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A Study of Biological Attributes and Morphometry of *Trichogramma japonicum* Ashmead

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ABSTRACT: *Trichogramma* species constitute one of the most commonly used bio agent of natural enemies for biological control programs worldwide. *Trichogramma* sp. are very difficult to identify because of their tiny size and uniform morphological characters. The present investigation aims to study several aspects of the biological attributes and morphological character of *T. japonicum*. The present study pointed out that the total developmental period of *T. japonicum* on *C. cephalonica* was 8.56 ± 0.22 days. Adult emergence was 96.67 ± 3.32 percent with a sex ratio of 1: 2.82 (Male: female). The female parasitic wasp lived longer (4.90 ± 1.12 days) as compared to the male (2.63 ± 1.10 days). Moreover, the total life cycle of female *T. japonicum* was 13.46 ± 1.21 days while the male has 11.19 ± 1.11 days. In addition, Dimorphism existed in *T. japonicum*. The overall body size as well as the wing span of the female was larger as compared to the male wasp while the antenna of the male (0.21 ± 0.01 mm) was noted far longer than that of the female parasitoid (0.13 ± 0.01 mm). The female had a long distinctive ovipositor of 0.22 ± 0.02 mm in length.

Keywords: *Trichogramma*, *Corcyra*, emergence, biological attributes, morphometry.

INTRODUCTION

The genus *Trichogramma*, a tiny hymenopteran egg parasitoid is cosmopolitan and commonly present in all terrestrial habitat and belong to the family Trichogrmmatidae. Primarily Trichogramma are parasitoids of eggs of Lepidoptera, but parasitism is also seen in eggs of the orders such as Diptera, Coleoptera, Hymenoptera, Hemiptera, and Neuroptera. It is one of the most important agents for plant protection because of its cosmopolitan nature and its success as a bio-control agent by mass release. Since it destroys the pest in the egg stage itself before the pest could damage the crop and also it is quite amenable to mass rearing in the laboratories. Further, a steady production, as well as a supply of egg parasitoids, is essential to achieve successful biological control. These Trichogrammatid parasitoids have low host specificity and thereby, can be mass-produced easily in large quantities on natural as well as factitious hosts. Intermediate or factitious host for *Trichogramma* spp. must be available at all times throughout the year because as stated by Buchori *et al.* (2010) the larval phase of the parasitoid will only well develop on the host of a specific phase (egg phase). If a female parasitoid is to oviposit its eggs but at that time there is no host of the right phase, the parasitoid will not be effective. Trichogrammatids are amenable to mass production, which can be accomplished by mass-rearing its factitious host, either *Corcyra cephalonica* Stainton or *Sitotroga cerealella* Olivier. Further, the rearing of *Trichogramma* spp. by using *Corcyra* eggs as factitious host is agro-technically feasible. The rice moth, *C. cephalonica* is available in all seasons and it can be the best factitious host under laboratory conditions. Moreover, one way to determine the potential of Trichogramma parasitoid in parasitizing host was by observing biological aspects of parasitoid (Sari *et al.*, 2021). Thus, the biological attributes of *T. japonicum* when reared on eggs of *Corcyra* need to be studied carefully. In addition, the size of the parasitoid is an important feature to determine the quality components of parasitoids. There is a positive relationship between performance and body size. Morphometry is a tool used to know the size of a parasitoid. Further, various researchers have tried to separate the different species of *Trichogramma* as well as the opposite sex of a single species by morphometric analysis. So far no basic study of biological aspects has been conducted for *T. japonicum.* Therefore, a detailed study of biological attributes as well as morphometry was carried out for *T. japonicum* during the present investigation.

