ECONOMIC DAMAGE CAUSED BY THE COTTON STEM BORER IN SOUTHERN BRAZIL[1]

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ABSTRACT - Cotton stem borer, *Eutinobothurs brasiliensis* damage showed a graded distribution from the margin of the field to the middle. Infestation was considerably higher in the border rows than in the center of the field. The study documented the behavior of this pest during the period when it migrates from overwintering sites around the field to cotton. The results confirm former observations that the levels of infestation are higher near humid overwintering areas with permanent vegetation. Early planted blocks of cotton had the highest rates of infestation, often reaching 70% of plant mortality. In later plantings a 20% reduction in plant mortality was observed every time planting was delayed for ten days. The data suggest that this pest may be controlled with insecticide applications in border rows. This procedure would eliminate the need of chemical treatments which are environmentally unsound. The data also suggest that planting densities of nine to ten plants per m would help to reduce the impact of this pest on cotton yield. The relationship between yield loss and plant mortality was assessed and the economic damage estimated.

Index terms: phenology, sampling, chemical control.

DANO ECONÔMICO CAUSADO PELA BROCA-DO-ALGODOEIRO NO SUL DO BRASIL

RESUMO - Os danos causados pela broca-do-algodoeiro, *Eutinobothrus brasiliensis* apresentam uma distribuição estratificada, da bordadura para o centro da área culivada. Estes danos foram consideravelmente maiores nas bordaduras do que nas áreas centrais. O estudo serviu também para documentar o comportamento da broca durante o período em que ela migra para as áreas cultivadas com algodoeiro. Os resultados confirmam que as faixas com altos níveis de infestação são as próximas aos locais onde a broca passa o período da entressafra, ou seja, áreas com vegetação permanente e relativamente úmidas. Os primeiros plantios apresentaram os maiores níveis de infestação, freqüentemente atingindo 70% de mortalidade de plantas. Em blocos plantados mais tarde, observou-se uma redução ao redor de 20% na mortalidade de plantas, para cada dez dias em que se prorrogou o plantio. Os estudos sugerem que este inseto pode ser controlado através de aplicações de inseticida nas bordaduras. Este procedimento eliminaria a necessidade de se aplicar tratamento químico em toda a área. Este trabalho sugere, também, que densidade de plantio com nove a dez plantas por m contribuiria para reduzir o impacto deste inseto - praga na produção de algodão. Avaliou-se a relação entre a mortalidade de plantas e a perda na produção, assim como o dano econômico.

Termos para indexação: fenologia, amostragem, controle químico.

INTRODUCTION

The cotton stem borer (*Eutinobothrus brasiliensis* (Hambleton, 1937) is a serious pest of cotton in Argentina, Southern Brazil and Paraguay, and was first reported on cotton (*Gossypium hirsutum* L.) in South America by Vert (1905). A complete review of the literature on this pest is found in Prudent (1985) and Parra (1972). The latter paper contains considerable information on the infestation patterns of stem borer, and evaluations of host plant resistance and chemical control trials. In the present paper, data on the phenology and within field distribution of stem borer are presented, and the effects of its damage on cotton yield are assessed concerning the time of planting, insecticide treatment of seed and plant survival. An economic evaluation of the problem is made, and recommendations for control which minimize environmental disruption are proposed.

During the early season, stem borers migrate from overwintering sites to cotton fields. The highest initial densities were observed in rows adjacent to permanent vegetation near water (Parra 1972), but subsequent summer generations disperse into the center of the field. Overwintering mortality of this pest is thought to be increased by dry winters. The adult females feed on the foliage and oviposit in the stem at the base of the plant. Plants may be killed or stunted by the damage caused by larvae burrowing and feeding inside the stem. Yield losses accrue from both causes.

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MATERIAL AND METHODS

The three experiments reported in this paper were conducted in different fields, and were designed to determine the phenology of stem borer and to develop and easy to use presence-absence sampling method (experiment 1); to examine the within field distribution and dispersal of stem borer (experiment 2); and to study the effects of time of planting and seed treatment on stem borer damage on cotton yield (experiment 3). All fields were planted with the variety IAPAR 4-PR1 at a rate of six plants/m.

