THE STATUS OF *ELDANA SACCHARINA* (LEPIDOPTERA: PYRALIDAE) IN THE SOUTH AFRICAN SUGAR INDUSTRY BASED ON REGULAR SURVEY DATA

GOEBEL F R[1], WAY M J[2] and GOSSARD C[3]

[1]*CIRAD-CA, Unité de recherche systèmes canniers, 34398 Montpellier, France*
regis.goebel@cirad.fr
[2]*SASRI, P/Bag X02, Mount Edgecombe, 4300, South Africa. mike.way@sugar.org.za*
[3]*ENITA Clermont-Ferrand, Site de Marmilhat- 63370 Lempdes, France*
christophe.gossard@wanadoo.fr

Abstract

Local Pest, Disease and Variety Control Committee (LPD&VCC) *Eldana saccharina* survey records from 2001 to 2003 were analysed to investigate the pest status of this stalk borer in the South African sugarcane industry. Percentage stalks damaged, percentage stalk length red and numbers of larvae per 100 stalks varied in different mill areas, thus confirming previously published patterns. Furthermore, damage levels were higher in the coastal than the inland regions. Higher levels of damage were correlated with older cane, and certain varieties suffered more damage than others. Infestations were lower in small-scale than commercial grower sectors. Higher levels of damage were associated with increased nitrogen applied to fields. An estimated economic injury level is given.

Keywords: sugarcane, *Eldana saccharina*, stalk borer, agricultural practices, economic injury level

Introduction

Since the early 1970s, *Eldana saccharina* Walker (Lepidoptera: Pyralidae) has persisted as the most injurious sugarcane pest in southern Africa. Borer damage remains a major production constraint in the coastal region of the South African sugar industry (Goebel and Way, 2003) causing an estimated R60 million/annum loss in revenue (Keeping, 1995).

Routine *E. saccharina* monitoring first started in 1982 at Amatikulu (Paxton, 1982), and now Local Pest, Disease and Variety Control Committees (LPD&VCCs) throughout the industry conduct regular surveys. Although the primary purpose of the surveys is to detect and harvest fields with excessive *E. saccharina* infestations (Mathew *et al*, 1990), it has been realised that during surveys additional information related to the borer is also recorded. The South African Sugarcane Research Institute (SASRI), which formerly provided mainly technical advice on borer control, therefore established more detailed investigations into agronomic factors that could affect *E. saccharina*.

Collaboration between SASRI and the Centre de Cooperation Internationale en Recherche Agronomique pour le Developpement (CIRAD) greatly furthered this effort, as shown by recent publications (Goebel and Way, 2003; Way and Goebel, 2003; Way *et al*, 2003; Gontier *et al*, 2003; Gossard, 2004).

Methods

E. saccharina surveys

The extent of the LPD&VCC survey effort for *E. saccharina* is summarised by Way (2004). During 2001 to 2003, between 1000 and 1500 surveys were completed in each mill region each year (Figure 1). Surveys covered about 14.7% of the total area (ha) planted to cane in South Africa. Some regions were surveyed more intensively than others, e.g. >35% of the cane planted at Pongola was surveyed and <10% of cane at Malelane, Umfolozi, Noodsberg and Eston. In this regard it is recommended that these figures be standardised across the industry to facilitate the study of this database.

