Research Article

Effect of Morphological Characters of Indigenous Sugarcane Varieties on Population of *Chilo infuscatellus* (Snellen) and its parasitoid, *Cotesia flavipes* (Cameron)

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Abstract | Sugarcane stem borer, *Chilo infuscatellus* Snellen. has caused severe losses in cane growing areas of Pakistan. Among natural enemies, *Cotesia flavipes* Cameron has been widely used in different regions of the world for its management. Considering the significant role of morphological characters of sugarcane varieties on infestation of *C. infuscatellus,* thus, on parasitism of *C. flavipes,* this study was conducted in 2013 and 2014. Ten sugarcane varieties i.e., NIA-98, NIA-2004, Thatta-10, Gulab-95, BL-4, L-116, SPS-26, AEC86-223, AEC82-1026 and Larkana-201 were used in the study, each sown on half acre area at Experimental field of Nuclear Institute of Agriculture, Tando Jam, Pakistan. Observations were taken on morphological characters of varieties i.e., cane length, number of internodes, length of leaf, sheath, trichome density along with infestation and larval population of *C. infuscatellus* and parasitism of *C. flavipes* were recorded. Results indicated a high variation in the morphological characters of different sugarcane varieties evaluated, that in response affected the population of both *C. infuscatellus* and its parasitoid, *C. flavipes*. Among varieties, the highest population of *C. infuscatellus* was recorded on Thatta-10 variety, whereas, L-116 suffered the lowest damage. The population trend of *C. infuscatellus* on remaining varieties was recorded in the order of AEC-821026 > AEC-86-223 > Gulabi-95 > SPSG-26 > BL-4 > Larkan-2001 > NIA- 2004 > NIA-98 > 98. In continuation of the maximum population of *C. infuscatellus,* the highest the highest parasitism of *C. flavipes* on *C. infuscatellus* was also recorded on Thatta-10, and the lowest parasitism on L-116 variety. Moreover, among morphological characters, only the number of internodes showed a significant influence the infestation and larval population of *C. infuscatellus* along with parasitism of *C. flavipes.* Therefore, it is suggested that cultivation of susceptible varieties should be avoided to restrict the infestation of *C. infuscatellus.*

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Introduction

Sugarcane (*Saccharum officinarum* L.) is presently considered as a cash crop in Pakistan due to high cash values (Hussain *et al.*, 2007). However, presently many factors are responsible for its lower yield and marketing values in the country i.e., low per acre yield, sugar recovery and higher cost of production (Arian *et al.*, 2011). Although, there are many reasons for the lower yield of sugarcane in the country, but the yield losses due to attack of borer is the most significant. Among the borers, stem borer, *Chilo infuscatellus*

Snellen is the most notorious and destructive pest of sugarcane (Raza *et al.*, 2014). It is more active and damaging during March to November, whereas, it overwinters in stubbles as full-grown larvae. The most significant symptom of its damage is dead hearts, yield losses of 30-70% is reported due to its attack (Shahid *et al.*, 2007; Sajid and Hamed, 2011). Mainly, granular pesticides are used for the management of *C. infuscatellus;* however, their continuous indiscriminate use has caused many negative impacts i.e., development resistance, environmental pollution and hazards to humans and livestock (Mohyuddin *et al.*, 1997; Soerjani, 1998).

Cotesia flavipes cameron is a gregarious larval endo-parasitoid that feeds on large to medium sized larvae of borers attacking gramineae family (Ngi-Song and Overholt, 1995; Raza *et al.*, 2014). Although, native to South and South-east Asia, *C. flavipes* has successfully established in many countries of the world against many noxious lepidopteran borers (Murrihead *et al.*, 2006). It has also shown promising impacts against *C. infuscatellus* in Sindh, Pakistan (Khan *et al.*, 2013).

It has been established that host plant resistance always played a significant role in infestation by pests and also on the occurrence and abundance of their natural enemies at no additional cost (Mondal *et al.*, 2012). This variation in pest infestation and natural enemy population may be attributed towards the morphological characteristics of plants i.e., cane length, sheath length, number of internodes, number of trichomes etc. In sugarcane, Raza *et al.* (2014) reported the significant role of various morphological characters of varieties on reducing the infestation of *C. infuscatellus* and the performance of their parasitoids especially *Trichogramma chilonis.* Thus, aim of this study is to evaluate the role of various morphological characteristics of sugarcane varieties on the incidence of *C. infuscatellus* and its parasitoid, *C. flavipes.*

Materials and Methods

Experimental area

The study was conducted in 2013-2014 at agriculture field of Nuclear Institute of Agriculture (NIA), Tando Jam, Pakistan.

