Incidence-Severity Relationships in the Pathosystem *Coffea arabica–Hemileia vastatrix*

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ABSTRACT

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Incidence-severity relationships for coffee rust were studied to determine if the easily assessed incidence could be used to evaluate host resistance and fungicide treatment. At two locations in each of 3 years, the incidence of rust on 300 leaves was compared with two assessments of severity: (i) the average number of sporulating pustules per leaf, and (ii) the estimated leaf area with rust. For nine or 10 assessments in time at one location and pooled over 3 years, the average number of sporulating pustules per leaf (Y_{sp}) was well related with the incidence of leaves with rust (X) as $Y_{sp} = 0.02982 + 0.017035X + 0.000573X^2$; $R^2 = 0.87$. The leaf area with rust (Y_{la}) was also well related with incidence of leaves with rust as $Y_{la} = 0.001 - 0.01076X + 0.008376X^2$; $R^2 = 0.92$. For two independent data sets from a second location obtained over two seasons, the above models satisfactorily fit the relationships for the average sporulating pustules per leaf (R^2 = 0.97 and 0.96) and for the estimated leaf area with rust (R^2 = 0.95 and 0.98). Therefore, the readily determined incidence can be used to estimate both measures of disease severity of coffee rust.

Additional keywords: disease assessment

Coffea arabica L. constitutes about 75% of total world production of coffee (10). Rust (*Hemileia vastatrix* Berk. & Broome) is one of the most important diseases of *C. arabica*. Crop losses in Brazil due to rust would be about 30% if no control measures were taken (10). Therefore, considerable research on rust has been accomplished mainly to evaluate plant resistance and disease control by chemicals. The intensity of coffee rust usually is assessed by severity, as the initiation of a fungicide program can be based on severity values.

The assessment of severity is tedious and time consuming and usually prone to bias and large experimental error. Therefore, the existence of a quantifiable relationship between incidence and severity would allow huge benefits in evaluating disease intensity and estimating crop loss (1,12). These benefits arise because incidence is determined easily, with more accuracy and precision than severity is determined, and with lower cost because of the savings in time. The incidence-severity relationships have been published for several pathosystems: e.g., *Erysiphe graminis* f. sp. *tritici* and *Puccinia recondita* f. sp. *tritici*—*Triticum aestivum* (7), *Podosphaera leucotricha*—*Malus pumila* (13), *Uromyces phaseoli* var. *typica* race 34—*Phaseolus vulgaris* cv. Bountiful (6), *Mycosphaerella fijiensis* var. *difformis*—banana (2), and *Puccinia sorghi*—*Zea mays* (4). Rayner (11) found a linear relationship between incidence of coffee leaves with rust and the $\log_{10}$ (number of lesions per 100 leaves). Unfortunately, Rayner provided neither the regression equation nor the fit (R^2) of the model. Eskes and Toma-Braghini (5) obtained a good relation (R^2 = 0.87) for $\log_{10}$ (rust lesions per coffee leaf) to logit (proportion of branches with lesions), the latter estimated by pictorial diagrams. However, the use of these diagrammatic scales would be subject to estimator bias with the possibility of large experimental error.

When the severity of disease is highly related with incidence, one may then opt to use the easily measured incidence to estimate severity (12). Kranz (8) analyzed 59 aerial fungal pathodemes on 42 plant species and found highly significant correlation between incidence and severity. If a regression equation for the relationship between incidence and severity of coffee rust holds true in different locations and in different years, then the program of resistance and chemical control of this disease will be greatly facilitated. In this research, we evaluated the incidence-severity relationships of coffee rust in two locations in different regions of Minas Gerais State over a 3-year period.