MATERIALS AND METHODS

Biological attributes of *T. japonicum*. The factitious host, *C. cephalonica,* and test insect, *T. japonicum* were cultured and mass-produced at Bio-control Laboratory, Department of Entomology, N.M.C.A., Navsari Agricultural University, Navsari. Sorghum grains were milled and sterilized broken sorghum grains were used as media for mass production of a test insect, *C. cephalonica,* and the parasitic wasp, *T. japonicum* was reared on eggs of *Corcyra* moth. The mass culture of *Corcyra* under laboratory conditions was done as per the methodology put forward by Naganna and Shinde (2017). The eggs of rice moths were collected daily in the morning hour and cleaned by rolling on blotting paper to separate the various impurities *viz*., scales and other damaged body parts of the moths. Further, the preparation of trichord and mass rearing of *T. japonicum* under laboratory conditions was made as per the methodology adopted by Mohapatra and Shinde (2021). Various observations recorded during the experiment were given below;

Total developmental period. The total developmental period was considered as the period between the date of egg parasitization to the date of adult emergence per egg strip. After 24 hrs of exposure to *T. japonicum*, each stripe was transferred to another clean vial for further study. The stripe was observed daily at 7 am until the eggs in all stripes turn black. The blackened egg indicates the grub of *T. japonicum* reached the pupal stage. These blackened eggs were observed daily for adult emergence and observations were recorded daily at two times (7 am and 7 pm) at an interval of 12 hrs to know the exact time taken for the adult emergence after eggs blackened with a maximum precision. The emerged adults of *Trichogramma* from blackened eggs were regularly transferred to other clean vials during each observation. These emerged adults were further used to know adult longevity. The time from the date of parasitization to the date when eggs turned black was recorded in days while the time required after the egg turned black to adult emergence was recorded in hours and values later on converted into days. The time is taken by *T. japonicum* to complete the developmental period (days) after egg blackening was calculated by employing the following formula. Thereafter, the total developmental period of *T. japonicum* was calculated by using the following formula. Total developmental period (Days) = The time taken by *T. japonicum* to turn *Corcyra* fresh eggs into black colour (Days) + The time taken by *T. japonicum* for adult emergence after egg blackening (Days).

Adult emergence. After the complete emergence of *Trichogramma* adult, the total number of adults who emerged from each stripe irrespective of sex was counted and recorded. The results were further cross verified by checking and counting the exuviaes from each egg stripe under the microscope. This was done by dissecting each egg of *Corcyra* with the help of a scalpel. The adult emergence (%) was calculated based on the total number of adults who emerged from the egg strip.

$$\text{Time taken for adult emergence after egg blackening (Days)} = \frac{\sum(\text{Number of adult emerged} \times \text{Days after blackening of eggs})}{\text{Total number of emerged adults}}$$

$$\text{Adult emergence (\%)} = \frac{\text{Total number of adults emerged}}{\text{Total number of blackened eggs taken for investigation}} \times 100$$

Adult longevity. The adults of *T. japonicum* after emergence from the parasitized *Corcyra* eggs were separated as male and female based on their morphological characters. The males were dull yellow with black thoracic sclerites and abdominal terga. Antennal hairs were long and sharply tapering, whereas, in the females, the antenna was clubbed with few short hairs on the flagellum and ovipositor nearly 1.37 times longer than the hind tibia (Hirai and Fursov 1998). To know the adult longevity, a total thirty number of females as well as males were maintained in separate plastic vials. Five percent honey solution was provided in the form of fine streak as adult food. The individual *Trichogramma* adult was observed daily till death during morning hours. The time taken by *T. japonicum* from the date of emergence to the date of adult death was considered adult longevity. Thus, male and female adult longevity was calculated.

Sex ratio. The adult who emerged from the parasitized eggs were counted individually as male and female based on the colour and shape of males and females during the present investigation. Thus, the sex ratio was worked out from the laboratory culture.

