PRESENCE-ABSENCE SAMPLING DECISION RULES
FOR THE DAMAGE CAUSED BY THE COFFEE LEAF MINER (*LEUCOPTERA COFFEELLA* (GUÉRIN - MENÉVILLE, 1842))[1]

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ABSTRACT - An accurate but simple presence-absence sampling method is proposed for estimating densities of lesions on leaves, caused by the coffee leaf miner (*Leucoptera coffeella* (Guérin - Menéville, 1842). This sampling method enables IPM Scouts to quickly determine whether the infestation has reached the action threshold of one leaf miner lesion per leaf. The accuracy of the sample size can also be determined.

Index terms: binomial sampling, Poisson distribution.

REGRAS DE DECISÃO NA AMOSTRAGEM PRESENÇA-AUSÊNCIA DO DANO CAUSADO PELO BICHO-MINEIRO (*LEUCOPTERA COFFEELLA* GUÉRIN-MENÉVILLE, 1842)

RESUMO - Um método preciso e simples de amostragem da presença-ausência de lesões causadas pelo bicho-mineiro (*Leucoptera coffeella* (Guérin-Menéville, 1842) é proposto para estimar a densidade destas lesões. Este método de monitoração permite aos especialistas do MIP determinar rapidamente se a infestação alcançou o limiar de ação de uma lesão por folha. A precisão do tamanho da amostra pode também ser determinada.

Termos para indexação: amostragem binomial, distribuição Poisson.

INTRODUCTION

Coffee (*Coffea arabica* L.) is an important export commodity in Brazil and many other tropical and subtropical countries. One of its principal pest throughout Latin America is the coffee leaf miner (*Leucoptera coffeella*) (Guérin-Menéville, 1842) (= CLM). Silvestri (1943) proposed the generic name *Perileucoptera* for *L. coffeella*, a name adopted only in Brazil. CLM mines the leaf reducing the photosynthetic area of the canopy when coffee berry growth rates are at their maximum (Villacorta 1980). Mean densities below 1 lesion per leaf (m*) appear not to cause economic damage, and levels above two lesions per leaf cause increasing levels of defoliation (Villacorta 1984). Dry season stress compounds the effects of CLM damage. Additional work is required across a wider range of CLM lesion densities to more accurately estimate the economic threshold (m*).

CLM populations grow most rapidly during dry periods of summer, as rainfall cause high mortality CLM larvae. Rainfall occurs throughout the year in Paraná, but is more abundant during the summer period. During some years, the CLM damage reaches economic levels during December-March. Natural enemies are thought not to be sufficiently effective in regulating CLM densities below m*, and insecticides are the primary method of control. However, to make sound recommendations for pest control, it is important to determine when the number of lesions is likely to exceed the current economic level. This paper describes an easy to use method for assessing this problem.

A sequential sampling plan based upon the negative binomial distribution was developed for CLM by Villacorta & Tornero (1982), but unfortunately the method proved too difficult for field workers to understand and use. For this reason, a simplified sampling method is developed here to fill this important need. In this work we use the methodology for estimating the accuracy of a sample size developed by Ruesink (1980) and Wilson & Room (1982, 1983). These methods are based upon Karandinos' (1976) formula [1] for estimating the accuracy of a sample size for different levels of accuracy (D) as a fraction of the mean (m) (equation [1]).

$$n = t^2 D^{-2} S^2/m^2 \qquad [1]$$

n in [1] is the number of samples required to reach a level of precision D, $t = t_{\alpha}/2$ is the standard normal

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deviate ($t = 1.282$ for $\alpha = 0.2$ or 0.1 on each tail of the distribution) and S^2 is the sample variance. Taylor (1961, 1984) proposed that the variance and the mean was described by [2]

$$S^2 = am^b, \quad [2]$$

where the coefficients a and b are quickly estimated by regressing log S^2 on log m. The coefficient a is a sampling factor and b is an index of aggregation characteristic of a species. Ruesink (1980) and later Wilson & Room (1982) substituted [2] for S^2 in [1] facilitating the development of rules for determining the number of samples required to meet a predetermined level of accuracy.