MATERIAL AND METHODS

Field assays were conducted during three years, 1991–1992, 1992–1993, and 1993–1994, at coffee farms at Teixeiras in "Zona da Mata" and Patrocínio in "Zona Alto Paranaíba," Minas Gerais State, Brazil. At Teixeiras, the assay was conducted at the Farm "Patrimônio" located at 20°39′00″S and 42°50′55″W, 690 m elevation, in a 6-year-old crop of *C. arabica* cv. Catuaí Amarelo (LCH-2077-2-5-86), planted at a spacing of 3.0 × 1.3 m (2,564 plants ha^{-1}). At Patrocínio, the experiment was at the farm of Empresa de Pesquisa Agropecuária do Estado de Minas Gerais (EPAMIG), located at 18°57′09″S and 46°59′43″W, 1,000 m elevation. The coffee was cv. Catuaí Vermelho (LCH-2077-2-5-99), 5 years old, planted at a spacing of 3.5 × 1.0 m (2,857 plants ha^{-1}).

At both locations, the coffee crop initially had good fruit production, uniformly distributed in the experimental area. The plants had good leaf formation and a good stand. At each location, 30 plants were marked in an area of 0.5 ha. Disease incidence and severity were assessed at 20-day intervals. In each of the assessments, 10 leaves were detached from the third or fourth node on plagiotropic branches that were randomly selected from the lower and middle thirds of the canopy around each of the 30 plants (n = 300). For incidence of disease, the percentage of leaves with rust was determined. For severity, the number of sporulating lesions per leaf was counted and the average area of rust lesions per leaf was estimated according the scale of Kushalappa and Chaves (9).

In 1992–1993, rust did not progress at Teixeiras, because of low coffee production. High production is an essential condition for epidemics to develop (14,16). Therefore, data from this year and location are not shown. At Teixeiras, the main flowering periods were around 10 October in both 1991 and 1993. Disease was assessed nine times in both 1992 and 1994, beginning 17 January 1992 and 6 January 1994. At Patrocínio, the main flowering periods were around 9 September 1991, 14 September 1992, and 13 October 1993. Nine disease assessments were made in the first crop, beginning 8 January 1992; 10 assessments were made in each of the next

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two crops, beginning 18 November 1992 and 13 November 1993.

The percent incidence of leaves with rust, the number of sporulating lesions, and leaf area with sporulation were analyzed by linear regression with the SAEG system (Sistema de Análises Estatísticas e Genéticas) developed at the Universidade Federal de Viçosa. For linear regression, the values of the independent and dependent variables were used nontransformed or transformed with $\log_{10}$ and square root. The best model was selected based on the lowest error mean square and largest coefficient of determination (3).

RESULTS AND DISCUSSION

At Teixeiras, from January to June, disease incidence increased from 4 to 79% in 1993 and from 0.66 to 60.7% in 1994. The respective increases in sporulating pustules were 0.07 to 6.60 and 0.01 to 2.61, which occupied 0.009 to 4.40% and 0.005 to 1.79% leaf area. At Patrocínio, the incidence ranged from 0 to 80% in 1992, 9.33 to 54% in 1992–1993, and 3.0 to 86.66% in 1993–1994. The respective increases in sporulating pustules were 0 to 3.5, 0.15 to 1.92, and 0.04 to 7.84, which occupied 0.0 to 4.68, 0.06 to 1.29, and 0.02 to 6.40% leaf area.

At both locations, the levels of incidence and severity were higher in the years of greatest production (1992 and 1994). In the 1993–1994 crop, both incidence and severity were higher in Patrocínio, when both sporulating pustules and sporulating leaf area were 3 to 3.6 times higher than in Teixeiras. Patrocínio had higher production and more rain. The rainy period began in September and October in all 3 years at both locations, but rain was more intense in 1993–1994 (15).

Linear regression analysis was performed to find the mathematical association between incidence and severity of coffee rust. The number of sporulating pustules (Y_{sp}) and the leaf area with sporulation (Y_{la}) were regressed on the incidence of leaves with rust (X). The best explanatory model was chosen according criteria recommended by Cornell and Berger (3). For both measures of disease severity of the individual crops, the simplest and best fitting model was a second order polynomial of nontransformed data. This model was used to estimate parameters for each location and year (Table 1).

