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Diversity of sugarcane borer species and their extent of damage status on cane and sugar yield in three commercial sugarcane plantations of Ethiopia

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Abstract The present study was carried out under field condition to determine the diversity of sugarcane borer insect species and their extent of damage on cane and sugar yield during wet and dry cropping seasons of 2007 to 2008 at three commercial sugarcane plantations *viz*. Wonji-Shoa, Metahara and Finchaa of Ethiopia. Of 192 surveyed fields, a total of four different *Lepidopteran* borer species namely *Sesamia peophaga* Tams and Bowden, *Sesamiacalamistis*Hampson,*Busseolafusca* Fuller and *Chilopartellus*Swinhoe were identified. Among the stem borer species identified, *Sesamiapoephaga* was reported for the first time on sugarcane cultivated fields in the country. Sugarcane borer diversity and their extent of damage was varied across the plantations and among the different factors considered, season, variety and crop type showed a significant effect on incidence and severity of stalk borer. Both incidence and severity of shoot and stalk borers increased in dry season (January to April, 2008) as compared to the wet season (end of May to December, 2007). Among the different crop types, first ratoon showed a significant variation in stalk borer incidence and severity both in the dry and wet season. Among the varieties, B52298 showed significant variation in incidence of stalk borer as compared to other varieties across the two seasons. In terms of severity, the co-varieties and N14 showed significant variation as compared to other varieties. Among the sugarcane plantations, the highest incidence and severity was recorded at Finchaa followed by Wonji-Shoa and Metahara. Sugarcane borer inflicted damage both at shoot and stalk formation stage of the crop. The pest caused 3.5 - 54% dead shoot and 5.6–28.8% of bored stalk, respectively. This study also confirmed that stalk borers significantly reduced cane and sugar yield by 25 and 34%, respectively, as compared to the healthy stalk. Therefore, the sugarcane plantations could give due attention for the management of complex borer species attack.

Keywords: diversity, borer species, damage status, Commercial sugarcane plantations, Ethiopia.

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Introduction

Sugarcane, *Saccharumspp.*L. belongs to the family Poaceae, is one of the most important widely grown cash crops in Ethiopia (Yoseph, 2006). Although the definite period is not well documented it is estimated that sugarcane was introduced into Ethiopia sometimes during the early 18th century. Commercial cultivation of the crop, however, started in 1954 by Dutch Company, Handles-Vereening Amsterdam (HVA). Currently, sugarcane is produced commercially by three government owned estates and it is the sole source of sugar produced for both export and domestic consumption.

Sugarcane is known to be attacked by many insects belonging to broad spectrum of orders such as *Lepidoptera, Homoptera, Coleoptera, Hemiptera, Orthoptera*and*Isoptera* (Leslie, 2004). The geographic distribution of most of these insect pests is very narrow except for few that are cosmopolitan. Studies in Africa reported that the insect pest species of sugarcane to be highly dominated by local insects that have adopted the crop as a host consequent to its cultivation (Leslie, 2004). In sugarcane plantations of Ethiopia, the recent survey study reportedthat a total of 14 different insect pests were recorded (Tesfaye and Solomon, 2007). However, despite the importance of the sugarcane crops in Ethiopia, so far no sugarcane borer diversity and economic importance study has been made well to measure the incidence and severity/their extent of damage on cane and sugar yield in commercial cultivated sugarcane fields in Ethiopia (Yoseph, 2006). Baseline information to conduct further research works that target in managing this important pest is essential. Information on the diversity and economic importance of insect pests is essential for effective prevention of damage to sugarcane and for designing insect management strategies. Estimation of the damage status and insect pest population is needed in decision making for pest management programs for better cultivation of the crop. Therefore, the present study was conducted to determine the diversity of sugarcane borer species and theirextent of damage on cane and sugar yield reduction in the three commercial sugarcane plantations of Ethiopia.

Materials and methods

The survey study was conductedunder selected field conditions in three commercial sugarcane plantations viz. Wonji-Shoa (8^o 30' N; 39^o 20' E; 1540 m. a. s. l), Metahara (8^{o}N; 39^o 52' E; 950 m. a. s. l) and Finchaa (9^o 31' to 10^o N; 37^o 15' to 37^o 30' E; 1350 to 1650 m. a. s. l) of Ethiopia(Fig 1), during both main rainy and dry cropping seasons of June 2007 to June 2008. The plantation areas received an average of 831, 554 and 1280 mm rainfall during the study period, respectively.