Total life cycle. The duration of the entire lifespan was considered as the period between the date of egg parasitization to the death of emerged adults. The total life cycle for each sex of *T. japonicum* was worked out as follows;

Total life cycle (Days) = Total developmental period (Days) + Adult period (Days)

Morphometrics. Detailed morphometric studies were carried out for *T. japonicum* at the maximum level of accuracy with the help of a stereo-trinocular microscope fitted with a brand Catcum-130 camera with software power Scope photo (Version 3.1) during this present investigation. Morphological characteristics reported by Khan *et al.* (2018) were taken into consideration out of which a total of 12 parameters of female and 11 parameters of male *T. japonicum* were investigated during the present investigation. The morphometrical observations which were taken during the study was discussed hereunder.

The male and female body. The body length of the *Trichogramma* was taken from starting point of the thorax (prothorax) to the last terminal point of the abdomen. Similarly, the maximum abdominal breadth was considered as the breadth of the respective sex of *T. japonicum*.

Male and female head capsule (frontal view). The length and breadth of the head capsule were taken after detaching it from the rest of the body. The length was measured from the vertex to the labium while the maximum breadth of the head capsule near the compound eye was taken as the breadth of the head capsule.

Male and female antenna. The length of the antenna was taken after detaching it from the head. Due to the curvature of the antennae, the whole length of the antenna was measured in two phases. At first, the length of the scape + pedicel was taken from the antennifer to the base of the flagellum (club in females). In the second phase, the length of the flagellum and club was taken for males and females, respectively. The antennal length of the male and female was calculated by adding the above two parameters.

Male and female wing. The length from the base of the wing to the point where the median anterior vein touches the margin was considered the length of the forewing whereas the length from the base to the last terminal point of the hind wing was measured as the length of the hind wing. Further, the maximum width of the wing was considered as the width of both fore and hind wings.

Male and female hind tibia. The length from the joint of the femur and tibia to the base of the tarsi was measured as the length of the hind tibia.

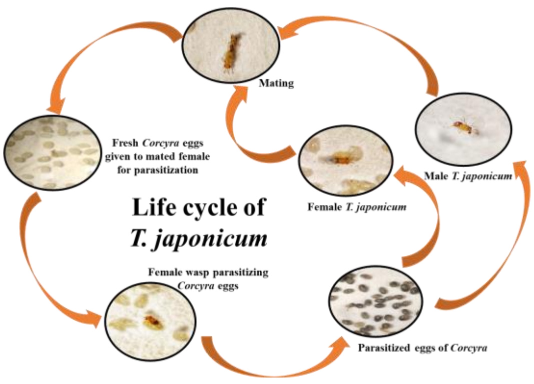
Female ovipositor. The length of the ovipositor was measured from the base of the 1st and 2nd valvulae to the tip of the 3rd valvula.

RESULTS AND DISCUSSION

Biological attributes of *T. japonicum*: The test insect, *T. japonicum*, a holometabolous hymenopteran wasp exhibited complete metamorphosis and passed through egg, maggot, pupa, and adult stages. The egg, maggot, and pupal stages of *T. japonicum* were completed within *Corcyra* eggs whereas adult wasp was free living in nature. A well understanding of the biology of the parasitoid is the foremost thing for the success of its utilization in pest management programme, therefore a study on "Biological attributes of *T. japonicum* on rice moth, *C. cephalonica*" was carried out under laboratory conditions. The results of this aspect are interpreted and discussed hereunder as follows.

Table 1: Biological attributes of *T. japonicum* on *C. cephalonica* under laboratory condition.

Sr. No.	Biological attributes		Min.	Max.	Avg. ± S.D
1.	Time taken by *T. japonicum* to turn *Corcyra* fresh eggs into black colour (Days) [a]		4.00	4.00	4.00 ± 0.00
2.	The time taken by *T. japonicum* to complete the developmental period after egg blackening (Days) [b]		4.18	4.94	4.56 ± 0.22
3.	Total developmental period (Days) [a+b]		8.18	8.94	8.56 ± 0.22
4.	Adult emergence (%)		85.00	100.00	96.67 ± 3.32
5.	Adult period (Days) [c]	Female	3.00	6.00	4.90 ± 1.12
		Male	1.00	5.00	2.63 ± 1.10
6.	Sex ratio (Male: Female)		1: 1.22	1: 5.33	1: 2.82
7.	Total life cycle (Days) [a+b+c]	Female	11.18	14.94	13.46 ± 1.21
		Male	9.63	13.73	11.19 ± 1.11