Experimental setup, data collection and analysis

Ten commercially cultivated sugarcane varieties of Sindh i.e., NIA-98, NIA-2004, Thatta-10, Gulab-95, BL-4, L-116, SPS-26, AEC86-223, AEC82-1026 and Larkana-201 were used in the study. Each variety was grown in a half-acre field in a randomized complete block design (RCBD), whereas, four replications were maintained for each variety. All the agronomic practices from sowing till harvesting of each variety was standardized. The data collection was started one month after the plantation of sugarcane and continued till harvesting. Ten canes from each variety were randomly selected per block to record the population of *C. infuscatellus,* infestation percentage of the borer and rate of parasitism of *C. flavipes* on the borer. In order to estimate the rate of parasitism, the collected larvae of *C. infuscatellus* were brought to the laboratory of NIA for further development and confirmation of parasitism.

Moreover, various morphological characters i.e., length of leaf along with sheath, trichome density, cane height and internode length were also recorded from the randomly selected ten canes of each variety as mentioned above. Correlation was performed to determine the influence of morphological characters of sugarcane varieties on the *C. infuscatellus* infestation and the rate of parasitism of *C. flavipes.*

Number of trichomes were determine by cutting one-inch sheath from top, middle and bottom of the plant and brought to the laboratory of Plant Protection Department, Sindh Agriculture University Tandojam and counted using a fine needle under an electron microscope. The length of cane was measured using measuring tape from top to bottom of the stalk. Total leaf length including the sheath was also measured along with counting of internodes per cane for each sugarcane variety.

Data analysis

Analysis of Variance was used to analyze the data, whereas the Least Significant Difference (LSD) was used to compare means with significant differences. Correlation was performed to determine the relationship of population of *C. infuscatellus* and its parasitoid *C. flavipes* with various morphological characters of sugarcane varieties.

Results and Discussion

Important morphological characters of sugarcane varieties in relation to infestation of *C. infuscatellus* and its parasitoid *C. flavipes* during 2013.

Table 1 showed the important morphological characteristics of various sugarcane varieties and their impact on the population of stem borer, *C. infuscatellus* and its parasitoid, *C. flavipes*. The detailed results are given hereunder:

Number of internodes

According to results, a significant difference (P< 0.05) was recorded among sugarcane varieties for the number of internodes. The results revealed that maximum number of internodes (25.87±.23 internodes/cane) were recorded in Thatta-10, followed by AEC86-223 (24.75±2.24 internodes/ cane) and AEC-82-1026 (23.70±2.16 internodes/ cane). The minimum internodes in a single cane were recorded in NIA-98 (17.16±1.38 internodes/ cane), followed by SPSG-26 (17.89±2.06 internodes / cane). Moreover, the remaining sugarcane varieties NIA-2004, L-116, Larkana-2001, Gulabi-95 and BL-4 produced 22.09±2.42 internodes/ cane, 21.67±2.00 internodes/ cane, 20.52±1.14 internodes/ cane, 19.84±1.75 internodes/ cane and 18.05±1.35 internodes/ cane, respectively.

Cane length

Results in Table 1 shows significant (P < 0.05) variation in cane length for different sugarcane varieties. Results revealed that the longest canes (224.05±14.90 cm) were obtained for variety NIA-2004, followed by AEC-82-1026 (216.82±13.59 cm) and AEC-86-223 (193.41±12.21 cm). Among all the planted varieties, BL-4 variety, was observed as the shortest in length which produced 96.13±3.62 cm canes, followed by SPSG-26 (115.77±4.23 cm). Cane length for remaining varieties observed were L-116 (183.97±12.38 cm), Thatta-10 (162.03±8.68 cm / cane), NIA-98 (151.19±9.56 cm), Larkana-2001 (140.52±5.70 cm and Gulabi-95 (126.75±10.21 cm.

Leaf length

The length of leaves for all the tested sugarcane varieties was measured and the results in Table 1 shows that the maximum leaf length (20.68±1.14 cm) was recorded in variety Larkana-2001 which was closely followed by AEC-82-1026 (20.14±1.27 cm). Relatively reduced or short leaves was recorded in NIA-2004 (18.38±0.87 cm), Thatta-10 (17.14±1.03 cm), AEC-86-223 (16.96±0.81 cm), NIA-98 (16.61±0.42 cm) and SPSG-26 (15.50±0.07 cm). The minimum leaf length was recorded in Gulabi-95 (12.64±0.35 cm), followed by L-116 (13.82±0.34 cm) and BL-4 (14.38±0.23 cm). Thus, the significant (P < 0.05.) difference was observed in leaf length among different cultivated sugarcane varieties.

