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Field Application of *Trichogramma chilonis* (Ishii) for the Management of Sugarcane Borers

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Abstract.- These studies were conducted at farmer's fields in Mardan district during the cropping season 2008-2009 to investigate the efficacy and potentiality of inundative and inoculative release methods of *Trichogramma chilonis* (Ishii) for the management of sugarcane borers. The experiment was laid out in Randomized Complete Block Design. There were three treatments and four replications in each treatment. The data revealed that both inundative and inoculative release methods of *T. chilonis* were more effective as compared with the control throughout the entire growing season. Inundative release method of *T. chilonis* was found the most effective technique against *Chilo infuscatellus* (Snellen) infestation in both sugarcane plant and ratoon crops with minimum mean percent infestation of 3.50 and 6.50 respectively. This was followed by Inoculative release method, where 6.75 and 10.00 mean percent infestation was recorded in sugarcane plant and ratoon crops respectively. Maximum infestation was recorded in control plots with mean percent infestation of 7.87 and 12.75 in sugarcane plant and ratoon crops respectively. The data further revealed that inundative release method of *T. chilonis* in both sugarcane plant and ratoon crops also effectively controlled *Acigona steniellus* (Hamp) with minimum borer's infestation by recording 3.25 and 3.37 mean percent infestations in both sugarcane plant and ratoon crops respectively. It was followed by the plots where *T. chilonis* were released as inoculative release method, where 4.87 and 6.25 mean percent infestation was recorded in sugarcane plant and ratoon crop respectively. Control plots showed maximum *A. steniellus* infestation in plant crop (7.27%) and ratoon crop (7.65%). The data further showed that no *Scirpophaga nivella* Fabric infestation was recorded in both sugarcane plant and ratoon crops. Maximum yield of sugarcane was recorded in both plant and ratoon crops of sugarcane in plots treated with inundative release method (101.5t/ha in plant crop and 69.25 t/ha in ratoon crop) followed by inoculative release method (95.84t/ha in plant crop and 63.14t/ha in ratoon crop). The lowest yield of sugarcane was recorded in control (91.14 t/ha and 58.33 t/ha).

Key words: Sugarcane borers, *Trichogramma chilonis*, inoculative and innudative release methods.

INTRODUCTION

Sugarcane is one of Pakistan's most important cash and industrial crops. It is grown on an area of 1028.8 thousand hectares in Pakistan. Its annual production is 54741.6 thousand tonnes with an average yield of about 53.2 tonnes per hectar (Arain *et al*., 2011). In the Khyber Pakhtunkhwa area,sugarcane crop cultivation in 2006-07 was 101.8 thousand hectares which produced 4645.1 thousand tonnes of sugarcane with an average yield of 45.6 tonnes per hectare (Food and Agriculture Division, 2007).

Many factors play a role in the low yield of sugarcane in Pakistan. Among all these factors, sugarcane borers is the most important (Gul and Saeed, 2007; Saljoqi and Walayati, 2013). More specifically, stem borer (*Chilo infuscatellus*/Snellen) and Gurdaspur borer (*Acigona steniellus)*/Hamp), are the serious pests of sugarcane in Pakistan especially in Khyber Pakhtunkhwa (Anwar *et al*., 2004).

Sugarcane stem borer, *C. infuscatellus*, is one of the serious pests of sugarcane in Pakistan especially in Khyber Pakhtunkhwa. The plants attacked by this pest produce dead hearts from April to June and after formation of canes, its attacks are confined to internodes only. The stem borer reduce sugarcane yield up to 30-45 percent (Anwar *et al*., 2004). The moths are active at night and females lay creamy white scales like eggs in clusters of 11-36

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on the lower surface of the leaves. Female lays 300-400 eggs which hatch in 4-5 days. The larvae reach the plant base, bore into the plant shoot and feed there. They grow through five stages and complete their development in 3-4 weeks. The moth lives for 2-4 days. The life cycle is completed in 5-6 weeks and the pest breeds 4 or 5 times a year (Rao and Babu, 2004).

