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Research Paper

Field Collection of Parasitized/Healthy Egg/Larval Stage of Maize Borer

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ABSTRACT

Among the areas surveyed, Kralpora (K.D. Farm), Lar and Kangan exhibited comparatively high level of infestation as compared to others. Extensive fortnightly surveys in the above mentioned three hot spot areas indicated an average of 19.89, 24.53 and 22.04 per cent plant infestation during July to October, at Kralpora, Lar and Kangan, respectively. At all these locations, larval infestation was found to increase from July to September and declined in October. Highly infested plants during September showed an average of 2.2 to 4.0 larvae/plant which was found positively correlated with number of exit holes in them. Among natural enemies, *Trichogramma chilonis* Ishii, *Cotesia ruficrus* (Haliday), *Euplectrus coimbatorensis* Ferriere and one unidentified species each of Ichneumonidae and Tachinidae were found associated with *C. partellus. Cotesia ruficrus* was distributed at all the studied locations, whereas *T. chilonis* was found at three studied hot spot locations. Negligible and sporadic occurrence of remaining species was found from one location only. On individual basis, average egg parasitism by *T. chilonis* was determined as 4.98, 7.7 and 6.08 per cent whereas larval parasitism by *C. ruficrus* was worked out to be 9.76, 14.43 and 11.25 per cent at Kralpora, Lar and Kangan, respectively. Together these two egg and larval parasitoids afforded an average of 14.73, 22.13 and 17.33 per cent parasitism with a maximum of 30.14 per cent at Lar. Comparatively better performance of *C. ruficrus* was due to its higher population density and manifestation of super parasitism. Per cent emergence both in *T. chilonis* and *C. ruficrus* ranged 83.67-93.32 and 86.26-90.38 respectively, with female oriented sex ratio in both cases. Pattern of parasitism was found varying in the studied three locations due to many abiotic and biotic factors. Positive correlation was found to exist between egg and larval and also combined parasitism, separately, with host abundance. Combined parasitism yielded positive correlation with maximum relative humidity, whereas negative correlation with maximum and minimum temperatures, minimum relative humidity, rainfall and sunshine hours.

***Key words*:** Maize borer, Infestation, Combined parasitism, Positive correlation, Larval stage

Maize is one of the most important grain crops in the agricultural economy of the world, providing human food and fodder. It is a wonderful crop with high yield potential; This is called the "queen of breasts". Cultivated in each province of India, it covers an area of about six million hectares and produces a total of 16 million tonnes [1]. This crop is grown in India in a variety of geographical and climatic conditions and in almost all seasons in 'Karif', 'Rabbi' and 'Spring'. The total area under maize cultivation in Jammu and Kashmir is 323.6 thousand hectares and the total production is about 4.6 lak tonnes [2]. In Kashmir, Baramulla (28090 ha), Anantnag (21943 ha), Kupwara (26643 ha), Putkam (13724 ha), Pulwama (7035 ha) and Srinagar (3955 ha) districts use about 1.1 lakh ha). The total maize production in Kashmir district is about 47.1 thousand tonnes, with an average yield of 10.05 qua / ha [3].

Despite the high yield potential, the current national average is 2.1 tons per hectare, which is much lower than in Italy (10 tons / hectare) [4]. Decreased yields are caused by a number of factors, including pests and diseases. In India, maize is attacked by a variety of insects that order Lepidoptera, Diptera, Orthoptera, Choleoptera and Hemiptera. Eighty-seven species of pests have so far been reported to exert significant pressure on maize in the tropics and subtropics world [5]. In India, stem borer, *Silo bartellus* (Swinho), *Sesamia inference* (Walker), Shootfly, *Atherocona spp*. Holmkar, Gray Weevils *Myloserus spp*., Cut Worm *Acrodis ipsilon* and White Crub are known to cause great damage to the plant. Of these, the broth of the corn stalk *Silo bartellus* (Swinho) is considered to be the most popular pest of corn and corn. The pest is endemic to Afghanistan, Ceylon, Cambodia, Ethiopia, Iraq, Indonesia, Japan, Kenya, Mauritius, Nepal, Pakistan, Tanzania, Taiwan, Thailand, Uganda and Vietnam [6]. Although the pest attacks maize at all stages, major losses occur at the beginning of the crop. After hatching, the larvae of *Chilo bartellus* (Swinho) feed on the leaves, where they form small abnormal holes and then enter the trunk of the tunnel. The caterpillar cuts off the growing part of the corn plant, which leads to the formation of a central tumor and

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the formation of a 'dead heart'. Puppy occurs under the soil or in a plant pot. After hatching from pupae, the female lays 300 eggs 2-21 days after mating. The incubation period is 4-5 days in summer, which is 14-28 days with caterpillar periods. The life cycle ends in about 3-4 weeks, with 6-7 generations scattered throughout the year.

This pest is active from March to October and exhibits 6-7 generation spread. However, in peninsular India, the pest is active throughout the year due to mild winters [7]. It passes winter through caterpillar stages by race or stem. Corn stem borers are said to be attacked by a number of biological control agents, including parasites, organisms and pathogens, which play an important role in the natural suppression of this pest. Thirty-six parasites are also found in Clovis, Cottonia, and Cotyledonus Considered important biological agents. The power of these pests has been documented by many workers, including [8-10]. Although maize cultivation has grown in the region for commercial purposes and due to fodder due to the growth of new organisms, little entomological knowledge about the plant is available to date. Since no information is available on this natural disease and its effects in controlling pests from Kashmir Valley such as Canterbury, Srinagar and - Uri, the present study was conducted for the following purposes:

1- Determination of field parasitism by egg / larval parasites of *Silo bartellus* (Swinho) in high maize growing areas.

MATERIALS AND METHODS

Determination of field parasitism by egg/larval parasitoids of *Chilo partellus* (Swinhoe). Fortnightly collection of egg batches/larvae and pupal cocoon from plants until maturity of crop.In order to find out the level of field parasitism of *Chilo partellus* in three selected hot spot areas i.e. Kralpora (K.D. Farm), Kangan and Lar, maize fields were intensively explored fortnightly for the occurrence of egg and larval parasitoids as per methods already discussed in 3.1.3. Apart from apparently present pupal cocoon of *Cotesia rufricrus* and other larval parasitoids, effort was also made to dissect the body of 3-4th instar larvae of *C. partellus*, collected from the infested plants, each fortnight, to observe the occurrence of parasitoids' larvae. An up-to-date data for egg and larval parasitism, location-wise, was maintained separately.

Separate laboratory rearing of collected egg/larvae and pupal cocoon

An attempt was made to rear the collected materials including parasitized eggs, infested/healthy larvae of the pest and pupal cocoon of *Cotesia ruficrus*, or ichneumonid in laboratory for the purpose of relevant information. Parasitized egg batches of *C. partellus* and pupal cocoon of *Cotesia ruficrus* were kept individually in test tubes and kept in thermostat BOD. The material was observed daily for the emergence of parasitoids. Upon complete emergence of egg/larval parasitoids, they were killed by exposing them to the fumes of ethyl acetate. For egg parasitoids, each egg batch was observed under the binocular microscope for counting the total number of eggs, number of eggs actually parasitized and number of parasitoids emerged from them. For the later part, dead parasitoids were gently transferred on to the slides and counted for total number of females and males. Similar approach was adopted for counting larval parasitoids, their sexes and total emergence from a cocoon mass, the latter was also counted for its pupal number. Infested/healthy larvae brought along with maize stalk were kept in insect rearing cages and observed daily for the appearance of cocoon mass, if any. The number of cocoon mass formed in insect cages was daily recorded, out of total number of larvae kept for observation. The cocoon masses were isolated and kept in test tubes and above-mentioned procedure was repeated for the purpose of desired parameters.