Fig. 1. Map of the study areas- Wonji, Metahara and Finchaa Sugar Factories, Ethiopia.

The survey of sugarcane borers was conducted on the representative soil cycle and/or class of light (sandy), medium (sandy loam) and heavy (clay) soil managemened groups in Wonji-Shoa and Metahara sugarcane plantations, while at Finchaa, the survey was conducted on Luvisols and Vertisols. Field selection to undertake the survey was done through systematical approach considering of the soil type, plantation types and age of the crop at all sites. The soil types or fertility status has greatly determined the plant vigor and also thesusceptibility of sugarcane varieties to borer complex attack. Moreover, infestation level of borer complex showed an increasing trend as the plantation age increased (i.e. from plant cane to ratoon crop). According to the above underlined facts, field selection was made from each soil cycle and/or soil class. And from each soil cycle and/or class of the sites, field selection was further stratified into plantation types (i.e. plant cane and ratoon crops) including all varieties and age groups. The ratoon crops were again stratified according to their ratooning stage into first and last ratoon. The first ratoon stage was a second cutting crop in all soil types, whereas the last ratoon stages were the fourth cutting in heavy-textured soil, the sixth in light textured soil, and the fifth cutting in medium-textured soil both for Wonji-Shoa and Metahara. The first ratoon stage was a second cutting crop in both soil types of Finchaa; whereas the last ratoon stage was fourth cutting in Vertisols and fifth in

Luvisols. In each strata, eight fields were surveyed by giving due attention for incorporating most sugarcane varieties.

The selected sugarcane fields were inspected for sign of borer infestation, such as the presence of dead shoot, larval frass and/or exit holes. In each field, dead shoot count was made from nine sampling spots (4 furrows of 10 m length each) following a 'W' shaped pattern as used by Tesfaye and Solomon (2007) on cane fields of 1-4 month old. A total of 100 stalk samples (per variety per crop type per soil type) were randomly collected using destructive sampling and data were collected on the number of stalk borer larvae, pupae, incidence, severity and plant damage by the method of Yoseph (2006) from 6 to 10 month old cane. Thirty of the 100 stalk samples were collected by walking diagonally from a corner to the opposite corner of the field, additional thirty from the opposite diagonal and the remaining 40 samples by walking through the field from the center of each side of the field. Stalks were examined *in situ* for frass or exit holes, and those with borer holes were recorded as bored plants.

To determine the occurrence of borers, severity and extent of damage caused by borers, out of the total 100 random stalk samples on average 30 infested stalks per variety were dissected longitudinally and carefully examined for any life stages of the borers and placed into a 30 ml plastic vial containing a piece of sugarcane stalk (Yoseph, 2006). All the immature stages were reared using pieces of stalk as a feed source by periodically changing the fresh ones until it reached to adult stage. While sending the samples for identification of pupal stage were also included. Incidence was determined using percentage bored stalk data out of a total 100 stalk samples. Severity was determined in terms of percent bored internodes per stalk out of a total of thirty infected stalk samples per variety per field. Tunnel length and number of exit holes were recorded to determine the extent of damage on cane and sugar yield by taking ten random stalk samples out of the thirty infested stalks. Moreover, species of the stalk borer (when known), developmental stage, sugarcane variety and crop type (plant cane and ratoon crop), age and collection site were recorded.

The recovered adult specimens were pinned and packed by the procedure stated by Schauff *et al.* (1986). The pupal specimens were put into perforated vials. Finally, adults and pupae specimens were sent to the South African Agricultural Research Council's Plant Protection Research Institute (ARC-PPRI) Quarantine Laboratory, Biosystematics Division in Pretoria for identification.