Gurdaspur borer, *A. steniellus* was first recorded in Gurdaspur (India) in 1923. It entered Khyber Pakhtunkhwa through the Southern Districts. This pest was recorded in Peshawar District in early 1980's. By 1990, it got the status of serious pest of sugarcane in Peshawar, Charsadda and Mardan districts (Gul and Saeed, 2007). The pest is active from July to October and passes the winter and the early part of the summer as full-grown larvae in sugarcane stubbles. The young larvae enter the top portion of a cane through a single hole just above a node, where they feed gregariously by making spiral galleries which run upwards. After 7-10 days, when the cane top has dried up, the larvae (in the third stage) come out and enter the adjoining canes single or in twos. The dried top can be spotted in a field because of the attack of this pest. The pest destroys 20-25 percent of the crop. In case of severe infestation, the loss may be as high as 70-75 percent and sugar recovery from the affected crop is greatly reduced. A loss of 17 percent in total solids, 29 percent in sucrose and an increase of 84 percent in glucose has been reported due to borer infestations (Dhaliwal, 2004).

Young plants attacked by top borer, *Scirpophaga nivella* Fabric show characteristic reddish streaks on the mid-ribs. They also show a number of shot holes in the leaves which ultimately cause dead-hearts. After the cane formation, the attacked plants show peculiar bunchy top. Damage is caused by caterpillars which are generally found in the top portion of a cane. The pest is active from March to November and passes the winter as a full-grown larva in the cane tops. The first two broods of this pest attack young plants before the formation of canes. These plants are killed and are a total loss. In subsequent broods, the pest attacks the terminal portions of the canes, causing bunchy tops. Damage by third and fourth broods may result in more than 25 per cent reduction in weight and a decrease in the quality of the juice. The loss in weight in different varieties may vary from 21 to 37 percent and loss in sugar recovery from 0.2 to 4.1 units (Ullah *et al.*, 2006).

Due to feeding behavior of borers which feed inside the plant parts where sprays are difficult to approach and the extensive and injudicious use of insecticides not only create the health hazards problem and environmental pollution but also resistance problem in large number of insect pests (Mohyuddin *et al*., 1997). It has been reported that more than 500 pest species have developed resistance against insecticides (Georghion and Lagunes, 1991). Indiscriminate use of pesticides kills the natural enemies resulting in flare up of pest population (Hamburg and Guest, 1997). To overcome resistance problem and also to meet the demand of international market, for producing good quality agro products, now more stress is on organic farming. It is imperative to use biological control programme for sugarcane. The inundative releases of bioagents for control of lepidopterous pests are being practiced in more than 32 million hectares each year around the world (Hassan, 1993). *T. chilonis* releases in China, Switzerland, Canada and former USSR reduced the damage up to 70-92% on sugarcane, corn and cotton crops (Lily, 1994), while in Asia, releases of *T. chilonis* remarkably reduced the incidence of cotton boll worm (*Helicoverpa armigera*) and sugarcane early shoot borer (*Chilo infuscatellus*) by 43 and 82%, respectively (Bhut *et al*., 2004; Bharati *et al*., 2002). In sugarcane *T. chilonis* reduces stalk borer incidence by 55-60% (Shenhmar *et al*., 2003). In Pakistan it has been recorded from *Chilo infuscatellus, C. partellus, Helicoverpa armigera, Agrotis ipsilon, Spodoptera litura, Acigonna steniellus* and *Emmalocera depressella* (Gul and Saeed, 2007).

Keeping in view the importance of the *Trichogramma* spp, a commercial biological agent of sugarcane borers, this study was initiated to evaluate the effectiveness of the *Trichogramma* application through innoculative and inundative release methods against Stem borer, Gurdaspur borer and Top borer in plant and ratoon crops of sugarcane and also to investigate the efficacy of *Trichigramma* on the yield of sugarcane crop.

MATERIALS AND METHODS

The experiment was laid out in randomized complete block design (RCBD). *Trichogramma* was applied on inundative and inoculative release methods. The parameters were the percent infestation and yield of sugarcane.