Determination of per cent egg/larval parasitism on hectare basis

In order to determine per cent egg parasitism, the egg batches collected from five quadrate of 2m^2 of a given locality were kept separately, for their laboratory emergence and counting, as already mentioned before. In view of rare occurrence of egg batches, the entire field was surveyed and egg batches obtained were grouped in five batches, treated as five replications. Per cent parasitism was determined by dividing total number of parasitoids emerged from total number of eggs in a batch. Mean of five replications was then taken out for a given locality for a given period. Larval parasitism was determined by counting the number of plants damaged in each of the five quadrate in a plot as discussed above and presence of number of pupal cocoons batch (Plate 7A-C) was recorded in relation to observed area. Assuming presence of a single larva, on an average, in one infested plant, and emergence of one batch of pupal cocoon from a parasitized larva. Per cent parasitism was determined by dividing total number of cocoon in each replication by corresponding number of observed larvae. Since larval density increased per plant during September/October, an average density of larvae per plant was determined by dissecting ten infested plants and per cent parasitism was determined accordingly. As the data on egg/larval parasitism was collected from the plots ranging 1000-5000 m^2, the results on parasitism are presumed representing the same on hectare basis.

Determination of pattern of parasitism at three different localities

Fortnightly observations on per cent egg and larval parasitism from three different locations during July to October were summed together to determine total parasitism. Month-wise as well as total parasitism represented by each of the three locations was also worked out and comparisons between egg and larval parasitism have also been depicted graphically to indicate the trend of individual species of parasitoids separately as well as in combination.

Survey of maize growing areas of Kashmir for the occurrence of maize borer

Identification of three different areas showing sufficient level of infestation by maize borer and Per cent maize plant infestation by maize stalk borer was determined by dividing damaged number of plants by total number of plants.

Determination of field parasitism by egg/larval parasitoids of Chilo partellus (Swinhoe)

Fortnightly collection of egg batches/larvae and pupal cocoon

Number of egg batches and cocoon masses, in all the five quadrates observed fortnightly, were averaged separately. Mean of five observation represented average cocoon mass per quadrate during a given period of a month. The mean values were transformed to arc sin before determining its ANOVA.

Separate laboratory rearing of collected egg/larvae and pupal cocoon for emergence of parasitoids

Emergence of egg and larval parsitoids was determined by counting number of parasitoids emerged as well as by examining number of exit holes. Per cent emergence was determined as follows:

$$\frac{\text{No. of exit holes}}{\text{Total No. of egg or larval cocoon}} \times 100$$

Per cent female was based on laboratory emerged parasitoids whose sex was determined under microscope and number of females counted. The percentage was determined as follows:

$$\frac{\text{No. of female parasitoids}}{\text{Total no. of emerged parasitoids}} \times 100$$

Since per cent values of above said parameters did not vary enough, hence ANOVA was done without transforming the values to arc sine. Sex ratio of *T. chilonis* and *Cotesia ruficrus* was determined by subtracting percent female from 100, which provided percentage of males. Dividing female percent values from male per cent values yielded female to male sex ratio.

Determination of per cent egg/larval parasitism on hectare basis

Per cent parasitism by egg/larval parasitoids was determined. The per cent values were transformed to arc sine before processing the data for ANOVA.

Determination of pattern of parasitism at three different locations

Pattern of parasitism was obtained by summing up fortnightly per cent egg and larval parasitism, which were subsequently transformed to arc sine, and ANOVA determined.

Correlation of parasitism with host and meteorological parameters

Fortnightly untransformed data on per cent egg, larval and egg + larval were correlated with fortnightly mean of per cent plant infestation (host) and correlation determined. Regression for similar parameters was worked out through Minitab. Significance test of correlation was determined by using the formula:

$$\frac{r\sqrt{n-2}}{\sqrt{1-r^2}}$$

Where r = coefficient of correlation and n=number of observations

Correlation between parasitism versus host and meteorological data was also determined by using fortnightly data of per cent parasitism by *T. chilonis* and *Cotesia ruficrus* separately as well as in combination against fortnightly data on plant infestation and also against fortnightly mean of metrological parameters.

Statistical analysis

The data was subjected to statistical analysis using R-software Package (2019), which is an implementation of Box *et al*. (1978). Level of significance used for F and t; test were 0.01 and 0.05.

RESULTS AND DISCUSSION

Present investigation on parasitic community of *C. partellus* found occurrence of one egg parasitoid and four different larval parasitoids associated with *Chilo partellus* (Swinhoe) during July-October, 2019.

Table 1 Larval density in highly infested plants at three hot spot locations during September 2019

Locations	Sample size	Average number of holes/plant	Average number of larvae/plant
Kralpora	10	5.4	2.2
Lar	10	6.6	4
Kangan	10	6.52	3.4

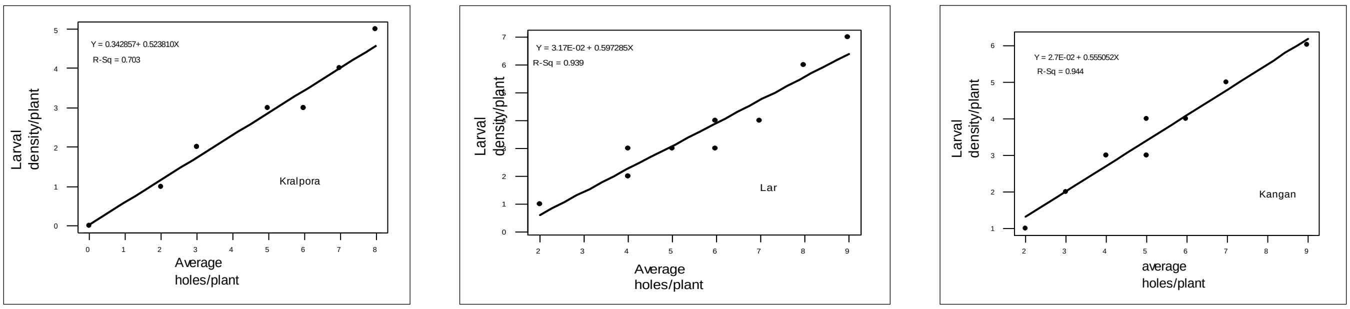


Fig 2 Coefficient correlation between holes and larval density/plant at three different locations during September 2019

The parasitoids largely belonged to the order Hymenoptera with the exception of tachinid that belonged to Diptera. *Trichogramma chilonis* Ishii was found to be an important egg parasitoid whereas, *Cotesia ruficrus* (Haliday) (Hymenoptera: Braconidae), *Euplectrus coimbatorensis* Ferriere (Hymenoptera: Eulophidae), an unidentified ichneumonid (Hymenoptera: Ichneumonidae) and tachinid (Diptera: Tachinidae) were found as larval parasitiods Tachinid that belonged to Diptera. *Trichogramma chilonis* Ishii was found to be an important egg parasitoid whereas, *Cotesia ruficrus* (Haliday) (Hymenoptera: Braconidae), *Euplectrus coimbatorensis* Ferriere (Hymenoptera: Eulophidae), an unidentified ichneumonid (Hymenoptera: Ichneumonidae) and tachinid (Diptera: Tachinidae) were found as larval parasitiods (Table 4). Identification of *Trichogramma chilonis* Ishii and *Euplectrus coimbatorensis* Ferriere was done by Dr. H. Nagarja (Expert Consultant), and Dr. Poorani, J., PDBC (Bangalore), respectively, whereas *Cotesia ruficrus* (Haliday) was identified by my guide, Dr. M. Jamal Ahmad, Division of Entomology, SKUAST-Kashmir, Shalimar. The identity of ichneumonid and tachinid however could not be established because of lack of expertise available [11].