Sheath length

The measured length of sheath showed significant (P < 0.05) variation among cane varieties studies and is represented in Table 1. The maximum sheath length (6.86±0.74 cm) was recorded for AEC-86-223 variety, followed by Gulabi-95 (5.64±0.62 cm) and Larkana-2001 (5.48±0.43 cm) varieties. Among the varieties, the shortest sheath length (2.66±0.23 cm) was observed in BL-4 variety, followed by AEC-82-1026 sugarcane variety (2.86±0.22 cm).

Trichromes at top sheath

The results regarding the number of trichomes on top sheath indicated that the maximum number of trichomes were observed in NIA-2004 variety (58.15±3.36 trichomes per one-inch sheath), followed by AEC-86-223 (57.75±3.19 trichomes per one inch sheath), and Larkana-2001 (56.05±3.22 trichomes per one-inch sheath). The lowest number trichomes on top sheath was counted on Gulabi-95 variety (14.25±0.12 trichomes per one-inch sheath), followed by BL-4 (16.15±0.10 trichomes per one-inch sheath) and Thatta-10 (16.80±0.11 trichomes per one-inch sheath) varieties (Table 1).

Mid sheath trichomes

The results regarding mid sheath trichomes is also presented in Table 1 that indicated a significant (P < 0.05) variation in trichomes counted among sugarcane varieties. The highest and lowest number of trichomes on mid sheath were recorded on Larkana-2001 (156.40±0.18 trichomes per one-inch sheath) and BL-4 (59.90±0.13 trichomes per one-inch sheath) varieties, respectively. The number of trichomes recorded on mid sheath of remaining varieties were NIA-2004 (153.50±0.79 trichomes per one-inch sheath), AEC-82-1026 (142.10±0.21 trichomes per one inch sheath), AEC-86-223 (125.65±0.17 trichomes per one-inch sheath), NIA-98 (121.75±0.10 trichomes per one-inch sheath), L-116 (98.95±0.10 trichomes per one-inch sheath), SPSG-26 (78.90±0.17 trichomes per one-inch sheath), Thatta-10 (69.25±0.17 trichomes per one-inch sheath) and Gulabi-95 (65.45±0.22 trichomes per one-inch sheath).

Bottom sheath trichomes

According to results obtained during 2013 study, the maximum number for bottom sheath trichomes (71.40±2.20 trichomes per one-inch sheath) was counted in Larkana-2001, whereas Gulabi-95 variety possessed the lowest number of trichomes on bottom sheath i.e., 16.20±1.24 trichomes per one-inch sheath (Table 1). The number of trichomes recorded in NIA-2004, AEC-86-223, AEC-82-1026, NIA-98, SPSG-26, BL-4, Thatta-10, and L-116 varieties were 66.70±2.42, 59.80±3.08, 58.40±3.14, 45.65±2.15, 22.90±2.26, 19.90±2.06, 18.35±1.09, and 16.90±1.13 trichomes per one-inch sheath, respectively (Table 1).

Stem borer infestation percentage

The infestation percentage caused by *C. infuscatellus* on different sugarcane varieties varied significantly ($P < 0.05$). According to results, the highest infestation percentage by *C. infuscatellus* larvae (16.80±1.45%) was observed on Thatta-10 sugarcane variety, followed by AEC-82-1026 (14.89±1.19%) and AEC-86-223 (10.98±1.02%). Moreover, the lowest infestation percentage due to the attack of *C. infuscatellus* was recorded on L116 (1.70±0.12 %) variety, followed by NIA-98 (4.15±0.47 %) and NIA-2004 (4.36±0.33 %) varieties. The infestation percentage recorded on remaining varieties i.e., Gulabi-95, SPSG-26, BL-4 and Larkana-2001 were 7.72±1.00%, 6.64±0.85%, 6.64±0.44% and 6.17±0.75 %, respectively (Table 1).

Larval population

The larval population of *C infuscatellus* observed on different sugarcane varieties is given in Table 1. The results show that sugarcane varieties have significant ($P<0.05$) effect on larval population as the highest population of larvae per cane was recorded in Thatta-10 variety (21.00±0.02 larvae/cane). Moreover, the lowest number of larvae per can was recorded in L-116 (0.38±0.02 larvae/cane), followed by NIA-98 variety (0.46±0.02 larvae/cane).

Parasitism percentage

The parasitism percentage of *C. flavipes* on *C. infuscatellus* attacking different sugarcane varieties is shown in Table 1. Analysis of variance revealed that there was a significant ($P < 0.05$) variation among sugarcane varieties to affect the parasitism of *C. flavipes* on *C. infuscatellus*. Maximum parasitism percentage (0.61±0.01 %) was recorded on larvae collected from L-116 variety, followed by AEC-86-223 sugarcane variety (0.14±0.01 %). The lowest parasitism percentage of *C. flavipes* on *C. infuscatellus* larvae i.e., 2.06±0.01% was observed from SPSG-26, BL-4 and NIA-98 sugarcane varieties.