Rearing host Sitotroga cereallela *(Olivier)*

Sitotroga adults were obtained from the infested grains and kept in oviposition jars having lid on the top while bottom of each jar was cut out and mesh no 25-30 or 35-40 fixed on their bottom. The jars were kept in a dish containing starch for oviposition. The eggs laid in the starch were separated daily by using a sieve (with mesh no. 50-70).The eggs obtained were spread out in sterilized grains and kept in glass jars in host rearing chambers for larval and adult emergence. The host eggs used for mass production of *T. chilonis* were stored at 25-30ºC and 70-80 % RH.

Rearing of T. chilonis *on* Sitotroga cereallela

Gum was spread uniformly on a piece of hard paper. The host eggs *i.e., S. cereallela* were sprinkled on the sticky cards. These egg cards were placed in UV radiation for one hour, to kill the larvae present inside the eggs. Then the egg cards were transferred to glass jars containing adults of *T. chilonis* for 1-3 h for parasitism. After 1-3 h the cards were removed and kept in incubators at 25-30ºC and 60-70% RH for parasitoid development. The parasitoid that emerged were used for further parasitization of host eggs.

Field application of Trichogramma *against sugarcane borers*

Agronomically well managed farmer's fields/plots with sugarcane crops were selected. The parasitoid cards by *T. chilonis* from which adult were ready to emerge in 24 h were stapled with sugarcane leaves in both plant and ratoon crops of sugar cane.

The cards were attached on ventral side of sugarcane leaves by an ordinary stapler randomly in the fields at 5 different places in each plots in both plant and ratoon crops of sugarcane.

Inoculative release of Trichogramma

It is a form in which releases may be made as frequently as once a year to re-establish a species of natural enemy that is periodically killed out in an area by unfavorable conditions during part of the year but which operates very effectively the rest of the year. Control is expected from the progeny and subsequent generations, and not from the release itself.

In this method the trichocards were applied before pest became abundant. Ten cards/acre were applied in May for the management of sugarcane root borer and sugarcane top borer, only one time *i.e.,* 10 cards, each having 500 eggs in both plant and ratoon crops of sugarcane. Similarly 10 cards/acre were applied in July for the management of Gurdaspur borer, only one time *i.e.* 10 cards, each having 500 eggs in both plant and ratoon crops of sugarcane.

Inundative release of Trichogramma

The objective was to completely overwhelm the pest with the release, with little or no reliance put on subsequent generations of the natural enemy. In this method the Trichocards were applied when the adult moths were seen in the field. These cards (10 cards/acre) were applied randomly in the field at 15 days intervals, until 105 days.

Percent infestation

The efficacy of *T. chilonis* at different release levels on percent infestation of Gurdaspur borer, top borer and root borer were monitored weekly on the bases of randomly selected sample from each treatment, which consisted of 25 plants from each replication and each treatment was replicated four times. From these selected samples, damaged plants by sugarcane borers were counted and % infestation was calculated in each plot of sugar cane in both plant and ratoon crops. The distance between each plot was 500 meters.

Gurdaspur borer infestation was conformed as the attacked canes with dry tops were counted during the grand growth period of July to October 2008. Top borer infestation were confirmed as dry central shoots (easily taken out) and bunchy tops and root borer infestation were confirmed as black tunnel in the root zone were counted during

the grand growth period of May to October 2008. The data collection was carried out on a weekly basis. The data collected were converted into mean percent infestation. Selected rows were tagged for identification and were not included in the next week count.

Yield

Yield data were collected for each treatment in both plant and ratoon crops of sugar cane and then were converted to tones/ha.

All the collected data were analyzed by using MState-C statistical packages. Means were separated by using Dunkans Multiple Rang Test (DMRT) as suggested by Gomez and Gomez (1984).

RESULTS

Data recorded for percent infestation by root borer is presented in Tables I and II, while data on the percent infestation by Gurdaspur borer is presented in Tables III and IV.

Plant crop, 2008-2009

Table I shows the effect of inundative and inoculative release methods of *T. chilonis* on percent infestation of *C. infuscatellus* in plant crop of sugarcane. Both methods were found significantly effective in almost entire growing season by recording lower mean percent infestation as compared with the control ($F<0.05$).