Dead shoot % (*DS*), bored stalk % (*BS*) and bored internodes % (BI) in each field was determined as follows:

$$DS = (DH/T)*100, \; BS = (BS_n/N)*100 \text{ and } BI= (NBI/TNI)*100$$

Where DH is total dead heart count, T is total tiller count per field., BS_n is the number of bored stalk per total sample, Nis the total number of stalk sample per field, NBI is the number of bored internodes per stalk and TNI is the total number of internodes per stalk (Yoseph, 2006; Tesfaye and Solomon, 2007). In addition, relative abundance (RA) and Berger-Parker dominance (D) were calculated as $RA = S/\Sigma S$ and $D = A/\Sigma A$,where Sis the number of individuals in a species, ΣS is the total number of all borer species in a given site, Ais the abundance of the dominant species and ΣA is the abundance of the total species (Le *et al.*, 2006).

Finally, association of on tunnel length and exit hole on growth parameters (like stalk height and diameter), cane and sugar yield were analyzed using an independent t- test. The association of different factors (site, soil types, seasons, crop status, and sugarcane varieties) with borer incidence and severity were also analyzed using Multiple Regression test of the SPSS computer software of 9.0 versions (SPSS, 1999).

Results and discussions

Distribution of Sugarcane borers

From 192 fields surveyed, during the present work, four different *Lepidopteran* borer species viz. *Busseola fusca* Fuller (Lepidoptera: Noctuidae), *Chilopartellus*Swinhoe (Lepidoptera: Crambidae), *Sesamiacalamistis*Hampson (Lepidoptera: Noctuidae) and *Sesamiapoephaga* Tams and Bowden (Lepidoptera: Noctuidae) were identified (Table 1). *Sesamiapoephaga* is the first report on sugarcane plantations of Ethiopia. The borer is known in Western and Central Africa and has never been reported from East Africa (Holloway, 1988). Because of its close relationship with the East and Southern African species of *Sesamiaepunctifera*, but proper identification of the species is very difficult. Further confirmation of the identification of this species is needed with more materials and use of molecular methods. *Sesamianonagroidesbotanephaga* (Lepidoptera: Noctuidae) was previously described by the Commonwealth Institute of Entomology from Wonji estate (Anonymous, 1975), was not encountered in this survey. In 1979 an outbreak of *Sesamianonagroidesbotanephaga* was reported from sugarcane fields at Wonji estate (Abera and Tesfaye, 2001). The absence of this species in the current study could be due to displacement by the presently recorded ones through high level inter-species competition (Kfir, 1997) or the number of immature specimen collected and reared may too few and did not reach adult stage for identification (Yoseph, 2006).

Variations were observed on the species of sugarcane borer among the plantations (Table 1). *S. calamistis* and *S. peophaga* were found in all the plantations. On the other hand, *B. fusca* was recorded in Wonji-Shoa and Finchaa while in Metahara, *C. partellus* was the only borer species. The variation in the composition of the borer species may have resulted from the variations in the altitude and diversity of natural host plants among the plantations. Finchaa and Wonji-Shoa are located at higher altitude (> 1500 m. a. s. l) as compared to Metahara (<1000 m. a .s .l).

Table 1. Diversity and relative abundance of Sugarcane borer's species in the sugarcane plantations of Ethiopia during wet and dry seasons

Species	**Wonji-Shoa**		**Metahara**		**Finchaa**	
	No. of adults/ 100 infected stalks/	Relative Abundance (%)	No. of adults/ 100 infected stalks/	Relative Abundance (%)	No. of adults/ 100 infected stalks/	Relative Abundance (%)
usseolaFusca	23(35)*	30(34)	0(0)	0(0)	55(67)	55(51)
Chilopartellus	0(0)	0(0)	13(22)	21(24)	0(0)	0(0)
Sesamia calamistis	36(41)	46(40)	28(36)	44(39)	30(42)	30(32)
Sesamia peophaga	19(27)	24(26)	22(35)	35(38)	15(23)	15(17)

*= Numbers within and outside parenthesis are dry and wet seasons values, respectively.

Studies in Ethiopia have reported that *B. fusca* dominated high altitude and cooler areas (Amanuel, 2006) whereas *C. partellus* was well established in the warm low and mid altitude (Emana, 2002). The study also indicated that season had an effect on the number and relative abundance of borer species. Berger-Parker dominance index analysis indicated that *S. calamistis* was the dominant species both in Wonji-Shoa and Metahara while *B. fusca* at Finchaa (Table 2).