Important morphological characters of sugarcane varieties in relation to infestation of *C. infuscatellus* and its parasitoid *C. flavipes* during 2014.

Number of internodes

The results regarding number of internodes counted for various sugarcane varieties showed almost similar trend as that of 2013, where maximum number of internodes (28.33±2.23 internodes/cane) was recorded in AEC-86-223 variety, followed by Thatta10 and AEC-82-1026 varieties with 27.11±2.06 and 27.10±2.27 internodes / cane, respectively. Moreover, the minimum internodes (18.63±1.19 internodes/cane) were observed in BL-4 variety, followed by NIA-98 variety (19.94±1.15 internodes / cane). Thus, overall a highly significant ($P < 0.001$) difference was noted among sugarcane varieties regarding the number of internodes (Table 2).

Cane length

A high variation with significant difference ($P< 0.001$) was also recorded for the length of canes among sugarcane varieties studied (Table 2). The results indicated that NIA2004 variety produced the longest canes (220.45±5.74 cm), whereas BL-4 was the shortest variety having can length of 89.45±2.21 cm. The cane length recorded for remaining varieties i.e., Larkana-2001, Thatta-10, SPSG-26, NIA-98, L-116, AEC-821026, AEC-86-223 and Gulabi-95 were 121.22±3.13 cm, 113.20±2.07 cm, 105.42±2.17 cm, 137.20±3.15 cm, 116.28±4.54 cm, 178.23±4.73 cm, 195.51±5.17 cm and 118.84±3.54 cm, respectively.

Leaf length

The results regarding the leaf length exhibited that the maximum leaf length (20.94±1.23 cm/ leaf) was recorded in NIA-2004, followed by Larkana-2001 (20.74±2.17 cm). Moreover, the minimum leaf length (7.28±0.19 cm) was recorded in BL-4, followed by Gulabi-95 variety with leaf length of 11.00±0.88 cm. Accordingly, a highly significant difference ($P < 0.001$) was observed in the leaf lengths among various sugarcane varieties (Table 2).

Sheath length

Results regarding the sheath length of various sugarcane varieties evaluated in the study also elicited

a significant difference (P < 0.05) as the minimum and maximum length of sheath i.e., 8.23±0.18 cm and 2.66±0.14 cm was recorded for Larkana-2001 and Gulabi-95 varieties, respectively. The sheath length of Thatta-10, SPSG-26, BL-4, NIA-98, NIA-2004, L-116, AEC-82-1026 and AEC-86-223 varieties was recorded as 2.85±0.11 cm, 4.88±0.22 cm, 3.26±0.13 cm, 4.74±0.25 cm, 5.48±0.51 cm, 7.80±6.56 cm, and 6.20±0.33 cm, respectively.

Trichomes at top sheath

Table 2 also indicated the number of trichomes counted at top sheath of different sugarcane varieties. According to results, maximum number of trichomes at top sheath were recorded in AEC-86-223 variety (59.75±4.09 trichomes per one-inch sheath), which was closely followed by Larkana-2001 (58.15±2.29 trichomes per one-inch sheath). The lowest trichomes counted at top sheath was recorded in Gulabi-95 (16.20±0.88 trichomes per one-inch sheath) and Thatta-10 (16.50±0.79 trichomes per one-inch sheath). Thus, the ANOVA results confirmed a highly significant difference (P < 0.001) in the number of trichomes at top sheath among various sugarcane varieties studied.

Mid sheath trichomes

The results for trichomes counted at mid sheath showed significant (P < 0.05) difference among various sugarcane varieties evaluated (Table 2). Accordingly, the maximum and minimum number of trichomes on mid sheath were recorded on Larkana-2001 (158.80±5.67 trichomes per one-inch sheath) and BL-4 (57.95±2.09 trichomes per one-inch sheath) varieties, respectively.

Bottom sheath trichomes

The number of trichomes recorded on various sugarcane varieties exhibited a highly significant (P < 0.001) difference among various sugarcane varieties. The maximum number of bottom sheath trichomes (78.30±3.17 trichomes per one-inch sheath) was observed on Larkana-2001 variety, followed by NIA-2004 (68.25±3.25 trichomes per one-inch sheath) and AEC-82-1026 (63.05±3.25 trichomes per one-inch sheath) varieties. Moreover, the minimum number of trichomes on bottom sheath (16.95±0.77 trichomes per one-inch sheath) was recorded on SPSG-26 variety, closely followed by L-116 (17.90±0.93 trichomes per one-inch sheath).

