PHENOLOGICAL PATTERNS AND SAMPLING DECISION RULES FOR ARTHROPODS IN COTTON FIELDS IN PARANÁ, BRAZIL:

BEFORE BOLL WEEVIL[1]

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ABSTRACT - Several species of arthropods commonly found in untreated cotton in Paraná, Brazil, were sampled using the accurate whole plant bag sampling method (WPBS). The data provide important background information for cotton prior to the expected increase in insecticide use for the control of the newly introduced cotton boll weevil (*Anthonomus grandis* Boh.) in Paraná, Brazil. Decision sampling rules base on Taylor's power law were developed for many of the common species. The relationship between the proportion of infested plants and the average density of arthropods per plant for cotton aphid and the cotton stem borer were assessed for the cotton aphid (*Aphis gossypii* Glover, 1876) and the stem borer (*Eutinobothrus brasiliensis* (Hambleton, 1937)). These functions may be used in the field to estimate the mean density of these pests in the field from presence-absence observations.

Index terms: whole plant bag sampling method, cotton, presence-absence sampling.

PADRÕES FENOLÓGICOS E REGRAS PARA DECISÃO EM AMOSTRAGENS DE ARTRÓPODES EM ALGODOAIS DO PARANÁ: ANTES DO BICUDO-DO-ALGODOEIRO

RESUMO - Diversas espécies de artrópodos comuns em uma área cultivada com algodoeiro (Londrina, PR, Brasil) e isenta de inseticidas foram amostradas usando o acurado método de amostragens de plantas inteiras (WPBS-whole plant bag sampling). Os resultados forneceram informações essenciais sobre os padrões das espécies comuns presentes em algodoais, antes do provável incremento no uso de inseticidas para o controle do bicudo do algodoeiro, *Anthonomus grandis* Boh., recém-introduzido no Paraná. Regras para decisão em amostragens, baseadas na lei do poder, de Taylor, foram desenvolvidas para muitas espécies comuns, usando o método de WPBS. A relação entre a proporção de plantas infestadas e o número médio de artrópodos por planta foi determinada para o pulgão *Aphis gossipii* Glover, 1876, e para a broca *Eutinobothrus brasiliensis* (Hambleton, 1937). Estas funções podem ser usadas para estimar a densidade média destes insetos-pragas em amostragens de presença-ausência.

Termos para indexação: método de amostragem da planta inteira, plantas infestadas, método de amostragem presença-ausência.

INTRODUCTION

Cotton (*Gossypium hirsutum* L.), in the state of Paraná, Brazil, has many pests; among the most important are the pink bollworm (*Pectinophora gossypiella* (=PBW)), and the cotton stem borer (*Eutinobothrus brasiliensis* Hambleton)). No systematic survey on the phenology and abundance of cotton insects for this area exists, hence this survey was made to provide background data in untreated cotton field. PBW was not included in this survey as ample data on its phenology has been published elsewhere (Gutierrez et al. 1986). These survey data assume increasing importance now that the cotton boll weevil (*Anthonomous grandis* Boh.) has been introduced into the region, as they help document the species composition in untreated cotton before possible massive spraying for this key pest begins. If heavy insecticide usage occurs, the frequency and species composition of arthropods in cotton are likely to change.

An additional, goal of this work was the development of sampling decision rules for several of the common species using the whole plant bag sampling (WPBS described below, cf. Byerly et al. 1978), and when appropriate using presence-absence methods (Wilson & Room 1982). The WPBS method

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is very labor intensive and not applicable to pest management decision making. However, in a scientific context, it provides a very accurate estimate of field densities of arthropods in cotton on a per plant basis. In contrast, presence-absence methods are very efficient, but not applicable to species which are difficult to observe.

MATERIAL AND METHODS

The study was conducted in a 0.7 hectare unsprayed cotton field at Londrina, PR., Brazil (i.e., 23.22° S) during the 1982 cotton season. The field was planted at a rate of six plants per m^2 with the IAC-17 variety.