Table 2. Berger-Parker dominance indices of sugarcane borer species in the sugarcane plantations of Ethiopia

Plantations	**IndividualAbundance (A)**	**Berger-Parker (D)**	**DominantSpecies**
Wonji-Shoa	46 (40)*	0.32 (0.31)	*S. calamistis*
Metahara	44 (39)	0.30 (0.30)	*S. calamistis*
Finchaa	55 (51)	0.38 (0.39)	*B. fusca*

*= Numbers within and outside parenthesis are dry and wet seasons values, respectively.

Levels of infestations and damage by sugar cane borers

Percent of sugarcane plants with dead shoots ranged from 3.5–54% and were influenced by seasons (Figure 2). Dead shoot incidence was high during the dry season period (January to April, 2008) and low in the wet season (end of May to December, 2007). A study on biology of sugarcane borer indicated that the pest population increases during the dry season (Leul, 2008). The study also revealed that incidence of bored stalks ranged from 5.6 to 28.8%, whilst, the severity (percent bored internodes) ranged from 8.3–20.5% (Figure 3). The highest incidence (percent bored stalk) was recorded at Finchaa (28.8%); whereas, the lowest was at Metahara (5.6%). Similarly, both the highest (20.5%) and lowest (8.3%) severity (percent bored internodes) were recorded at Finchaa in the dry and wet seasons, respectively.

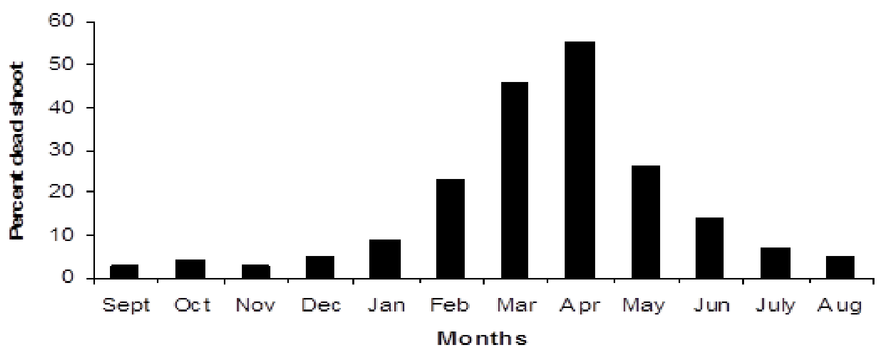

Fig. 2. Incidence of sugarcane shoot borer in the sugarcane plantations of Ethiopia.

Multiple regression analysis of stalk borer incidence and severity indicated that the pest attacks the sugarcane plantations regardless of site and soil types. On the other hand, the incidence of stalk borer was significantly affected by crop type/cuttings, variety and season (Table 3). Among the crop types, first ratoon had a strong and significant variation ($P \leq 0.01$) in stalk borer incidence both in the dry and wet seasons in the plantations. Moreover, sugarcane varieties showed significant variations in incidence and severity of stalk damage in both seasons. This could be resulted due to the direct effect of climatic factors (temperature, rainfall, relative humidity) on the pest's life cycles and activity as reported by Polasezk (1998) and Emana (2002) and Amanuel (2006).

