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SCREENING NEW SUGAR-CANE VARIETIES FOR RESISTANCE TO MOTH BORER: THE POSSIBLE EFFECTS OF ENVIRONMENTAL CONDITIONS ON VARIETAL RESISTANCE AND THE NEED FOR AN IPM APPROACH

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ABSTRACT

Twenty-one new and three commercial sugar-cane varieties were screened for posssible resistance to the sugar-cane moth borer *Diatraea saccharalis* at four different sites. Varietal resistance was evaluated using percentage dead hearts in young canes and percentage joint infestation in millable canes. Variety rankings according to both indices of infestation were site specific and in the case of dead heart rankings, time specific. These results are discussed in the context of the impact of environmental factors on varietal resistance and the need for an integrated pest management (IPM) approach to the management of the pest in Barbados.

INTRODUCTION

The moth borer *Diatraea saccharalis* (F.)(Lepidoptera: Pyralidae) is a major pest of sugar cane in Barbados. The borer deposits her eggs on cane leaves and after hatching the larvae burrow into the stems, sometimes gaining entry through the bud primordia, where they complete their life cycle. Detailed descriptions of the insect and its life history are provided by Ingram and Bynum (1941), Fennah (1947), Mathes and Charpentier (1969) and Schmutterer (1990). The pest causes significant losses in yield by the destruction of stem tissue, a reduction in the sucrose content of remaining tissue and by the effect of secondary infections by pathogens such as the fungus *Glomerella tucumanensis* (Speg.) Arx and Muller, the causal organism of red rot disease (Metcalfe 1969, Mathes and Charpentier,1969). In young cane larvae can destroy the growing points causing the leaf spindles to die and become dead hearts.

Biological control, involving the mass rearing and release of a number of parasitoid species the most important of which are the larval parasitoids *Cotesia flavipes* (Cam.)(Hymenoptera: Braconidae) and *Lixophaga diatraeae* Tns. (Diptera: Tachinidae), has been used in Barbados since the 1920s to reduce the pest populations to acceptable levels. In spite of this, increases in the level of moth borer infestation beyond the accepted economic threshold level of 5% of millable joints bored occur from time to time.

Sugar-cane varieties differ in their intrinsic resistance to the pest, this being due to certain physical characteristics which render the plant unattractive for egg deposition and unfavourable for the establishment of larvae and their development to adults (Mathes and Charpentier, 1969; Coburn and Hensley, 1971). Characteristics which confer resistance, e.g stalk thickness, degree of trashing and rind hardness, tend to be environmentally variable, so that variety resistance to the pest may be affected by environmental factors.

Varietal resistance is a vital component of an integrated pest management approach through its impact on both the population levels of the pest and the efficiency of biological control. Studies in Louisiana, USA by Bessin et al. (1990) showed that although varietal resistance contributed only 24% of the control of plant injury, it supplied more than 40% of the suppression of moth emergence. Moderate levels of varietal resistance substantially reduced sugar-cane borer emergence suggesting that the impact of susceptible varieties on borer populations may be mitigated if they are dispersed among varieties with greater resistance. Citing van Emden (1966) and Bessin et al. (1990) added that it has been shown mathematically that even low levels of resistance can have profound effects on the efficiency of natural enemies.

In order to minimize the effect of moth borer on future crop yields, a more integrated approach to the management of the pest is required in Barbados. To this end resistance screening of new varieties to moth borer has recently been introduced into the sugar-cane variety evaluation and selection programme. This paper reviews the preliminary results of the screening of the first series of new varieties (B88/89) to moth borer infestation and the possible impact of the environment on the expression of resistance and on pest population levels.

METHODS

Screening was carried out in trials established by the Agronomy Research and Variety Testing Unit to evaluate 21 new varieties against three commercial standards – B62163, B74541 and B80689 – for yield and quality. The varieties were planted during October and November 1993 according to a randomized complete block design at four sites: Constant, St George; Ridge, Christ Church; Todds, St John and Three Houses, St Phillip. The first two sites are in intermediate rainfall areas while the latter two are in high and low rainfall areas, respectively. Plots comprised six rows 7.6 m long and each plot was replicated three times with a plant density of 10–12 plants per plot row.

