SCREENING SUGARCANE VARIETIES FOR RESISTANCE TO ELDANA BORER

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Abstract

Sugarcane varieties selected to the final selection stages were planted routinely in drums for screening for resistance to eldana borer. When the cane stalks had four to six internodes, the cane was stressed by withholding water for four weeks after which it was inoculated with eldana eggs. The trials were harvested and eldana numbers and mass were recorded. Eldana occurs naturally in some selection (field) trials with the same varieties. The results from all trials were variable, with high coefficients of variation and low to moderate F-values. The coefficients of correlation between results from the drums and the field were also variable, some being very small and others highly significant. About 76% of the clones showed an intermediate and resistant reaction to eldana. The screening trials serve a useful purpose in indicating the response of eldana to the different varieties.

Introduction

In the sugarcane breeding programme at Mount Edgecombe 12 to 18 years are required to produce a new variety. More than 130 000 new genotypes are planted annually in a five stage selection programme. Selection criteria include sucrose yield, agronomic traits, disease resistance and resistance to *Eldana saccharina* Walker.

Eldana is a serious pest of sugarcane in South Africa and resistance is thus an important selection criterion. Varieties reaching the later stages of selection are planted in drums and inoculated with eldana eggs, because eldana does not occur consistently at all selection sites. Screening procedures were described by Nuss and Atkinson (1983) but have since been improved. Moreover eldana has spread to other areas of the sugar industry. This paper discusses the results of routine screening trials and compares results with those obtained in field trials.

Methods

Varieties

In both 1985 and 1986, about 25 varieties which had reached the Secondary Variety Trial stage (VT2) at the long season sites, CFS (L), Mtunzini (M) and Midlands (H), and about 25 varieties which had reached the same stage at the short season sites, Experiment Station (E) and Shakaskraal (W), were planted in the screening trials in drums (TID) annually, in spring and autumn, respectively. At least six control varieties were included in each trial. The regular controls are N11 (susceptible), NCo376 (intermediate) and N12 (moderately resistant). From 1987, varieties reaching the VT2 stage at the irrigated site, Pongola (F), were planted in a separate series of TIDs in autumn, while varieties reaching the Primary Variety Trial (VT1) stage at E (25 varieties) and W (30 varieties), were planted annually in TIDs in autumn. Varieties reaching the VT1 stage at H (15), L (30) and M (30) were planted annually in TIDs in spring. These VT1 trials included only the standard controls N11, N12 and NCo376.

Trials in Drums (TID)

Five plants, each grown from a single-budded sett, were established in 20 l drums filled with river sand. Drip irrigation was applied daily, and 9 g of 5.1.5 (45) fertilizer per drum were applied monthly. Trials done with VT1 varieties were planted in four replications, and those with VT2 varieties in eight replications, each drum representing a plot.

The TIDs grew on open terraces and, once the stalks had four to six mature internodes, the drums were placed in shade tents with plastic roofs. The cane plants were stressed by withholding water until there were only three to four green leaves per stalk. After four weeks of stress, the plants were inoculated with laboratory-reared eldana eggs. About 100 eggs were placed on one or two stalks in each drum, between the leaf sheaths and stems. The sugarcane plants were kept in a stressed condition.

The trials were harvested four to six weeks (depending on seasonal temperature) after inoculation. Trash was then carefully removed and the stalks dissected. The following data were collected: number of stalks, number of internodes and number damaged, number and mass of eldana larvae and pupae.

Field Trials (FTs)

Field trials (FTs) were the standard selection trials in stages VTI and VT2, consisting of three replications. Eldana occurred at the M and W sites and at one irrigated site (Mhlume). The same varieties were established in FTs and TIDs, which facilitated the comparison of varietal reaction to artificial and natural infestation. When the FTs were harvested the damage due to eldana was ascertained by sampling 20 stalks per plot for the presence of eldana, and number of damaged stalks and internodes.

Analysis of data

The eldana data from TIDs is presented as number of eldana per drum (ENUM) and total biomass of eldana per drum (EMASS). The data from FTs is presented as % red internodes (%RI), % stalks damaged (%SDAM), or as number of eldana/100 stalks (E/100).