Data regarding the inundative release method of *T. chilonis* for the management of C. *infuscatellus* in plant crops of sugarcane shows that initially the *C. infuscatellus* population was found very low by recording 0.50 mean percent infestations. The population was found to increase progressively with time.. Peak population of *C. infuscatellus* at tillering stage was recorded during the 1st week of July with 2.75 mean percent infestations. After this the *C. infuscatellus* population was recorded on the decreasing rate. But during the 4th week of July the population of *C. infuscatellus* increased again and reached to peak in the 1st week of September with 3.50 mean percent infestations. After this again the population decline was started. The lowest mean percent infestation (0.50) was recorded during the 4th week of October (Table I).

Table I.- Effect of different releases of *T. chilonis* (Ishii) on percent infestation of sugarcane stem borer, *Chilo infuscatellus* (Snell) in plant crop of sugarcane during 2009.

Treatments	Inundative release	Inoculative release	Control (No application)
1st week of April, 2009 (T_1)	0.00m	0.00o	0.00o
2nd week of April (T_2)	0.00m	0.25o	0.50o
3rd week of April (T_3)	0.50lm	1.00n	1.37n
4th week of April (T_4)	0.87kl	1.62lm	2.00lmn
1st week of May (T_5)	1.25hijk	2.25ijk	2.75ijkl
2nd week of May (T_6)	1.75efgh	2.62hij	3.37ghi
3rd week of May (T_7)	2.37cd	3.37f	3.75fgh
4th week of May (T_8)	2.50cd	3.25fg	4.00efg
1st week of June (T_9)	2.75bc	3.12fgh	3.37ghi
2nd week June (T_{10})	2.37cd	2.75ghi	2.87ijk
3rd week of June (T_{11})	2.00defg	2.75ghi	2.50jklm
4th week of June (T_{12})	1.62fghi	1.75klm	2.12klmn
1st week of JulyT_{13})	1.25hijk	1.62lm	1.87mn
2nd week of July (T_{14})	1.25hijk	2.00klm	2.50jklm
3rd week of July (T_{15})	1.00jkl	2.75ghi	3.37ghi
4th week of July (T_{16})	1.50ghij	3.12fgh	4.37ef
1st week of August (T17)	2.12def	3.37f	5.37cd
2nd week of August (T18)	2.50cd	4.37e	5.87bc
3rd week of August (T19)	2.75bc	5.00cd	6.50b
4th week of August (T20)	3.25ab	5.37c	7.50a
1st week of September (T21)	3.50a	6.75a	7.87a
2nd week of September (T22)	3.12ab	6.12b	6.50b
3rd week of September (T23)	2.75bc	5.00cd	5.87bc
4th week of September (T24)	2.25cde	4.62de	4.75de
1st week of October (T25)	1.62fghi	3.12fgh	4.37ef
2nd week of October (T26)	1.37hijk	2.87fgh	3.00hij
3rd week of October (T27)	1.12ijk	2.12jkl	2.75ijkl
4th week of October (T28)	0.50lm	1.50mn	1.87mn
Seasonal Pooled Mean	1.78c	3.01b	3.67a
LSD	**0.5285**	**0.5629**	**0.808**

Figures in columns having same letters are non-significantly different at $\alpha = 0.05$

LSD value for Seasonal Pooled Means = 0.1321

Data regarding the inoculative release method of *T. chilonis* for the management of *C. infuscatellus* in plant crops of sugarcane is also presented in Table I. The table shows almost the same trend as of *C. infuscatellus* mean percent infestation as observed by using the inundative release methods. Initially the population was found low by recording

Table II.- Effect of different releases of *Trichogramma chilonis* (Ishii) on percent infestation of gurdaspur borer, *Acigona steniellus* (Hamp) in plant crop of sugarcane during 2009.

