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RESEARCH ARTICLE

Yield Loss in Sugarcane Due to *Diatraea tabernella* Dyar (Lepidoptera: Crambidae) in Panama

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Abstract The moth borer *Diatraea tabernella* Dyar (Lepidoptera: Crambidae) feeds on sugarcane causing holes and tunnels in the stalks resulting in yield losses. Damage facilitates the entry of red rot (*Colletotrichum falcatum*) causing inversion of sucrose in the sugarcane juice. Two types of damage that can be related to sugar loss were assessed and analyzed: the percentage of internodes bored in the stalk and the internal damage (=length of borer tunnels). After a preliminary assessment on borer damage in 2012, a new study was conducted in 2016 to thoroughly investigate the impact of *D. tabernella* not only on cane and sugar yield, but also on stalk parameters (length, diameter, stalk mass, etc.). This assessment was conducted on eight varieties and was carried out on three samples (replicates) of five stalks per variety grouped in five damage levels (0, 1, 2, 3 and 4 internodes bored). The results indicated that stalk mass, fiber and sugar yield were significantly affected by the stalk borer. Sugar yield decreased up to 2.56 t of sugar per hectare, with damage level 3 similar to the yield with no damage (level 0). Internodes of cultivars E07-09, Na56-42, SP01-2050 and SP81-3250 were less damaged at the two-internode category and had lower sugar losses. There was an exact linear relationship negative (decreasing) between sugar yield (t/ha) and damage levels ($y = -0.579x + 9.324$, $R^2 = 0.9069$) with a range from 12.9% with damage level 1 to 26.47% loss with damage level 4.

Keywords Sugarcane · Borers · Damage · Yield losses

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Introduction

Quantification of crop losses due to insect pests is required to estimate the cost–benefit ratios that justify the cost of implementing any control strategy. In sugarcane, stalk borers are considered as the most damaging pests and cause significant yield losses. Recent studies on two species, *Chilo sacchariphagus* (Lepidoptera: Crambidae) and *Eldana saccharina* (Lepidoptera: Pyralidae), showed significant reductions in terms of biomass and sucrose due to their damage (Goebel and Way 2009; Goebel et al. 2014). *Diatraea* (21 species) are the main pests of sugarcane in the Americas, particularly *Diatraea tabernella* Dyar in Costa Rica, Panama and Colombia. Internal stalk damage is associated with red rot (*Colletotrichum falcatum* Went) that causes inversion of sucrose (Alonso et al. 1991; Bonzi

2008). Díaz et al. (2003) found that 87.4 kg of sugar is lost per ha for a level as low as 2% of internodes bored. A more recent study (Gómez et al. 2009) indicated that losses from *Diatraea* spp. amounted to 145 kg of sugar/ha for each 1% of internodes bored.

In Panama, a preliminary study conducted in 2012 by a Cuban team highlighted the damage and impact on sugar yield from *D. tabernella*. Based on these unpublished data, it was decided to conduct a more detailed study to specifically determine the damage levels caused by this borer on commercial varieties in Panama and then investigate the impact not only on sugar losses but on stalk parameters. The impact of this species has never been determined.

Materials and Methods

The study was conducted at Compañía Azucarera La Estrella S.A. (CALESA), Natá, Panama, in January and February 2016 during the harvesting season. We tested eight commercial varieties (B74-125, BT77-42, B80-689, CR74-250 and four promising new varieties, E07-09, Na56-42, SP81-3250 and SP01-2050). Crops were aged from 10 to 12 months.

To assess overall borer damage, we sampled 100 stalks per variety taken at random, consisting of four replicates each of 25 millable stalks. These were taken from the four end points of each 2-ha field. Each stalk was then split longitudinally, and the number of bored internodes counted [percentage of internodes bored (% IB)] and the length of tunnels within each internode that were bored were measured (Fig. 1). We also recorded individual stalk length, stalk mass and diameter (data not presented).

