

INVESTIGATION OF THE IMPACT OF *ELDANA SACCHARINA* (LEPIDOPTERA: PYRALIDAE) ON SUGARCANE YIELD IN FIELD TRIALS IN ZULULAND

F R GOEBEL and M J WAY

*South African Sugar Association Experiment Station, P/Bag X02,
Mount Edgecombe, 4300, South Africa*

Abstract

Through a joint SASEX/CIRAD, project the effect of *Eldana saccharina* Walker (Lepidoptera: Pyralidae) damage on stalk yield components was studied in fields at the SASEX farms at Gingindlovu and Empangeni. The formal experiment design consisted of randomised plots to compare natural infestation, artificial infestation and chemical treatments. Damaged stalks from infested plots had lower sucrose, higher fibre and lower stalk mass levels than treated plots. Stalk length and other parameters were also affected, particularly at Gingindlovu, where the level of damaged internodes reached 18%. The relationship between damage level and various other stalk components was also investigated. Stalk weight, stalk length and sucrose parameters were negatively correlated with percentage internodes bored. Increased fibre content, resulting in less juice, was positively correlated with the damage.

Results are generally consistent with past studies and with other methods used to assess loss. Information on the effect of stalk mass and height in damaged sugarcane was obtained for the first time in this study.

Keywords: sugarcane, *Eldana saccharina*, stalk borer, stalk damage, yield characteristics, crop loss

Introduction

Eldana saccharina Walker (Lepidoptera: Pyralidae) is a serious pest of sugarcane in various African countries, and since 1970 has reached key pest status in the South African sugar industry (Atkinson *et al.*, 1981). Research programmes on integrated pest management (IPM) are currently undertaken at the South African Sugar Association Experiment Station (SASEX) to develop strategies for controlling this stalk borer. Despite some encouraging research results this task remains difficult, mainly because *E. saccharina* has a cryptic biology which differs from other stalk borers (Conlong, 1994).

At SASEX, the ecology and behaviour of the borer are also studied, with the intention of increasing knowledge of these important aspects. Detailed information on the effects of stalk borers on the sugarcane crop, and particularly on the stalk components that impact negatively on yield, is important when assessing crop loss. Of the various approaches that may be adopted to assess crop loss due to insect damage, manipulation of pest pressure in the field through insecticide treatment and/or appropriate artificial infestation techniques, is the most effective and results in the most accurate assessment (Walker, 1987). Accordingly, the formal field experiment design that was adopted for *E. saccharina* consisted of naturally infested plots, artificially infested plots and plots treated with insecticide to eliminate the borer.

This protocol was developed in Reunion Island to assess sugarcane yield loss caused by *Chilo sacchariphagus* Bojer (Lepidoptera: Crambidae) (Goebel et al., 1999).

The objectives of this study were to confirm the loss results that were obtained using a different technique (Way, 2001), and to determine whether stalk weight and plant growth parameters are also influenced by attack from *E. saccharina*. The results presented are preliminary findings in a comprehensive programme that has as the ultimate aim the development of an estimated economic threshold for this pest in sugarcane. Economic thresholds are crucial for determining when, and if, a certain control option should be used (Pedigo et al., 1986).

Materials and Methods

Experiment design

The field was divided into five blocks of three treatments in a randomised design. Parallel experiments were conducted on two SASEX farms over the period May 2001 to May 2002, one at Gingindlovu (GING) (Zululand South) and the other at Empangeni (EMPA) (Central Zululand). The variety used in both experiments was NCo376. Each of the 15 plots were about 130 m² in size and consisted of 11 rows 1,2 m apart and 10 m in length. Two unplanted rows between plots served as protection from the insecticide treatment. In addition, the crop was cleared around the perimeter of each plot to create an effective break.

Each plot received one of the following treatments: no protection from insect pressure (T1), representing plots naturally infested by feral moths; plots inoculation with laboratory bred eggs and larvae (T2), representing artificially infested plots with elevated pest pressure; and insecticide applied to eliminate borers (T3), representing *E. saccharina*-free plots. T3 plots were intended to provide an indication of potential yield in an undamaged crop.