$$n = t^2 D^{-2} am^{b-2} \quad [3]$$

Counting the number of coffee leaf miner lesions on a 100 leaf sample is cumbersome in the field; however, estimating the proportion of leaves with lesions is quite easy. Wilson & Room (1982, 1983) proposed presence-absence sampling rules (i.e., binomial sampling rules) also based upon Karandinos' work [4].

$$n = t^2 D^{-2} p^{-1} q \quad [4]$$

In [4], p is the proportion of infested leaves and $q = 1\text{-}p$. However, the accuracy of the sample is not the same across all values of m, hence to maintain the same level of accuracy $\underline{D} = (D, m)$ and not a constant as in [4] (Wilson & Room 1983). This problem may be illustrated by plotting the proportion of infested sampling units ($PI = p$) against the mean number of organisms per sample unit, and based upon estimates of the coefficient b in [2], one of the four models proposed by Wilson & Room (1983) is fitted to the data. If $b < 1$ the population is under dispersed, if $b = 1$, the population is randomly dispersed, and if $b > 1$ the population is aggregated or clumped. The four models have the general form

$$PI = 1. - e^{-f(m)}, \quad [5]$$

This model was used to determine the relationship between the proportion of leaves having CLM lesions and the mean number of lesions per leaf. It is this relationship ([5]) upon which our treat-no treat decision rule for CLM is based. However, predicting m from estimates of PI produces different error limit for m. This can be seen by projecting various band PI $\pm$ 1 PI to the m axis and computing the error limits for the predicted m. In general these error limits increase in m for over the range of PI, and hence [4] must be corrected for this (i.e., [6], Wilson & Room (1983).

$$n = t^2 \underline{D}(D,m)^{-2} p^{-1} q \quad [6]$$

MATERIAL AND METHODS

The samples in this study were taken in a commercial coffee plantation located in Ibiporã, Paraná, Brazil, on the coffee variety "Mundo Novo" during August 1979 through July 1981. The experimental area consisted of three blocks each with 120 "covas" (= 2 plants per site). One block was the untreated control and the other two blocks were treated respectively with Permethrine (at the rate of 100 ml/ha of the commercial product followed by one application of sulphur WP 2 kg/ha to control mites induced by the insecticide), and Temik (i.e., aldicarb, 10 g of commercial per cova).

In the field study, the action threshold for applying the insecticide was set between 1.2 to 1.5 lesions per leaf. 100 leaf samples were taken at random at monthly interval in each of 10 random selected coffee "covas". Coffee rust (*Hemileia vastatrix* Ber. & Br.) in the plots was controlled with copper base fungicides. Strickly speaking, the variance of the data has two components; that due to between cova variation and the other between leaves. Here we ignore the between cova variation because the data are not available.

The leaf samples from the check were taken to laboratory and the leaf and CLM lesion areas measured using an area meter model AAD400 (Hayashi Denkoh, Go. Ltd. Japan). Average temperature and rainfall were obtained from the weather station maintained by the Instituto Agronômico do Paraná (IAPAR), at Ibiporã.

RESULTS

The phenology of CLM lesions per leaf and the average percentage of the leaf area with lesions in the untreated control block is shown in Fig. 1. The two trends are correlated (Fig. 2, $p < 0.05$) but the predictive value of the regression equation is low ($r^2 = 0.45$). The two dips in the trends occur during periods of prolonged rains when high mortality of CLM larvae occurred. CLM populations were above the economic threshold for a considerable period of time.