Experiment 1 was conducted at Londrina, PR, Brazil, during 1982-83, in a 0.7 ha field. One hundred plants were sampled at random (Byerly et al. 1978), and the number of stem borer life stages was counted per plant. The proportion of sampling plants infested was regressed on pest density (Wilson & Room 1983). A complete discussion of the sampling and statistical methods for stem borer and other cotton insects in southern Brazil area presented in Pizzamiglio et al. 1989.

Experiment 2 was conducted at Cambará, PR, in a three ha field planted on 13.1.83 and germinated on 9.2.83. The field was divided into twelve blocks (20 m x 110 m) with rows within blocks oriented in the same direction as the 20 m width. The number of dead plants was counted in al 20 m lengths of row 90 and 117 days after planting. On day 90, all dead plants were removed, but this did not affect the stem borer populations because dead plants harbor few of the pest. Systematic counting of dead plants mapped the initial and subsequent patterns of infestation and dispersal of the pest into the field.

Experiment 3 was conducted on 0.162 ha of a eight ha field at Cambará during 1983. The study area was divided in four blocks, each block containing all time of planting treatments (t_i, i-1,4) and each planting treatment containing four replicates planted with chemically treated and untreated (control) seed (i.e., a randomized complete block design). The first planting (t_1) was 20.9.83 and the other three (T_2, t_3, t_4) at nine to ten day intervals later. Treated seed received 50 g active ingredient of the systemic insecticide Disulfuton plus 300 g of the fungicide PCNB (pentachloronitrobenzene) per 3 kg of seed. The number of stem borer life stages per ten plants and the number of dead plants/m were counted in all replicates six times during the season. The initial and final stand of plants and yield were adjusted in all treatment to m^2 and 49 m^2 values.

RESULTS

The analysis covers three main areas: 1. the phenology of stem borer and the development of a simple method for estimating stem borer densities; 2. analysis of the effect of time of planting (t), of seed treatment with insecticide (T) and of plant survival (S) on yields (Y); 3. estimates of the economic loss due to stem borer damage to cotton and development of control recommendations.

Phenology of stem borer

Data on the phenology of stem borer adults, larvae and pupae are shown in Fig. 1. The end of the first generation is seen in the data as a drop in stem borer larval and adult numbers thirty days after the beginning of the infestation. Stem borer populations increased linearly thereafter. The phenology of the infestation depicted in Fig. 1 can be accepted with reasonable certainty, as such pattern in insects once triggered by some event (e.g., planting in this case) are fairly regular (Huffaker 1982).

An accurate and easy to use presence-absence sampling rule for estimating stem borer larvae and pupae is shown in Fig. 2. To use this rule, 100 plants should be examined at random, and the proportion of infested plants determined. This value is then used as the y-value in the regression equation $Y = 0.607M$ (r - 0.953) to predict the mean number (M) of stem borer per plant. This methodology is summarized by Wilson & Room (1983).

Within field distribution and dispersal

Data on the number of plants killed by stem borer before day 90 and 27 days later are summarized in Fig. 3A, B. The vegetation surrounding the field is depicted in Fig. 3C. The times of these surveys are depicted in Fig. 1 as the two upward arrows labeled E_1 and E_2, respectively.

As expected, the initial pattern of infestation of stem borer in the field as measured by the number of dead plants was highest in the border areas, especially at the eastern end near water and permanent ground cover. The greatest number of dead plants 27 days later also occurred where the initial infestations had been highest. All dead plants had been removed after the first survey, hence the results of the second survey depicts the subsequent pattern of plant mortality. Unfortunately the within field pattern of dispersal of the pest cannot be predicted with any degree of precision, but this may not be important in practice, as shown below.

Analysis of the time of planting x seed treatment experiment.

In this analysis, time t_1 is the beginning of the stem borer infestation, and t_2, t_3 and t_4 are the times spaced nine to ten day intervals later. These times are also indicated in Fig. 1 by the downward arrows. The t_4 experiments started after most of the overwintered beetles had entered the field. The analysis of variance statistics are presented in Table 1.