Stem borer infestation percentage

The analyzed data for cane infestation caused by *C. infuscatellus* is presented in Table 2 that indicated a significant (P < 0.05) variation in varietal preference of stem borer on sugarcane as the highest infestation percentage (15.15±1.21%) was recorded on Thatta10 variety, followed by AEC-82-1026 variety (12.10±1.11%). Among sugarcane varieties, *C. infuscatellus* showed the least preference on L-116 variety with infestation percentage of 0.89±0.10%, followed by NIA-2004 variety (3.90±0.22%). The infestation percentage of *C. infuscatellus* on remaining sugarcane varieties i.e., Larkana-2001, SPSG-26, BL-4, NIA-98, AEC-86-223 and Gulabi-95 were 7.14±0.41%, 5.10±0.72%, 5.25±0.81%, 4.10±0.45%, 9.10±0.95% and 6.15±0.66%, respectively.

Larval population

Among sugarcane varieties, the maximum and minimum population of *C. infuscatellus* larvae was recorded on Thatta-10 (1.94±0.27 larvae per cane) and L-116 (0.26±0.06 larvae per cane). Moreover, the population of 0.58±0.11 larvae per cane, 1.06±0.21 larvae per cane, 0.86±0.10 larvae per cane, 0.38±0.08 larvae per cane, 0.54±0.11 larvae per cane, 1.66±0.15 larvae per cane, 1.38±0.22 larvae per cane and 1.18±0.17 larvae per cane were recorded in Larkana-2001, SPSG-26, BL-4, NIA-98, NIA-2004, AEC-821026, AEC-86-223 and Gulabi-95 varieties, respectively (Table 2). Accordingly, a highly significant difference (P < 0.001) was recorded among different sugarcane varieties regarding the larval population of *C. infuscatellus*.

Parasitism percentage

The parasitism percentage of *C. flavipes* on *C. infuscatellus* damaging different sugarcane varieties is shown in Table 2. The results indicated that percent parasitism of *C. flavipes* on *C. infuscatellus* on various sugarcane varieties differ significantly (P < 0.05). Accordingly, the maximum parasitism of *C. flavipes* was observed on *C. infuscatellus* collected from Thatta-10 (14.82±1.27%), followed by AEC-82-1026 (13.60±0.86%). Moreover, the lowest *C. flavipes* parasitism was noticed on *C. infuscatellus* collected from L-116 (1.71±0.02%), followed by NIA-98 (3.38±0.09%), and NIA-2004 (3.72±0.09%). The parasitism percentage of *C. flavipes* observed on Larkana-2001, SPSG-26, BL-4, AEC-86-223 and Gulabi-95 varieties was 5.54±0.79%, 6.63±0.26%, 5.94±0.12%, 10.31±0.92% and 9.31±0.86%, respectively.

Table 1: *Effect of various morphological characters of sugarcane varieties on the infestation of C. infuscatellus and its parasitoid C. flavipes during 2013 (Mean+SE).*

Varieties	No of Internodes	Cane length (cm)	Leaf length (cm)	Sheath length (cm)	Trichomes			Infestation%	Larval population	Parasitism %
					Top sheath	Mid bottom	Sheath sheath			
Larkana-2001	20.52±1.14ab	140.00±5.70d	20.68±1.14a	5.48± 0.43ab	56.05±3.22a	156.40±6.18a	71.40±2.20a	6.17±0.75e	0.70±0.08e	8.14±0.83c
Thatta-10	25.87±2.23a	162.03±8.68c	17.14±1.03bc	4.86±0.33c	16.80±1.11e	69.25±3.17f	18.35±1.09f	16.80±1.45a	2.0±0.18a	10.61±0.12a
SPSG-26	17.89±2.06c	115.77±4.23	15.50±0.74cd	4.51±0.25c	31.50±2.13c	78.90±3.47e	22.90±2.26e	6.64±0.44e	1.10±0.11d	2.06±0.01f
BL-4	18.05±1.35	96.13±3.62f	14.38±0.23d	2.66±0.22d	16.15±1.09e	59.90±3.13g	19.90±2.06ef	6.64±0.85e	0.98±0.09d	2.06±0.01f
NIA-98	17.16±1.38c	151.19±9.56c	16.61±0.42c	5.10±0.77bc	29.50±2.13cd	121.70±6.09c	45.65±2.15d	4.15±0.47f	0.46±0.06f	2.06±0.01f
NIA-2004	22.09±2.02ab	224.05±14.90a	18.38±0.87b	5.10±0.79bc	58.15±3.36a	153.50±7.79a	66.70±2.42b	4.36±0.33f	0.62±0.09e	5.12±0.03d
L-116	21.67±2.00ab	183.97±12.38b	13.82±0.34	4.90±0.55bc	36.55±2.17c	98.95±5.09d	16.90±1.13g	1.70±0.12g	0.38±0.03f	3.10±0.02e
AEC-82-	23.70±2.16a	216.82±13.59a	20.14±1.27a	2.86±0.22	49.30±3.06b	142.10±6.21b	58.40±3.14c	14.89±1.19b	1.78±0.15ab	3.12±0.04e
1026 AEC-86	24.75±2.04a	193.41±12.21b	16.96±0.81bc	6.86± 0.74a	57.75±3.19a	125.65±5.17c	59.80±3.08c	10.98±1.02c	1.54±0.14bc	9.14±0.45b
Gulabi-95	19.84±1.75bc	126.75±10.21e	12.64±0.35e	5.64±0.62ab	14.25±0.42f	65.45±3.22f	16.20±1.24g	7.72±1.00d	1.22±0.22d	4.06±0.01de