Sampling methods

In the WPBS method, plastic bags with draw strings at both ends were placed over 100 individual plants one week prior to the date that the plant samples were to be taken. The bags were collapsed around the base of the plants to allow the mobile arthropods to reestablish during the one week pre-sample period. All samples were collected in the cool of early morning when the arthropods were least active by closing the bottom draw string of each bag, pulling the bag quickly up over the plant, closing the bag at the top, cutting the plant at the base and taking all 100 plants to the laboratory where all of the arthropods in each bag were washed off into individual containers, the common species identified and all organisms counted at least to the Order level. The less common or noneconomic species were sumed by order, while the common pests and natural enemies were counted by species (Table 1). Only data for the common economically important species are analyzed in detail.

Statistical methods

Byerly et al. (1978) used the Iwao & Kuno (1971) method to estimate the number of samples required to achieve a predetermined level of accuracy for sampling arthropods in cotton in California. This method was criticized by Taylor (1984), who had proposed an exponential relationship between the variance (s^2) and mean (m) (eg., (1)). Taylor's criticism, while self serving, is correct, and his relationship is adopted here. For a further discussion of this problem, interested readers are referred to the Taylor's paper, and to Wilson et al. (in press) for recent improvements.

Taylor's equation (1) describes the relationship between the variance (s^2) and the mean (m) as follows:

$$s^2 = am^b. \quad (1)$$

The parameters a and b in equation (1) were estimated by regressing $\log_e s^2$ on $\log_e m$. The meaning of the parameter a in (1) is vague, while b is a measure of contagion. In this method, a value of $b < 1$ implies that the distribution is under dispersed (approaching uniform), $b = 1$ implies a Poisson or random distribution, and $b > 1$ implies a clumped distribution. Wilson & Room (1982) used (1) to estimate the variance in Karandino's (1976) equation (2) for determining the number of samples (n) required to achieve a prescribed level of accuracy (D) expressed as a fraction of the mean.

$$n = (t_{\alpha/2}/D)^2 \cdot am^{b-2}, \quad (2)$$

t in (2) is Student's t = 1.282 for $\alpha = .2$ (i.e., 0.1 each tail), and -2 in the exponent results when (1) is substituted for s^2 in Karandino's formula. The arithmetic is not reproduced here, and interested readers are referred to that paper for a complete description of the methodology.

RESULTS

Phenology

Of the less common species (Fig. 1), those in the orders Coleoptera and Diptera were most common during the early season. The beetle *Diabrotica speciosa* Germar is of economic importance in other crops but not in cotton. Species of Hemiptera and Homoptera were only infrequently encountered during the early season, but increased as the season progressed. Among these was the hemipteran *Horcius nobilellus* (Berg) which is thought to be an early season pest. Species of the family Ciccadellidae, some of which are vectors of plant viruses, had similar phenologies. Few Hymenoptera, principally ants, and still fewer lepidoptera were found occuring at densities of less than one per plant. The predaceous hemipteran *Ceratocapsus* sp. and the assassin bug *Heza* sp. were also found, but they were not common.

Fig. 2a-j show the phenological patterns for the more common pest and beneficial species sampled in this study, while table 2 presents a correlation matrix of the relationships among them. The data suggest that spider numbers are strongly correlated to *Dysdercus* sp. numbers, r = 0.928 which buildup during late season. A similar buildup of other species of heteropterans and homopterans was observed and they are also potential prey. Some of these species are predators in their own right (eg., *Orius* and *Geocoris*). The high correlation between cotton stem borer larvae and spiders in spurious, as spiders are unlikely to feed on them. A multiple regression analysis adding the species in increasing order of their correlations (above 0.5, i.e., *D. lineare* and *Geocoris* sp.) increased the R^2 value to 0.979.

Significant correlations also exist between cotton aphid (*A. gossypi*) its two coccinellid predators (*C. sanguinea* and *E. connexa*). All of the above relationships are aparent by examining the phenology data.

TABLE 1. List of common species found in the WBPS in cotton at Londrina, PR, Brazil.