Yield differences between planting times were close but not significantly different at the 5% level,

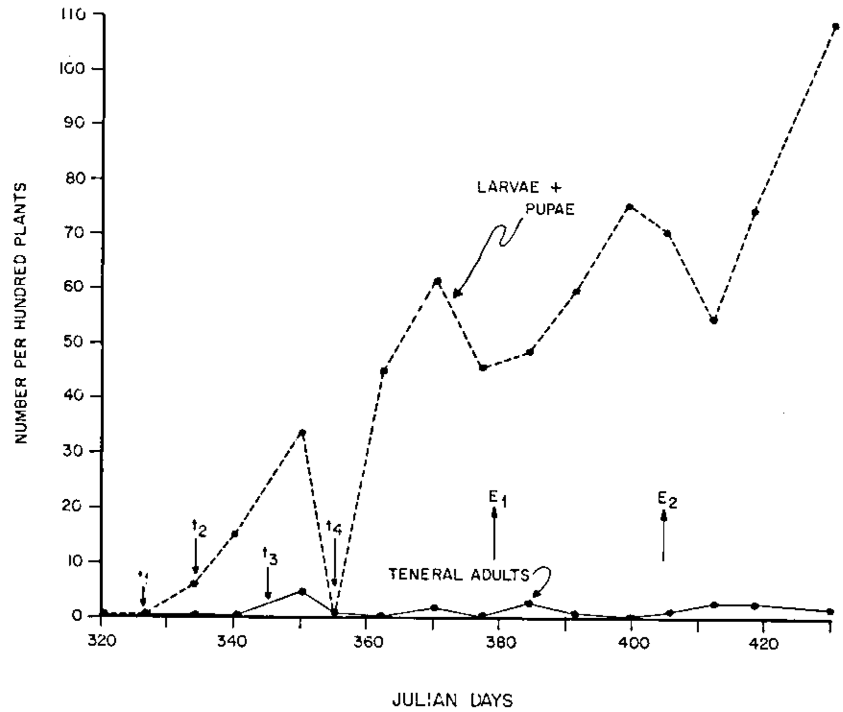

FIG. 1. The phenology of the cotton stem borer during the 1982-83 cotton season at Londrina, PR, Brazil (cf., Pizzamiglio et al. 1989). The downward arrows labeled t_1, t_2, t_3 and t_4 are the times of the planting trials analyzed in Table 1, and the upward arrows (E_1 and E_2) indicate the times of samples taken to examine the within field distribution of stem borer (Fig. 3). These arrows indicates the times of the studies relative to the phenology of stem borer.

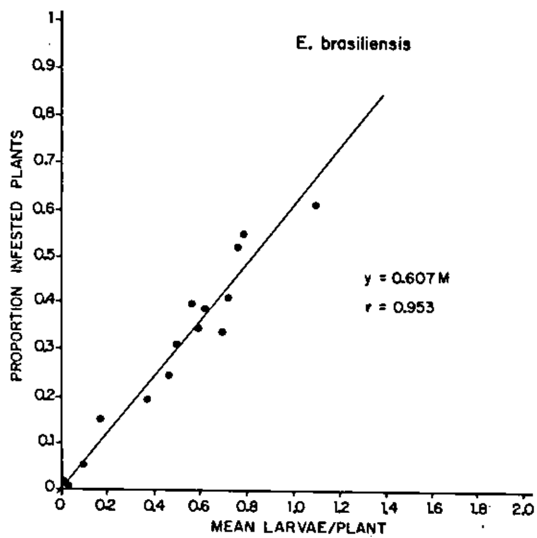

FIG. 2. The relationship between the proportion of infested plants and mean stem borer density (cf. Pizzamiglio et al. 1989).

suggesting a real effect due to planting time. The early and late planted treatments had the lowest yields, while the t_2 and t_3 treatments had similar yields. The plants in the t_1 plots suffered the highest rate of stem borer infestation, while the t_4 plots suffered little stem borer damage but experienced a 30-day shorter growing season. Yields in the seed treated plots were significantly higher than those in the untreated plots ($p < .01$) with an average across planting times loss of 494 kg of seed cotton in the untreated plots. These data are depicted in Fig. 4A. The t x T interaction was significant, showing that the losses due to a shorter season were compound by stem borer damage.

An analysis of the initial plant density showed that the t_1 treatment had significantly lower numbers of plants per meter of row ($t_1 < t_2 = t_3 = t_4$; $p < .05$). The number of surviving plants differed among times ($p < .01$, Fig. 4B) and between seed treatments ($p < 0.1$). The interaction of t x T was also significant ($p < .05$).