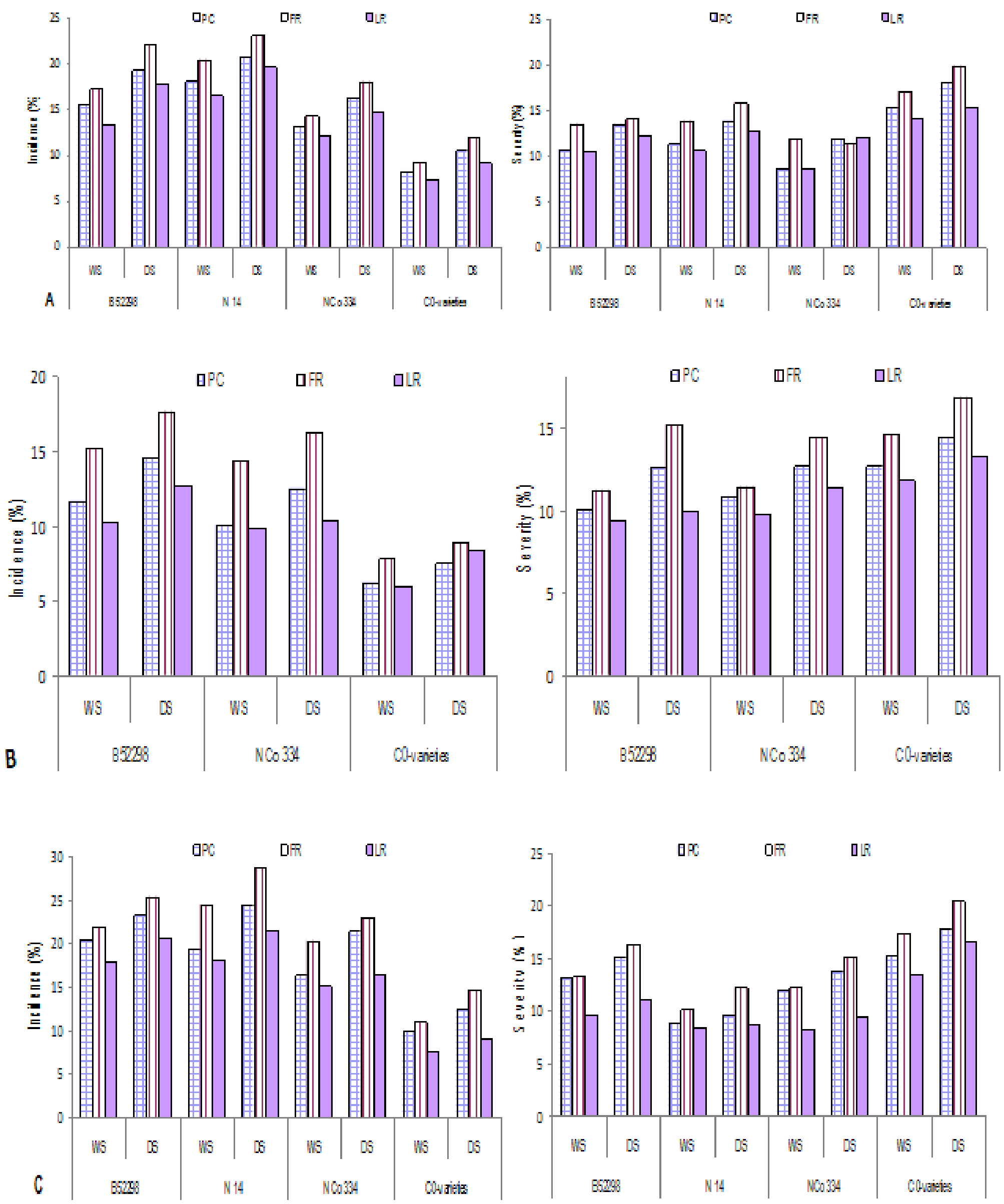

Fig. 3. Incidence and severity of stalk damage of sugarcane by stalk borers in (A) Wonji-Shoa, (B) Metahara and (C) Finchaa sugarcane plantations of Ethiopia; PC, FR and LR are plant cane, first and last ratoon; and WS and DS denote wet and dry seasons, respectively.

In Wonji-Shoa and Metahara infestation was high in first ratoon crop than in plant cane and last ratoon crop in light soil management group. This also holds true for the other soil management groups of the three plantations. It was observed that stalk borers invariably attacked the different cuttings across the different soil management groups. The differences in percent stalk infestation across cuttings could be attributed to the progressive establishment of natural enemies besides difference in crop management practices. Natural enemies such as larval parasitoids, *Cotesiasesamiae* (Hymenoptera: Braconidae) and *Cotesiaflavipes* (Hymenoptera: Braconidae), and pupalparasitoid, *Linnaemya*sp. (Diptera: Tachnidae) were reported prevalent in the three sugarcane plantations of Ethiopia (Yoseph, 2006). In addition, stalk borer incidence was significantly affected by season (Table 1).