**Mean followed by the same letters in same column are not significantly different (LSD < 0.05).*

Table 2: *Effect of various morphological characters of sugarcane varieties on the infestation of C. infuscatellus and its parasitoid C. flavipes during 2014 (Mean + SE).*

Varieties	No of internodes	Cane length (cm)	Leaf length (cm)	Sheath length	Trichomes (cm)			Infestation %	Larval population	Parasitism %
					Top sheath	Mid sheath	Bottom sheath			
Larkana-2001	21.31±1.11bc	121.22±3.13f	20.74±2.17a	8.23±0.18a	58.15±2.29a	158.80±5.67a	78.30±3.17a	7.14±0.41d	0.58±0.11e	5.54±0.79d
Thatta-10	27.11±2.06a	113.20±2.07g	15.68±0.34c	2.85±0.11e	16.50±0.79f	67.10±2.13e	18.65±1.09f	15.15±1.21a	1.94±0.22a	14.82±1.27a
SPSG-26	23.33±1.83bc	105.42±2.17h	15.68±0.55c	4.88±0.22c	33.00±2.08e	96.70±3.21d	16.95±0.77g	5.10±0.72f	1.06±0.21cd	6.63±0.26d
BL-4	18.63±1.19c	89.45±2.21i	7.28±0.19f	3.26±0.13 d	17.90±1.56f	57.95±2.09g	21.95±1.15e	5.25±0.81ef	0.86±0.10d	5.94±0.12d
NIA-98	19.94±1.15c	137.20±3.15 e	15.58±0.99 c	4.74±0.25 c	34.90±2.26 c	124.70±4.13 e	53.30±3.24d	4.10±0.45fg	0.38±0.08g	3.38±0.49e
NIA-2004	22.55±1.91b	220.45± 5.74a	20.94±1. 23 c	5.48±0.51 b	55.95±3.05	155.9±5.09a	68.25±3.55b	3.90±0.22g	0.54±0.11e	3.72±0.44e
L-116	166.28±4.54 d	13.60±0.38 a	7.80±0.71 d	39.15±2.79 g	17.90±0.93f	27.10±2.27a	117.9±3.13c	0.89±0.10h	0.26±0.06h	1.71±0.12f d
AEC-82-1026	178.23±4.73 c	17.28±1.18 b	6.56±0.31 b	46.80±2.83 c	152.40±4.27 a	28.33±2.23a	63.05±3.25c	12.10±1.11b	1.66±0.15ab	13.60±0.86b
AEC-86-223	24.57±1.79a	195.51±5.17 b	17.88±0.89 b	6.20±0.33 b	59.75±4.09 b	129.5±3.19b	61.90±3.06c	9.10±0.95c	1.38±0.22bc	10.31±0.92c
Gulabi-95	20.38±1.26b	118.84±3.54 c	11.00±0.88 g	2.66±0.14 e	16.20±0.88 e	61.85±2.21f	18.10±0.86f	6.15±0.66e	1.18±0.17c	9.31±0.86c

**Mean followed by the same letters in same column are not significantly different (LSD < 0.05)*

Correlation between various morphological characters of sugarcane varieties with population and infestation of C. infuscatellus and its parasitoid C. flavipes during 2013