The aim of the treatment in T2 plots was to obtain stalks with a relatively high level of damage, should natural infestation during the season be low. The inoculation technique comprised placing eggs and larvae in the centre row of each T2 plot, thus facilitating an even dispersal of neonates. Fertile (orange coloured) egg batches from the laboratory culture at SASEX were placed on paper towelling and carefully inserted between the stalk and leaves. The row was treated with a total of 1000 eggs (One batch of 100 eggs per 1 meter).

To supplement this technique, and in the event of high neonate mortality, a complementary technique was carried out to further elevate borer numbers. This consisted of attaching a plastic Appendorf vial, containing one third-instar larvae, to the bottom section of each stalk where it would be protected from predators. Two stalks per stool in the centre row of each T2 plot, comprising 10 stools per row, were inoculated in this manner in April, when the crop was between 9 and 10 months old.

Deltamethrin, an insecticide commonly used against lepidopteran stem borers (Moyal, 1998), was applied to T3 plots with a knapsack sprayer at a rate of 12.5 g a.i./ha every 14 days from the time the crop was four months old until the cane was harvested.

Assessment of damage (field or laboratory)

Borer damage was determined by field examination of 120 successive millable stalks in the centre row of each plot. These samples were then assessed for various stalk yield parameters in the laboratory. The length, diameter and weight of each stalk was recorded before it was split longitudinally to assess borer damage.

Also noted for each stalk were: number of internodes, number of internodes bored (INB), number of larvae present and length of red tissue in the stalk (SLR = stalk length red).

Assessment of yield (quantity and quality)

From each site, samples of 30 bundles of four stalks each for each of the three treatments, replicated five times, were analysed for various stalk parameters by the millroom at SASEx such as stalk weight, DM % cane (dry matter), Fibre % cane, Brix % cane (total soluble solids in cane juice), Purity, Pol % cane (total recoverable sugar), ERC % cane (Estimated Recoverable Crystal) and sucrose content (g/stalk).

Statistical analysis

Data were analysed with SAS software (SAS Institute, 1997). Initially data were subjected to analysis of variance (ANOVA) to compare the effect of each treatment on yield components. Then the relationship between the percentage of stalk internodes bored (independent variable) and yield characteristics (dependant variables) was determined. Regression lines were fitted using a general linear model (Proc GLM, SAS Institute).

Results

Differences between treatments

Results are given in Tables 1-4. The methods used in this study to manipulate borer levels were effective, with infestations being highest in T2 plots and negligible in T3 plots at both sites (Table 1 and 3). Infestations in T1 plots appeared to be fairly low, particularly at EMPA (Table 3).

Table 1. Effect of treatments T1, T2 and T3 on stalk damage by *E. saccharina* and stalk characteristics of sugarcane at Gingindlovu.

Plot	% Internodes bored	Stalk length (cm)	Stalk diameter (cm)	Stalk weight (g/stalk)	Yield (t cane/ha)	Sucrose (t/ha)
T1	6,2 b	135,5 a	2,14 a	513,8 b	73,2 b	10,8 b
T2	18,4 a	129,4 b	2,05 b	459,2 b	67,7 c	8,9 c
T3	2,1 b	140,7 a	2,19 a	566,9 a	79,9 a	12,3 a
Loss					12,2 (15%)	3,4 (28%)
CV%	33,9	3,9	3,1	8,4	3,8	4,5
F	39,1	5,78	4,94	7,80	25,50	46,53
P	<0,0001	0,0280	0,0040	0,0132	0,0003	<0,0001

T1 = natural infestation T2 = artificial infestation T3 = insecticide applied

Yield (tons cane/ha) = Y (10 m) x 833,33 and Yield loss % = T3-T2/T3 x 100.

For each variable, the means followed by the same letter (a, b, c) are not statistically different ($P > 0,05$, Student-Newmans-Keuls)

Table 2. Effect of treatments T1, T2 and T3 on fibre and sucrose contents of sugarcane at Gingindlovu.