The survival and rate of growth of eldana in cane in slightly different environments was evaluated by keeping two replications on the terrace (E_1), placing another two replications in a shade tent (E_2), and the other two in a shade tent and stressing them (E_3). Eldana incidence was recorded in a FT at M with the same varieties, and the results were compared.

The trial means and F values from the analysis of variance of eldana data from 15 FTs and the corresponding TIDs are presented to indicate the degree to which the trials were successful in being able to detect differences among varieties. The degree of genetic determination can be obtained as F-1/F.

Coefficients of correlation (r) of eldana data from different crops in nine FTs were determined, as well as those between the values obtained in two VT1s and observation plots (OPs) – a selection stage prior to VT1. The correlation coefficients of eldana data between FTs and TIDs were also calculated.

Varieties in TIDs were rated resistant (2), intermediate (5) and susceptible (8), to eldana by reference to the average in each trial.

Results

Eldana performance in different environments

The survival and growth of eldana were greater in cane that was placed in a shade tent and stressed, than in cane left on the terrace or placed in the shade tent, but not stressed (Table 1). The F values were low, although marginally higher in the stressed treatment. The coefficient of variation (CV%) was high in all treatments, all values being 60% or more. A FT at M showed improved F values but the variation was still high. The correlation of eldana data in the FT and those of the mean of TID values were highly significant ($p \leq 0,01$).

Table 1

Means, correlations and statistical parameters of the effect of eldana on 25 varieties of sugarcane in three treatments in TIDs, and the incidence of eldana in a FT with the same varieties

Statistical parameter	Treatments in TID						FT at M	
	E_1 (outside no stress)		E_2 (in shade but no stress)		E_3 (inside stressed)			
	ENUM	EMASS	ENUM	EMASS	ENUM	EMASS	%SDAM	%RI
Mean	4,0	200	3,4	176	5,9	502	30,7	2,2
F value	1,0	1,1	1,1	1,5	1,6	1,9	3,4	3,7
SE (±)	2,3	156	2,3	124	2,9	282	13,3	1,2
CV (%)	79	95	85	88	60	97	53	66
r ENUM ($\overline{X}$ $E_1 - E_3$)							0,52**	0,56**
R EMASS ($\overline{X}$ $E_1 = E_3$)							0,58**	0,61**

** Significant at the 1% level

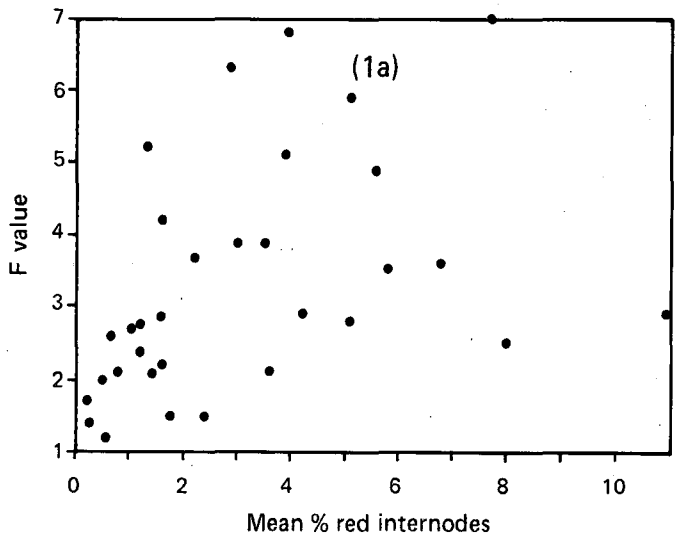

FIGURE 1a Mean red internodes (%RI) vs F value.