E. saccharina surveys followed a standard procedure (Anon, 2005) requiring examination of 100 stalks selected at random from 10 ha (300 stalks in 10-20 ha fields and 400 in larger fields). Stalks were split longitudinally to identify those with tunnels and the numbers so obtained were converted to the percentage stalks damaged, abbreviated as %SD. This measure was used to assess the extent of damage. The length of stalk tissue with red colouration was measured and converted to a percentage of the total length of the stalk examined, abbreviated as %SLR. This index assesses the intensity of damage. In other sugar industries where stalk borers are a problem and there is no secondary red colouration associated with tunnelling, a measure of internodes bored (%INB) would suffice (Goebel, 1999). Number of larvae and pupae recovered were used to assess *E. saccharina* populations and these figures were converted to numbers in 100 stalks, abbreviated as e/100. This procedure was generally adhered to, although Gossard (2003) pointed out some of the shortcomings that require addressing. For example, there are instances where red colouration in the stalk is caused by cracks, but is ascribed to borer tunnelling and is recorded as %SLR.
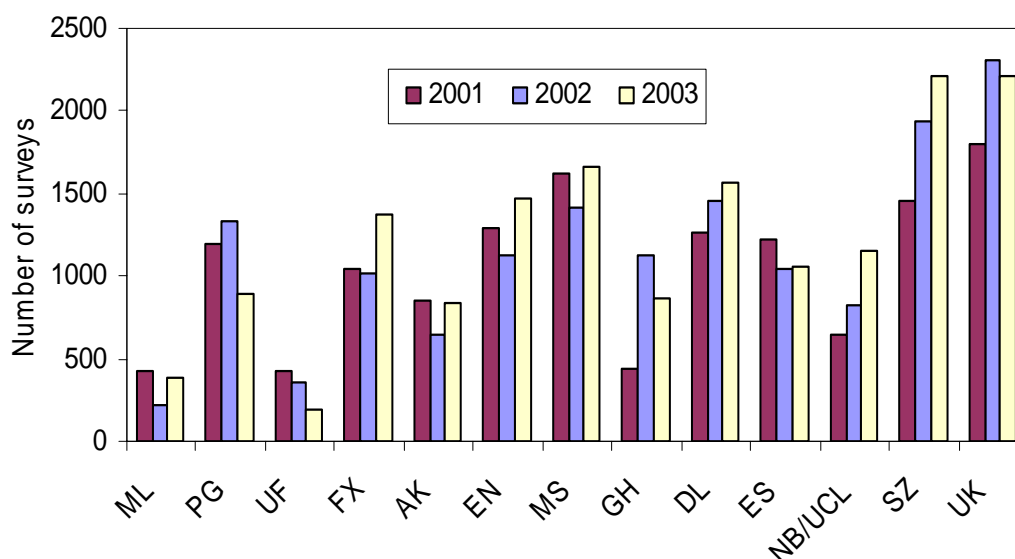

Figure 1. Number of surveys completed in each mill area from January 2001 to December 2003.

Key to mill regions:
ML=Malelane, PG=Pongola, UF=Umfolozi, FX=Felixton, AK=Amatikulu, EN=Entumeni, MS=Maidstone, GH=Gledhow, DL=Darnall, ES=Eston, NB/UCL=Noodsberg/Union Co-operative Ltd, SZ=Sezela, UK=Umzimkulu.

LPD&VCC Excel database

The system used to collate the LPD&VCC *E. saccharina* survey data from the industry has been revised (Anon, 2002). In this study, results from detailed analyses of a vast number of records (40 000) collected from January 2001 to December 2003 (inclusive) are discussed. Some data manipulation was necessary prior to the study to facilitate meaningful interpretation to account for differences in survey conditions. The relationship between cane age and infestations was studied by first sorting the records into the following age categories: 0-9, 9.1-12, 12.1-15, 15.1-18 and >18 months. In this study, only those varieties with at least 100 survey records were considered, which in most cases were the most commonly grown varieties. To investigate any differences between the grower sectors, the records were categorised as Miller-Cum-Planter (MCP), Commercial Grower (CG) or Small-Scale Grower (SSG). Figure 2 shows that the number of surveys in each category was skewed towards the MCP and CG sectors, with few, or no surveys being completed in some SSG areas. The nitrogen factor was studied by grouping its use into classes as follows: 0-50, 51-75, 76-100, 101-125, 126-150, >150 kg N/ha.
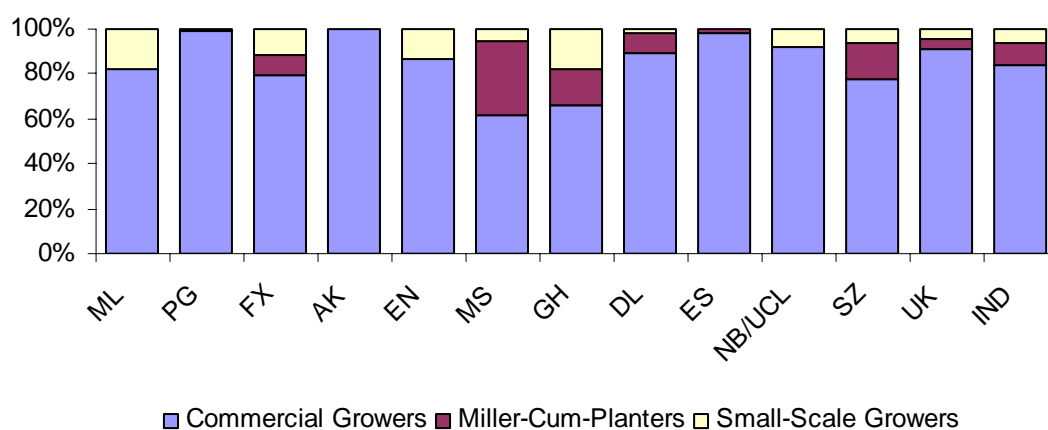

Figure 2. Frequency of surveys per category of grower sector expressed as a percentage of all LPD&VCC pest surveys.