To develop general predictive models, the data for the three seasons at Patrocínio were pooled. For both the number of sporulating pustules and the estimated leaf area with rust, the simplest and best-fitting models were second order polynomials of the nontransformed data (Fig. 1A and B). For the pooled data, the model to estimate the number of sporulating pustules per leaf (Y_{sp}) from disease incidence (X) was $Y_{sp} = 0.02982 + 0.017035X + 0.000573\,X^2$; $R^2 = 0.87$. The model to estimate the percent leaf area with rust (Y_{la}) from disease incidence (X) was $Y_{la} = 0.001 - 0.01076X + 0.008376X^2$; $R^2 = 0.92$.

The two seasonal assessments from Teixeiras then were considered as independent data sets, as these values had not been used to develop the predictive models. The above models developed from the data collected at Patrocínio satisfactorily fit the relationships found at Teixeiras (1991–1992 and 1993–1994) for the average number of sporulating pustules per leaf (R^2 = 0.97 and 0.96) and for the estimated leaf area with rust (R^2 = 0.95 and 0.98) (Fig. 2). Therefore, the models can be used to estimate the diseased area of coffee rust and the average number of sporulating lesions from incidence of diseased leaves.

The application of these models in the field would be of great value in the program to manage coffee rust, mostly by chemical control. The main advantage is reduction of the time to estimate severity. Because incidence of leaves with rust is highly correlated with the number of sporulating lesions and with the leaf area with sporulation, either of the two variables can be estimated depending on the objective. Most importantly, since chemical control of coffee rust usually is based on levels of disease severity, these models could be applied to save time and to gain accuracy, and to determine the appropriate time to initiate a program to spray coffee leaves with protectant or systemic fungicides.

Table 1. Regression equations of number of sporulating lesions (Y_{sp}) or leaf area with sporulating lesions (Y_{la}) on incidence of coffee leaves with rust (X)

Location	Year	Model	R^{2a}
Teixeiras	1991–1992	$Y_{sp} = 0.35 - 0.03X + 0.001X^2$	0.95
	1993–1994	$Y_{sp} = 0.01 + 0.01X + 0.0004X^2$	0.98
Patrocínio	1991–1992	$Y_{sp} = -0.13 + 0.04X + 0.00002X^2$	0.98
	1992–1993	$Y_{sp} = -0.02 + 0.01X + 0.0004X^2$	0.91
	1993–1994	$Y_{sp} = -0.08 + 0.02X + 0.0007X^2$	0.99
Teixeiras	1991–1992	$Y_{la} = 0.30 - 0.02X + 0.0008X^2$	0.94
	1993–1994	$Y_{la} = 0.02 + 0.005X + 0.0003X^2$	0.98
Patrocínio	1991–1992	$Y_{la} = 0.04 + 0.005X + 0.0006X^2$	0.98
	1992–1993	$Y_{la} = -0.39 + 0.04X + 0.0002X^2$	0.96
	1993–1994	$Y_{la} = 0.35 - 0.03X + 0.001X^2$	0.89

[a] Coefficient of determination.

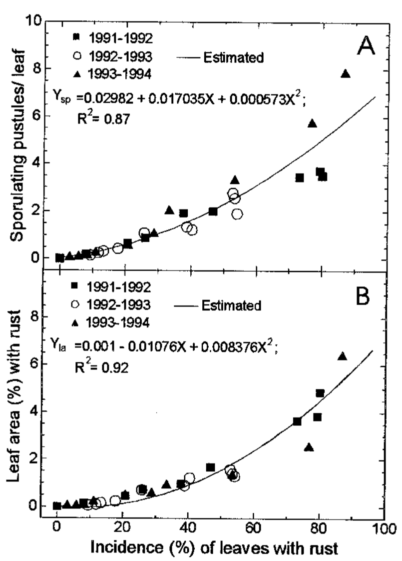

Fig. 1. Relationships of the incidence of coffee rust on sampled leaves to **(A)** the average number of sporulating pustules per leaf, and **(B)** the percent leaf area with rust. Data from the Patrocínia site were pooled over 3 years.