Total developmental period. The total development period of *T. japonicum* was calculated in two phases. In the first phase, the time taken by the majority of the parasitized *Corcyra* eggs in stripe to turn black while the time taken by those blackened eggs for adult emergence was noticed in the second phase. The perusal of data on the developmental period of *T. japonicum* revealed that the time taken by the majority of the *Corcyra* eggs in stripe to turn black was 4 days whereas, the time taken for the emergence of the adult from those blackened eggs varied from 4.18 to 4.94 days with an average of 4.56 ± 0.22 days. Moreover, the total developmental period of *T. japonicum* on *C. cephalonica* ranged from 8.18 to 8.94 days with an average of 8.56 ± 0.22 days.

The present studies on developmental period are in accordance with Baitha *et al*. (2003) who registered that the developmental period of *T. japonicum* was 8.04 days at 30ºC temperature on *C. pertelus* eggs as compared to 12.68 days at 25ºC and 7.04 days at 35ºC temperature; 10.6 days on *S. cynthia ricini*, 8.6 days on *S. litura*, 8.2 days on *H. armigera* and 7.8 days on *C. cephalonica* (Firoz, 2015); 9.2 days at 26ºC temperature on *C. cephalonica* which became 7.2 and 6 days at 31 and 36ºC temperature (Ghosh *et al.*, 2017). Furthermore, Nadeem *et al.* (2009) pointed out that the developmental period of *T. chilonis* was 17.3 days at 20ºC followed by 8.3 days at 25ºC, 7.6 days at 31ºC and 7 days at 35ºC temperature on *S. cerealella*; 9.6, 8.2 and 7.4 days at 24, 28 and 32ºC temperature on *S. cerealella* (Sultan *et al.*, 2013); 9.2 days at 24ºC, 8 days at 28ºC and 7.2 days at 32ºC temperature on *C. cephalonica* (Perveen *et al.*, 2012); 11 days on *S.*

cerealella (Zahid *et al.*, 2007), which are in line with the present findings. Honnayya and Gawande (2018) also supports the present findings who noted that the developmental period for *T. chilonis* was 8 days on 24, 48 and 72 hrs old eggs of *C. cephalonica*. Additionally, Dahlan and Gorth (1998) and Ekhlass and David (2002), who revealed that developmental period of *T. australicum* was 174 to 191 hrs and 184 to 188 hrs, respectively on *H. armigera* which again agree with the present investigation. The present findings are more or less similar to Nordlund *et al.* (1997) who reported that developmental period of *T. minutum* ranged from 9.36 to 9.46 days on *H. zea* and Mansour (2019) who observed that *T. cacoeciae* required 8.2 days for adult emergence on *C. pomonella* at 30ºC temperature. Ayvaz *et al.* (2008) noticed that egg to pupal period of *T. evanescens* was completed within 4.50 days (highest) at 24ºC and 2.60 days (lowest) at 33ºC temperature. The result further indicated that the developmental period (egg to adult) of *T. evanescens* was 11.02 and 10.90 days for female and male, respectively at 24ºC temperature whereas the corresponding parameters were 8.50 and 8.67 days at 33ºC temperature, respectively which is more or less in favour with the present findings. The slight variation in the developmental period might be due to changes in *Trichogramma* sp., host eggs used for study as well as prevailing weather conditions during the investigation.