As a result of intensive survey on the distribution of parasitoids conducted during May-October, *Cotesia ruficrus* (Haliday) was found to be the predominant larval parasitoid, distributed at all the thirteen locations, whereas *Trichogramma chilonis* Ishii was reported from three different locations. Rare occurrence of *Euplectrus coimbatorensis* Ferriere, *Ichneumonid* and *Tachinid* sp. was however reported, each species at one location (Table-5), and only once during entire period of survey.

Table 2 Parasitic community of *Chilo partellus* (Swinhoe) at thirteen different locations of Kashmir valley during May-October' 2019

Parasitoids	Order	Family	Genus and species
Egg parasitoid	Hymenoptera	Trichogramatidae	*Trichogramma chilonis Ishii**
		Larval parasitoids	
a) Endoparastoid	Hymenoptera	Braconidae	*Cotesia rufricrus* (Haliday)*
	Hymenoptera	Ichneumonidae	Unidentified ichneumonid
	Diptera	Tachinidae	Unidentified tachiniid
b) Ecto-parasitoid	Hymenoptera	Eulophidae	*Euplectrus coimbatorensis* Ferriere*

*Reported first time from the Kashmir valley

Identification and detail taxonomical studies of hymenopter parasitoids:

Taxonomical terminologies used

A & B. Head of braconid in facial and dorsal view	
1. Lateral ocellus	14. Eye width
2. Median ocellus	15. Occiput
3. Antennal torulus	16. Vertex
4. Inter torular distance	17. Inter ocellar distance
5. Eye	18. Ocello ocular distance
6. Inner ocular margin	19. Distance between median and lateral ocellus
7. Torulo ocular distance	
8. Malar space	20. Head width in dorsal aspect
9. Clypeus	
10. Distance from torulus to median ocellus	**C. Antenna of Eulophidae**
	21. Radicula
11. Distance from torulus to clypeus	22. Scape
	23. Pedicel
12. Mandible	24. Ring segment
13. Eye length	Stigma = BGE
25. Funicle segments (F_1- F_4)	Medial cell = 1
26. Club	Sub medial cell = 7
27. Sensillae	Anal cell = 8
D. Thorax of braconid	**F. Hind wing of braconid**:
28. Pronotum	Sub costella = abd
29. Mesoscutum	Mediella = ch
30.Scutellum	Sub mediella = eg
31. Propodeum	Nervellus = fg
32. Fore coxa	**G. Fore wing of Ichneumonidae**
33. Mid coxa	
34. Hind coxa	Costa = AB
E. Forewing of braconid	Stigma = BEC
Costa = AB	R1 = CD
Meta carpus = EF	M+Cu = AF
Radius = GHIJ	1A = AG
Cubitus = KLT	RS & M = BF
Recurrent = OP	Cu- a = FG
1m- Cu = MH	Cu- 1 = FH
2m- Cu = LK	Cu- 1b = IJ
Areolet = A	**I. Female genitalia of Eulophidae**
3 r-m = LP	
H. Leg of braconid	First valvifer = 1
Coxa = 1	Second valvifer = 2
Trochanter = 2	Ovipositor sheath = 3
Femur = 3	First valvula = 4
Tibia = 4	
Tarsal segments = 5-9	
Tibial spurs = 10	

The present study indicated largest representation by *Cotesia ruficrus* (Haliday), among all the larval parasitoids observed at all the locations, and also, at every period of observation, as compared to only one-time occurrence of above mentioned remaining larval parasitoids. Data on larval parasitism and relevant parameters in present study therefore has been presented for *Cotesia ruficrus* (Haliday) only [12].

Table 3 Distribution of parasitoids of *Chilo partellus* (Swinhoe) in different maize growing areas of Kashmir valley during May- October' 2019

District	Location	Egg parasitoid	Larval parasitoids: Endo parasitoids	Larval parasitoids: Ecto parasitoids
Anantnag	Larnu	X	✓	X
Budgam	Kralpora	✓	✓	X
	Pakherpora	X	✓	X
Kupwara	Hafrada	X	✓	X
	Hengnikote	X	✓	X
Pulwama	Sedow	X	✓	X
	Tral	X	✓	X
	Padgampora	X	✓	X
	Keller	X	✓	X
Baramulla	Salamabad	?	✓	?
	Chandusa	X	✓	X
Srinagar	Lar	✓	✓	✓
	Kangan	✓	✓	X

? = Not-known
✓ = Present
X = Absent

Diagnostic characters: This species is identified on the basis of male characters. The key characters of this species are: forewings with RS1 with 6 setae and Dorsal Expansion of Gonobase (DEG) of male genitalia with lateral expansion [13]. The species is being redescribed in view of some morphometrical differences in Kashmir strain as compared to Stewart IARAI material [14-15].

Male (Redescribed) (6 B-C)

Body length: 0.43- 0.46 mm (including exserted portion of aedeagus). Body in general brown. Head honey yellow except vertex brownish black. Eyes and ocelli red. Antennae honey yellow, except pedicel and club slightly infuscated. Prothorax and abdomen dark brown, remaining part of thorax, all legs except last tarsal segments, venation light brown. Aedeagus hyaline [16].

Head: Head in facial view1.2 times as wide as long. Eyes slightly longer than wide, a little shorter than inter orbital distance (1.2: 1.5). Length of malar space equal to the width of an eye (1:1). Inter ocellar distance slightly more than ocello ocular length. Antennae (Plate 5C) inserted almost in the centre of face. Scape 4.0 times, pedicel 2.25 times and club

3.88 times as long as wide. The latter with 32 hairs, the longest hair 0.13 mm. long, as long as the length of scape (2:2).

Thorax: Thorax 1.25 times as long as wide, as long as the length of the abdomen (2.5:2.5).

Wings: Forewings (Plate 5E) 2.25 times as long as wide, hyaline, disc thickly setose in the middle and beyond, apically with few hairs only; setal hairs on the disc in radiating rows; marginal vein sub equal to stigmal (1:.9), the former with four stout bristles, sub marginal vein with one bristle only; RS1 with six setae [17]. The longest hair on the marginal fringe, as long as the marginal vein (1:1).