Lesions do not always contain live CLM life stages, and leaves with lesions tend to accumulate over time until they abscise. Hence, the observed number of lesions is greater than the number of larvae per leaf. The reduction in photosynthetic potential of the plant is, however, due to the loss of leaf area caused by the CLM lesions. Thus lesion density and not the density of CLM life stages is a

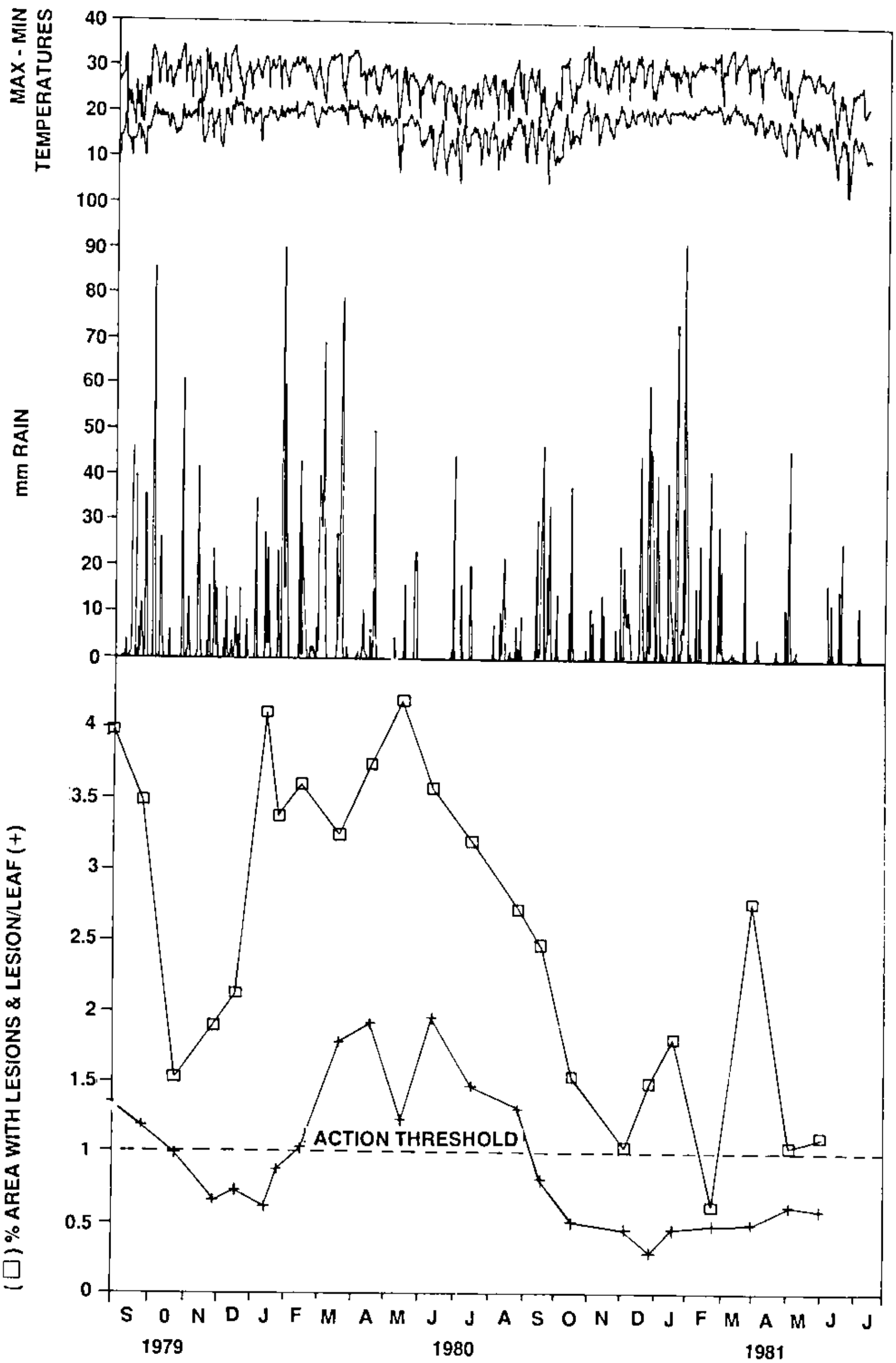

FIG. 1. Phenology of CLM lesions per leaf and their average percentage of leaf area in the control block. Also shown are the daily maximum and minimum temperatures and rainfall.

better indicator of damage. This is fortunate, as lesion density is much easier to assess in the field.