Treatments	Inundative release	Inoculative release	Control (No application)
1st week of July, 2008 (T_1)	0.00g	0.00j	0.75i
2nd week of July (T_2)	0.00g	0.25ij	1.12ij
3rd week of July (T_3)	0.25fg	0.75ih	1.70ih
4th week of July (T_4)	1.00ed	1.27h	2.00h
1st week of August (T_5)	1.12ed	1.92g	2.62g
2nd week of August (T_6)	1.16d	2.29fg	3.12g
3rd week of August (T_7)	2.00cb	2.62ef	3.75f
4th week of August (T_8)	2.12b	3de	4.50e
1st week of Sept. (T_9)	2.75a	3.5cd	5.12d
2nd week of Sept. (T10)	2.87a	4.00bc	6.00bc
3rd week of Sept. (T11)	3.25a	4.37ab	6.50b
4th week of Sept. (T12)	3.25a	4.87a	7.27a
1st week of Oct. (T13)	2.75a	4.12b	5.62cd
2nd week of Oct. (T14)	2.00bc	3.12de	4.25ef
3rd week of Oct. (T15)	1.50cd	2.25fg	3.00g
4th week of Oct. (T16)	0.58ef	1.25h	2.00h
Seasonal Pooled Mean	**1.66c**	**2.47b**	**3.70a**
LSD	**0.547**	**0.579**	**0.607**

Figures in columns having same letters are non-significantly different at α=0.05
LSD valve for seasonal pooled means=0.372

0.25 mean percent infestations. Also progressive increase was observed in the mean percent infestation of *C. infuscatellus*. Peak population of *C. infuscatellus* at tillering stage was recorded during the 3rd week of May by recording 3.37 mean percent infestations. After this the *C. infuscatellus* population was recorded on the decreasing rate. But during the 2nd week of July the population of *C. infuscatellus* was found again on the increasing rate and reached to peak in the 1st week of September by recording 6.75 mean percent infestations. After this the population of *C. infuscatellus* was found once again on the decreasing rate. The lowest mean percent infestation (1.50) was recorded during the 4th week of October.

The seasonal pooled mean infestation of *C. infuscatellus* in plant crop of sugarcane was significantly lower (1.78%) in plots treated with inundative release method as compared with the inoculative release method of *T. chilonis*. However both methods were found significantly effective as compared with the control (F<0.05) (Table I).

Table III.- Effect of different releases of *T. chilonis* (Ishii) on percent infestation of sugarcane stem borer, *Chilo infuscatellus* (Snell) in ratoon crop of sugarcane during 2009.

Treatments	Inundative release	Inoculative release	Control (No application)
1st week of April, 2009 (T_1)	0.00m	0.00o	0.00r
2nd week of April (T_2)	0.50lm	0.50o	1.00q
3rd week of April (T_3)	1.37jk	1.37n	1.62pq
4th week of April (T_4)	1.75ij	2.50lm	2.37op
1st week of May (T_5)	2.12hi	3.25kl	3.50n
2nd week of May (T_6)	2.50gh	3.37k	4.50m
3rd week of May (T_7)	3.37ef	3.87ijk	5.00lm
4th week of May (T_8)	3.87de	4.75fgh	6.50hij
1st week of June (T_9)	4.00de	6.50d	7.50fg
2nd week June (T_{10})	3.37ef	7.25cd	8.75e
3rd week of June (T_{11})	2.87fg	5.50ef	8.25ef
4th week of June (T_{12})	2.12hi	4.37hi	7.00ghi
1st week of JulyT_{13})	2.50gh	3.75ijk	5.75jkl
2nd week of July (T_{14})	3.00fg	3.25kl	4.50m
3rd week of July (T_{15})	4.00de	4.50ghi	5.12klm
4th week of July (T_{16})	4.87c	5.25efg	6.00jk
1st week of August (T17)	5.87ab	6.62d	7.25gh
2nd week of August (T18)	6.25ab	7.75c	8.50e
3rd week of August (T19)	6.37ab	9.00b	10.00cd
4th week of August (T20)	6.50a	9.50ab	11.25b
1st week of Sept. (T21)	5.75b	10.00a	12.75a
2nd week of Sept. (T22)	4.75c	8.75b	10.75bc
3rd week of Sept. (T23)	4.25cd	6.75d	9.75d
4th week of Sept. (T24)	3.75de	5.62e	8.25ef
1st week of Oct. (T25)	3.00fg	4.87efgh	6.25ij
2nd week of Oct. (T26)	2.62gh	4.12hij	4.62m
3rd week of Oct. (T27)	1.75ij	2.50lm	3.25no
4th week of Oct. (T28)	1.00kl	1.87mn	2.25p
Seasonal Pooled Mean	**3.36c**	**4.90b**	**6.15a**
LSD	**0.6302**	**0.8361**	**0.9958**