Results regarding correlation between various varietal characters of sugarcane varieties with population and infestation of *C. infuscatellus* and its parasitoid *C. flavipes* during 2013 are presented in Table 3. According to results, a significant and positive relationship was found between *C. infuscatellus* percentage infestation (r= 0.8612, p< 0.0301), larval population (r = 0.5790, p < 0.044) along with parasitism percentage of *C. flavipes* (r= 0.5050, p < 0.047) with the number of internodes on the various sugarcane varieties. Moreover, the infestation percentage of *C. infuscatellus* also showed significant, positive and intermediate correlation (r= 0.5925, p <0.0261) with parasitism percentage of *C. flavipes*. In addition, the larval population of *C. infuscatellus* also exhibited a significant and positive association with *C. infuscatellus* infestation percentage (r = 0.6929, p < 0.0263) and *C. flavipes* percentage parasitism (r = 0.4282, p < 0.0414). No significant relationship was observed for the rest of the varietal characters of cane varieties with both pest and parasitoid population.

Correlation between various varietal characters of sugarcane varieties with population and infestation of C. infuscatellus and its parasitoid C. flavipes during 2014

The correlation results for 2014 study were almost similar with that of 2013, as the number of internodes of sugarcane varieties elicited a significant, moderate and positive correlation (r = 0.5974, p < 0.0482) only with percentage infestation of *C. infuscatellus*. Moreover, during 2014, rate of *C. flavipes* parasitism also showed a medium, positive and significant relation with infestation percentage of *C. infuscatellus* (r = 0.4613, p < 0.0465), but a highly significant relationship with its larval population (r = 0.9849, p < 0.0001). A significant inter-relation was also observed between infestation percentage and larval population of *C. infuscatellus* (r = 0.5221, p < 0.0374). No other significant relationship was recorded in the study (Table 4).

Two years studies confirmed that there were significant variations among the sugarcane varieties for their morphological characteristics, which in turn affected the population and infestation of *C. infuscatellus* and parasitism percentage of *C. flavipes* on *C. infuscatellus*. Among sugarcane varieties studied, L-116 variety was found comparatively resistant with minimum infestation and larval population of *C. infuscatellus*, whereas, Thatta-10 variety was found to be the most susceptible showing maximum borer population and infestation. The infestation of other varieties was given in descending order towards the susceptibility as, AEC-821026 > AEC-86-223> Gulabi-95 > SPSG-26 > BL-4 > Larkan-2001> NIA- 2004 > NIA-98 > 98. Thus, no complete resistant variety of sugarcane was found against the *C. infuscatellus*. Moreover, the presence of host i.e., *C. infuscatellus* on various cane varieties attracted the variable population of its parasitoid, *C. flavipes* as its maximum and minimum population was also recorded on Thatta-10 and L-116 variety. This variable population of both pests and parasitoid may be attributed to the highest number of internodes counted on Thatta-10 variety as they may support the feeding and movement of the pests, and accordingly, its parasitoid. Moreover, no significant effect of other varietal characters of sugarcane i.e., leaf length, sheath length, cane length and number of trichomes was recorded either on infestation of *C. infuscatellus* or parasitism percentage of *C. flavipes*. The findings of this study support the findings recorded by Sohu *et al.* (2008) who found that L-116 showed very good results against sugarcane borer with minimum losses. However, our results did not support the findings of Keerio *et al.* (2003) and Memon *et al.* (2003) who reported that the BL-4 sugarcane variety showed minimum infestation of *C. infuscatellus*.

Table 3: *Correlation between various varietal characters of sugarcane varieties with population and infestation of C. infuscatellus and its parasitoid C. flavipes during 2013.*

Parameters	No. of internodes	Cane length	Leaf length	Sheath length	Trichomes			Infestation percentage	Larval population
					Top	Middle	Bottom		
Infestation percentage	r = 0.6812 p = 0.0301	r = 0.1887 p = 0.6016	r = 0.3451 p = 0.3288	r= - 0.1424 p= 0.6947	r = - 0.0898 p = 0.8052	r = - 0.1150 p = 0.7518	r = 0.0218 p = 0.9523	-	r = 0.6929 p = 0.0263
Larval population	r = 0.5790 p = 0.044	r = 0.0179 p = 0.9608	r = 0.0807 p = 0.8247	r= 0.0085 p= 0.9814	r = - 0.3843 p = 0.2729	r = - 0.3587 p = 0.3087	r = - 0.3172 p = 0.3718	-	-
Parasitism percentage	r = 0.5055 p = 0.047	r = 0.3231 p = 0.3624	r= -0.2161 p= 0.5487	r= 0.0972 p= 0.7893	r = 0.1702 p = 0.6384	r = 0.0769 p = 0.8328	r = - 0.1867 p = 0.6056	r = 0.5925 p = 0.0261	r = 0.4282 p = 0.0414

Table 4: *Correlation between various varietal characters of sugarcane varieties with population and infestation of C. infuscatellus and its parasitoid C. flavipes during 2014.*