Monitoring of moth borer dead heart infestation began in March 1994 and was repeated monthly until October 1994. Percentage dead hearts were determined for each variety plot by computing the total number of tillers with dead hearts as a percentage of the total number of tillers recorded from five randomly selected plants. The trials were harvested in March 1995 at which time stalks were surveyed for joint infestation determined as the proportion of joints bored expressed as a percentage of all joints. A randomly selected sample of ten canes from each variety plot was used for this estimate of joint infestation.

Varietal differences for dead heart and joint infestation were determined using Analysis of Variance (ANOVA). Where there were significant differences, Tukey's Test was used to determine which of the new varieties were different from the standards. Separate analyses were done on individual monthly dead heart data combined over locations. The varieties were ranked on a scale of 1 to 24 (1 being the lowest infestation level) according to their mean dead heart infestation at each site in each month from May to October 1994. A similar ranking was performed on joint infestation data from each site. Kendall's Coefficient of Concordance (Zar 1984) was used to determine whether there was agreement between: (i) the monthly ranks based on dead hearts at each site; (ii) the site ranks for dead hearts in each month; (iii) the site ranks based on joint infestation.

Varietal resistance as indicated by the two indices of infestation were compared by Spearman's Rank Correlation analysis using rankings based on mean joint infestation over all sites and mean dead heart infestation levels over all sites and months.

RESULTS AND DISCUSSION

Variety resistance screening

In the early stages of growth, i.e up to April (6 months of age), there were very low levels of infestation and no significant differences in percentage dead hearts were found among the varieties (Table 1). As a result, data for March and April were not used in further analyses. According to Fuentes et al. (1983), the optimum plant age in sugar cane for carrying out assessment for resistance to moth borer is 9 months. However, in this study significant varietal differences in percent dead hearts appeared from 7 months onwards. The significant differences were between new varieties and not between new and standard varieties, the exception being during June when three varieties (B89452, B89593 and B89712) had significantly lower levels of infestation than the B62163 standard.

Table 1 Variance ratios (F) of the dead heart infestation levels for varieties and sites over the period March to October 1994

Month	Variety $F_{23,184}$	Site $F_{3,8}$
March	1.03 NS	5.49 *
April	0.62 NS	1.43 NS
May	1.71 *	5.59 *
June	3.71 ***	32.98 ***
July	4.09***	19.66 ***
August	3.03 ***	2.70 NS
September	3.27 ***	8.82 ***
October	3.74 ***	10.34 **

*, ** and *** refer to significance at the 5, 1 and 0.1 percent levels
NS – no significant difference

Barbados experienced a severe drought during March to August 1994 (Hudson, 1994) which impacted on the growth of the young canes reducing the rate of stalk elongation and suppressing tiller production. The individual varieties would have varying tolerances to this stress which may be linked to the significant differences in the degree of dead heart infestation found during some months.

The joint infestation levels indicated varietal variablity at each site and differences in the degree of resistance of each variety between sites. However, the analysis of variance of percent joint infestation showed that the varietal differences observed were not significant ($F_{23,184}$ = 1.14, P>0.05). Therefore, the new varieties have statistically the same level of 'resistance/susceptibility' to borer attack as the present major commercial varieties. When these results are compared with the varietal differences in dead heart infestation, they suggest that there is greater genetic variabilty in the physical traits that confer resistance to the establishment of the borer in young canes than those which offer resistance to stalk penetration and larval development in older canes.

The variety ranks for dead heart infestation levels at each site in each month from May to October are listed in Table 2. Comparisons of the rankings between months at each site and between sites at each month using Kendall's Coefficient of Concordance showed that there was no agreement between the various rankings (P >0.05). The rankings based on joint infestation levels, which are given in Table 3, also showed no agreement between the four sites. These results indicate that varietal resistance to both dead heart and joint infestation varies from place to place and, in the case of dead heart infestation, with time.