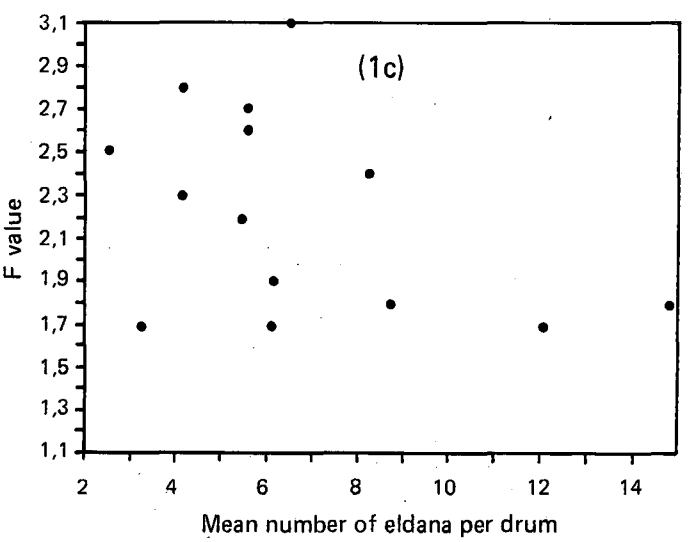

FIGURE 1c Mean number of eldana per drum (ENUM) vs F value.

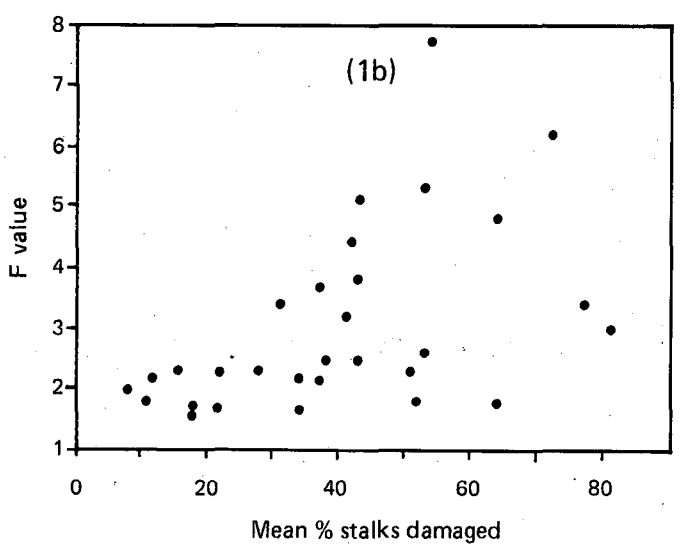

FIGURE 1b Mean % stalks damaged (%SDAM) vs F value.

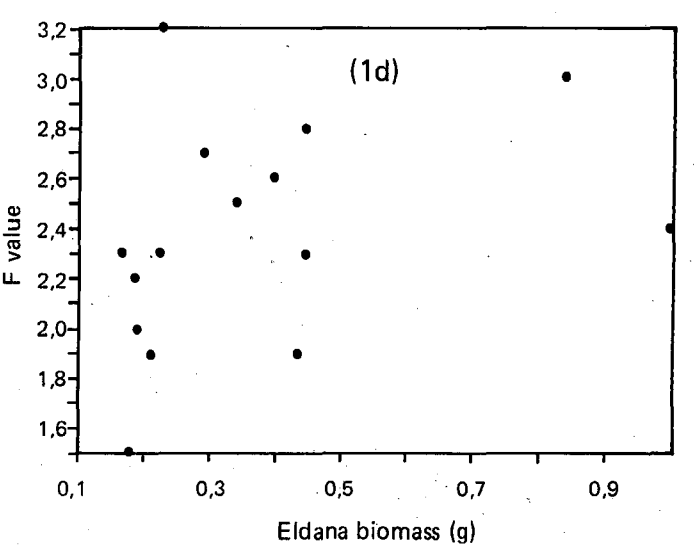

FIGURE 1d Eldana biomass (EMASS) vs F value.

Means and F values

The means of eldana data from 15 FTs in one to three crops each and 15 TIDs were compared to the F values in each trial (Fig 1). The F values of less than two occurred only at low levels of %RI and there was little association between the two parameters (Fig 1a). The F values for %SDAM were lower than those for %RI and low over a wide range of values of %SDAM. The F values for the two traits in TIDs were lower than those in FTs (Figs 1c, 1d). ENUM varied widely and F values did not appear to be related to the variation.

Correlations among FTs and TIDs

The coefficients of correlation of eldana traits in the same trial, but in different crops, were almost all significant (Table 2, Trials 1 to 8). The mean correlation coefficient for the nine comparisons was 0,61 ($p \leq 0,01$) ± 0,116. The correlations of eldana values between different selection trials, OP to VT1, were lower; the mean was 0,27 ± 0,089. (This is to be expected because, from OP, a selected group only were planted in VT1.)