Figures in columns having same letters are non-significantly different at α =0.05
LSD value for Seasonal Pooled Means= 0.141

Table II shows the effect of inundative and inoculative release method of *T. chilonis* on percent

infestation of *A. steniellus* in plant crop of sugarcane. Both methods were found significantly effective in almost entire growing season by recording lower mean percent infestation as compared with the control (F<0.05).

Table IV.- Effect of different releases of *Trichogramma* on percent infestation of Gurdaspur borer, *Acigona steniellus* (Hamp) in ratoon crop of sugarcane in district Mardan during, 2009.

Treatments	Inundative release	Inoculative release	Control (No application)
Ist week of July,2008 (T_1)	0.66h	0.75j	1.25j
2nd week of July (T_2)	0.66h	1.12ij	2.00ij
3rd week of July (T_3)	1.29g	1.37ij	2.12i
4th week of July (T_4)	1.37g	1.87gh	2.62hi
1st week of August (T_5)	2.00f	2.37fg	3.12gh
2nd week of August (T_6)	2.25ef	3.00ef	3.62fg
3rd week of August (T_7)	2.50de	3.25e	4.00ef
4th week of August (T_8)	2.75cd	4.00d	4.75de
1st week of Sept. (T_9)	2.87bcd	4.50cd	5.25cd
2nd week of Sept. (T10)	3.00abc	5.37b	6.12b
3rd week of Sept. (T11)	3.37a	6.12a	7.12a
4th week of Sept. (T12)	3.37a	6.25a	7.65a
1st week of Oct. (T13)	3.25ab	4.75bc	5.87bc
2nd week of Oct. (T14)	2.62cde	4.00d	4.50de
3rd week of Oct. (T15)	2.00f	2.87ef	3.50fg
4th week of Oct. (T16)	1.08gh	1.75ghi	2.37hi
Seasonal pooled Mean	**2.19c**	**3.33b**	**4.11a**
LSD	**0.462**	**0.667**	**0.770**

Figures in columns having same letters are non-significantly different at α =0.05
LSD value for seasonal pooled means= 0.3978

Data regarding the population of *A. steniellus* after inundative release method of *T. chilonis* in plant crop of sugarcane crop shows that in the beginning population of *A. steniellus* was observed very low by recording 0.25 mean percent infestations. With the passage of time the population was found progressively increased. Peak population of *A. steniellus* was observed during the 3rd and 4th week of September by recording 3.25 mean percent infestations. After this the *A. steniellus* population was recorded on the decreasing rate. The lowest mean percent infestation (0.58) was recorded during the 4th week of October (Table II).

Data regarding the population of *A. steniellus* after inoculative release method of *T. chilonis* is presented in Table II. The table shows similarity in the population trend of *A. steniellus* mean percent infestation as observed by using the inundative release methods. In the beginning the population was found very low by recording 0.25 mean percent infestations. Also progressive increase was observed in the mean percent infestation of *A. steniellus.* Maximum population of *A. steniellus* was recorded during the 4th week of June by recording 4.87 mean percent infestations. After this again the population of *A. steniellus* was found on the decreasing rate. The lowest mean percent infestation (1.25) was recorded during the 4th week of October.

Table II also shows that seasonal pooled mean infestation of *A. steniellus* in plant crop of sugarcane was significantly lower (1.66%) in plots treated with inundative release method as compared with the inoculative release method of *T. chilonis.* However, both methods were found significantly effective as compared with the control (F<0.05).