Table 3. Chi-square test of stalk borer incidence and severity in the sugarcane plantations in Ethiopia in 2007 and 2008

Parameter	d.f	Incidence		Severity	
		Chi-square Value	P-value	Chi square value	P-value
Site	2	4.71	0.095	2.06	0.35
Soil type	2	3.86	0.145	0.54	0.76
Crop type/cuttings	2	17.56	< 0.01	0.79	0.67
Variety	4	13.36	0.01	39.29	< 0.01
Season	1	115.00	< 0.01	18.84	< 0.01

Moreover, sugarcane varieties had showed significant variation in incidence and severity of stalk borer in both seasons (Table 4). Among the varieties, B52298 had showed significantly different variation (10 times higher) at $P < 0.01$ in incidence as compared to the other varieties in all the plantations across the two seasons (Table 4) whereas, in terms of severity, the Co-varieties had showed significantly different variation at $P < 0.01$ unlike the other varieties in all plantations (Table 4). Different authors indicated that varietal characteristics like leaf angle, nodal length, leaf sheath tightness, rind strength, rind color, fiber and pith percentage has effect on the incidence and severity of borer species (White *et al*., 2001; Posey, 2004). The study also showed variation in mean percent of incidence and severity among the estates irrespective of the soil management groups. At Wonji-Shoa and Finchaa, the variety N 14 and Co-varieties had showed highest mean incidence and severity as compared to the other varieties, respectively (Figure 3). Similarly at Metahara variety B 52 - 298 had showed the highest incidence whereas in terms of severity Co-variety is the highest. Different authors reported that varietal differences had significant importance both on incidence and severity of stalk borers (White *et al*., 2001 and Posey, 2004).

Table 4. Logistic regression of borer incidence and severity in the sugarcane plantations of Ethiopia in 2007

Parameter	**ß**	**d.f**	**Significance**	**Exp (ß)**	**95% C.I. for Exp (ß)**	
					Lower	Upper
NCO 334	-	4	0.00(0.03)	-	-	-
B52298	2.31(18.26)	1	0.00(0.99)	10.16(85.88)	2.04(0.00)	49.99
N14	0.12(-2.05)	1	0.88(0.06)	1.12(0.12)	0.22(0.01)	45.60(1.15)
CO680	0.40(-3.48)	1	0.61(0.00)	1.50(0.03)	0.31(0.00)	37.22(0.27)
CO421	-0.19(-3.61)	1	0.82(0.00)	0.82(0.02)	0.15(0.00)	34.32(0.24)
Last	-	2	0.00(0.52)	-	-	-
Plant Cane	1.66(0.32)	1	0.32(0.59)	5.26(1.37)	1.14(0.42)	24.11(4.52)
First	3.01(0.67)	1	0.00(0.26)	20.44(1.96)	4.39(0.59)	95.20(6.51)
Constant	-3.42(2.62)	1	0.00(0.01)	0.03(13.83)		

Note: Values within and outside parenthesis are severity and incidence, respectively. Variety NCO-334 and last ratoon were used as a comparison factor among varieties and cutting groups, respectively.

Extent of stalk borer damage on cane and sugar yield

On the average 16 % of the stalks sampled showed stalk borer infestation and live larvae and pupae of stalk borers were recovered from about 6% of them in all the three plantations. The study showed that stalk borer damage expressed in terms of stalk tunnel length and number of bored internodes significantly reduced stalk length; cane and sugar yield. The sugarcane stalks damaged by the stem borers on the average had stalk borer tunnel length of 13.25 cm. The average length of affected stalk was about 10.24 % less than the non-affected stalks. Besides, cane and sugar yield of affected stalks were about 24.86 and 34.34 % less than the non-affected stalks, respectively (Table 5). This was in agreement with the report by Schexnayder *et al.* (2001) that showed high levels of stalk borer damage results in poor cane growth and yield.

There were significant differences between tunneled and non-tunneled stalks for all plant growth parameters except for stalk diameter (Table 5). In general stalk borer tunneling had a strong linear relation with stalk height (Y= -2.2906 + 207.4, R^2 = 0.9488 and P <0.05); cane (Y= -27.302 + 1764.5, R^2 = 0.9370 and P <0.05) and sugar yield (Y= -4.1558 + 216.27, R^2 = 0.88 and P <0.05). Similar findings were alsoreported by Songa *et al*. (2001) who indicated that tunnel length is a good indicator of stalk borer damage.