Table 2

Coefficients of correlation of eldana incidence in successive crops in variety and observation trials

Trial No	Selection stages (1)	No of varieties	Comparison (2)	Coefficient of correlation
1	VT2	27	P - R1	0,61**
2	VT2	22	P - R2	0,37
3	VT2	25	P - R1	0,71**
4	VT2	25	PS - P	0,76**
5	VT2	28	PS - R1	0,66*
			P - R1	0,70**
6	VT2	22	PS - P	0,64**
7	VT2	30	P - R1	0,48*
8	VT1	31	P - R1	0,56**
	OP to VT1		PVT1 OP E/100	0,35
			PVT1 OP %RI	0,23
			R1VT1 - OP E/100	0,15
			R1VT1 - OP % RI	0,22
9	OP to VT1	32	VT1 to OP	0,39

(1) VT1, VT2: Primary and Secondary Variety trials, respectively; OP = observation trial

(2) PS, P, R_1, R_2 = preharvest sample, plant cane, first ratoon, second ratoon crops respectively, in variety trial. E/100 = number of eldana/100 stalks, %RI = % red internodes

* Significant at the 5% level
** Significant at the 1% level

The coefficients of correlation of data from TIDs and FTs varied from as little as -0,17 per %RI and EMASS in Trial 8, to the highly significant r ($p \leq 0,01$) value of 0,63 of %RI and EMASS in Trial 2 (Table 3). The correlations were high in Trials 2, 3, 5 and 6 and very low in Trials 1, 7, 8 and 9. The overall mean correlation coefficient between field data and ENUM was 0,28 ± 0,195, and with EMASS it was 0,27 ± 0,166.

Resistance ratings

The combined result of resistance ratings of 713 test varieties in 19 screening trials is shown in Table 4. Thirty-four per cent of all the varieties were classified as resistant, and 47% of the varieties from M and 40% of those from L were similarly classified. Twenty-six per cent of the F varieties gained a rating of 2. Varieties from H were evidently more susceptible than those from the other sites; 36% were rated at 8, compared with 20% from M, 21% from W and 22% from L.

Table 3

Coefficients of correlation of eldana measures %RI and E/100 in FT, with EMASS and ENUM in TIDs

Trial No	No of varieties	Eldana traits in field trials	Crop+	Coefficients of correlation with	
				ENUM	EMASS
1	27	% RI in VT2	P	0,14	0,33
		% RI in VT2	R1	0,14	0,04
2	22	E/100 in VT2	P	0,54*	0,44
		% RI in VT2	R2	0,62**	0,63**
3	25	% RI in VT2	P	0,57**	0,55**
		% RI in VT2	R1	0,40	0,35
4	25	E/100 inVT2	PS	0,24	0,33
		% RI in VT2	P	0,23	0,27
		% RI in VT2	R1	0,05	0,15
5	28	% RI in VT2	P	0,41	0,51*
6	22	E/100 in VT2	PS	0,63**	0,32
		% RI in VT2	P	0,45	0,30
7	30	E/100 in VT2	P	0,06	0,20
		E/100 in VT2	R1	0,11	0,13
8	31	% RI in VT1	P	0,01	−0,17
		% RI in VT1	R1	0,30	0,32
		% RI in OP	P	0,20	0,20
		E/100 in OP	R	0,20	0,09
9	32	% RI in VT1	P	0,08	−0,06
		% RI in OP	P	0,20	0,30

\+ Crop: PS = Preharvest sample, P = plant cane, R1 = first ratoon, R2 = second ratoon

* Significant at the 5% level
** Significant at the 1% level

Table 4

Number of varieties in eldana screening trials, and proportions in ratings 2, 5 and 8

Source of varieties	No of varieties tested	% of varieties in rating		
		2	5	8
VT2 Dryland, long season	121	30	46	24
VT2 Dryland, short season	119	31	45	24
VT2 Irrigated	84	26	48	26
VT1 from E	77	30	39	31
VT1 from W	98	35	44	21
VT1 from L	93	40	38	22
VT1 from M	85	47	33	20
VT1 from H	36	33	31	36
Total/mean	713	34	42	24