To determine the impact on sugar quality and biomass, we took stalk samples (three replicates of five stalks each) from each of five damage levels: 0 = no internodes bored (IB); 1 = 1 IB, 2 = 2 IB, 3 = 3 IB and 4 = 4 IB (Fig. 1, right). Stalk samples were taken to the Laboratory of Quality and Sugar of CALESA for sugar quality and yield measurements: Pol, sucrose, Brix, purity, fiber and sugar yield (t/ha). Data were subjected to Analysis of Variance (ANOVA) using Statgraphics Plus 50, and regression graphs were generated to determine the relationship between damage and loss.

Results and Discussion

Overall Damage

Damage over the whole population of stalks (undamaged and damaged) was generally low in the eight varieties surveyed, with percentage of internodes bored ranging from 0.22% (SP01-2050) to 4.1% (B74-125) and with significant differences leading to two distinct groups of varieties, the 'low damage level' group (E07-09, Na56-42, SP01-2050 and SP81-3250) with internodes bored <0.40% and a 'high damage level' group (B74-125, B80-689, BT77-42, CR74-250) with internodes bored >1% (Fig. 2).

In terms of sucrose levels, cane yield and sugar yield, there was also significant differences with the highest sugar yields recorded for the varieties E07-09 (10.92 t/ha), Na56-42 (9.79 t/ha), SP01-2050 (9.03 t/ha) and SP81-3250 (9.03 t/ha) (Table 1) which were also the less damaged. Despite a relatively low level of internodes bored, these results showed an effect of borer damage on yield components. These findings confirm data recorded by Díaz et al. (2003).

Impact of Borer Infestation Within Different Classes of Damage

The different groups of damage level from 0 (0% internodes bored) to 4 (16.17% with 28.7 cm of tunnel length) allowed us to better investigate the effect of borer attack on stalk parameters. Even though there was no significant difference in individual stalk length between classes of damage, there was a trend to a difference of 14 cm between

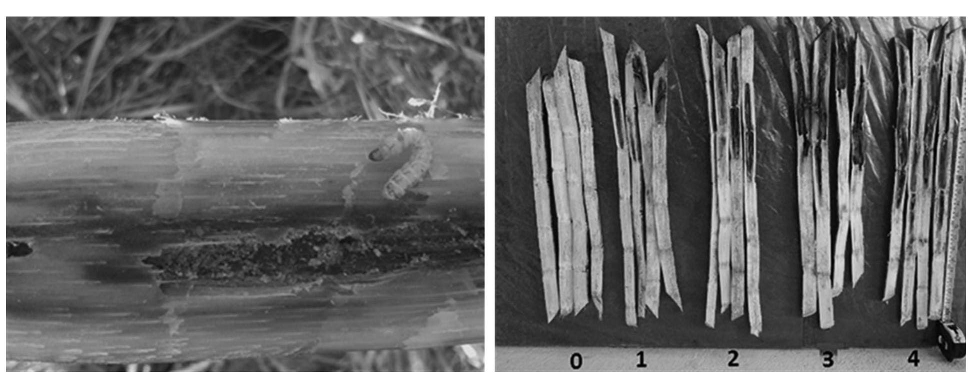

Fig. 1 Tunnels caused by *D. tabernella* (*left*) and classes of damage levels (*right*)

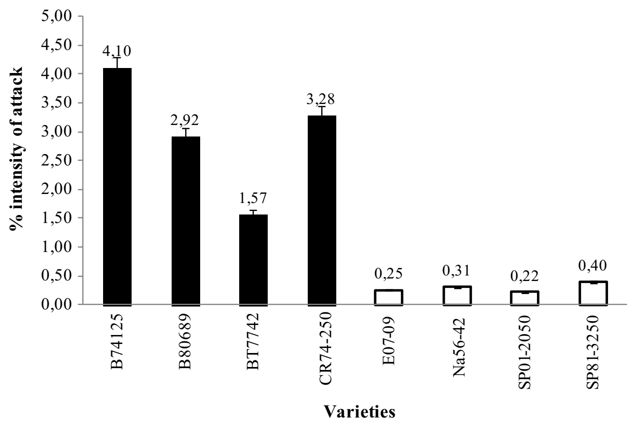

Fig. 2 Damage level in each variety. High damage level (*black columns*) and low damage level (*white columns*)

the highest damaged samples (level 4) compared to undamaged stalks (level 0). Stalk mass was significantly affected with a loss of 21.9% in the level 4 group (Table 2).