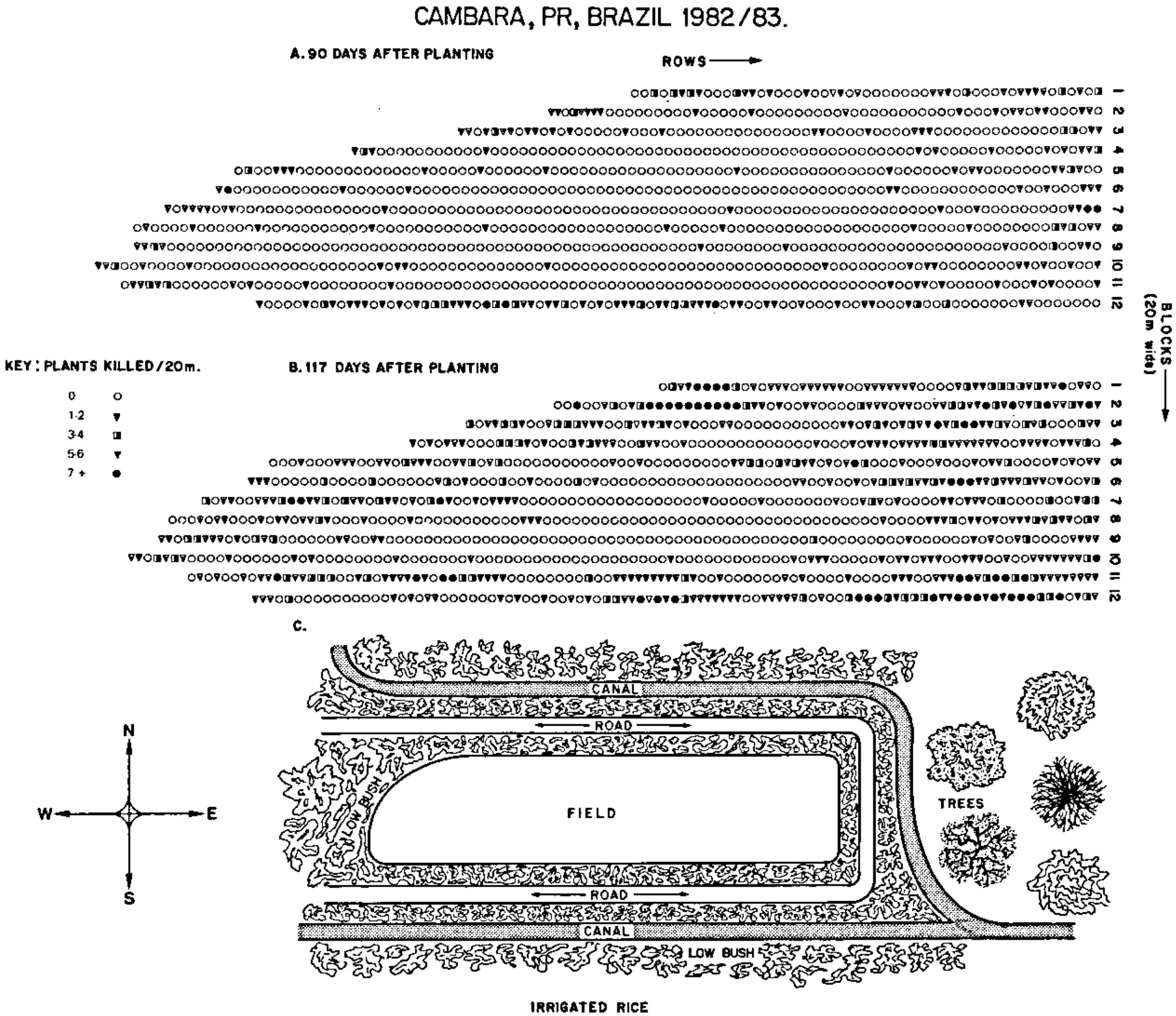

FIG. 3. The distribution of plants killed by stem borer per 20 meters of row across a two ha field at Cambará, PR, Brazil, during the 1983 season, 90 (A) and 117 (B) days after planting. The relationship of the vegetation surrounding the field is depicted in C.

TABLE 1. Analysis of variance of cotton yields, initial and final stand density

Factors	df	Yield	Initial Stand density	Final Stand density
Time	t: 3	3.66(*)	21.71**	47.84**
Insecticide	T: 1	29.56**	1.71	36.48**
t x T	: 3	3.99*	0.78	4.69*
Replicates	R: 3	2.74	0.17	2.30
t x R	: 9	1.54	1.73	1.64
T x R	: 3	1.78	0.71	1.45
t x T x R	: 9			
Total	:31			

(*) near p = .05.
* p < .05.
** p < .01.