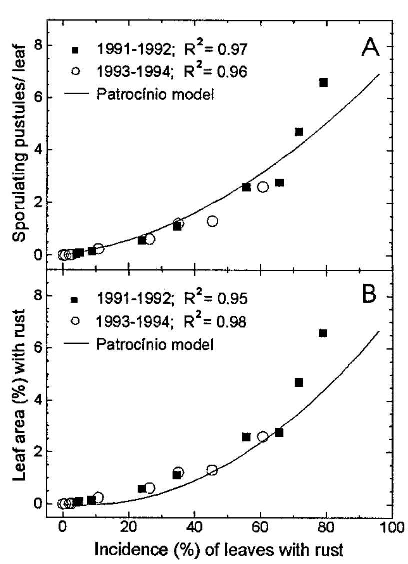

Fig. 2. Evaluation of the Patrocínio prediction models (given in Figure 1) of coffee rust for **(A)** the average number of sporulating pustules per leaf, and **(B)** the percent leaf area with rust for two crop seasons at Teixeiras.

LITERATURE CITED

1. Campbell, C. L., and Madden, L. V. 1990. Introduction to Plant Disease Epidemiology. John Wiley & Sons, New York.
2. Chuang, T. Y., and Jeger, M. J. 1987. Relationship between incidence and severity of banana leaf spot in Taiwan. Phytopathology 77:1537-1541.
3. Cornell, J. A., and Berger, R. D. 1987. Factors that influence the value of the coefficient of determination in simple linear and nonlinear regression models. Phytopathology 77:63-70.
4. Dillard, H. R., and Seem, R. C. 1990. Incidence-severity relationships for common maize rust on sweet corn. Phytopathology 80: 842-846.
5. Eskes, A. B., and Toma-Braghini, M. 1981. Assessment methods for resistance to coffee leaf rust *Hemileia vastatrix* Berk. & Br.).

FAO Plant Prot. Bull. 29:56-66.
6. Imhoff, M. W., Leonard, K. J., and Main, C. E. 1982. Analysis of disease progress curves, gradients, and incidence-severity relationships for field and phytotron bean rust epidemics. Phytopathology 72:72-80.
7. James, W. C., and Shih, C. S. 1973. Relationship between incidence and severity of powdery mildew and leaf rust on winter wheat. Phytopathology 63:183-187.
8. Kranz, J. 1968. Eine Analyse von annuellen Epidemien pilzlicher Parasiten. I. Die Befallskurven und ihre Abhängigkeit von einigen Umweltfaktoren. Phytopathol. Z. 61:59-86.
9. Kushalappa, A. C., and Chaves, G. M. 1980. An analysis of the development of coffee rust in the field. Fitopatol. Bras. 5:95-183.
10. Kushalappa, A. C. , and Eskes, A. B. 1989. Advances in coffee rust research. Annu. Rev. Phytopathol. 27:503-531.
11. Rayner, R. W. 1961. Measurement of fungicidal effects in field trials. Nature 190:328-330.
12. Seem, R. C. 1984. Disease incidence and severity relationships. Annu. Rev. Phytopathol. 22:133-150.
13. Seem, R. C., and Gilpatrick, J. D. 1980. Incidence and severity relationships of secondary infections of powdery mildew on apple. Phytopathology 70:851-854.
14. Silva-Acuña, R. 1994. Intensidad de la roya (*Hemileia vastatrix* Berk. y Br.) en cafetos con diferentes niveles de producción controlada en Venezuela. Cafe, Cacao, Thé 38:19-24.
15. Silva-Acuña, R. 1996. Epidemiologia e controle químico da ferrugem (*Hemileia vastatrix* Berk. & Br.) do cafeeiro (*Coffea arabica* L.). D.S. thesis. Universidade Federal de Viçosa, Viçosa.
16. Zambolim, L., Silva-Acuña, R., Vale, F. X. R., and Chaves, G. M. 1992. Influência da produção do cafeeiro sobre o desenvolvimento da ferrugem (*Hemileia vastatrix*). Fitopatol. Bras. 17:32-35.