Legs: Legs (Plate 6D) with following dimensions (L:W): Fore Legs : Coxa (1.2:.8), femur (3:.5), tibia (2.5:.5), tarsus as long as tibia (2.5 : 2.5). first tarsal segment comparatively smaller than last two segments. Middle legs (L:W): Coxa (1.0:.8), femur (3:.5), tibia (2.5:.4), tarsus as long as tibia (2.5:2.5); second and third tarsal segments sub equal, slightly longer than the first. Hind legs (L; W): Coxa (2.5:.9), femur (3.7:.8), tibia (3.8:.4), first and last tarsal segments sub equal, slightly shorter than mid tarsal segment [18].

Abdomen: Abdomen 1.25 times as long as wide. Aedeagus distinctly exserted, its exserted portion as long as the length of first tarsal segment of the hind legs.

Female (Plate 6 A-F): Body length (including ovipositor): 0.47 mm. Body colour in general as that of male

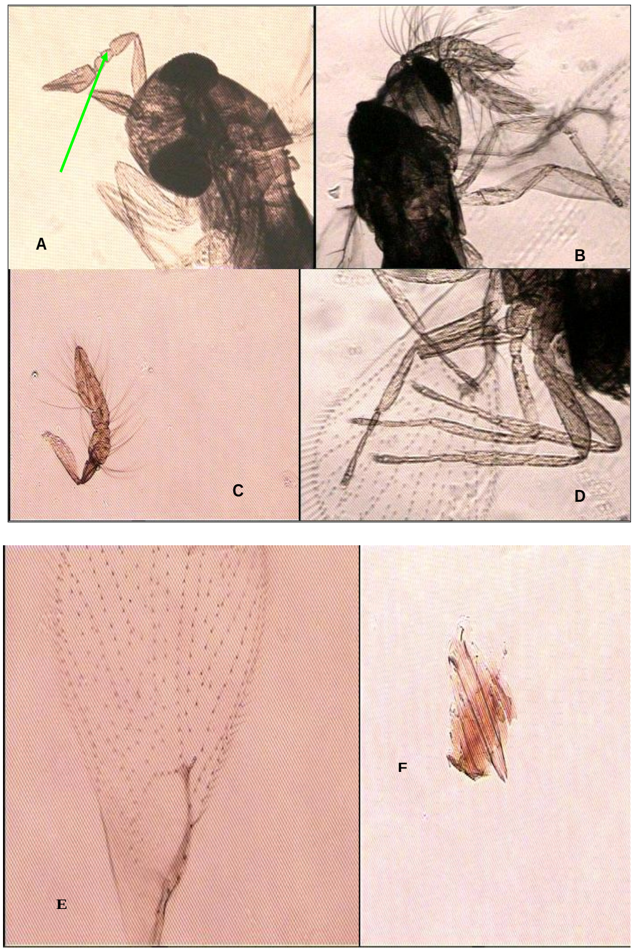


Plate 6: A-F *Trichogramma chilonis*. A. Female showing antennae B. Male with antenna. C. Antenna of male D. Body showing 3- Segmented legs. E. Fore wing venation. F. Female genitalia

Head: Head facially 1.35 times as wide as long. Eyes2.25 times as long as wide, distinctly longer than the length of malar space. Median ocellus as long as wide. Antennae inserted close to clypeus than the median ocellus, just reaching the latter. Antennal formula (1:1:1:2 :1), with scape, pedicel, anellus, 2-segmented funicles, and a club (Plate 6A). The latter though appears solid in 10x, however showed a transverse demarcation in 40x objective. Scape 5.2 times and pedicel 2.0 times as long as wide. Funicle segment first (F_1) slightly longer than wide, second (F_2) sub quadrate. Each funicle with two setae, anellus minute but distinct; club 2.6 times as long as wide Paul- [19].

Thorax: Thorax slightly longer than wide (9:8.5), distinctly shorter than abdomen (9.0:13).

Wings: Fore wings a little more than two times as long as wide (8.0:3.8), with remaining characters similar to as mentioned in male, except sub marginal vein with two stout bristles.

Legs

Fore legs: Femur 5.83 times and tibia 6.5 times as long as wide, tarsal length sub equal to the length of tibia; all tarsal segments sub equal.

Middle legs: Coxa, femur and tibia 1.5, 5.33 and 9.5 times as long as wide respectively; tarsal length a little shorter than the femur; first tarsal segment longer than second and third, the last two sub equal.

Hind legs: Coxa, femur and tibia 3.3, 4.0 and 5.0 times as long as wide respectively; tarsal length a little shorter than the femur; first and second tarsal segments sub equal, slightly longer than the third.

Abdomen: Abdomen (with exserted ovipositor) 1.24 times as long as wide (13:10.5).

Material examined: 15 males, 45 females. 10. viii. 2019 (Kralpora, K.D. Farm), 10 males, 39 females. 15. ix. 2019. (Lar), 18 males, 43 females 10. x. 2019 (Kangan).

Comments: *Trichogramma chilonis* Ishii has been recorded from eggs of *Chilo partellus* (Swinhoe) for the first time from Kashmir. In view of sufficient level of infestation caused by the pest to maize crop in the valley, the present egg parasitoid can be exploited in future to overcome the incidence.

Miscogaster ruficrus Haliday, 1834 : 253.

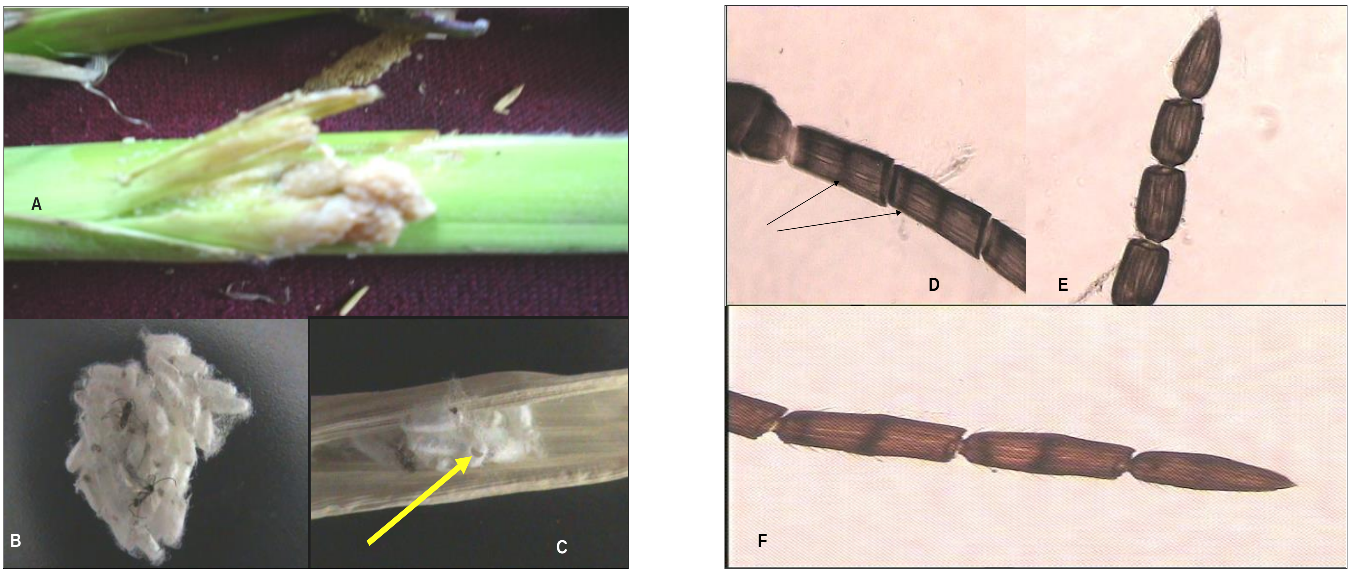
Diagnostic characters: This species can be easily identified on the basis of following characters: Body dorso ventrally not flattened; legs with hind coxae black; apical portion of aedegus of male genitalia slightly obtuse, not truncated.