Multiple regression analyses

The effects of the above factors plus the proportion of surviving plant on yield were examined using multiple regression (Table 2). Including all variables in the regression gave a highly significant regression ($p < .01$), but of questionable predictive value ($R^2 = 0.66$). Deleting initial density from the analysis reduced R^2 to 0.65, while the additional deletion of the proportion of surviving plants caused a further reduction to 0.64. The resulting regression (eqn. (1)) is presented below.

$$Y = 1422.2 + 0.0152t - 0.568T + 0.519S, \quad R^2 = 0.64, F = 16.7. \qquad (1)$$

Deleting any of the variables in (1) caused serious reductions in R^2. The following trends are clear: seed treatments (i.e., T = 1) enhanced yield by increasing plant survival; higher plant densities produced higher yields, suggesting that densities in the range of eight to ten plants per meter of row are more suitable.

The higher yields in t_2 and t_3 treatments occurred because the t_1 treatment acted as a trap crop for migrating stem borer adults, and because the initial and surviving plant densities were higher. However, simply planting cotton later does not solve the problem, as the attack of stem borer adults on cotton is delayed until the plants are 20-25 days of age. The

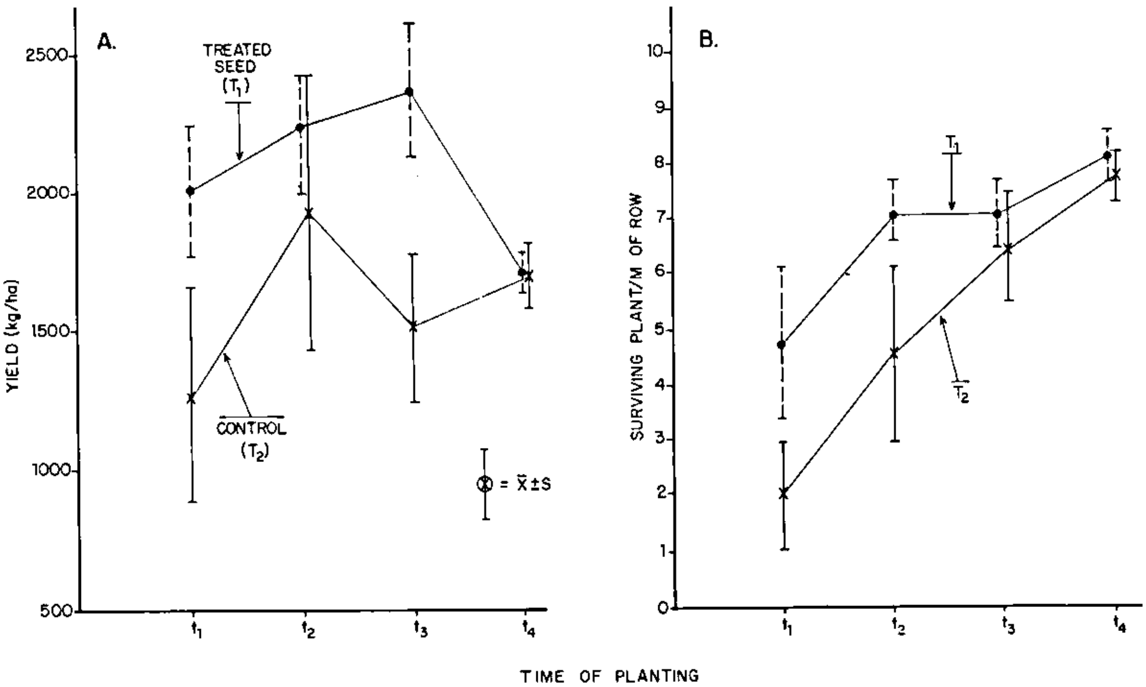

FIG. 4. Mean seed cotton yields and plant survivorship as a function of time of planting (t_i) and seed treatment (T_j).

TABLE 2. Multiple regression analysis of yields on time (t), seed treatment (T), plant survival (S), initial stand density (I) and the proportion of surviving plants (P).