Plot	DM % cane	Fibre % cane	Brix % cane	Purity (%)	Pol % cane	ERC % cane	Sucrose (g/stalk)
T1	29,3 a	13,0 b	16,3 a	90,3 a	14,7 a	13,4 a	74,1 a
T2	28,9 a	13,8 a	15,1 b	86,9 b	13,2 b	11,6 b	59,8 b
T3	28,9 a	12,6 b	16,4 a	90,5 a	14,8 a	13,5 a	82,9 a
CV%	1,9	4,1	3,3	1,1	3,4	3,7	8,7
F	0,59	6,56	8,34	20,23	17,71	22,68	17,05
P	0,5484	0,0206	0,0111	0,0007	0,0012	0,0005	0,0013

T1 = natural infestation T2 = artificial infestation T3 = insecticide applied

DM = dry matter ERC = estimated recoverable crystal

For each variable, the means followed by the same letter (a, b, c) are not statistically different

($P > 0,05$, Student-Newmans-Keuls)

Table 3. Effect of treatments T1, T2 and T3 on stalk damage by *E. saccharina* and stalk characteristics at Empangeni.

Plot	% internodes bored	Stalk length (cm)	Stalk diameter (cm)	Stalk weight (g/stalk)	Yield (t cane/ha)	Sucrose (t/ha)
T1	2,3 b	152,3 a	22,3 b	630,8 a	86,0 a	11,9 a
T2	17,4 a	145,9 a	21,9 b	578,5 b	78,4 b	9,4 b
T3	1,1 b	154,5 a	22,9 a	633,9 a	87,0 a	12,0 a
Loss					8,6 (9,9%)	2,6 (22%)
CV%	18,0	9,0	1,9	3,15	2,5	2,8
F	274,7	0,54	7,13	12,9	26,24	108,37
P	<0,0001	0,6050	0,0167	0,0031	0,0003	<0,0001

T1 = natural infestation T2 = artificial infestation T3 = insecticide applied

Yield (tons cane/ha) = $Y (10\text{ m}) \times 833,33$ and Yield loss % = $T3 - T2 / T3 \times 100$.

For each variable, the means followed by the same letter (a, b, c) are not statistically different

($P > 0,05$, Student-Newmans-Keuls)

Table 4. Effect of treatments T1, T2 and T3 on fibre and sucrose contents of sugarcane at Empangeni.

Plot	DM % cane	Fibre % cane	Brix % cane	Purity (%)	Pol % cane	ERC % cane	Sucrose (g/stalk)
T1	28,0 a	12,4 a	15,6 a	88,5 a	13,8 a	12,3 a	85,5 a
T2	27,3 b	13,0 a	14,3 b	83,8 a	12,0 b	10,3 b	68,3 b
T3	27,9 a	12,0 a	15,8 a	87,1 a	13,8 a	12,2 a	86,1 a
CV%	0,86	5,4	3,54	3,8	1,5	3,5	3,7
F	10,74	2,71	4,45	2,66	135,0	40,1	58,68
P	0,0054	0,1260	0,0283	0,1298	<0,0001	<0,0001	<0,0001

T1 = natural infestation T2 = artificial infestation T3 = insecticide applied

DM = dry matter ERC = estimated recoverable crystal

For each variable, the means followed by the same letter (a, b, c) are not statistically different ($P > 0,05$, Student-Newmans-Keuls)

Differences in stalk weights, lengths and diameters were significant between T2 and T3 plots. It was thus deduced that borer damage may impact negatively on stalk biomass. Sugar quality (ERC %) and sucrose content were lower in T2 plots, and fibre content was higher (Tables 3 and 4).

At GING, yield loss in T2 plots was estimated at 15%, based on comparison with T3 plots, while a 10% reduction was measured at EMPA. there was also a reduction in tons sucrose/ha due to the effect of a reduction in stalks combined with inferior juice quality. This yield parameter was affected the most, with an average decrease of 28% in T3 plots at GING, and 22% at EMPA (Tables 1 and 3). The difference in yield between the sites may be due to the better growing conditions at EMPA resulting in greater tolerance to borer attack.

Damage and sugarcane yield relationships

At each site, data from the 15 sample units were pooled and regressed against damage as % internodes bored. Estimated recoverable crystal (ERC % cane), juice purity, sucrose and stalk weight were inversely related to % internodes bored (Table 5 and Figures 1-4).

Sucrose parameters were strongly negatively correlated with damage, except fibre content, which was positively correlated. Percentage internodes bored was strongly correlated with stalk length red, $y=0,95x-0,24$ ($r^2=0,99$) (data pooled from both sites). It was concluded that stalk length red was 0,9 times the value of % internodes bored. This result concurs with other findings (¹unpublished data).