Table 2 Variety rankings of dead heart infestation levels on a scale of 1 to 24 (1 being lowest infestation) at four sites over the period May to October 1994

Variety	No.	1	2	3	4	1	2	3	4	1	2	3	4
		May				June				July			
B881602	1	3.5	6	18	5	7	3	6	10.5	18	6	2	7
B881603	2	7	24	11	15	16.5	18	10	24	1	10	17	15
B881607	3	10	5	6	3	1	4	17	5.5	4	5	5	3
B881686	4	21.5	17	9	13	18.5	12	4	19	15	16	15	20
B881911	5	6	4	17	2	21	6	15	4	14	22	10	16
B8930	6	12	12	15	16	12	16	11	15	7	14	6	9
B8931	7	19	21	24	22	16.5	19	22	22	16	15	24	19
B89132	8	17	10.5	21	7.5	10	8	9	17.5	24	12	16	24
B89447	9	11	8.5	10	14	8.5	15	12	3	8	9	13	4
B89452	10	20	7	7	1	3	1	3	12	5	3	3	2
B89491	11	16	15	16	19	18.5	24	23	21	6	21	20	21

B89529	12	15	8.5	12	9	13	20	20	2	10	13	4	18
B89570	13	18	1.5	1.5	10	14	14	14	5.5	13	17	18	8
B89594	14	3.5	18	4.5	21	11	23	24	14	23	20	23	12
B89577	15	21.5	14	4.5	17.5	24	5	5	9	11	2	7	6
B89591	16	8.5	21	8	11	22	9.5	8	1	22	8	11	5
B89593	17	13.5	1.5	3	6	5	2	7	8	2	4	8	10
B89640	18	3.5	13	22	12	6	11	18	16	19	18	12	17
B89708	19	24	19.5	14	23	4	17	13	23	17	23	22	23
B89712	20	1	3	1.5	7.5	2	9.5	2	7	3	1	1	14
B90666	21	3.5	10.5	13	20	20	13	16	13	9	7	19	1
B62163	22	23	23	19	17.5	23	21.5	1	17.5	20	24	14	11
B74541	23	8.5	16	20	24	15	7	21	20	12	11	9	13
B80689	24	13.5	19.5	23	4	8.5	21.5	19	10.5	21	19	21	22

		August				September				October			
B881602	1	17	9	1	10	16	6	4	9	11	3	9.5	14
B881603	2	5	10	18	13.5	7	7	10.5	6	17	18	13	15
B881607	3	1	12	2	16	3.5	3	18	5	9.5	4	12	10
B881686	4	10	19	16	15	22	14	20	12	24	12	16	17.5
B881911	5	18	15	17	6	17.5	5	15	4	21	6	21.5	12
B8930	6	6	11	9	19	11	19	19	16	3	16	3	16
B8931	7	24	17	23	11	23	17	21	23	16	19	16	23
B89132	8	14	5	6.5	13.5	19	8	3	18.5	18	8	20	22
B89447	9	21	8	10	7.5	12	13	9	17	22	15	5	9
B89452	10	8	2	21	12	1	1	5	3	2	1	14	5
B89491	11	9	21	22	24	10	20	17	24	20	24	23	24
B89529	12	22	22	12	17.5	24	21	22	22	8	20	8	17.5
B89570	13	13	17	3	7.5	5	23	2	2	14	14	6	1
B89574	14	19	23	24	17.5	17.5	12	23	13.5	15	23	21.5	20.5
B89577	15	11	6	5	5	3.5	2	6	21	13	5	1	8
B89591	16	12	4	6.5	1	9	11	14	10	1	9.5	18	6
B89593	17	3	1	14	9	8	10	24	15	6.5	2	19	19
B89640	18	20	14	11	21	21	22	10.5	20	23	11	16	20.5
B89708	19	15.5	20	8	23	20	24	7	19	19	17	4	7
B89712	20	2	3	4	4	2	4	13	13.5	12	9.5	7	3
B90666	21	23	13	14	2.5	6	9	16	1	6.5	13	9.5	11
B62163	22	7	24	20	2.5	14	15	8	8	4	21.5	11	13
B63118	23	4	7	14	20	13	16	1	18.5	5	7	2	2
B806896	24	15.5	17	19	22	15	18	12	11	9.5	21.5	24	4