Female

Body length: 2.06 mm. Body dorso ventrally not flattened, mosothorax and abdomen in same plane dorsally, in general shiny black. Head, thorax, abdomen, scape, eyes, hind coax and terminal part of ovipositor black. Antennae dark brown. Except apices of hind femur, hind tibia and its tarsal segments, which are dark brown, wing venation, maxillae and labial palpi honey yellow to light brown. Mandibles reddish brown. Body with minute puctures with distinct white pubescence, slightly thicker on the propodeum, laterads; Reticulation normal on body parts except propodeum alveolate, first two abdominal tergites rugose, remaining tergites shiny smooth [20].

Head: Head shiny with minute punctures, circular in frontal view, 1.26 times as wide as long (7.6:6). Eyes hairy, 1.5 times as long as wide (3:2); length of malar space a little shorter than the width of an eye (1.8:2). Inter orbital space 1.26 times as wide as the length of an eye (3.8:3). Antennal toruli closer to median ocellus than the clypeal margin (1.2:3.8). Ocelli arranged in obtuse triangle, with distance between lateral ocelli 2.0 times as long as the diameter of an ocellus. Mandibles strong, bi dentate (Plate 8D). Maxillary and labial palpi 4- and 3- segmented respectively.

Antenna (Plate 7 D-E) 18- segmented with 15 funicle segments. Club solid, undivided. Scape 1.5 times as long as wide (1.8: 1.2); Pedicel slightly longer than wide (1:.8). Funicle segments 1-8 sub equal, 2.62 times as long as wide (2.1:.8); F_1 shorter than the combined length of scape including radicula and pedicel (2.1:2.8); segments 9-10, 2.25 times (1.8:.8); 11-12, 2.0 times (1.6:.8); 13^{th} 1.5 times and 14-15, 1.37 times (1.1:.8) as long as wide. Club 2.16 times as long as wide (1.3:.6). Funicle segments with prominent transverse medial partitioning which is distinct in segments 1-10 (Plate 7 D), faint in 11-12 and absent in 13-15 (Plate 7 E). Sensillae in the antennal flagellum in two rows, except in last three funicle segments and club.



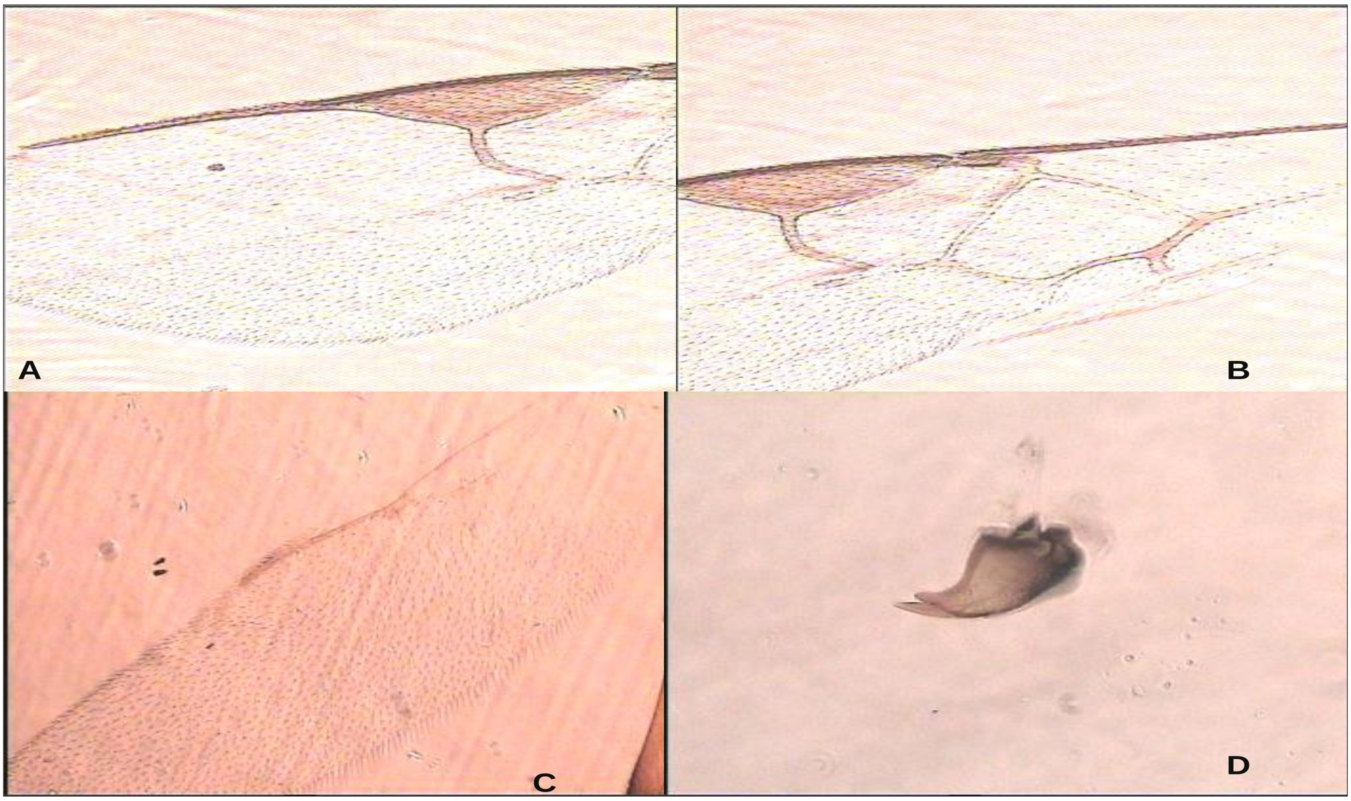


Plate 7 A-F. Pupal cocoon of *Cotesia ruficrus* and antenna. A. Cocoon under preparation. B. mature cocoon. C. Cocoon showing exit holes of the emerged parasitoid. D. Parts of basal funicle segments (female). E. Parts of distal funicle segments(female). F. Parts of distal funicle segments (male)

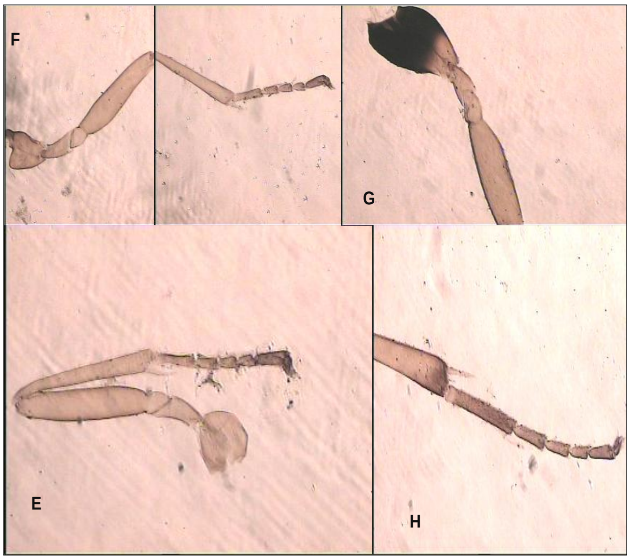


Plate 8 A-H Wings, mandible and legs of *Cotesia ruficrus* (female). A & B. Distal and central portions of forewing. C. Hind wing D. Mandible. E. Fore leg. F. Middle leg G & H. Parts of hind leg.