Key to mill regions:
ML=Malelane, PG=Pongola, FX=Felixton, AK=Amatikulu, EN=Entumeni, MS=Maidstone, GH=Gledhow, DL=Darnall, ES=Eston, NB/UCL=Noodsberg/Union Co-operative Ltd, SZ=Sezela, UK=Umzimkulu, IND = Industry.

Data analysis

Data were analysed with SAS statistical software employing General Linear Model (GLM) procedure to determine Coefficient of Variation (CV), F value, probability and means ranking, with corresponding square root values. Before analysis of variance, means were weighted to allow comparison between samples of different sizes (numbers of fields surveyed). The GLM procedure was performed on data from non-orthogonal experimental designs and allowed comparisons of infestations where year was considered as a block (repeat), while the agronomic factors (i.e. nitrogen, cane age and variety) were regarded as treatments. To give rankings of means interaction with the 'year' factor was accounted for. Regression allowed investigation of effects of cane age on damage level. Due to asymmetric distribution of the values as percentages, data were transformed, using the square root to stabilise experimental variance between treatments. In some cases, Principal Component Analysis (PCA) developed by software ADE-4 was used to confirm results from analysis of

variance (e.g. variety). Economic Injury Level (EIL), defined by Pedigo *et al.* (1986), was investigated in this study by combining these findings with previously published results (Goebel and Way, 2003).

Results and Discussion

Damage

The indices %SD, %SLR and e/100 were highly correlated ($r^2 > 0.9$) across mill areas and seasons. Their relationship is described by the following equations:

$$\%SLR = 0.16\%SD - 1.5 \text{ and (it could be); } e/100 = 0.61\%SD - 7.1$$

An analysis of the frequency of occurrence of surveys with increasing %SD damage (Figure 3) showed most fields recorded from 5.1%SD to 10%SD. This result was consistent across seasons. Over this 3-year survey, Maidstone was the worst affected and, in certain regions, e.g. Amatikulu, damage levels increased significantly between seasons (Table 1). In contrast, in other mill regions seasonal fluctuations were recorded. For example, in the Malelane, Umfolozi and Entumeni mill regions infestations were higher in the 2003 season than in the previous two seasons. As expected, the lowest infestations were detected in the Midlands (Noodsberg/Union Co-operative Ltd and Eston mill regions) since relatively high altitude (500 to 1000 m above sea level) results in cooler ambient temperatures and consequently a slower rate of *E. saccharina* development. Lower infestations in irrigated mill regions, such as the Malelane mill area, are well documented (Way, 2004) and explained by the effect of unstressed crops.
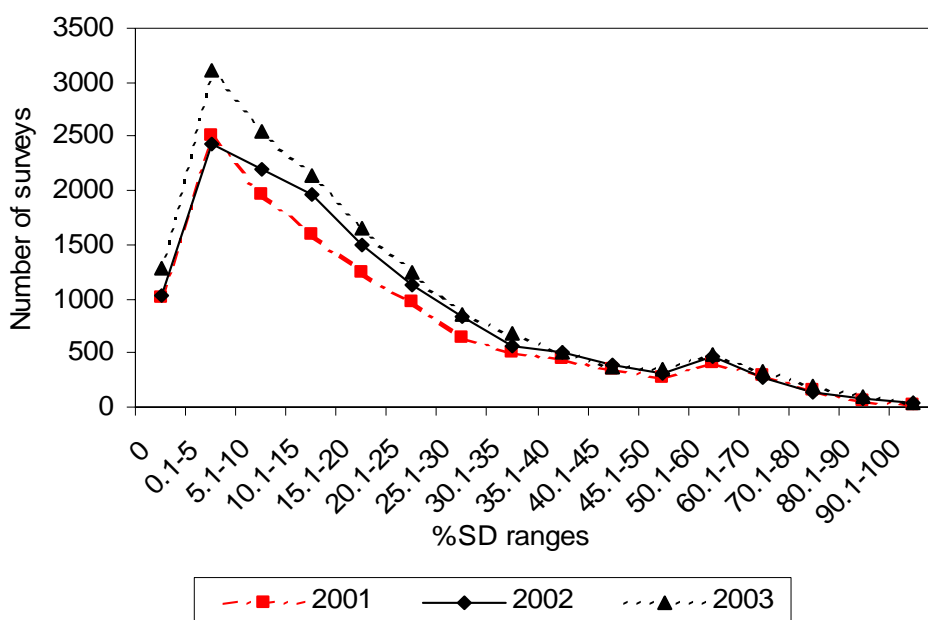

Figure 3. Number of surveys in categories of percent stalks damaged (all survey data pooled).