Species	Common name	Trophic[1] level	Pest[2] status
Aphis gossypii	aphid	H	H
E. brasiliensis	stem borer	H	H
Alabama argillacea	leaf worm	H	H
Dysdercus sp.	cotton stainer	H	L
Cycloneda sanguinea	lady beetle	P_1	*
Geocoris sp.	bigeyed bug	P_1	*
Doru lineare	earwig	P_1	*
Orius sp.	minute pirate bug	P_1	*
Scymnus sp.	lady beetle	P_1	*
Spiders		P_1	*

[1] Herbivore (h), Predator (P_1)

[2] Pest status High (H), Medium (M), Low (L) and predators(*)

Sampling decision rules

Table 3 presents a summary of the regression parameters a and b of $\log_e s^2$ on $\log_e m$. Nine of the 12 r^2 values are greater than 0.9, with those for spiders, *Dysdercus* and *Geocoris* being 0.856, 0.752 and 0.066 respectively. The low value for *Geocoris* was expected because of their extremely low densities. The b parameters suggets that most of the species are nearly randomly distributed among plants (b = 1), with only *Dysdercus* spp. and the cotton aphid showing pronounced clumping, and *Geocoris* trending to be under dispersed (b < 1).

Based on equation (2), the numbers of samples required to achieve prescribed levels of accuracy D = 0.1, 0.15 and 0.2 are illustrated in Fig. 3a-k for all species except *Aphis gossypii,* whose large number make the presence-absence methods more' appropriate (Wilson et al., in press). The data presented in Table 3 enables one to calculate the curves to any desired scale.

In general, for the same level of accuracy, the number of samples required increases as the species density decrease, and as the level of precision increases (i.e., as D approaches zero). For example, stem borer larvae can be adequately sampled early in the season at m = 2.5 and D = 0.1 with 120 plants. This is an important finding as this species is as serious pest that can readily be sampled visually using presence-absence method with approximately the same degree of accuracy without resorting to WPBS. In sharp contrast, *C. sanguinea* numbers were low and despite the good fit of (1) to the data nearly 400+ WPBS samples would be required to achieve the same level of accuracy. The other patterns are easily interpretable, hence they are not discussed further here.

Presence-Absence Methods

The proportion of plants (P) with the cotton aphids and cotton stem borers are plotted against the mean numbers per pant in Fig. 4. Function (3i) was fitted to the cotton aphid data with constants c, c' and d (see Wilson & Room 1982), but a linear function gave better results for the stem borer data.

$$\log_e(1.-P) = c' + d\log_e m \qquad (3)$$

$$P = 1. - e^{c'}m^d = 1. - cm^d.$$

Such functions may be used to estimate the mean densities of the two pests per plant using only the proportion of plants infested. The equations and the coefficient values are presented in the Fig. 4.

DISCUSSION

The level of accuracy provided by the 100 WPBS as measured by the regressions statistics was quite good, hence the phenology patterns in Fig. 2 and the decision rules in Fig. 3 may be accepted with confidence. The WPBS method is not useful for pest management (IPM) decision making, but does provide a very good measure of expected patterns and numbers of common arthropods found in cotton.