There were significant differences between damage levels, particularly between level 4 and level 0 for quality and yield parameters (Table 3). Brix, sucrose content, fiber content, cane and sugar yield were affected by borer damage. The increase in fiber content from 12.81% at level 0 to 13.57 at level 4 combined with a reduction in sucrose content (from 17.5% at level 0 to 14.7% at level 4). To reduce sugar yield (t/ha), with a maximum loss of 2.56 t/ha (yield level 0–yield level 4) representing a yield reduction of 26.5% when 16.2% of internodes are damaged (Tables 2, 3).

Using the data generated by the eight commercial varieties (considering the real scenario of harvest) we generated an exact linear relationship negative (decreasing) between sugar yield (t/ha) and damage levels ($y = -0.579x + 9.324$, $R^2 = 0.9069$) (Fig. 3).

B74-125 is the variety with the highest % internodes bored (4.10) showed an exact linear relationship negative (decreasing) between sugar yield and internodes bored ($y = -0.5636x + 8.7783$; $R^2 = 0.9908$) (Fig. 4). For this variety, there was a yield reduction from 0.60 t/ha for level 1 damage to 2.23 t/ha for level 4 damage; a fourfold increase. These results are similar to those from other studies (Gupta and Avasthy 1959; Ferrer and Guedez 1990; Shrivastava and Solomon 2009). These studies confirmed that juice quality is reduced when the intensity of infestation is increased, confirming a negative impact of borer damage on this parameter.

Table 1 Damage levels, quality parameters and yields for each variety (mean ± SE)

Variety	% Internodes bored	Brix (%)	Sucrose (%)	Cane yield (t/ha)	Sugar yield (t/ha)
E07-09	0.25 ± 1.45d	21.35 ± 0.57a	18.80 ± 0.75a	94.91b	10.92 ± 0.53a
SP01-2050	0.22 ± 1.19d	19.88 ± 0.68b	17.19 ± 0.81de	93.75c	9.78 ± 0.54b
Na56-42	0.31 ± 1.32d	21.52 ± 1.03a	18.07 ± 1.29ab	90.84d	9.79 ± 0.84b
SP81-3250	0.40 ± 1.58d	19.12 ± 1.55bc	16.80 ± 1.60cd	97.05a	9.03 ± 1.25c
B74-125	4.10 ± 5.47a	18.79 ± 1.75cd	15.75 ± 1.88de	81.47g	7.65 ± 1.05d
BT77-42	1.57 ± 4.05c	18.89 ± 0.67bcd	15.70 ± 1.53bc	78.71h	8.08 ± 0.87d
CR74-250	3.28 ± 5.69b	18.56 ± 1.10dc	15.62 ± 1.18e	82.54e	7.71 ± 0.67d
B80-689	2.92 ± 5.89b	17.99 ± 0.98d	15.26 ± 1.00e	81.95f	7.51 ± 0.56d
P value	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

Values within a column followed by the same letter are not significantly different (alpha = 0.05); Brix (%), percentage of total soluble solids in solution (juice); sucrose (%), percentage of sucrose in dry matter

Table 2 Parameters of stalks at different damage levels (all varieties) (mean ± SE)

Damage level	Stalk length (cm)	Stalk mass (kg)	Internodes per stalk	% Internodes bored	Tunnel length (cm)
0	198.41 ± 29.77a	1.07 ± 0.33c	18.76 ± 3.45b	0.00e	0.00e
1	192.55 ± 32.28a	1.14 ± 0.37bc	20.01 ± 4.46a	2.17 ± 2.47d	3.99 ± 4.37d
2	193.05 ± 34.01a	1.22 ± 0.38ab	19.81 ± 4.09ab	5.87 ± 3.08c	10.62 ± 6.70c
3	191.56 ± 38.16a	1.26 ± 0.34ab	20.81 ± 4.75a	8.79 ± 5.18b	16 ± 10.55b
4	184.00 ± 30.39a	1.37 ± 0.50a	19.38 ± 4.11ab	16.17 ± 6.03a	28.69 ± 10.06a
P value	0.1689	0.0001	0.006	<0.0001	<0.0001