Adult emergence. The data recorded on the adult emergence of *T. japonicum* from the parasitized *Corcyra* eggs varied from 85.00 to 100.00 per cent with an average of 96.67 ± 3.32 per cent. The present findings are akin with Nadeem *et al.* (2009) who noted that the highest and lowest adult emergence of *T. chilonis* was 98 and 33.7 percent on *S. cerealella* at 28 and 35ºC temperature, respectively; 90.13 percent on *S. litura* and 89.4 percent on *C. cephalonica* (Dileep, 2012); maximum and minimum adult emergence were 96.30 and 89.40 percent on *S. cerealella* at 24 and 32ºC temperature, respectively (Sultan *et al.*, 2013); highest and lowest emergence were 93.3 and 88.3 percent on *C. cephalonica* and *A. moorei*, respectively (Rathi and Ram 2000); 96.2 and 94.5 percent on 24 hrs old eggs of *C. cephalonica* and *H. armigera*, respectively (Laurentis *et al.*, 2019); 86 per cent when Corcyra eggs were parasitized by 48 hrs aged *T. japonicum* (Pandi *et al*., 2021). The present findings disagree with Firoz (2015) who found that maximum and minimum adult emergence of *T. japonicum* was 71.4 and 40.9 percent when fresh and 96 hrs old *Corcyra* eggs were offered for parasitism, respectively. The result also revealed that the highest 72.3 percent and lowest 38.3 percent emergence were observed at 28 and 32ºC temperature which again deviates from the present investigation. A difference was seen between the present study and the findings of Perveen *et al.* (2012) who recorded that maximum adult emergence of *T. chilonis* was 80.3 percent at 28ºC temperature. Furthermore, Ayvaz *et al.* (2008) recorded 90 percent emergence of *T. evanescens* on *E. kuehniella* eggs and Mansour (2019) noticed highest emergence of *T. cacoeciae* was 89.5 percent at 25ºC temperature, which supports the present findings. Ghosh *et al.* (2017) showed evidence to the present findings who recorded 92.60 percent adult emergence of *T. japonicum* at 26ºC temperature on *C. cephalonica*. Moreover, Nasrin *et al.* (2016) support the present findings who noted that the highest adult emergence of *T. chilonis* was 98.6 percent when host *Corcyra* was fed with chopped wheat. Most of the findings of the above workers support the present investigation however, slight variation is seen with the adult emergence which might be due to different factitious hosts and prevailing weather conditions at the study locality.

Adult period. The data about the adult period of *T. japonicum* are presented in Table-01. It can be seen from the results that the male of *T. japonicum* lasted for 1 to 5 days with an average of 2.63 ± 1.10 days while the female parasitic wasp survived for 3 to 6 days with a mean period of 4.90 ± 1.12 days. Looking at the present investigation it can be concluded that the female *T. japonicum* survived longer than that of the male.

In the past, Miura and Kobayashi (1995) revealed that female *T. chilonis* survived for 5 and 6 days when reared on *E. kuehniella* and *P. xylostella*, respectively; 5.6 days on *S. cerealella* at 31ºC temperature (Nadeem *et al*., 2009); highest and lowest female longevity were 4.1 and 2.6 days on *C. cephalonica* at 24 and 32ºC temperature, respectively (Perveen *et al.*, 2012); 4.8 days when reared on *S. cerelella* at 24ºC temperature (Sultan *et al*., 2013); 4.9 days on *C. cephalonica* (Jalali *et al*., 2006), which are in support with the present investigation. Manickavasagam *et al.* (1994) stated that female and male *T. chilonis* lived for 5 and 4 days, respectively whereas it was 1 day for both the sex of *T. japonicum*, which partly support the results of the present investigation. In addition, Mehendale (2009) found that the longest and shortest longevity of female *T. chilonis* was 4.47 and 1.73 days emerged from the eggs of *Corcyra* female when fed on media containing [sorghum + groundnut + powdered yeast] and sorghum alone, respectively. He also revealed that the female and male of *T. chilonis* lasted for 4.03 and 3.00 days, respectively, when fed with 10 percent honey solution, which is in line with the present findings. In contrast to the present findings, Rathi and Ram (2000) showed that the male and female of *T. chilonis* lived for 4.6 and 7.8 days when reared on *C. cephalonica*. The findings of Shirazi (2006) also deviate from the present findings noted that females of *T. chilonis* lasted for 10.08 days at 20ºC temperature which reduced to 6.73 days at 30ºC temperature. The present findings are in concurrence with Dileep (2012) who reported that the male and female of *T. chilonis* survived for 3.67 and 5.33 days when emerged from the eggs of *S. litura*, respectively while it was 3.67 and 4.5 days when *C. cephalonica* eggs were used. Further, Firoz (2015) reported that the female and male of *T. japonicum* lived for 3.1 and 4.1 days when emerged from the eggs of *C. cephalonica*, respectively; the highest female longevity of *T. japonicum* was 6.6 days at 16ºC temperature and declined to 4.6 days at 26ºC temperature and then to 3.0 days at 36ºC temperature (Ghosh *et al.*, 2017), which are again in tally with the present findings. The work of the above scientists are in favour of the present investigation. However, a slight difference is observed with the adult period which might be due to changes in adult food, different rearing media for factitious hosts, test insects as well as ambient temperature during the investigation.