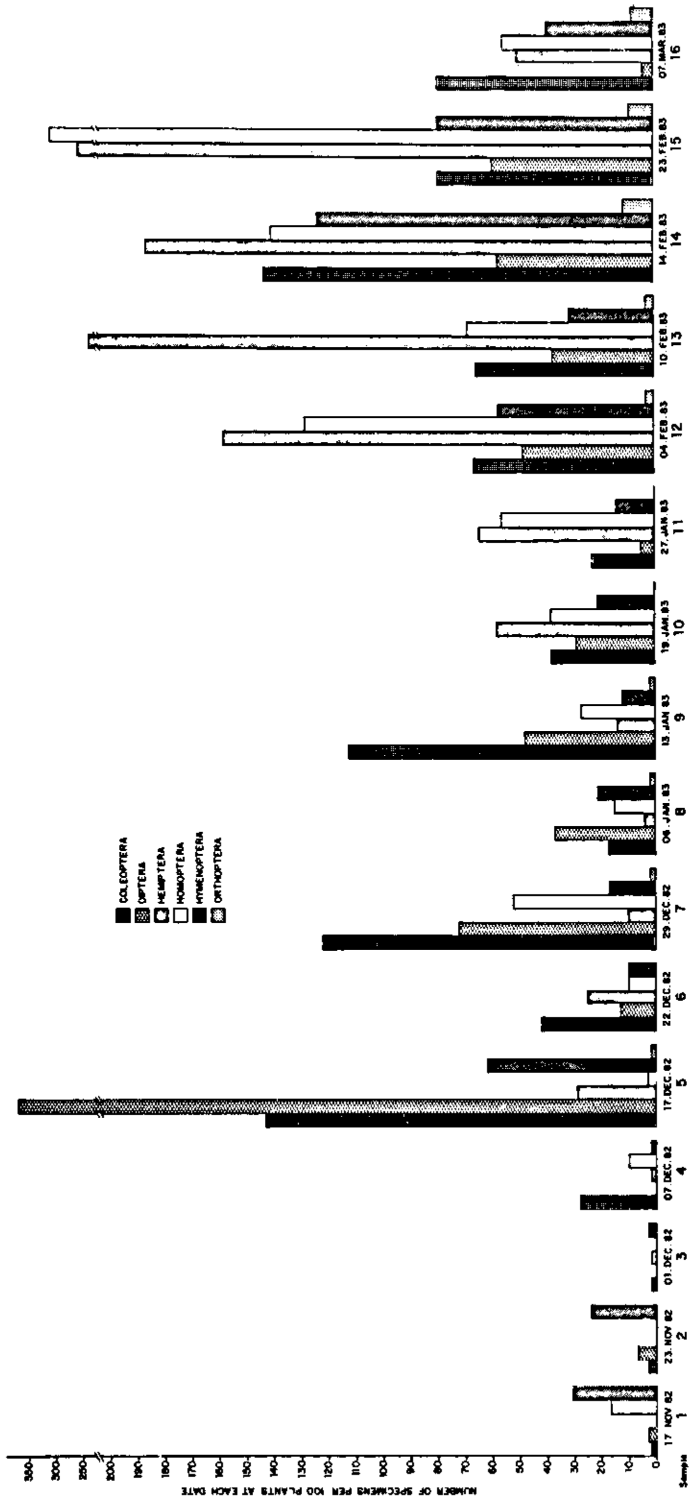

FIG. 1. Phenology of non-economic insects found in cotton grouped by Order during the 1982-83 season at Londrina, PR, Brasil.