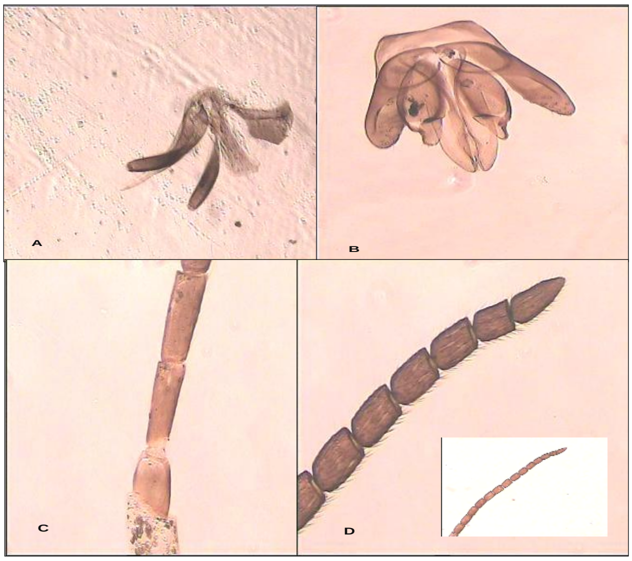


Plate 9 A-B Genitalia of *Cotesia ruficrus*. A. Ovipositor (Female)B. Aedeagus (Male). C-D. Part of female antenna of Ichneumonid sp. C. Basal segments D. Distal segments (Inset, portion of flagellum)

Thorax: Thorax 1.43 times as long as wide, slightly narrow anteriorly and broad posteriorly. Pronotum sloping, convex; Mesothorax 1.5 times as wide as long. Scutellum 2.0 times as long as wide. Propodeum rectangular, twice as wide as long.

Wings: Fore wings (Plate 8A-B) hyaline, with disc densely setose, 2.83 times as long as wide; costa, stigma and meta carpus brown, remaining veins light brown. Costa thick, more than twice as long as meta carpus; stigma 2.66 times as long as wide (3.2:1.2), a little longer than the meta carpus (3.2:3.0); recurrent vein half the length of meta carpus (1.5:3.0) radial, cubitus and sub discoidal veins indistinct (Plate 8A); anal vein almost parallel to median; areolet small; medial cell much wider than sub median and anal cell.

Hind wings (Plate 8C): Hind wings 3.81 times as long as wide; subcostella, mediella, sub mediella and nervellus transparent but distinct; sub costal margin bare; disc setose.

Legs (Plate 8 E-H): Fore legs (Plate 8E): Coxa as long as wide (2.5:2.5), trochanter 2.22 (2:.7), femur 6.25 (7.5:1.2), tibia 7.0 (7:1) times as long as wide; tarsi 5- segmented, a little shorter than the length of tibia (6.8:7). Length of tarsal segment 1-5 in the ratio of 2:1:1:1:1.8. tibial spur one, slightly longer than 2^{nd} tarsal segment.

Middle legs (Plate 8F): Coxa slightly wider than long (2.5:2.0), trochanter 2.0 (2:1), femur 4.66 (7.0:1.5), tibia 8.0 (8:1) times as long as wide; tarsi 5- segmented, distinctly shorter than the length of tibia (7.1:8). Length of tarsal segment 1-5 in the ratio of 2.2:1.1:1:.8:2.0. tibial spur one, slightly longer than 2^{nd} tarsal segment (1.3:1.1).

Hind legs (*Plate 8 G-H*): Coxa densely punctuate, 1.53 (5.8:3.8), trochanter 1.82 (2:1.1), femur 5.26 (10.0:1.9), tibia 8.33 (10.0:1.2) times as long as wide; tarsi 5- segmented, distinctly longer than the length of tibia (12.2:10). Length of tarsal segment 1-5 in the ratio of 5.0:2.0:2.0:1.2:2.0. tibial spur two, slightly longer than 2^{nd} tarsal segment.

Abdomen: Abdomen distinctly longer than the thorax (14:11.5), slightly more than twice as long as wide (14:6.5). First two abdominal tergites.

Rugose, the first tergite with prominent raised carina, the latter slightly wider than long (5:4), second tergite 2.16 times as wide as long (6.5:3); combined length of first two tergites as long as remaining abdominal tergites. Ovipositor (Plate 9A), visible from ventral side with sheath exserted.; the latter distinctly longer than the second valvifer (4.1:3.0).

Cocoon mass (Plate 7A-C): Milky white in colour with 35-84 pupal cocoon in a mass. Average length and width of a pupal cocoon in the ratio of 3.01:1.1 mm.

Male: Body length 1.62 mm. The male of *Cotesia ruficrus* (Haliday) resembles female in several respects such as general body coloration, body sculpture and pubescence etc., however differs in following characters: Antenna with first funicular segment (F1) as long as combined length of scape including radicula and pedicel (2.5:2.5); F1-F12 (2.5:2.5) and F13- F15 (2:.7) sub equal in length (Plate 7 F); all funicular segments with medial partitioning. Forewings 3.0 times as long as wide, radial and cubital veins distinct. Hind wings 4.06 times as long as wide (13:3.2), veins more prominent than those of female hind wings. Thorax slightly longer than the abdomen (9.5:9.1). Punctures and rugosity on mesoscutum, propodeum and first two abdominal tergites as in females. Remaining characters as those of females. Terminal end of aedeagus nearly pointed (Plate 9 B).

Material examined: 25 males, 85 females. 10. viii. 2019 (Kralpora, K.D. Farm), 35 males, 139 females. 15. ix. 2019 (Lar), 48 males, 124 females 10. x. 2019(Kangan).

Female: Body length 2.01 mm. (excluding exserted portion of ovipositor). Body black with metallic reflections; back of head, scutellum and propodeum shiny; eyes bare, coppery; ocelli blackish brown; antennal scape, base of mandibles, maxillary and labial palpi, all legs light yellow; teeth of mandibles reddish brown; antennae and ovipositor brown, venation honey coloured to light brown; abdomen except second and third tergites which are yellowish brown, blackish brown. Reticulation on head and thorax except propodeum fine, the latter with alveolae, with faintly indicated median and lateral carinae; post occiput of head finely punctured, setose.