Factors	R^2	F	Prob.	
t, T, S, I, P	0.66	9.88	$p < 0.01$	N = 32
t, T, S, I	0.65	12.39	$p < 0.01$	
t, T, S	0.64	16.68	$p < 0.01$	

yield losses due to delayed planting sufficient to avoid stem borer damage appear to be as great as that due to stem borer (t_1 versus t_4).

Analysis of the time of planting data

The cumulative numbers of stem borer life stages found per ten plants during the six sampling times in each of the eight t_1 plots are shown in Fig. 5. The highest stem borer populations developed in one of the seed treated plots, and the lowest population developed in one of the untreated plots. This apparent discrepancy arose because of the patchy initial distribution of stem borer among the within treatment replicates. The data show that seed treatment alone is insufficient to control stem borer population growth - it merely slows it. In general, the highest populations developed in the untreated plots. The yields in kg/ha are indicated at the end of each curve, and a cursory examination shows that yield is not directly related to stem borer density. This was verified for all four time trials using regression analysis.

A maximum yield of 2325 kg/ha observed in one of the t_1 plots is not uncommon in the NE part of Paraná. Despite the large average difference of 727 kg/ha (i.e., 2004 kg/ha versus 1277), yields in the seed treated t_1 plots were not significantly higher than those in the untreated plots ($F - 6.24$, $.05 < p < .10$). The difference is believably real, but was obscured by the high within treatment variation. The average 727 kg/ha net gain in the treated plots again demonstrates the accepted advantage of seed treatment for stem borer control.

Yields in the seed treated and untreated treatments were not significantly different in the t_2 and t_4 treatments, but were different in the t_3 treatment. A high degree of variability occurred in the t_2 plots due to patchy stem borer attack, while the absence of stem borer damage in the t_4 plots explains that lack of difference. The variation among the T_3 plots was low and significant losses due to stem borer damage was demonstrated.

The earlier planting times are likely to be the predominant ones in practice as a longer season allows surviving plants to compensate for other kinds of pest damage and some stem borer induced plant mortality. Integrated pest management strategies (IPM) to control stem borer must consider this fact. For this reason, further analysis on planting t_1 is focused.

Early season prediction of cotton yields (t_1 experiment)

The number of plants killed, the cumulative number of stem borer life stages and the number of plants surviving across seed treatment at various time in the season were regressed on end of season yields (Table 3). However, only the number of plants surviving (S) at the end of the season proved to be a good predictor of yield (Y; eqn. 2), and this occurred despite the fact that both initial and final densities varied considerably among replicates within seed treatments.

$$Y = 760.4 + 254.6S, r = 0.96, n = 6 \quad (2)$$

TABLE 3. Regression statistics of yield on factors affecting yield in the t_1 plots.

Factors	a	b	r
Surviving plants	760.9	254.5	0.958
Initial plant density	769.5	132.7	0.351
Cumulative dead plants	1984.6	-35.7	-0.717
Cumulative stem borer/ ten plants	1117.3	-76.2	-0.204

One plot had approximately half the number of plants as did the replicate with the highest density. The relationship shows that stem borer damage acts to reduce plant density, and in this manner reduces yields. The linear model (2) predicts a loss of 254 kg/ha of seed cotton per plant killed per meter of row across a ha. However, the model predicts that zero plant would yield 760 kg/ha of cotton, which of course is impossible. Thus, ($Y = 0, S = 0$) is a valid point, and a nonlinear model appears more suitable ((3), Fig. 6).