	No. of internodes	Cane length	Trichomes Sheath	Infestation sheath length	Larval parameters			Percentage	Population
					Top	Middle	Leaf length bottom		
Infestation percentage	r = - 0.5974 p = 0.0482	r = - 0.6144 p = 0.0587	r = - 0.3715 p = 0.2905	r= - 0.4598 p= 0.1812	r = - 0.4847 p = 0.1557	r = - 0.5240 p = 0.1200	r = - 0.1794 p = 0.6199	-	r= 0.5221 p= 0.0374
Larval population	r = 0.2718 p = 0.4474	r = 0.1190 p = 0.7434	r = - 0.0347 p = 0.9242	r= - 0.5055 p= 0.1361	r = - 0.2676 p = 0.4548	r = - 0.3183 p = 0.3701	r = - 0.1574 p = 0.6641	-	-
Parasitism percentage	r = 0.3164 p = 0.3732	r = 0.1721 p = 0.6346	r = 0.0197 p = 0.9569	r= - 0.4901 p= 0.1504	r = - 0.2172 p = 0.5466	r = - 0.2378 p = 0.5082	r = - 0.0544 p = 0.8813	r= - 0.4613 p= 0.0465	r= 0.9849 p= 0.0001

This variation in level of infestation on different varieties may be attributed to difference in geographical regions where the studies were undertaken. Moreover, significant influence of number of internodes was recorded on the population and losses of *C. infuscatellus* as Makhdum *et al.* (2001) also reported that *C. infuscatellus* infestation on cane stalks was higher compared to leaves and cane stubbles. Moreover, the same study also found significant role of number of tillers had with stem borer infestation. Khaliq and Warning, 2003) reported that stem borer infestation caused significant decrease in yield and juice quality for all evaluated varieties. However, sugarcane varieties with maximum trichomes on leaves were found partially resistant against stem borer infestation. Accordingly, no sugarcane variety was found completely resistant in this study although they showed great variation in the number of trichomes on their various parts. Therefore, it is evident from previous study of Abdullah *et al.* (2006) that morphological characteristics of different sugarcane varieties showed association with the stem borer infestation. As such, a significant but negative correlation between stem borer infestation and total shoot length has been reported by Kumar *et al.* (2018). Studies also reported that sheath length at bottom, mid and top cane portion also had association with the stem borer infestation and losses were decreased in canes with stronger bottom and mid portion sheath (Abdullah *et al.*, 2005). Kishore *et al.* (2002) and Mailafiya *et al.* (2009) examined various sugarcane varieties against sugarcane stem borer infestation. They observed that varieties with higher number of trichomes showed minimum stem borer infestation, while the varieties having lower number of leaves and trichomes showed maximum infestation. Khan *et al.* (2013) reported that the infestation of *C. infuscatellus* was significantly highest on SPF-234, which possess maximum number of internodes, hence, their results supported the findings of this study. Another study by Muhammad *et al.* (2014) confirmed that *C. partillus* cause damage to both early and late maturing sugarcane varieties, where, its parasitoid's i.e., *C. flavipes* population was higher on the varieties which showed maximum infestation. Similarly, relatively higher population of *C. flavipes* was also recorded on the varieties which showed maximum infestation and larval population of *C. infuscatellus*.

Conclusions and Recommendations

A high variation was found in the morphological characters of different sugarcane varieties evaluated, that in response affected the population of both *C. infuscatellus* and its parasitoid, *C. flavipes*. Among varieties, highest population of *C. infuscatellus* was recorded on Thatta-10 variety, whereas L-116 suffered the lowest damage. Consequently, the highest parasitism of *C. flavipes* on *C. infuscatellus* was also recorded on these varieties respectively. Moreover, among morphological characters, only the number of internodes showed a significant influence the infestation and larval population of *C. infuscatellus* along with parasitism of *C. flavipes*.

Novelty Statement

The morphological characters of sugarcane varieties especially number of internodes exhibited a significant impact of population of *Chilo infuscatellus* and accordingly to parasinization od *Cotesia flavipes* on it. Therefore, desirable sugarcane varieties should be exploited to lower the losses of *C. infuscatellus* and Enhance the parasitization of *C. flavipes*.

Author's Contribution

Bina Khanzada: Conducted the study and prepare

the initial draft.

Arfan Ahmed Gilal: Overall management of the article including conceiving and designing the study, and finalization of manuscript.

Bhai Khan Solangi: Perform the analysis of data.

Imtiaz Ahmed Nizamani: Help in designing the study and finalization of manuscript.

Conflict of interest

The authors have declared no conflict of interest.

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