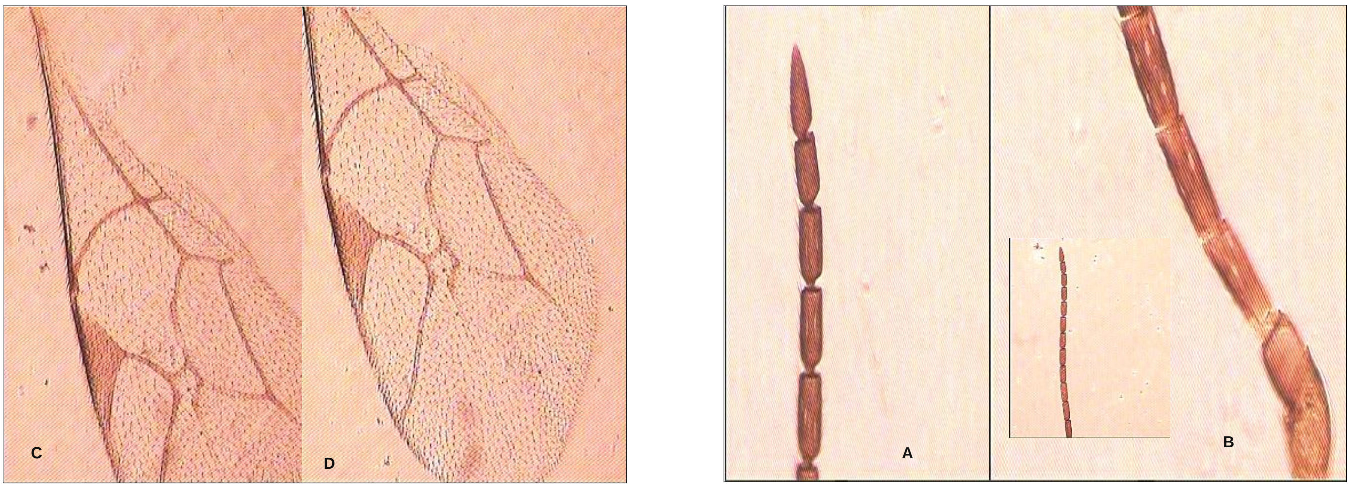


Plate 10 A-D Parts of male antenna and fore wings of Ichneumonid sp. A. Distal segments B. Basal segments C. Basal and central potion. D. Central and apical portion

2 : 3 respectively; stigma 2.77 times as long as thick; areolet incomplete, 3 -rm absent (Plate 10C-D).

Legs (Plate 11 A-D): *Fore legs* (Plate 11 A): Coxa as long as wide (2: 2), trochanter 1.5 times (1.5:1), femur 3.22 (5.8:1.8) and tibia 5.5 (5.5:1) times as long as wide; tarsus 5-segmented, 1.36 longer than the tibia (7.5:5.5), tarsal segments 1-5, in following ratio of their lengths: 3.1 : 1.5 : 1 : .9 : 1; tibial spur one, curved.

Female (Plate 12 B): Body length 2.0 mm.

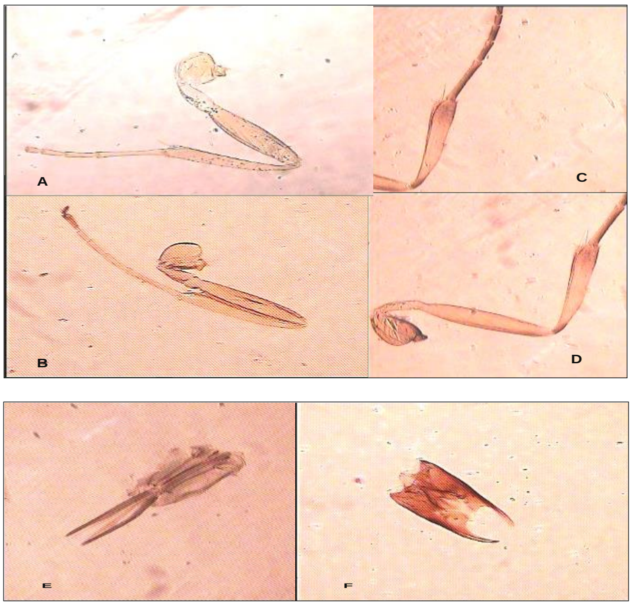


Plate 11 A-F Legs and genitalia of Ichneumonid sp. (Female). A. Fore leg. B. Middle leg C & D. Parts of hind leg. E. Ovipositor (Female). F. Aedeagus (Male). *Euplectrus coimbatorensis* Ferriere, 1942: 32-33

Middle legs (Plate 11B): Coxa 1.33 times (2.8:2.1), trochanter 2.0 times (2:1), femur 3.52 (6:1.7) and tibia 7 times (7:1) as long as wide; tarsus 5- segmented, 1.15 times as long as tibia (8.1:7), tarsal segments 1-5, in following ratio of their lengths : 3.8:1.5:1:.7:1.1; tibial spur one, straight.

Hind legs (Plate 11 C-D): Coxa 1.42 times (4:2.8), trochanter 2.0 times (2:1), femur 4.5 (9:2) and tibia 7.69 times (10:1.3) as long as wide; tarsus 5- segmented, a little longer than the tibia (10.3:10), tarsal segments 1-5, in following ratio of their lengths : 5 : 2 : 1.4 : .8 : 1.1; tibial spurs two, 2.5 times shorter than the first tarsal segment (2:5).

Fore wings (Plates 10 C-D): Forewings hyaline, 2.72 times as long as wide (30:11), Lengths of Costa, Stigma, R1, M + Cu, 1A, Rs and M, Cu-a, Cu- 1, Cu- 1b, Im- Cu and 2m-Cu in the ratio of 13: 5 : 7 : 11:16: 3.3 : 1.7 : 3.0: 2:

Material examined: 9 males, 36 females 10. x. 2019 (Kangan).

Diagnostic characters: This species can be easily identified on the basis of following characters: Body black; forewing with the sub marginal vein smoothly joining the parastigma; mesoscutum with notauli complete; hind tibia with spurs longer than the first tarsal segment; propodeum with one median carina.

Head and thorax black; eyes and ocelli blackish brown; face shiny smooth with metallic reflections; antennae, wings, wing venations and all legs honey yellow; abdomen reddish brown except yellow medially. Body sculpture on head, pronotum, mesoscutum, scutellum, axillae and petiole identically reticulate; propodeum abdomen and shiny smooth. Setae long and white, projected backwards on vertex, mesoscutum and scutellum; sides of propodeum thickly setose.

Head: Head dorsally 4.7 times as wide as thick (4.5:1.0), facially 1.34 times as wide as long (4.7:3.5); triangular, converging after lower level of eyes, width below eyes 1.88 times less than across the width of eyes (2.5:4.7); eyes 1.3 times as long as wide (2.0:1.5), twice as long as malar space (2.0:1.0); ocelli arranged in obtuse angled triangle; distance between lateral ocelli equal to its distance from outer eye margin (1:1), and twice from median ocellus (2:1). Antennae (Plate 12C) 8- segmented, inserted at about lower level of eyes with antennal toruli much closer to clypeal margin than the median ocellus (1:2.5); inter torular distance distinctly less than interocular distance (1: 1.5).

Hind legs (Plate 12E): Coxa 1.75 (7: 4), femur 4.4 (11:2.5) and tibia 9.54 (10.5:1.1) times as long as wide; tarsus 4 segmented, its length slightly more than the length of coax (8:7); segments first and fourth sub equal (2.5:2.5), second 1.5 times as long as third (1.5:1); tibial spurs two, in the ratio of 3:4.5 of their length, the latter 1.8 times as long as the first tarsal segment (4.5:2.5).