Table 1. Level of stalk damage due to *E. saccharina* in the South African sugar industry in 2001 to 2003.

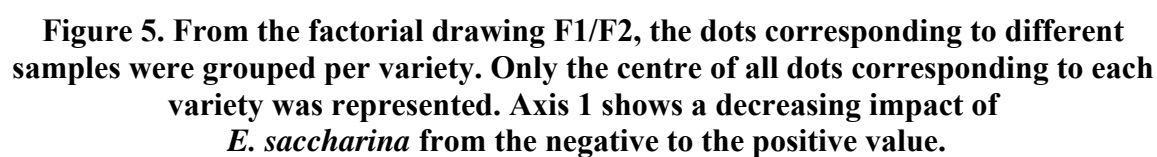| LPD&VCC mill area	%Stalks Damaged, (Mean ± SE) (√SD)			CV %	F value	P
	2001	**2002**	**2003**			
ML	7.5 ± 0.4 b (2.4)	9.0 ± 0.8 b (2.5)	12.0 ± 0.6 a (3.0)	54.6	16.4	0.0001
PG	10.3 ± 0.3 c (2.8)	12.5 ± 0.5 b (3.8)	18.2 ± 0.4 a (3.1)	49.6	109.1	0.0001
UF	8.9 ± 0.6 b (2.3)	9.7 ± 0.7 b (2.4)	17.8 ± 1.5 a (3.5)	76.6	26.8	0.0001
AK	26.9 ± 0.7 c (4.8)	29.5 ± 0.7 b (5.0)	35.3 ± 0.7 a (5.7)	34.1	47.9	0.0001
EN	17.0 ± 0.4 b (3.7)	15.6 ± 0.5 c (3.5)	19.5 ± 0.5 a (3.9)	42.1	45.6	0.0001
FX	25.2 ± 0.6 a (4.6)	11.8 ± 0.4 c (3.0)	15.0 ± 0.3 b (3.5)	45.1	218.4	0.0001
DL	13.2 ± 0.3 b (3.3)	17.5 ± 0.3 a (4.0)	17.5 ± 0.2 a (4.0)	28.5	244	0.0001
GH	23.5 ± 0.4 b (4.8)	30.4 ± 0.4 a (5.4)	25.7 ± 0.6 b (4.8)	22.4	85.1	0.0001
MS	36.1 ± 0.9 a (5.7)	36.1 ± 1.0 a (5.7)	34.1 ± 0.8 b (5.3)	32.4	28.1	0.0001
NB	6.3 ± 0.3 c (2.0)	9.8 ± 0.3 a (2.8)	7.6 ± 0.2 b (2.4)	52.4	77.2	0.0001
ES	-	-	3.6 ± 0.2	-	-	-
SZ	22.3 ± 0.4 a (1.8)	18.8 ± 0.2 b (1.2)	23.9 ± 0.4 a (1.9)	109.3	71.1	0.0001
UK	8.3 ± 0.3 c (2.1)	10.3 ± 0.3 c (2.4)	8.2 ± 0.2 b (2.3)	72.4	18.7	0.0001

SE=Standard Error, CV=Coefficient of Variation. Means within a line followed by the same letter are not significally different =p<0,05, Ranking test of Student Newman Keuls Test (General Linear Model, SAS Institute). Data transformed in √SD before analysis of variance (parenthesis). Infestations from Commercial grower sector only and no records in Eston mill area (ES) in two seasons (2001 and 2002).

Grower categories

The data showed that in most mill areas infestations were significantly lower in surveys of SSG sugarcane in general, compared with CG and MCP sectors (Figure 4). These results concur with past and more recent research (Atkinson and Nuss, 1989; Goebel and Way, 2003). Some of the reasons advanced to date to explain these findings are that SSGs usually harvest crops at a younger age thus limiting infestation build-up, coupled with smaller fields interspersed with other crops and grassland, which resulted in increased flora and fauna biodiversity (Gontier *et al*, 2003).