Constant (1), Ridge (2), Three Houses (3) and Todds (4)

Table 3 Variety rankings of joint infestation levels on a scale of 1 to 24 (1 being lowest infestation) at four sites

Variety	Variety number	Ranking			
		Constant	Ridge	Three Houses	Todds
B881602	1	16	6	4	12
B881603	2	3.5	17.5	7	6.5
B881607	3	10.5	8	1	10
B881686	4	5.5	16	10	8
B881911	5	7	3	16	3
B8930	6	1	9	18	1
B8931	7	3.5	14.5	24	14
B89132	8	22.5	14.5	6	21
B89447	9	12	13	3	9
B89452	10	24	22	14	14
B89491	11	5.5	5	9	19
B89529	12	10.5	4	13	16
B89570	13	19	17.5	21	4
B89574	14	22.5	7	23	20
B89577	15	13.5	21	11.5	22
B89591	16	9	24	5	17
B89593	17	15	23	2	24
B89640	18	21	19	17	18
B89708	19	2	2	19	2
B89712	20	20	20	20	5
B90666	21	13.5	10	15	23
B62163*	22	8	1	11.5	14
B74541*	23	17	12	22	6.5
B80689*	24	18	11	8	11

* Commercial standards

The difference in rankings at the various sites for both indices of infestation suggest a possible environmental impact on the mechanisms that confer resistance. The variation over time may be linked to differential growth rates among varieties and thus differences in the time at which joint infestation takes over. Once joints are present on the stems larvae would more likely feed and develop in lower stem tissue thus reducing the incidence of dead hearts.

The variety means for dead heart infestation over all sites and months and joint infestation over all sites as well as their individual rankings are given in Table 4. When the two rankings were compared by Spearman's Rank Correlation Analysis, they were not found to be associated (r_s = -0.036, P>0.05). This may be due to the different resistance mechanisms that contribute to the two indices of infestation. Dead heart infestation levels indicate the presence of larvae whereas joint infestation levels also address their successful development to adults.

Table 4 Mean variety infestation levels and their rankings

I. Variety	Variety number	Mean % dead hearts	Variety rank	Mean % joint infest.	Variety rank
B881602	1	4.3	2	13.3	3.5
B881603	2	8.3	20	13.5	6
B881607	3	8.0	17	12.2	1
B881686	4	8.1	18	14.3	9
B881911	5	6.6	12	13.3	3.5
B8930	6	5.0	4	13.9	8
B8931	7	6.7	13	17.1	19
B89132	8	5.1	5	16.2	13.5
B89447	9	4.9	3	13.1	2
B89452	10	3.8	1	18.2	23
B89491	11	7.0	15	14.6	10
B89529	12	5.7	9	14.9	11
B89570	13	5.2	6	16.9	15.5
B89574	14	8.6	21.5	18.6	24
B89577	15	5.3	7.5	17.6	21
B89591	16	5.5	10	16.2	13.5
B89593	17	5.3	7.5	17.6	21
B89640	18	7.2	16	17.7	22
B89708	19	8.2	19	13.4	5
B89712	20	5.8	11	16.9	15.5
B90666	21	6.8	14	17.0	17.5
B62163*	22	9.0	24	13.8	7
B74541*	23	8.6	21.5	17.0	17.5
B80689*	24	8.8	23	15.2	12

* Commercial standards

The variation in the degree of varietal plant resistance observed at different times and sites suggests that plant resistance screening to moth borer needs to carried out over many crops (years) and over as wide a range of climatically and topographically different areas as possible before final resistance ratings can be achieved.

Moth borer population dynamics

Significant differences were found between the mean dead heart infestation levels at the four sites during most months (Table 1), but these differences were not the same each month. The monthly mean percent dead heart infestation for each site and the rainfall for the corresponding period are shown in Figure 1. All sites showed a sigmoidal pattern in the incidence of dead hearts with rapid increases occuring during the drought period April to August. During this period joint elongation was considerably slowed which may exaggerate the incidence of dead hearts since there is less joint tissue available for larvae to migrate and establish. On the other hand, these increases may not be due entirely to the increasing population growth of the pest since it is possible that the suppression of tiller growth by the drought conditions would result in reduced tiller numbers and hence exaggerate the percent dead hearts found.