Table 5. Comparison of yield and quality characteristics of sugarcane at Gingindlovu (GING) and Empangeni (EMPA) as functions of borer damage, using the general linear model analysis.

Dependent variable	GING			EMPA		
	r^2	F	P	r^2	F	P
Stalk mass (grams)	0,46	11,22	0,0052	0,79	49,15	<0,0001
Stalk length (cm)	0,31	6,04	0,0288	0,35	7,02	0,0200
Stalk diameter (cm)	0,37	7,77	0,0154	0,11	1,72	0,2122
Sucrose weight (grams)	0,70	30,69	<0,0001	0,94	193,03	<0,0001
ERC % cane	0,55	15,91	0,0015	0,84	67,71	<0,0001
Brix % cane	0,46	11,10	0,0054	0,66	25,63	0,0002
Pol % cane	0,52	14,35	0,0023	0,92	148,64	<0,0001
Purity (%)	0,57	17,44	0,0011	0,31	5,74	0,0323
Fibre % cane	0,56	16,87	0,0012	0,31	6,09	0,0283

Note: Regressions are based on 15 sample units (plots) in each locality.

¹Internal report 1989, South African Sugar Association Experiment Station, Mount Edgecombe.

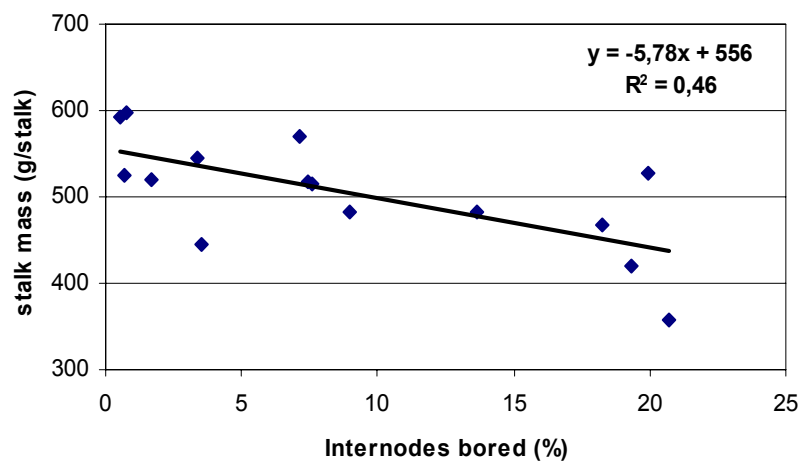


Figure 1. Relationship between stalk damage (% internodes bored) and stalk mass (g) in sugarcane at Gingindlovu.

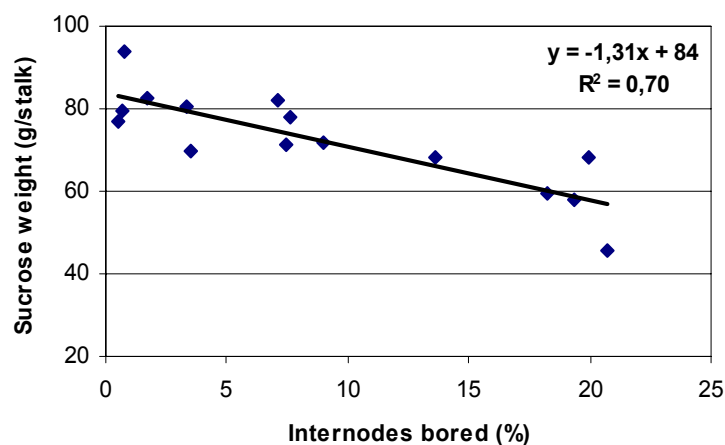


Figure 2. Relationship between stalk damage (% internodes bored) and sucrose weight (g) in sugarcane at Gingindlovu.