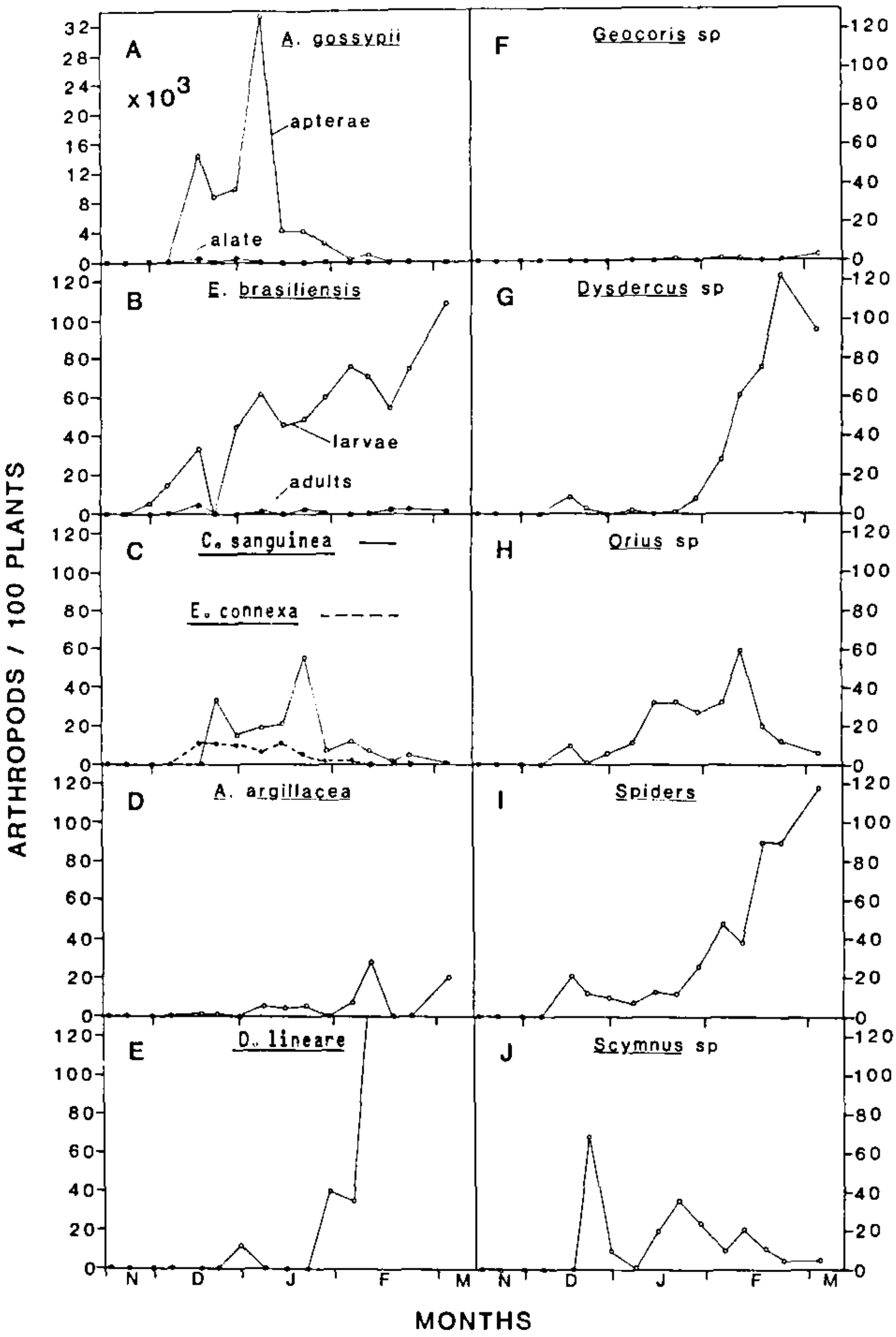

FIG. 2. Phenology patterns for several cotton insects in unsprayed cotton during the 1982-83 season at Londrina, PR, Brazil.

TABLE 2. Correlation matrix of common species found in cotton using the WPBS method at Londrina, PR, Brazil, during the 1982-83 season.

Species	*E. brasiliensis* (larvae) 1	*A. argillacea* 2	*Dysdercus* spp 3	*A. gossypii* 4	Spiders 5	*D. lineare* 6	*Scymnus* spp 7	*Orius* spp 8	*Geocoris* spp 9	*C. sanguinea* 10	*E. connexa* 11
1. *E. brasiliensis* (larvae)	1	.71	.68	.04	.77	.36	.23	.53	.53	.15	.53
2. *A. argillacea*		1	.42	-.09	.46	.29	.002	.68	-.001	-.14	-.21
3. *Dysdercus* spp			1	-.35	.93	.68	-.019	.28	.65	.34	-.43
4. *A. gossypii*				1	-.24	-.28	.47	-.05	-.23	.52	68
5. Spiders					1	.62	-.11	.18	.58	-.24	-.34
6. *D. lineare*						1	-.34	.40	.04	-.25	-.37
7. *Scymnus* spp							1	.28	-.04	.71	.70
8. *Orius* spp								1	.12	.18	-.05
9. *Geocoris* spp									1	.00	-.22
10. *Cycloneda sanguinea*										1	.81
11. *Eriopis connexa*											1

TABLE 3. Fitted parameters for Taylor's model for WPBS samples taken in cotton at Londrina, PR, Brazil, during the 1982-83 season.

		Taylor $S^2 = am^b$		
Species	N	a	b	r^2
E. brasiliensis adult	9	1.116	1.041	.999
larvae	13	1.029	.903	.944
C. sanguinea	12	2.461	1.253	.985
A. argillacea	8	2.375	1.247	.936
Dysdercus sp	10	.883	1.912	.752
D. lineare	8	2.655	1.139	.956
E. connexa	8	1.538	1.093	.969
Geocoris sp	5	.046	.132	.066
Orius sp	12	1.356	1.048	.965
Scymnus sp	12	2.145	1.230	.975
Spiders	12	1.703	1.052	.856
A. gossypii	13	1.855	1.741	.988

Byerly et al. (1978) and Wilson & Room (1982) compared the effectiveness of the commonly used relative sampling methods such as sweepnet, D-vac and visual estimates with the more accurate WPBS method, but their attempts to correlate the WPBS sample counts to those obtained using the relative methods gave erratic results for many species. Both studies showed that the whole bag plant sampling method was considerably more accurate than the relative methods. Hence, in this study, the WPBS method was used to get an accurate measure of the species composition in cotton without concern for such correlations.