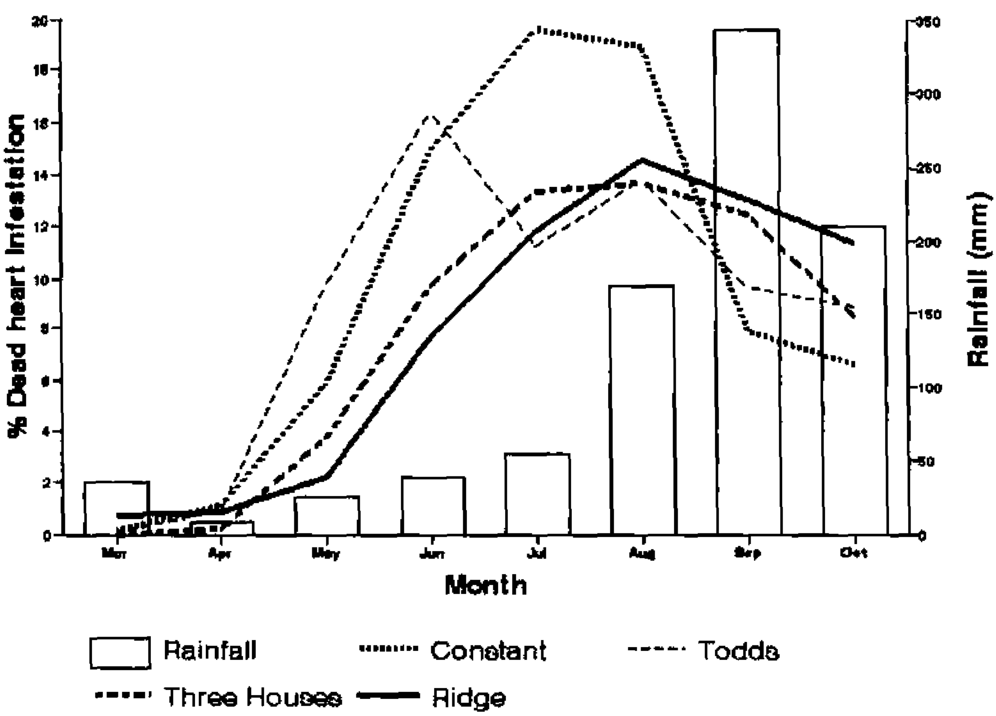

Figure 1 The progression of dead heart infestation at four sites over the period March to October and the corresponding average rainfall for the period

The analysis of variance for joint infestation also showed significant differences between the four sites ($F3_{,8}$= 178.34, P<0.001). Three Houses and Todds had significantly higher levels of infestation (28.6 and 16.2% respectively) from each other and from Constant and Ridge which were not significantly different (6.7 and 10.5% respectively).

The levels of joint infestation found at the four sites are of concern since they all exceed the accepted economic threshold level of 5%. It is hoped that these high levels of joint infestation are just as anomalous as the rainfall conditions under which the cane grew in 1994 and that the two factors are somehow inter-related.

The potential of resistant sugar cane cultivars for reducing sugar cane borer damage is well established (White and Hensley, 1987 citing Hensley and Long, 1969) but the techniques to identify resistance are difficult to develop due to the complex nature of the relationship between the crop and the pest. In addition to the search for pest resistant varieties, the existing biological control programme for moth borer is currently being stengthened by the re-introduction of mass breeding and release of its larval parasitoid *Cotesia flavipes*.

This research is ongoing and will be continued on successive ratoon crops of the trials. At its conclusion a clearer picture of the interactions between the pest and the varieties should emerge. Based on the results, an integrated pest management (IPM) programme for sugar-cane moth borer in Barbados could then be developed, the core components of which would be biological control and site specific varietal resistance.

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