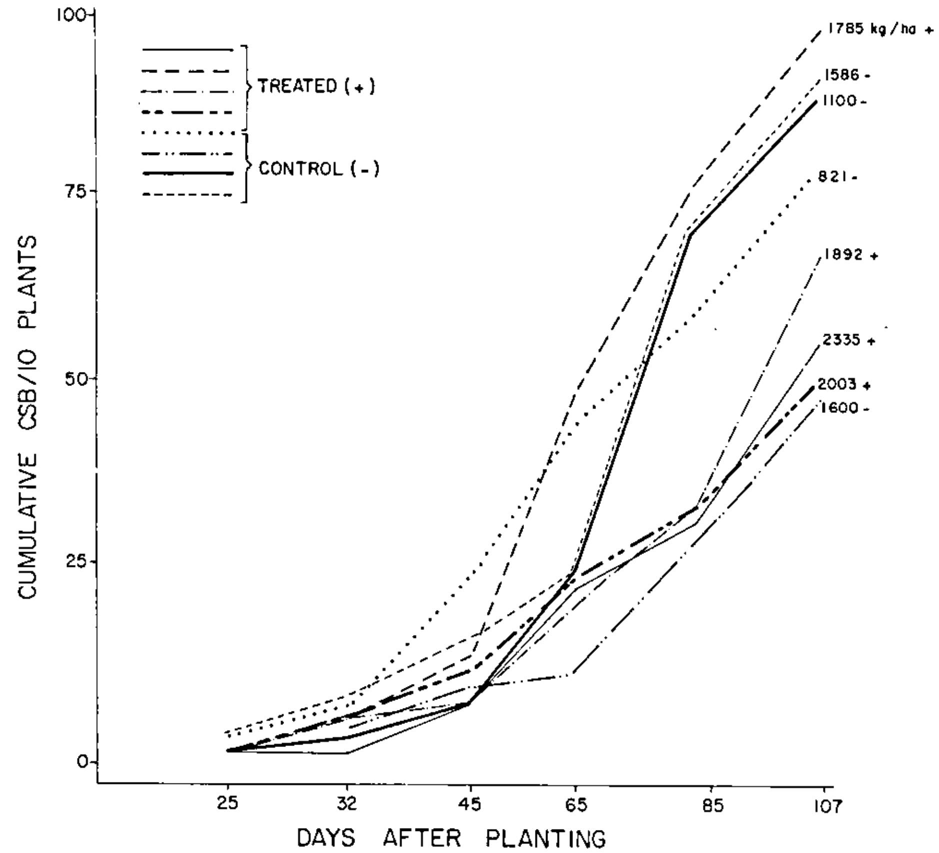

FIG. 5. The cumulative number of stem borer life stages observed over six sampling periods early planted cotton with (+) and without (-) seed treatment (t_1 experiment). Yields and treatments (+ or 0) are indicated at the end of each line.

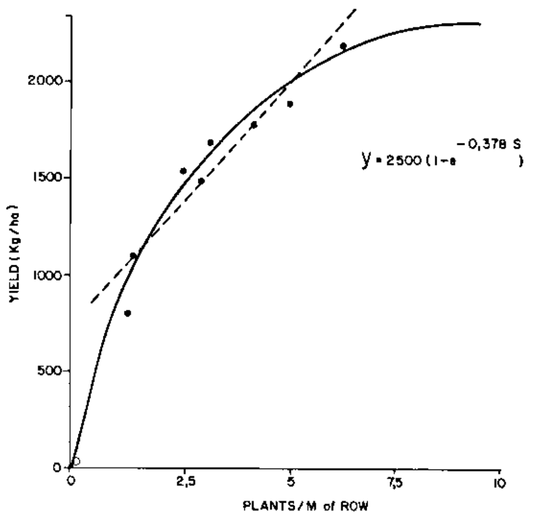

FIG. 6. Yield versus surviving plants per meter row of cotton in the early planting (t_1) x seed treatment experiments.

$$Y = 2500\,(1. - e^{-0.378S}) \quad (3)$$

The constant 2500 kg/ha is the assumed maximum yield for these plots, while the coefficient -0.378 was estimated by least squares. The loss rate per plant killed is lower at high plant densities and higher at low densities. This is further confirmation that higher plant densities are desirable.

All of the data for the four planting times are shown in Fig. 7. The slopes for the t_1 and t_2 yield data on surviving plant density are very similar; that for the t_3 treatment is quite steep and that for t_4 is not significantly different from zero. A ten day planting delay produced ca. the same rate of yield per surviving plant, but a further ten day delay caused the loss rate per plant killed to be ca. 2.5 fold greater. This latter result accrued because the shorter season did not allow the surviving plants to compensate for plants killed by stem borer. The variation in yield and surviving plants and stem borer pressure was low in the t_4 treatment because of the low infestation rate, hence the effects of stem borer on yield during this time period could not be assessed.