Estimating the Taylor coefficients

The coefficients a and b estimated by regressing log S^2 on log M are presented in Table 1. Note that a in Taylor's model ([2]) a equals $e^{a'}$, where a' is the intercept of the regression equation. The data from all blocks and the regression lines are shown in Fig. 3. The slopes for the control, Permethrine, aldicarb and the pooled data were not significantly different from unity or each other. The aldicarb treatment had a few divergent points which lowered r^2 and affected the slope. The analysis suggests that the lesions are randomly distributed among leaves.

The regression coefficients for the pooled data were used in [3, 4, 6] to determine the number of samples required to estimate the mean number of lesions per leaf m with levels of accuracy D = 0.1 and 0.2. Using equation [3] at a level of precision D = 0.2, the one hundred leaf sample estimates m = 1 with a better than 20% accuracy (Fig. 4A). However, to achieve a 10% level of accuracy at m = 1, a sample of approximately 220 leaves is required.

Figure 4B shows the binomial sampling rules using [4] assuming a constant value for D. The observed values of p (i.e. the data) are shown in relation to the predicted function n(m) (i.e. the solid lines). In general, the predictions over the range of observed m are reasonably close. The predictions of n assuming D = (D = .2,m) (i.e. [6]) are shown as the dashed line suggesting that n is higher over the entire range of m, and is at odds with the data.

Presence absence sampling decision rule for CLM

The proportion of infested leaves is plotted in Fig. 5 showing that the range of observed PI is below 0.8. The parameter b in [2] for the different data sets (Table 1) suggest that Poisson distribution model [7] would be appropriate.

$$PI = 1 - e^{-m} \quad [7]$$

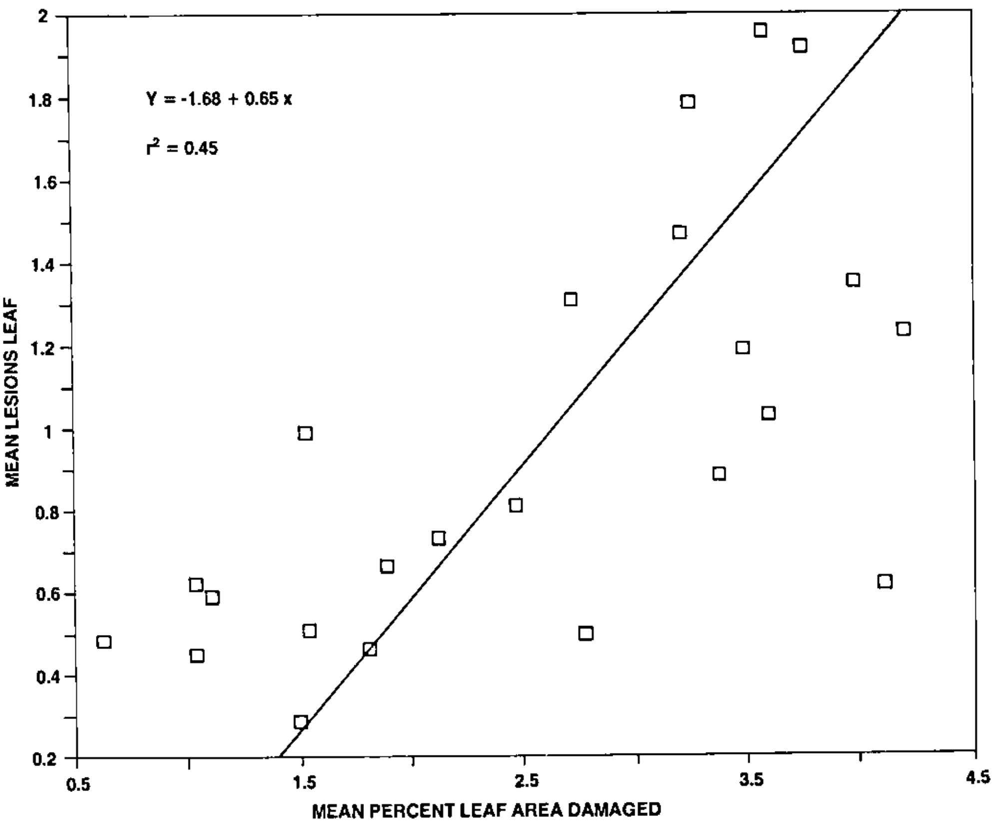

FIG. 2. Regression of mean percentage of leaf area with CLM lesions on the mean lesions per leaf.