Discussion

The long term solution to the eldana borer problem may lie in the release of resistant varieties. An earlier outbreak of the pest was short-lived, possibly because of the widespread use of a resistant variety, Co281 (Dick, 1950). The role of varietal resistance to eldana (Carnegie, 1974 and Nuss *et al.*, 1986) and *Diatraea saccharalis* in Louisiana has also been recognised (Hensley *et al.*, 1977). A screening procedure has been described for eldana (Nuss and Atkinson, 1983), for *Diatraea* (Reagan and Brenin, 1988; White *et al.*, 1989 and White and Fanguy, 1988) and for the Mexican rice borer (Ring and Browning, 1990). Screening trials to identify resistant varieties by inoculating sugarcane plants growing in drums were started in 1985 to ensure the assessment of varieties which would not otherwise be exposed to eldana, or to obtain additional results and gain more information regarding eldana infestations.

In the screening procedure described in this report, eldana eggs rather than newly emerged larvae were placed on cane plants to make use of any possible resistance factors in the plants that might affect the emergence and survival of the larvae. Unpublished work indicates strongly that larvae which survive for five days are likely to reach the adult stage.

The greater survival rate and faster growth of larvae in the stressed treatment E_3 confirms earlier work (Nuss and Atkinson, 1983, Nuss *et al.*, 1986, and Atkinson and Nuss, 1989), and therefore all TIDs are currently stressed to obtain a uniform and greater infestation and growth of larvae.

The small differences in environment imposed by treatments E_1, E_2 and E_3 caused noticeable differences in eldana survival and biomass. However, the coefficients of correlation with the eldana data from M were significant, indicating that screening trials as well as FTs could be used for testing eldana reaction to varieties, and that a comparable result could be expected.

The relationship of F values and eldana parameters %RI, %SDAM, EMASS and ENUM did not indicate improved statistical confidence with increased eldana incidence in field trials and the TIDs. The parameter %RI appears to discriminate more between varieties than %SDAM because of the greater F values for %RI. Variation were high in all trials, the mean coefficients of variation for the FTs being 50% (± 25,3) for %RI and 45% (± 23,6) for %SDAM. The CVs were greater in TIDs - 86% ± 14,4 for ENUM and 75% ± 8,4 for EMASS - but the standard errors were lower. Eldana values between trials were more variable in FTs than in TIDs, which were uniformly high. Greater emphasis is being placed on reducing the latter variation by the uniform establishment of TIDs with transplants, controlled water supply with drip lines and reduced water supply before inoculation to improve the survival and growth of larvae. Eldana values are, however, still variable, despite additional attention to ensure uniformity. Such variation, although smaller, is also present in screening trials with lettuce, where both the crop and the insect are reared in controlled conditions (Reinink and Dieleman, 1989).

The coefficients of correlation of eldana traits in TIDs with those in FTs were variable. In some trials, the correlations were significant and in others the values were very small. These values are similar to correlations of eldana values in different FTs, which varied from 0,15 to 0,39, and comparable with those obtained with *Diatraea* (White *et al.*, 1989 and White and Fanguy, 1988).

The proportion of varieties with a resistance rating to eldana of 2 was large, while a further 42% of the clones had an intermediate rating of 5 which is similar to that of variety NCo376. At all sites except M, this result was obtained without using eldana resistance as a criterion in the choice of parents. At M, parents were used which had been selected for their resistance to eldana. The variety N21, released because of its resistance to eldana, originated at E where no selection pressure for eldana resistance was imposed. The large proportion of clones with some resistance to eldana is probably due to the breeding strategy and the germplasm being used, which is variable and has a broad genetic base, with special emphasis being placed on hardiness.

Conclusion

Eldana data obtained from field trials and from trials in drums were variable but despite that, the coefficients of correlation between results from fields and drums were similar to those between different field trials.

The screening of varieties in drums ensures that late stage varieties from all selection sites are exposed to an infestation of eldana, and provides an additional result to those obtained from the field. A large proportion of varieties show a tolerant and resistant reaction to eldana, indicating that resistance to eldana is common in the local germplasm.

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