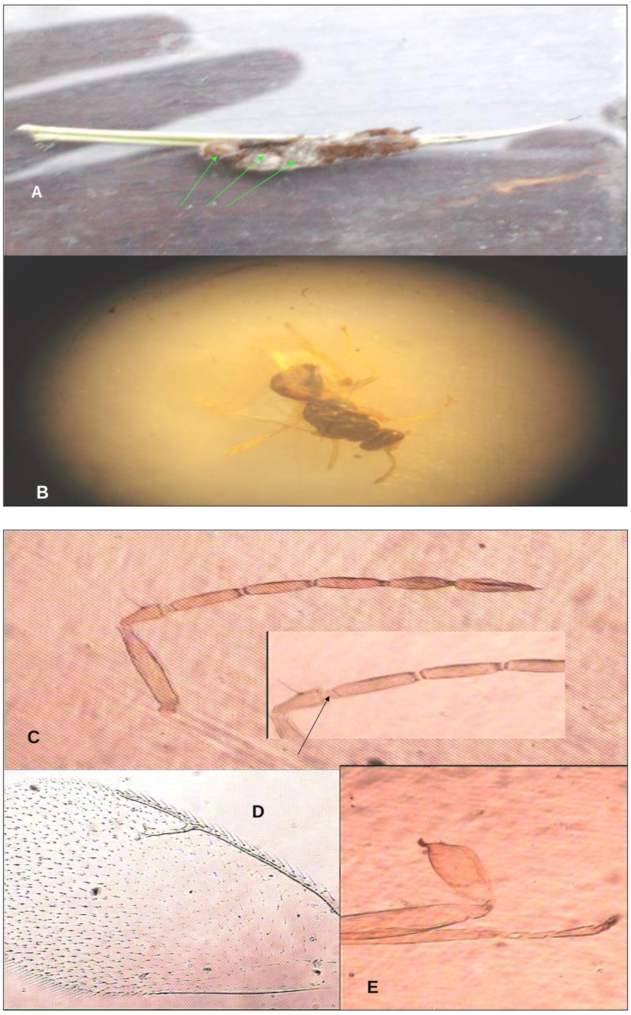


Plate 12A-E *Euplectrus coimbatorensis* (Female). A. Cocoon of *Euplectrus coimbatorensis* developing externally on larva of *C. partellus* B. Adult of *Euplectrus coimbatorensis* (Female) C. Antenna (Inset – showing ring segment) D. Part of fore wing. E. Hind leg

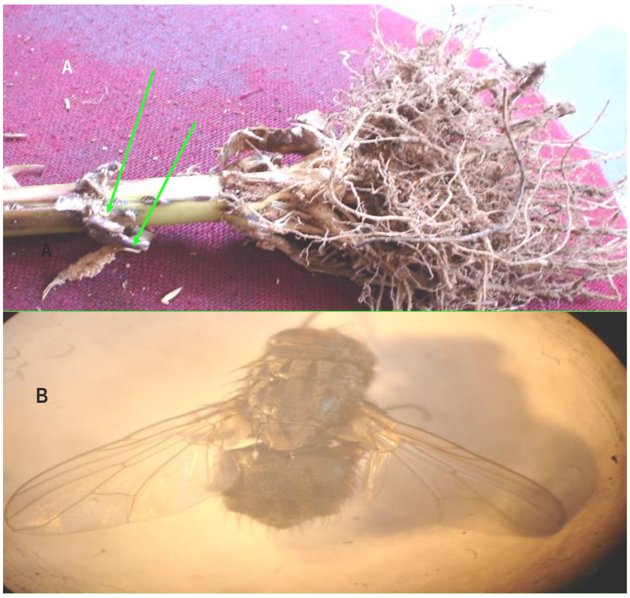


Plate 13 A-B Tachinid parasitoid. A. Pupal cocoon of tachinid parasitoid. B. Adult tachinid

Abdomen: Abdomen petiolate, petiole small, as long as wide (1:1); abdomen 1.2 times as long as wide (6: 5), first tergite longest, medially emarginate, 1.4 times as long as remaining tergites (3.5:2.5). Ovipositor hidden; second valvifer 3.1 times as long as ovipositor sheath (3.1 :1). Material examined: 9 females. 15. ix. 2019 (Lar). Male: Not known

Preliminary survey of thirteen maize growing areas representing six districts of Kashmir valley, revealed an average of 1.53 to 13.45 per cent plant infestation caused by *C. partellus* during May to July. Among the areas surveyed, Kralpora (K.D. Farm), Lar and Kangan exhibited comparatively high level of infestation as compared to others. Extensive fortnightly surveys in the above mentioned three hot spot areas indicated an average of 19.89, 24.53 and 22.04 per cent plant infestation during July to October, at Kralpora, Lar and Kangan, respectively. At all these locations, larval infestation was found to increase from July to September and declined in October. Highly infested plants during September showed an average of 2.2 to 4.0 larvae/plant which was found positively correlated with number of exit holes in them. Among natural enemies, *Trichogramma chilonis* Ishii, *Cotesia ruficrus* (Haliday), *Euplectrus coimbatorensis* Ferriere and one unidentified species each of ichneumonidae and tachinidae were found associated with *C. partellus. Cotesia ruficrus* was distributed at all the studied locations, whereas *T. chilonis* was found at three studied hot spot locations. Negligible and sporadic occurrence of remaining species was found from one location only. On individual basis, average egg parasitism by *T. chilonis* was determined as 4.98, 7.7 and 6.08 per cent whereas larval parasitism by *C. ruficrus* was worked out to be 9.76, 14.43 and 11.25 per cent at Kralpora, Lar and Kangan, respectively. Together these two egg and larval parasitoids afforded an average of 14.73, 22.13 and 17.33 per cent parasitism with a maximum of 30.14 per cent at Lar. Comparatively better performance of *C. ruficrus* was due to its higher population density and manifestation of super parasitism. Per cent emergence both in *T. chilonis* and *C. ruficrus* ranged 83.67-93.32 and 86.26-90.38 respectively, with female oriented sex ratio in both cases. Pattern of parasitism was found varying in the studied three locations due to many abiotic and biotic factors. Positive correlation was found to exist between egg and larval and also combined parasitism, separately, with host abundance. Combined parasitism yielded positive correlation with maximum relative humidity, whereas negative correlation with maximum and minimum temperatures, minimum relative humidity, rainfall and sunshine hours.

CONCLUSIONS

The present discovery and natural association of *Trichrogramma chilonis* and *Cotesia ruficrus* with *Chilo partellus* is nevertheless an important step necessitating their mass production and future exploitation in the pest prone areas of Kashmir valley. In view of the reported potentials of the above-mentioned parasitoids, their augmentative releases right from the last week of May, can result in early suppression of the larval incidence and keep them below economic injury level. Incorporation of these parasitoids as important component of IPM can be both an acceptable and useful tool for farmers. Simultaneously, their natural conservation through judicious and selective use of insecticides, crop residue management, differential period of sowing, staggered harvesting and cropping of alternative host plants, etc. can play important role in providing natural refuge to the parasitoids to help their survival for targeted performance against the studied pest in Kashmir valley.

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