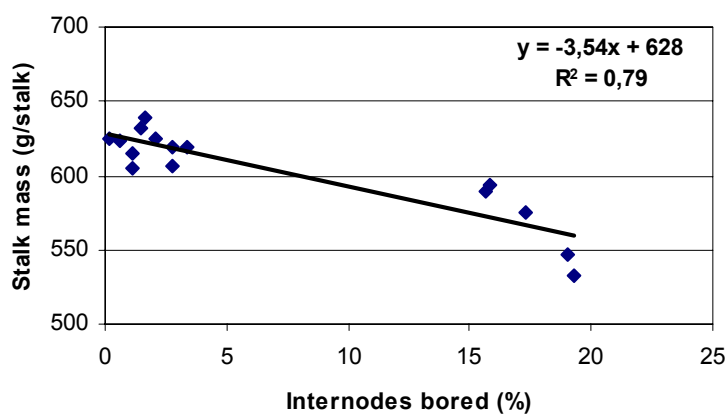


Figure 3. Relationship between damage (% internodes bored) and stalk mass at Empangeni.

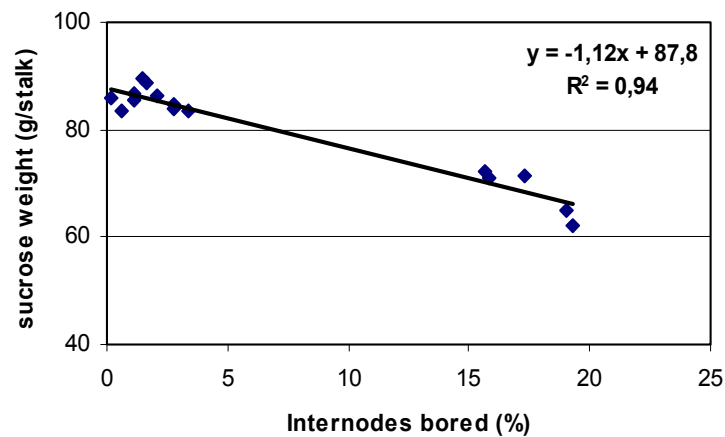


Figure 4. Relationship between damage (% internodes bored) and sucrose weight at Empangeni.

Discussion

This was the first formal trial conducted in the field to assess yield loss from *E. saccharina*. The approach used was successful because it was possible to compare undamaged cane with damaged cane under natural field conditions. Another aspect was to facilitate comparisons between plots by using insecticide applications (no infestation) and artificial infestation. The use of insecticide has proven its efficiency in identifying crop loss due to maize stalk borers (including *E. saccharina*) in Côte d'Ivoire (Moyal, 1998). In this study, the aim was to create a desirable level of infestation, which is impossible with natural infestation because of its unpredictability.

The study showed that *E. saccharina* causes a reduction in cane yield and inferior cane quality, which corroborates the findings from a less detailed formal method adopted in a preliminary study by Way (2001). An increase in fibre content, which is a consequence of a reduction in water uptake, was also detected using both approaches. The reduction in sugar quality could also be linked to the presence of a fungus associated with *E. saccharina* borings, which is known to cause deterioration of sucrose molecules (Metcalf, 1969; Ogunwolu *et al.*, 1991). These results are consistent with previous studies on other stalk borers, such as *Diatraea saccharalis* (Martorell and Bangdiwala, 1954; Hensley, 1971; Gonzales *et al.*, 1977; Reagan and Martin, 1989), *Eoreuma loftini* (Legaspi *et al.*, 1999) and *Chilo sacchariphagus* (Rajabalee *et al.*, 1990; Goebel *et al.*, 1999).

E. saccharina also impacted negatively on total cane weight. Although this factor is not as strongly correlated with damage levels as it is with sucrose, regressions nevertheless showed that plant biomass is significantly affected. This direct 'agricultural' loss in the field has not been evident in previous studies, and suggests that *E. saccharina* might have influenced plant growth negatively, since there was a significant reduction in stalk length and, to a lesser degree, stalk diameter. Similar effects were reported for *C. sacchariphagus* in Reunion (Goebel *et al.*, 1999); however, there the effect of this borer on stalk mass was more evident. The age at which the crop is attacked may influence biomass accumulation, as *C. sacchariphagus* characteristically attacks younger crops than does *E. saccharina*. Loss in cane weight is not easy to detect, and requires a specific study with samples taken within the same population of stalks. However, most loss assessment studies have been based on single stalks collected in fields with different degrees of damage (Samson and Kumar, 1983; Rajabalee *et al.*, 1990).

It has been recognised that the single stalk method can be used only to show a possible reduction in sucrose, and cannot be used to investigate a possible reduction in stalk weight, due to the variability in stalks. Way (2001) discussed the problem of variability in stalks within a single field. In contrast, the formal field trial conducted in this study allowed a comparison between bundles of stalks from the same field. This minimised any bias and thus reduced problems with interpretation of the data.