TABLE 1. Linear regression statistics for S^2 on m and log S^2 on log m for the CLM lesion data.

Treatment	S^2 on m			log S^2 on log m			
	a'	b	r^2	a'	b	r^2	n
Control	0.071	1.491	0.76	0.422	1.012	0.86	92
Permethrine	0.108	1.436	0.86	0.245	1.078	0.91	76
Aldicarb	0.167	1.074	0.61	0.182	0.793	0.73	76
All data	0.452	1.345	0.73	0.292	0.946	0.81	244

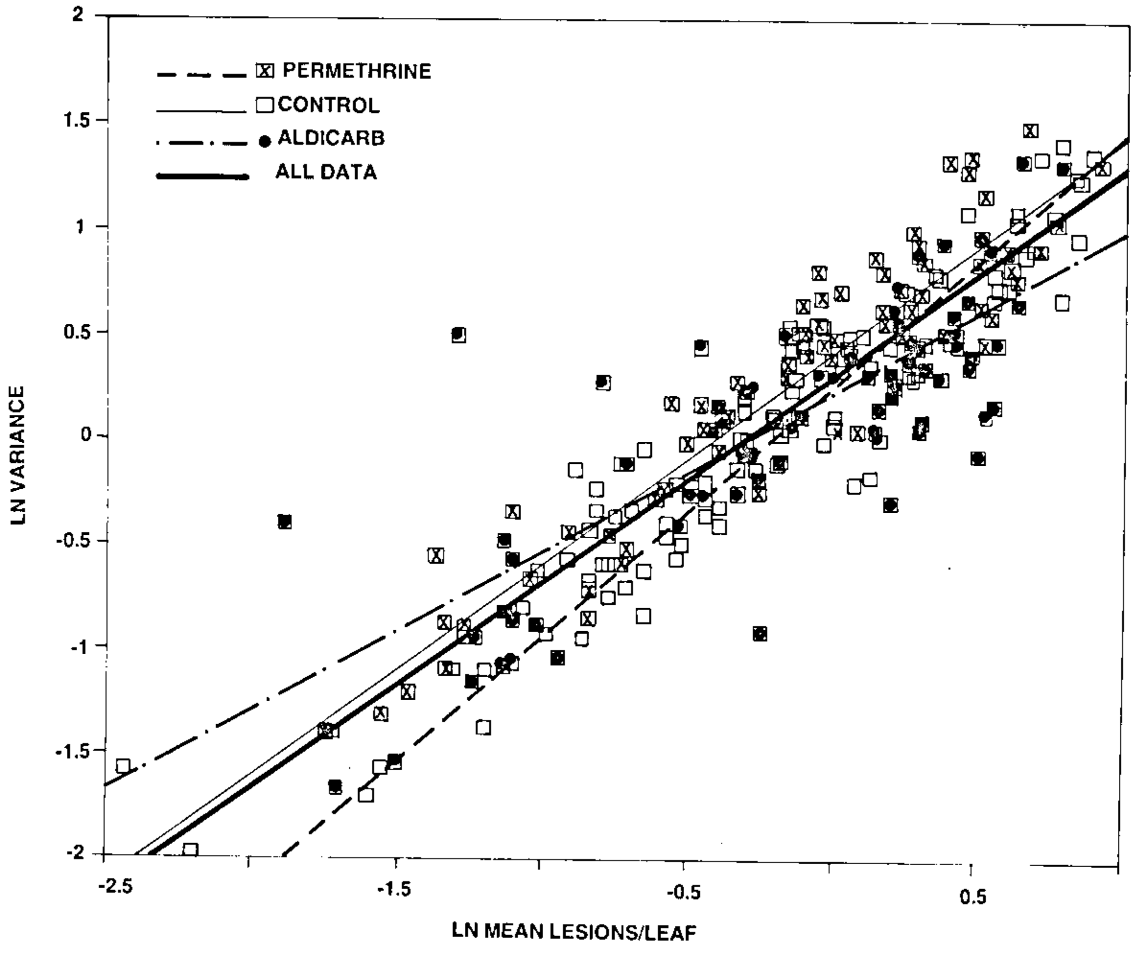

FIG. 3. Regression of log variance of lesions per leaf on log mean lesions per leaf for all treatments.