Values within a column followed by the same letter are not significantly different (alpha = 0.05)

Table 3 Sugar quality parameters and yield at different damage levels (mean ± SE)

Damage level	Brix (%)	Sucrose (%)	Fiber (%)	Purity	Sugar yield (t/ha)	Loss (t/ha)
0	20.32 ± 1.31a	17.51 ± 1.48a	12.81 ± 0.82b	85.70 ± 3.01a	9.67 ± 1.21a	0.00
1	19.24 ± 1.56b	16.32 ± 1.64b	12.84 ± 0.96ab	84.74 ± 3.08a	8.42 ± 1.09b	1.25
2	18.83 ± 1.34b	15.74 ± 1.61bc	12.93 ± 1.23ab	83.61 ± 5.35a	7.88 ± 0.88bc	1.69
3	18.67 ± 1.51cd	15.73 ± 1.35bc	13.11 ± 0.66ab	84.28 ± 1.50a	7.75 ± 1.01bc	1.92
4	17.35 ± 0.95d	14.68 ± 1.07c	13.57 ± 0.86a	84.56 ± 3.02a	7.11 ± 0.52c	2.56
P value	<0.0001	<0.0001	0.3195	0.3715	0.0001	

Values within a column followed by the same letter are not significantly different (alpha = 0.05)

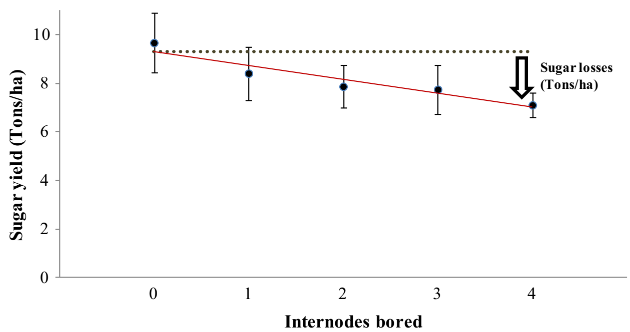

Fig. 3 Relationship between internodes bored and sugar yield (varieties within the harvest)

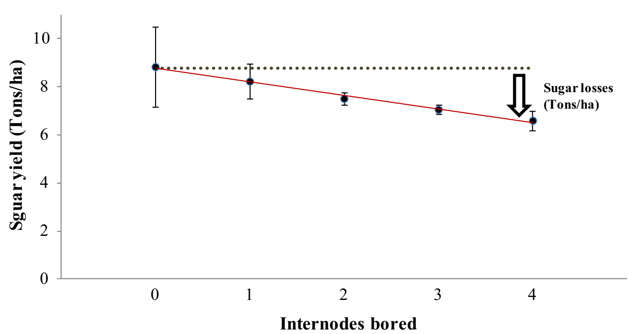

Fig. 4 Relationship between internodes bored and sugar yield for variety B74-125

Conclusion

Our studies show that *D. tabernella* reduces the quantity and quality of sugar and of biomass. Fiber content increased with higher levels of internodes bored. This is a consequence of borer tunnels and reduction in water uptake that would be reflected by lower juice levels. These results are in accordance with other studies on stalk borers such as *Eldana saccharina* in Africa and *Chilo sacchariphagus* in Réunion (Goebel and Way 2009) and Indonesia (Goebel et al. 2014), even though the overall damage during our study was generally lower. Moreover, biomass loss appeared to be more difficult to estimate and require more research particularly to determine the relationship between internodes bored and cane yield components. The data from damage assessments can also be used to establish an approximate economic threshold for *D. tabernella* and examine the feasibility of developing a reliable model for predicting yield losses based on damage levels.

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Compliance with Ethical Standards

Conflict of interest Randy Atencio has received research Grants from Secretaria Nacional de Ciencia y Tecnologìa de Panamá (SENACYT). François-Regis Goebel has received research grants from Centre de coopération internationale en recherche agronomique pour le développement (CIRAD). José Pérez Milián and Mérida Rodríguez have received research Grants from Instituto de Investigaciones de la Caña de Azúcar de Cuba (INICA). Luisana Fernández has received research grants from University of Panama. The authors declare that they have no conflict of interest.

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