Because cotton aphid and cotton stem borer are easily estimated visually, the presence-absence method provides a viable alternative to the labor intensive WPBS method. Unfortunately, the behavior of most of the other species makes it impossible to observe them with any degree of accuracy, and thus precludes the development of practical presence absence relationships for them.

These data are important because they establish the basic phenological and distribution patterns for several important species prior to the establishment of the cotton bollweevil in the area, and the possible associated disruptive effects of pesticides used to control it.

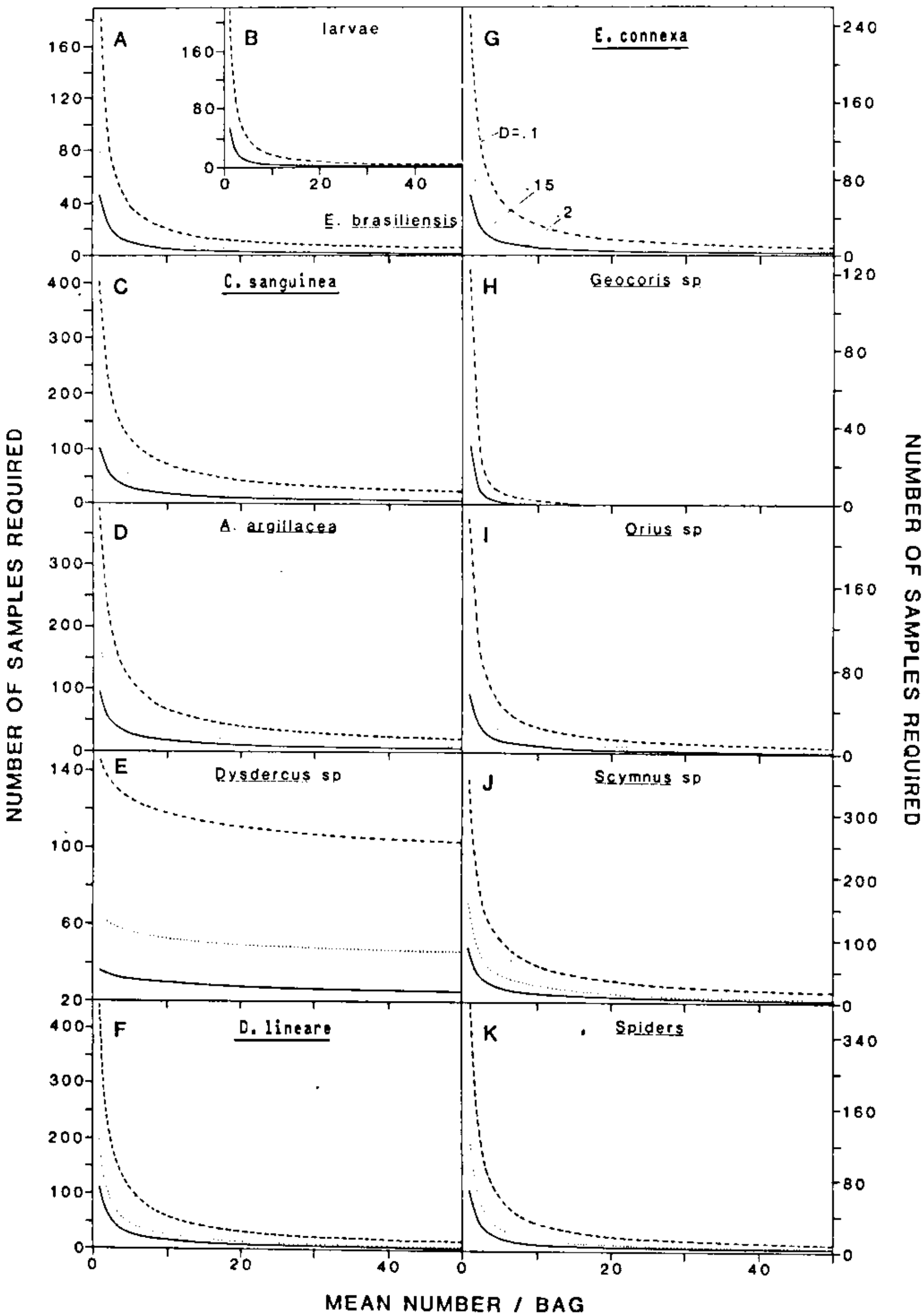

FIG. 3. Sampling decision rules for many of the pests shown in Fig. 1, using the WPBS method.