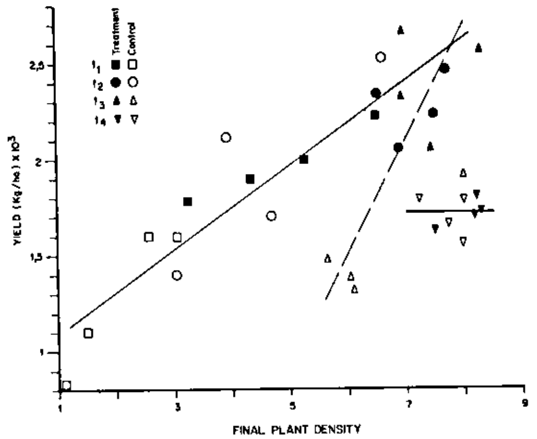

FIG. 7. Yield versus surviving plants per meter row of cotton for all planting times x seed treatment experiments. The open symbols are the untreated control replicates.

An economic evaluation

In a classical integrated pest management project, one would attempt to determine the economic injury level of the pest during the early season, and based on this make control recommendations. A reasonable, significant regression (4) was found between the number of plants killed (S_m) and the sum of the number (N) of stem borer life stages per meter of row of plants ten and twenty days after the infestation began (i.e., ca. 35 and 45 days after planting).

$$S_m = 0.393 + 0.777\,N,\ r^2 = 0.626,\ P < .05 \quad (4)$$

The intercept of (4) is not significantly different from zero, hence the regression forced through the intercept was accepted as the approximation shown in the present work.

$$S_m = 0.867N \quad (5)$$

To predict the number of S_m, stem borer densities must first be estimated using the sampling rule (1) or some other similarly accurate method. Next, the number of surviving plants computed as the difference between the initial stand density and the number killed (i.e., $S = S_I - S_M$). Over the relevant range of plants observed in this study (four to seven plants per meter of row), the linear model (2) may be used with confidence to estimate yield losses.

If a price of $ .22/kg of seed cotton is assumed, then on the average only 0.158 plants killed per meter of row across a ha would be sufficient to pay for a $ 10/ha insecticide treatment. The treatment costs compare poorly to the estimated $ 61.60/ha loss per plant killed per meter of row. The results are little affected by the fact that the predictive value of (4,5) are suspect, or the fact that stem borer populations normally have a very patchy distribution, and the damage is not uniform across the field.

DISCUSSION

Controlling stem borer in cotton is important (Parra 1972), but recommending field wide applications of pesticides specifically for stem borer may not be the best solution for the problem. Such treatments are likely to be ineffective because stem borer larvae burrow into the stem of the plant where the insecticide is not likely to reach them, and additionaly area wide treatments may induce outbreaks of other primary and secondary pest which may cause as much or more damage (Bosch 1978, Huffaker 1982). A preplant treatment of seed is still an important method for stem borer control, but as shown here it may not be sufficient.

To be most effective, the control recommendations should utilize full knowledge of stem borer behavior. During the early season the pest is found in the perimeter of the field, hence prophylactic treatments with insecticides of an early planted border row trap crops is recommended. Intensive pesticide applications on the trap crop area are economically justifiable and socially responsible. The use of area wide applications specifically for stem borer may not be justified, and would increase environmental degradation. The cotton boll weevil (*Anthonomus grandis* Boh.), which is expanding its range in Brazil, has a similar early season behavior, and trap cropping has long been a recommendation for its control.

Plant densities should be increased beyond the normally recommended six m commonly planted in the area studied. This change would help to minimize stem borer losses by decreasing the per-plant loss rate, and also increase the yield potential of the crop. Gutierrez et al. (1984) showed, using simulation studies of pest free IAC-17 cotton, that yields were directly related to plant density, with maximum yield predicted in the range of nine to ten plants per meter of row.

Lastly, pest free cotton is an ideal, but not a practical reality. The increasing public awareness of the negative health and environmental effects of pesticides has provided a strong stimulus for seeking safer pest control strategies. Regev (1984) and Bosch (1978) suggest that pesticide costs should be regulated with increasing penalties if growers can not regulate pesticide use in their own best interest and in society's interests. Hopefully, the recommendations made here will help brazilian cotton growers affected by stem borer to avoid pesticide abuse and maximize profits.

CONCLUSIONS

1. Cotton stem borer (*Eutinobothrus brasiliensis*) damage showed a graded distribution. It was considerably higher (9 times) in the border areas than in the center of the cotton.

2. Early planted cotton had the highest rates of infestation, often reaching a 70% plant mortality. In later plantings a 20% reduction in plant mortality was observed every time planting was delayed for ten days.

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