.06	85.54	13.71 [ns]	13.22 [b]	16.39 [ab]	15.94 [ab]	19.25 [a]	43.42 [**]
49	94.64	94.52	93.74	95.11	10.68 [ns]	14.24	16.30	15.65	17.30	11.07 [ns]
57	92.04	93.62	91.97	94.62	22.26 [ns]	13.60 [b]	16.38 [ab]	14.12 [ab]	18.01 [a]	31.10 [*]
66	87.04 [b]	90.24 [ab]	88.93 [ab]	91.87 [a]	43.32 [*]	12.75	15.26	13.37	16.94	27.41 [ns]
75	91.64 [b]	94.03 [ab]	91.68 [ab]	95.48 [a]	69.67 [**]	15.19	16.45	14.01	19.23	39.61 [ns]
84	97.99	96.85	97.73	98.46	22.09 [ns]	20.02 [ab]	23.00 [ab]	18.01 [b]	25.68 [a]	66.01 [**]
95	98.38	98.00	98.11	98.81	25.15 [ns]	20.54 [a]	24.79 [ab]	19.22 [b]	26.70 [a]	70.71 [**]
102	98.95	99.50	99.05	99.56	14.66 [ns]	24.16 [a]	25.42 [a]	22.15 [b]	28.80 [a]	40.62 [*]

1 CT = Conventional tillage (plowing and rotovator labor); MT-1 = Minimum tillage and mulching covering crop residues; MT-2 = Minimum tillage leaving crop residues as mulch; OT = No tillage.

2 Figures followed by the same letter do not differ statistically according to Duncan's multiple range test (0.05).

3 ns: not significant (0.05); * significant (0.05) and ** significant (0.01).

Table 3. Average values for incidence and severity of *Diplodia* leaf spot of maize as affected by three crop sequences. Turrialba, Costa Rica.

Days after emergence of maize	Incidence (%)				Severity (%)			
	B → M	M + B → M	M → M[1]	Mean Square	B → M	M + B → M	M → M	Mean Square
12	25.33	26.67	29.17	15.44 [ns]	0.68	0.73	0.89	0.83 [ns]
16	25.75	33.63	27.00	55.61 [ns]	0.71	0.95	0.79	1.30 [ns]
20	56.30	48.80	50.60	39.81 [ns]	4.26	4.43	4.99	2.68 [ns]
28	84.76	87.69	87.25	36.11 [ns]	7.48	8.94	7.79	8.82 [ns]
35	88.33	86.79	88.84	17.85 [ns]	11.66 [b]	13.12 [a]	13.68 [a]	14.25 [**][2]
43	85.00	84.81	83.77	3.19 [ns]	15.53	16.68	16.39	3.19 [ns]
49	93.96	95.29	94.26	13.56 [ns]	15.11	16.47	16.04	4.81 [ns]
57	92.87	92.82	93.34	3.95 [ns]	15.10	15.84	15.64	1.56 [ns]
66	89.90	88.80	89.85	6.49 [ns]	14.08	14.63	15.06	2.83 [ns]
75	93.54	92.65	93.43	1.26 [ns]	16.06	16.17	16.43	0.64 [ns]
84	98.41	97.43	97.43	22.78 [ns]	22.05	20.71	22.32	5.43 [ns]
95	98.61	98.60	98.37	3.52 [ns]	23.14	22.13	23.17	3.48 [ns]
102	98.99	99.09	94.71	12.81 [ns]	25.78	23.13	26.50	22.71 [ns]

1 M = Maize; B = Common Bean; + crops in association; → crop sequence

2 Figures followed by the same letter are not significantly different according to Duncan's multiple test (0.05) ns: not significant (0.05) and ** significant (0.01).

In general, incidence shows the same trend as severity, but incidence values tend to be higher at the end of the life cycle of maize cultivated after bean monoculture because more healthy tissue is exposed to a high amount of inoculum in the environment. This phenomenon has been previously reported (1).

The daily rate of severity and incidence increase is higher in the M → M and M + B → M sequence than in the B → M sequences (Table 4).

Diplodia leaf spot in maize is frequently severe in the lowland tropics of Costa Rica where rainfall ranges from 3 600 – 4 200 mm annually and average temperatures range from 25 – 27 °C. The results of this study, conducted at Turrialba's Experimental Station, indicate a tendency towards more *Diplodia* leaf spot in maize cultivated under soil management practices including the use of maize residues. Although Turrialba has mean annual precipitation of approximately 2 700 mm and temperature of 22°C, this tendency could represent an important factor to consider in the design and testing of land preparation practices for high rainfall conditions. Minimum tillage and no-tillage frequently have been recommended to small farmers to reduce soil erosion and turn-around period. This study indicates that the implications of including residues from the same crop or from crops belonging to the pathogen's host range as mulch should be evaluated.

Table 4. Average daily rate of increase of incidence and severity of *Diplodia* leaf spot of maize in three different crop sequences. Turrialba, Costa Rica.

Crop sequences	Incidence	Severity
B → M[1]	0.096[2]	0.067[2]
M + B → M	0.103	0.070
M → M	0.107	0.068

1 B = Common Beans; M = Maize; + = crops in association; → = crops in succession

2 Units per day According to Van der Plank (10).

It should be pointed out that most of the studies of botanical epidemics carried out in experimental stations are always affected by other factors; notably the size of experimental plots and the proximity of plots with different amount of infection

Summary

The influence of soil management and crop sequence on the incidence and severity of a leaf spot disease of maize caused by *Diplodia macrospora* Earle was studied at Turrialba, Costa Rica.

Both incidence and severity of the disease were influenced by soil management. Soil treatments that

included mulching invariably resulted in more diseased tissue than did treatments including the removal of crop residues. Daily rate of increase of the disease was also higher for treatments that included mulching than for the rest of the soil management treatments.

Maize cultivated after maize and after an association of maize plus common beans showed higher values of incidence and severity than the sequence of maize following a common bean monoculture.

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