Conclusion

This study showed the importance of considering all aspects of loss, including the quality (sucrose) to quantity (biomass) ratio of sugarcane. Further research is required to investigate the relationship between internodes bored and yield components to establish an approximate economic threshold for *E. saccharina*. The data from these trials can also be used to examine the feasibility of developing a reliable model for predicting crop losses based on infestation levels.

Acknowledgements

Som Desraj and Kelvin Naidoo are thanked for technical help. The insect rearing unit at SASSEX provided *E. saccharina* for the trials.

REFERENCES

- Atkinson, PR, Carnegie AJM and Smaill, RJ, 1981. A history of the outbreaks of *Eldana saccharina* Walker, in Natal. *Proc S Afr Sug Technol Ass* 55 : 111-115
- Conlong DE (1994). A review and perspectives for the biological control of the African sugarcane stalkborer *Eldana saccharina* Walker (Lepidoptera : Pyralidae). *Agriculture, Ecosystems and Environment* 48: 9-17.
- Goebel R, Fernandez E and Alauzet C (1999). Dégâts et pertes de rendement sur la canne à sucre dus au foreur *Chilo sacchariphagus* (Bojer) à l'île de la Réunion. *Annales de la Société entomologique de France* 35: 476-481.
- Gonzalez PP, Montenegro RC and Labrada AR (1977). Influence of the degree of attack by the stemborer *Diatraea saccharalis* Fabricius on some sugarcane yield constituents. *Proc int Soc Sug Cane Technol* 16: 569-582.
- Hensley SD, 1971. Management of sugarcane borer populations in Louisiana, a decade of change. *Entomophaga*; 16 : 133-146
- Legaspi JC, Legaspi BC Jr, Irvine JE, Johnson J, Meagher RL Jr and Rozeff N (1999). Stalkborer damage on yield and quality of sugarcane in Lower Rio Grande valley of Texas. *J Econ Ent* 92: 228-234.
- Martorell LF and Bangdiwala IS (1954). Sucrose content of sugarcane as affected by moth borer (*Diatraea saccharalis*) infestation. *Proc int Soc Sug Cane Technol* 8: 602-614.
- Metcalf JR (1969). The estimation of loss caused by sugar cane moth borers. pp 61-79 In: JR Williams *et al.* (Eds) *Pests of Sugarcane*. Elsevier Publishing Company, The Netherlands.

Moyal P (1998). Crop losses caused by maize stem borers (Lepidoptera : Noctuidae, Pyralidae) in Côte d'Ivoire, Africa: statistical model based on damage assessment during the production cycle. *J Econ Ent* 91: 512-516.

- Ogunwolu EO, Reagan TE and Flynn JL (1991). Effects of *Diatraea saccharalis* (Lepidoptera : Pyralidae) damage and stalk rot fungi on sugar cane yield in Louisiana. *Crop Protection* 10: 57-61.
- Pedigo L, Hutchins SH and Higley LG (1986). Economic injury levels in theory and practice. *Ann Rev Ent* 31: 341-368.
- Rajabalee A, Lim Shin Chong LCY and Ganeshan S (1990). Estimation of sugar loss due to infestation by the stem borer *Chilo sacchariphagus*, in Mauritius. *Proc S Afr Sug Technol Ass* 65: 120-123.
- Reagan TE and Martin FA (1989). Breeding for resistance to *Diatraea saccharalis*. pp. 313-331. In : TV Sreenivasan and MN Premachandran (Eds.), *Proceedings of international Symposium on Sugarcane Varietal Improvment*.
- Sampson MA and Kumar R (1983). Borer damage and estimation of loss caused by sugarcane stem borers in Southern Ghana. *Insect Science and its Application* 6: 705-710.
- Walker PT (1987). Empirical models for predicting yield loss caused by one type of insect: the stem borers. pp 133-138 In: PS Teng (Ed) *Crop Loss Assessment and Pest Management*.
- Way MJ (2001). Characteristics of sugarcane bored by *Eldana saccharina* (Lepidoptera: Pyralidae). *Proc S Afr Sug Technol Ass* 75: 257.