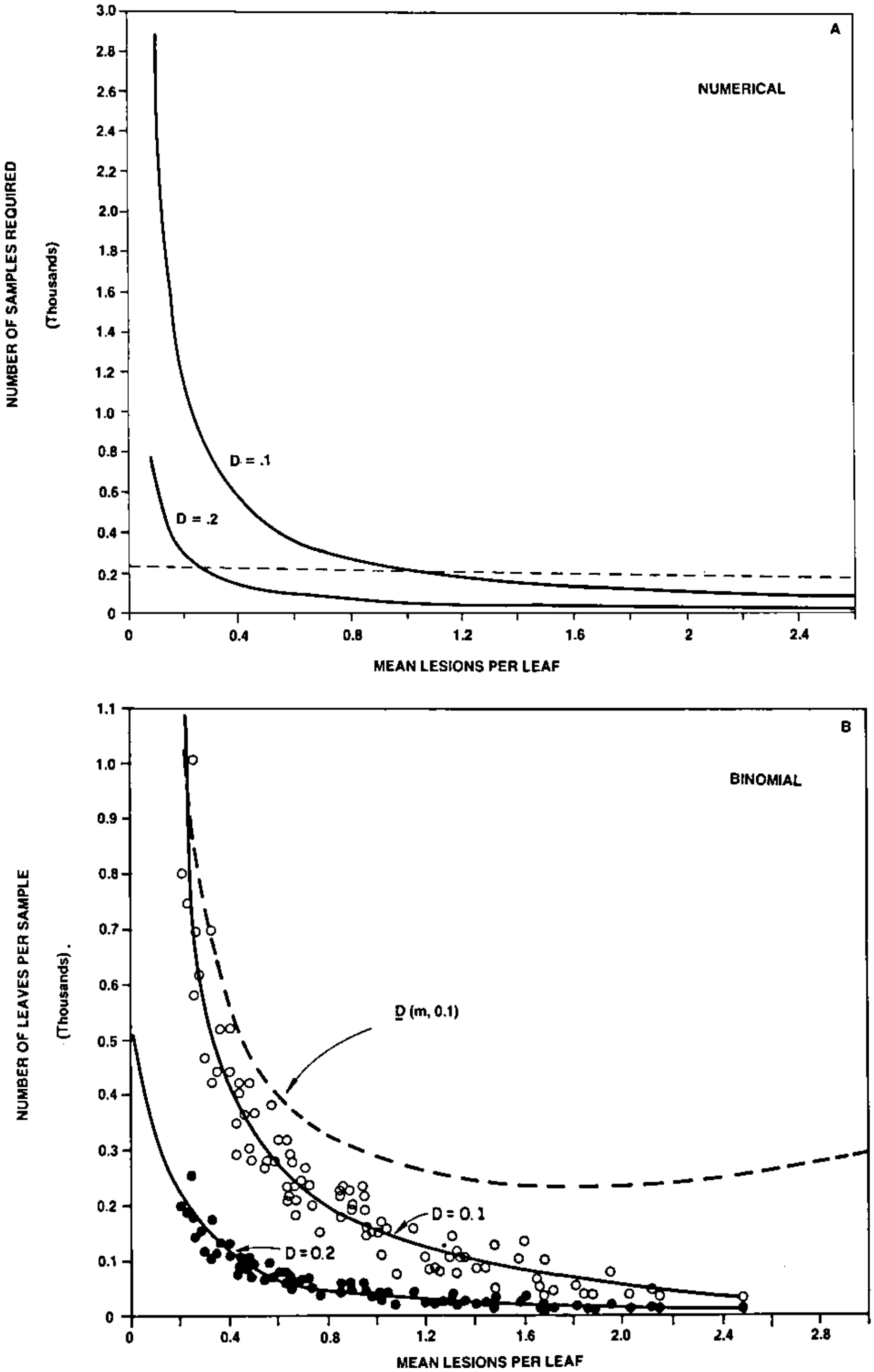

FIG. 4. Number of leaves required at different CLM lesion densities required to meet predetermined levels of sampling precision (D = 0.1 and 0.2): (A) numerical sampling and (B) binomial sampling (i.e., presence-absence) with constant level of precision (solid lines) and with the level of precision which varies with mean lesions per leaf (D = (m, 0.1), see text).

The term e^{-m} in [5] is the zero term of the Poisson distribution (i.e., the proportion of non-infested leaves (P(0)), and PI = $1 - e^{-m}$ is the proportion of leaves having 1 or more lesions. This line is shown in Fig. 5 as the dashed line. This model tends to systematically over estimate PI, hence a modified Poisson model was fit to the data (solid line, model 4 of Wilson & Room, 1982; [8])

$$PI = 1 - e^{-cm} \qquad [8]$$

If 220 leaves are sampled to estimate PI, then m at a 10% level of accuracy is predicted projecting the PI value to the function (the solid line) and then projecting from that point to the m- axis to estimate the mean lesions per leaf (m). Because the error is not equal on both the PI and m axis, the number of samples required to meet the 10% level must in theory be increased with higher values of PI (Wilson & Room 1983). All this means is that as the proportion of leaves approaches unity, it becomes increasingly difficult to estimate m unless an increasing sample size is taken. Given the limitation of not including the between cova variance in our analysis, the model is quite adequate for estimating CLM densities near or above an action threshold of one lesion per leaf.

The line perpendicular to the m axis (± the 10% error limits) separates the treat/no treat areas. If the predicted number of lesions per leaf falls within this error limit, a field scout must use judgement as to whether an insecticide application is warranted. This rule is conservative, but used it is likely to reduce the excessive pesticides currently used in the absence of any scientifically based decision rule. Villacorta & Sánchez-Rodrigues (1984) showed that a single insecticide applications timed at the level m = 1 is sufficient for season long control of CLM.

Steps to follow to use the binomial sampling method.

The method proposed here similar to the methods used to gather the data used in the analysis.

1. Divide the area to sampled in sampling areas no more than one ha, and map the coffee plantation giving a number to each sampling unit area.