Variety

The largest number of varieties studied per mill region was eight at Darnall. The difference in damage level (%SD) between varieties was particularly significant in five mills: Umzimkulu (CV=80.8, *F*=113.7, *P*=0.0001); Sezela (CV=44,7, *F*=82.6, *P*=0.0001); Maidstone (CV=34.5, *F*=33.1, *P*=0.0001); Pongola (CV=50,1, *F*=29.1, *P*=0.0001) and Darnall (CV=30.5, *F*=18.4, *P*=0.0001). From these data, PCA analysis indicated a separation into three distinct groups of varieties according to *E. saccharina* infestations (Figure 5). The susceptible group (in ranked order, N26 and NCo 376, then N17 and N16), an intermediate group moderately attacked (N27, N12, N29, N19, N14, N25 and N23), and the least attacked and most resistant variety was N21. Generally, the ranking of infestations were in accordance with the SASRI *E. saccharina* resistance ratings, with the exception of N17 and N14.

Figure 4. Mean percentage stalks damaged (%SD) per category of grower in each mill region in the South African sugar industry.

Figure 5. From the factorial drawing F1/F2, the dots corresponding to different samples were grouped per variety. Only the centre of all dots corresponding to each variety was represented. Axis 1 shows a decreasing impact of *E. saccharina* from the negative to the positive value.

Nitrogen application

Atkinson and Nuss (1989) reported links detected between nitrogen and *E. saccharina* occurrence. Recent studies by Gossard *et al*. (2003) showed that amounts of nitrogen applied to fields appear to be associated with high *E. saccharina* damage, especially from class 3 (Table 2). In the study sites at Sezela and Felixton over this period the quantity of nitrogen applied was significantly higher in CG (between 129.0 - 138.5 kg/ha) compared with SSG (between 89.2 - 89.5 kg/ha) sectors (F-Test, F=1.749, P=0.038) and Gontier *et al*. (2003) in a study found that %SD was significantly correlated with increased nitrogen concentration (r^2=0.31). These findings have been partly attributed to resource-limitation, although cognisance of factors such as variety N use efficiency and soil N mineralisation ability are important as well. Lopez *et al*. (1983) reported that in Cuba nitrogen application above 100 kg/ha led to increased attack by sugarcane borer, *Diatraea saccharalis* (Fabricius). Moreover, this damage was exacerbated when nitrogen was applied at the start of the main growth period: which was attributed to softer stalks that facilitate insect boring ability during the period of high infestation risk.

Table 2. Infestation levels and nitrogen categories at Sezela and Felixton mill areas (data extracted from Gossard, 2003).

Nitrogen class (kg/ha)	% Stalks Damaged (mean ± SE)
0-50	7.3 ± 1.7 b
51-75	11.3 ± 1.7 b
76-100	8.7 ± 0.9 b
101-125	14.6 ± 2.2 b
126-150	23.9 ± 1.9 a
> 150	26.1 ± 5.2 a
CV%	78.4
F value	2.3
P	0.0444

Means within a column followed by the same letter are not significantly different =p<0,05, Ranking test of Student Newman Keuls Test (General Linear Model, SAS Institute)