Table 5. Effect of stalk borer tunneling on sugarcane growth, cane and sugar yield averaged for the seasons

Parameters	**Non tunneled stalks (n = 77)**	**Tunneled stalks (n = 23)**
Average tunnel length per stalk (cm)	-	13.25*
Average stalk length (cm)	210	188.5*
Average stalk diameter (cm)	2.99	2.93
Average stalk weight (kg)	1.81	1.36*
Yield (sugar % cane)	12.83	11.03*
Sugar yield (gm)	232.22	152.47*

Note: Two sample t-test assuming unequal variances was performed for tunnel length 1 up to 35.3 cm against the control (tunnel length zero); * indicate significance at 5 % probability level; n= number of samples.

Stalk with exit holes had showed strong linear relation with stalk height (Y=-1.895x + 207.63, R^2=0.9132 and P<0.05), cane (Y=-29.501x + 1760.60, R^2=0.9510 and P<0.05) and sugar yield (Y=-4.022x + 215.16, R^2=0.9522 and P<0.05).Stalks with exit hole(s) were about 9.02 % shorter than stalks with no holes, and cane yield was reduced by 27.07 % (Table 6). Similar to tunnel length, the number of holes had little effect on stalk diameter.

Table 6. Effect of stalk borer exit holes on sugarcane growth, cane and sugar yield averaged for the seasons

Parameters	**Stalks without exit holes (n = 77)**	**Stalks with exit holes (n = 23)**
Average tunnel length per stalk(cm)	-	12.04*
Average stalk length (cm)	210	191.05*
Average stalk diameter (cm)	2.99	2.92
Cane yield per stalk (kg)	1.81	1.32*
Yield (sugar % r cane) per stalk	12.83	11.03*
Sugar yield per stalk(gm)	232.22	147.78*

Note: Two sample t-test assuming unequal variances was performed for number of exit hole 1 up to 4 against the control (no exit hole); * indicate significance at 5 % probability level; n= number of samples.

On the other hand, number of larvae per stalk showed strong relationship with stalk height (Y=-1.261x + 206.94, R^2=0.8912 and P<0.05), cane (Y=-27.55x + 1755.95, R^2=0.9514 and P<0.05) and sugar yield (Y=-4.7120x + 215.10, R^2=0.9502 and P<0.05). The study indicated that infested stalks had on the average two alive larvae per stalk (Table 7), which corresponded to a decrease in plant height from 210 to 197.4 cm. The stalk borer damage also reduced cane and sugar yield from 1.82 to 1.27 kg and from 233.6928 to 139.45 g per plant, respectively. The study indicated that, a single stalk borer per stalk can cause about 5.22 % loss of potential yield (field yield). This result implies that a single stalk borer per stalk can cause about 35 g yield loss, equivalent to 2.61 % of sugar yield.

Table 7. Effect of number of stalk borer on sugarcane growth, cane and sugar yield averaged for the seasons

Parameters	Stalks without borer larvae (n = 84)	Stalks with borer larvae (n = 16)
Average tunnel length per stalk (cm)	-	12.3*
Average stalk length (cm)	210	197.4*
Average stalk diameter (cm)	2.99	2.93
Cane yield per stalk(gm)	1.82	1.27*
Yield (sugar % cane) per stalk	12.84	10.98*
Sugar yield per stalk(gm)	233.69	139.45*

Note: two sample t-test assuming unequal variances was performed for number of stalk borer larvae = 0 and 1 up to 5; * indicated the significance at 5 % probability level; n= number of samples.

Conclusion and Recommendations

A total of four different *Lepidopteran* stalk borer species that belongs to two different families were identified. Among the species, *S. peophaga* was reported for the first time in the sugarcane plantations of Ethiopia. In addition, species composition and distribution varied among the plantations due to the climatic factors, altitudinal variation, variety grown, crop type, seasons and the cultural practices followed in the plantations. This study also confirmed that stalk borer had a significant effect on stalk height, cane and sugar yield. Therefore, the sugarcane plantations of Ethiopia could give due attention in managing stalk borer by considering the different cutting groups and varieties. In addition, the record of new stalk borer species has necessitated periodic survey of the pest in the plantations.

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