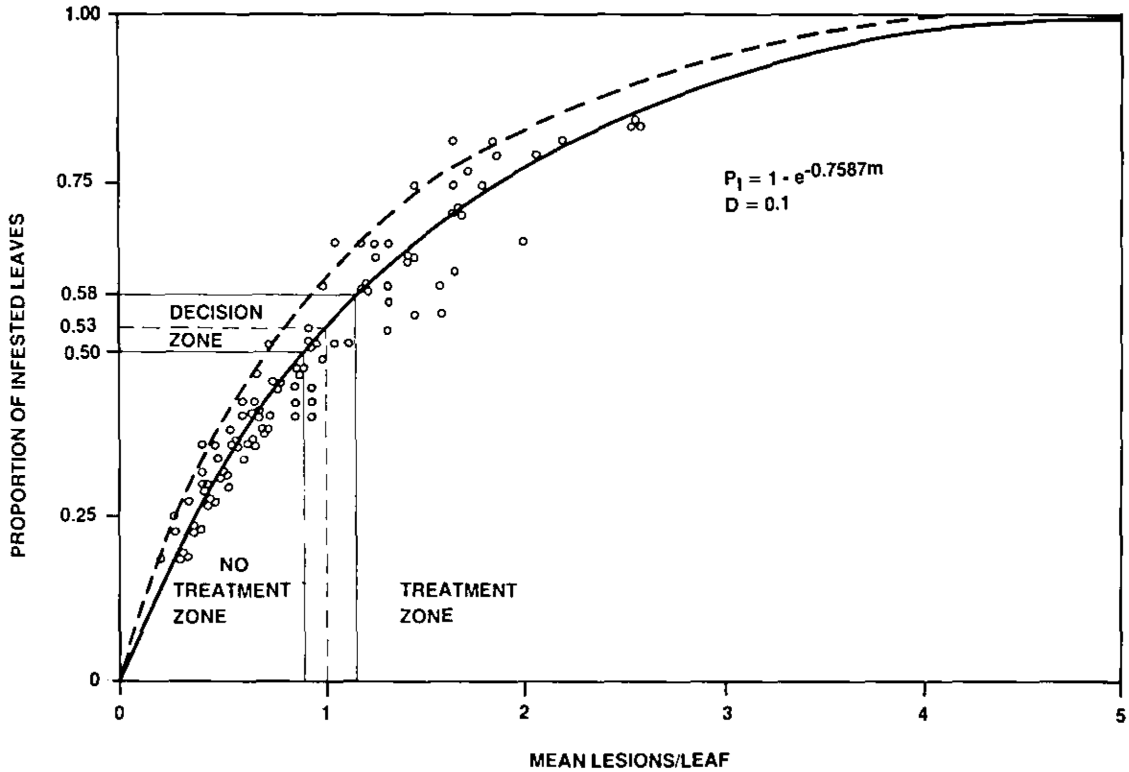

FIG. 5. Proportion of infested leaves (PI) on mean lesions per leaf. The dashed line is the Poisson model, and the solid line is the modified Poisson model fit to the data and used for the treat-no treat decision rule (see text).

2. Walk across the sampling unit area and from nine random trees (cova) make visual observations on the presence or absence of CLM lesions on 25 random middle aged leaves per tree. Avoid sampling new leaves from the first two pair of leaves from the branch.

3. Calculate the proportion of infested leaves and use this value in Fig. 5 to estimate the mean lesions per leaf.

4. If the proportion of infested leaves (i.e., PI) is less than 0.50, the predicted lesions (i.e., m) fall within the NO-TREATMENT ZONE. If PI is between 0.50 and 0.58, m falls in the DECISION ZONE. In this case, either take another round of samples or sample 15 days later. If PI is greater than .58, the predicted m falls in the TREATMENT ZONE.

5. Sampling should begin at the time of flower initiation and continue at monthly intervals until coffee berry growth ceases. There are two periods during summer: the less critical four to five month period from the time of flower initiation until the coffee berries begin rapid growth, and the critical period of rapid berry growth. In general, levels of CLM infestation higher than 1 lesion per leaf do not cause economic damage during the first period as the high rates of leaf production enable the plant to compensate. However, when berry growth rates are at maximum, and densities of 1 CLM lesion per leaf may cause economic damage. Hence, if a short dry period occurs, the time between samples must be reduced to 15 days.

The data presented here relates specifically to the CLM phenology as modified by the weather pattern common to Paraná. With additional data, the same model could be applied to other areas.

DISCUSSION

The presence-absence sampling decision rule for CLM presented here is designed for practical utilization in the field by IPM scouts. For this reason, the formulae were kept to a minimum and easy to understand explanations were offered. The rule was related to theory, but in the final analysis a least squares fit to the proportion infested data proved the most accurate predictor of mean lesions per leaf.

Natural enemies are known from CLM, but they do not appear to be effective. (Villacorta 1980). Hence, while we might wish for natural control of CLM, pesticide applications are required on occasions, but at frequencies far less than is the current practice. In the final analysis, farmers wish to maximize profit, hence killing pests is merely an necessary inconvenience in that endeavor. Putting more resources than necessary into pest control reduces profits, and hence is contrary to farmer objectives. The use of this binomial sampling rule could greatly reduce the number of pesticide application against CLM in coffee, and over time enable farmer to learn to detect the zone of frequent infestation on their farms further increasing the efficiency of their pest control efforts.

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