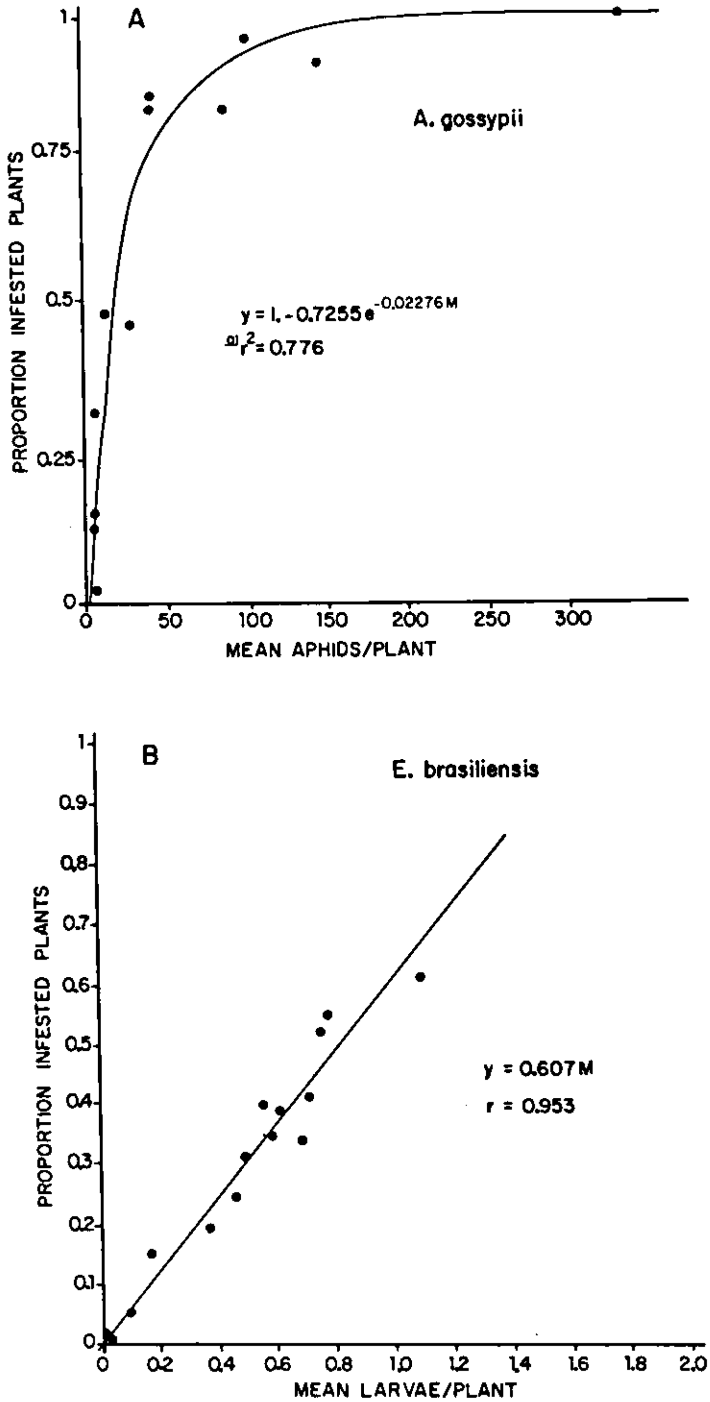

FIG. 4. The relationship of presence-absence observations to pest density. Note that the r^2 value is for the log transformation of the data.

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CONCLUSIONS

1. The whole plant bag sampling method is effective for detecting many mobile species in cotton, but in general is too labor intensive to be of practical value in pest scouting.

2. The presence-absence sampling rules developed for *A. gossypii* and *E. brasiliensis* are quite useful as they may be implemented by visual inspection of plants in the field. Unfortunately, this method may be inappropriate for species that are not amenable to visual inspection because of large sampling error or for species which are more uniformly distributed because the method looses accuracy as the proportion of infested plants asymptotically approaches one.

3. The data of this survey provide important background information for the species composition in Paraná cotton before the invasion of cotton by the boll weevil. It will provide a means of assessing the ecological disruption of this system by the expected increase in insecticide use to control this pest.

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