Ratoon crop, 2008-2009

Data regarding the mean percent infestation of *C. infuscatellus* in ratoon crops of sugarcane after inundative and inoculative release methods of *T. chilonis* is presented in Table III. It is evident from the data that initially 0.50 mean percent infestations of *C. infuscatellus* were recorded by using the inundative as well as inoculative release methods of *T. chilonis*. With the passage of time the population builds up was started. Peak population of *C. infuscatellus* at tillering stage was recorded during the 1st week of June by recording 4.00 mean percent infestation in the inundative while 7.25 in the 2nd week of June in the inoculative release method. During the 1st week of July the population was found again on the increasing rate. Peak population of *C. infuscatellus* was recorded during the 4th week of August and Ist week of September, by recording 6.50 and 10.00 mean percent infestations in case of inundative and inoculative release methods respectively. After this the population of *C. infuscatellus* was found once again on the decreasing rate in both release methods by recording 1.00 and 1.87 mean percent infestation (for inundative and inoculatove release methods respectively) during the 4th week of October.

Table III also shows that seasonal pooled mean infestation of *C. infuscatellus* in ratoon crop of sugarcane was significantly lower (3.36%) in plots treated with inundative release method as compared with the inoculative release method of *T. chilonis* (4.90%). However both methods were found significantly effective when compared to the control ($F<0.05$).

Data regarding the inundative and inoculative release methods of *T. chilonis* for the management of *A. steniellus* in ratoon crops of sugarcane shows almost same trend as recorded for *C. infuscatellus*. Initially the *A. steniellus* population was found very low by recording 0.66 and 0.75 mean percent infestations respectively. With the passage of time the population was found progressively increased. Peak population of *A. steniellus* was recorded during the 3rd and 4th week of September by recording 3.37 and 6.25 mean percent infestations for inundative and inoculative release methods respectively. After this the *A. steniellus* population was found on decline. Also lowest mean percent infestation 1.08 and 1.75 was recorded during the 4th week of October for inundative and inoculative release methods. Seasonal pooled mean infestation of *A. steniellus* in plant crop of sugarcane was significantly lower (2.19%) in plots treated with inundative release method as compared to the inoculative release method of *T. chilonis*. However both methods were found significantly effective when compared to the control ($F<0.05$) (Table IV).

Yield (tones ha^{-1})

The data regarding the yield of sugarcane plant crop after different release methods of *T. chilonis* is presented in Figure 1. Mean values of the data indicated that highest yield (101.5 tones ha^{-1}) was recorded in inundative treated fields followed by inoculative treated fields (95.84 tones ha^{-1}), while lowest yield of 91.14 tones ha^{-1} was noted in controlplots. All the yields were significantly different from each other. Highest increase in yield was recorded in inundative treated plots as compared to the control.

Figure 2 shows the yield of sugarcane ratoon crop. Highest yield (69.25 tones ha^{-1}) was recorded in fields treated with inundative release method of *Trichogramma* followed by fields treated with inoculative release (63.14 tones ha^{-1}), while lowest yield of 58.33 tones ha^{-1} was recorded in control.

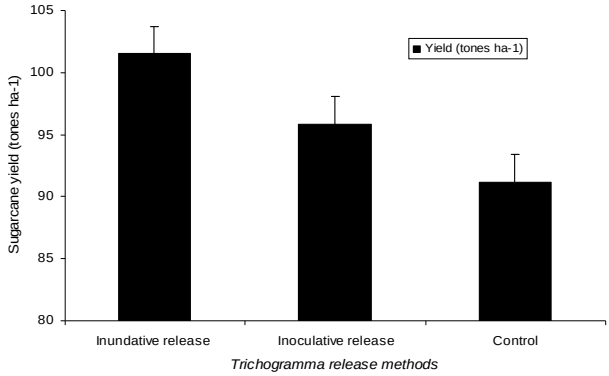

Fig. 1. Effect of different release methods of *T. chilonis* in comparison with control against borers infestation on the yield of sugarcane (tones ha^{-1}) in plant crop sugarcane in district Mardan during 2009.