Cane age

At Darnall, Amatikulu and Entumeni mill areas, the mean damage level increased significantly with a corresponding increase in cane age (Figure 6). Regression equations describing this relationship were: %SD = 1.57 cane age + 3.54 (r^2 = 0,98) at Darnall, and %SD = 3.48 cane age + 0.94 (r^2 = 0,91) at Amatikulu. Differing rates of increase in damage were partly attributed to different thresholds for selecting carry-over fields, i.e. 20% SD at Amatikulu versus 10% SD at Darnall. At Amatikulu a greater number of infested fields over this period resulted in a dramatic increase in *E. saccharina* populations as the cane age increased. These results concur with past findings (Paxton, 1982; Atkinson and Carnegie, 1989).
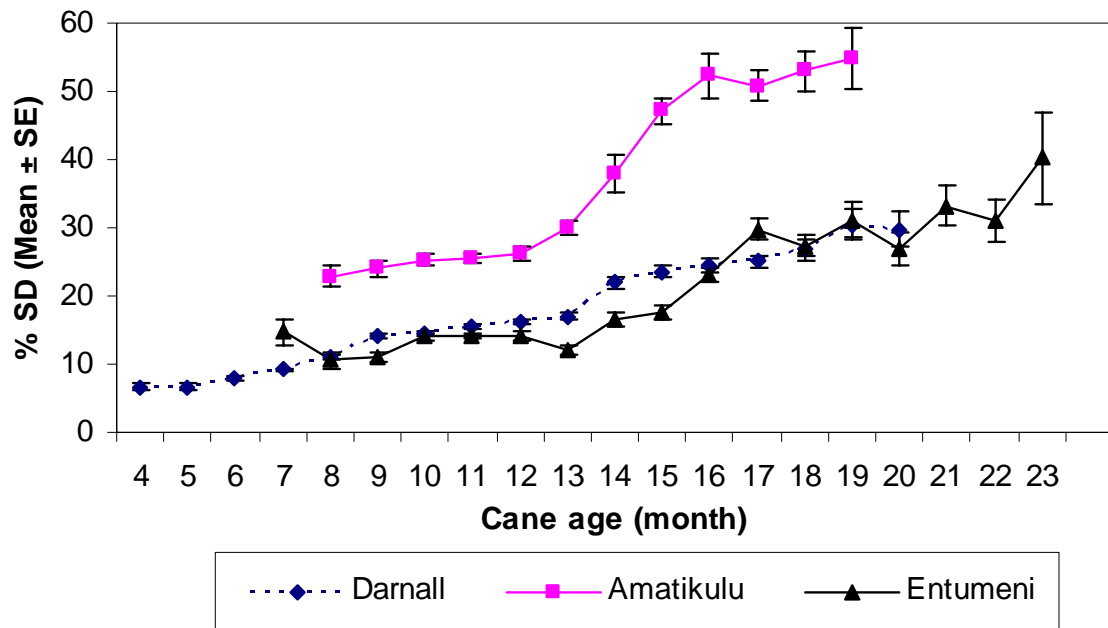
Figure 6: Relationship between age and damage (%SD).

Economic Injury Level (EIL)

An estimated economic injury level was derived based on the model: EIL = C/VDK (Pedigo *et al*, 1986). Yield loss equations derived by Goebel and Way (2003) for *E. saccharina* in NCo376 crops grown in Zululand were used for these calculations. The details of applying an insecticide control programme were used to calculate EIL. According to the EIL model: the cost of control (C) was taken as an estimated R750/ha (Leslie, 2003), the value of the crop (V) at the time was the industrial price of R170/ton sucrose, and the value for K was taken as 0.7 (the level of reduction is about 70%[1]). The equation describing the relationship between damage and loss as derived by Goebel and Way (2003) was: Loss = 1.21 x %SLR – 2.4. Percentage SLR is equivalent to yield (sucrose) loss. The economic threshold level (EIL) where costs incurred through damage are equivalent to costs of control were computed by solving for %SLR in the EIL equation: R730/ha = R170 x (1.21 x Threshold %SLR – 2.4) x 0.7. Accordingly, the estimated EIL under these conditions was an estimated 7% SLR. Equations giving the relationship between %SLR and %SD allow conversion of this figure to approximately 54% SD.

To put this figure into practical context within the industry it was determined that in 2003, as one example, 5% of the fields surveyed (787 of 15 886) exceeded this threshold level (Table 3). In this particular example Maidstone, Sezela, Amatikulu, Entumeni and Gledhow mill areas were the worst affected, which is consistent with patterns recorded in the past (Way and Goebel, 2003).

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[1] Personal communication, GW Leslie, Head: Entomology Dept, South African Sugarcane Research Institute, Mount Edgecombe, South Africa.

Table 3. Numbers of fields exceeding the Economic Injury Level (EIL) threshold in each mill area in the 2003 survey season.

LPD&VCC mill area	Number of fields	Total surveys (2003)
ML	4	387
PG	15	895
UF	12	194
AK	131	832
EN	69	1468
FX	14	1375
DL	4	1568
GH	56	867
MS	280	1661
NB/UCL	0	1151
ES	3	1060
SZ	196	2216
UK	3	2212
Total	**787**	**15886**

Conclusions

This study illustrates the value of the LPD&VCC *E. saccharina* survey database, thus prompting its wider use. These data provide long-term and area wide evidence to support well-known associations between various factors and infestations. Further, in conjunction with other research results, it was possible to estimate an EIL for this pest. Such information is needed to assist in better managing this pest in this industry, which will help to curb damage levels and concomitant yield decline causing revenue loss.

Acknowledgments

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