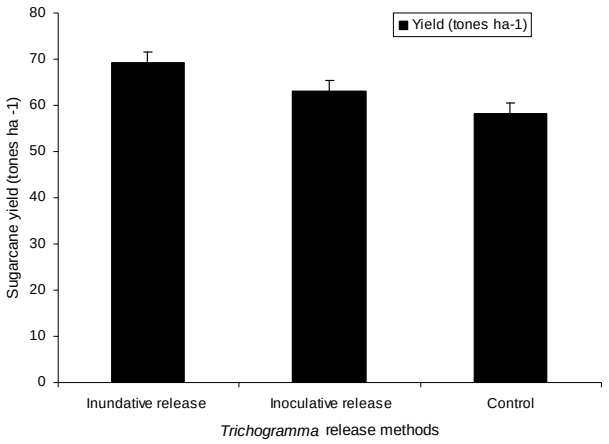

Fig. 2. Effect of different release methods of *T. chilonis* in comparison with control against borers infestation on the yield of sugarcane (tones ha^{-1}) in ratoon crop of sugarcane in district Mardan during 2009.

DISCUSSION

In plant crop, both inundative and inoculative release method of *T. chilonis* were found significantly effective against *C. infuscatellus* and *A. steniellus* as compared to the ratoon crop. The data showed that inundative release of *T. chilonis* was found to be the most effective method in reducing the *C. infuscatellus* and *A. steniellus* infestation.

These results are in agreement with those of Shenhmor *et al.* (2003) who conducted large scale field demonstration using *T. chilonis* against sugarcane borer in Punjab, India during 2000-2001. *T. chilonis* was released @ 50, 000 per hectare from July to October. In terms of borer incidence, they recorded a reduction in damage over the control by 52.04 % during 2000 while 60.03% during 2001.

In ratoon crop, almost the same trend was observed as recorded in plant crop. Lowest percent infestation of *C. infuscatellus* (6.50%) was recorded in plots treated with inundative release method of *T. chilonis* followed by inoculative method and control with 10.00 and 12.75% respectively. So it is clear that Inundative release method of *T. chilonis* is effective in controlling sugarcane stem borer infestation. These results are in agreements with the findings of Gul and Saeed (2007) who reported that inundative method of releasing *T. chilonis* is effective and is a recommended method for the management of sugarcane borers. Significantly low mean percent infestation of *A. steniellus* (3.37%) was also recorded in inundative release method as compared to the inoculative release and control plots, where 6.25 and 7.65 mean percent infestation were recorded respectively. It is also clear from these results that inundative release method of *T. chilonis* is effective with less infestation as compared to the inoculative release and control. These results are in agreement with the work of Khan and Khan (2006) who conducted field experiments at the Sugar Crops Research Institute Mardan during 2000-2004 on IPM of sugarcane borers. Results of 3 plant + 3 ratoon crops revealed that treated plots significantly reduced shoot, Gurdaspur and root borers infestation as compared to check plots.

Our result further showed that infestation of *S. nivella* was not recorded at any field of sugarcane crops in both plant and ratoon crop. This statement is in conformity with Gul and Saeed (2007) in which he showed that this borer had very restricted distribution. He reported that the varieties on which *S. nivella* was recorded were grown in different localities of district Peshawar (Eastern part), Charssada (Eastern and Western part), Mardan, Sawabi and Malakand. No infestation of *S. nivella* was recorded in these districts which indicated that there is no infestation of sugarcane top borer in this locality. The negligible infestation of *S. nivella* in this area may be because of its life cycle, which is different from other borers. The larvae of the last generation hibernate in tops of sugarcane in winter and pupate in mid February, while the adult of this borer become active during early March. In this area, the farmers mostly harvest sugarcane crops before March. This could explain why *S. nivella* is not able to protect its hibernating stage of the last generation in the cane tops in district Mardan. These investigations are in agreement with those of Aheer *et al.* (2003).

Maximum yield was recorded in inundative treated fields both in crop as well as in ratoon crop followed by inoculative treated fields, while lowest yield was recorded in control plots. Highest yield (101.5 tones ha^{-1}) was obtained in the inundative release treated fields in the plant crop. Our findings are in conformity with those of Bharati *et al.* (2002), Shenhmor *et al.* (2003), Soula *et al*. (2003) and Bhut *et al*. (2004). They found highest yield in the inundative release method in the crop plants.

CONCLUSION

This study revealed that sugarcane borers are widely distributed in both plant and ratoon crops of sugarcaneand the Inundative release method of *T. chilonis* was found to be the most effective and is the recommended method for the management of sugarcane borers.

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