Sex ratio. The adults were differentiated into their sexes based on their morphological characteristics and the sex ratio was worked out from the laboratory culture of *T. japonicum*. The data obtained are summarized in Table 1 and the results revealed that out of 580 individuals who emerged from the laboratory culture, 411 were females and 169 were males which indicated the preponderance of females. Moreover, the sex ratio of *T. japonicum* on *C. cephalonica* was female-biased and the sex ratio (Male: female) varied from 1: 1.22 to 1: 5.33 with an average of 1: 2.82.

A more or less similar trend was seen about the sex ratio of *T. japonicum* wherein Mehendale (2009) recorded the highest sex ratio of *T. chilonis* (1: 4.48) on eggs of *S. cynthia ricini* and lowest (1:1.24) on eggs of *E. vittella* whereas it was 1: 1.30 for *C. cephalonica*; 1: 2.50 on *C. cephalonica* at 25ºC temperature (Kumari *et al*., 2020). Further, Dileep (2012) showed that sex ratio of *T. chilonis* was 1: 2.10 and 1: 1.53 on eggs of *S. litura* and *C. cephalonica*, respectively. He also found the sex ratio was 1:2.25 on fresh eggs of *C. cephalonica* which decreased with an increase in host egg age, which doesn't in line with the present findings. Moreover, the present investigation is in agreement with Firoz (2015) who revealed that sex ratio of *T. japonicum* was 1:4.7, 1:3.0, 1:2.8 and 1:2.4 on eggs of *S. cynthia ricini*, *C. cephalonica*, *H. armigera* and *S. litura*, respectively. According to Dahlan and Gorth (1998), the sex ratio of *T. australicum* on eggs of *H. armigera* was 1:30; the sex ratio of *T. chilonis* on eggs of *M. vitrata* was 1: 2.2 (Unmole, 2010) are in favour with the present outcomes. Some discrepancy among the results about sex ratio was seen which might be due to changes in *Trichogramma* species, host egg used, the methodology adopted and prevailing weather conditions during the investigation.

Total life cycle. The total life cycle of both male and female wasps was studied and the results revealed that the total life cycle of female wasps ranged from 11.18 to 14.94 days with a mean of 13.46 ± 1.21 days while that of males varied from 9.63 to 13.73 days with an average of 11.19 ± 1.11 days. The present investigation showed that the total life cycle of female *T. japonicum* was longer as compared to that of male wasps. In the past, Firoz (2015) reported that the total life cycle of *T. japonicum* was 12.2 ± 0.5 days in *S. cynthia ricini*, 10.9 ± 0.8 days in *S. litura*, 10.2 ±0.7 days in *H. armigera* and 9.3 ± 0.8 days in *C. cephalonica.* Carvalho *et al.* (2022) revealed that total life cycle of *T. marandobai* and *T. manicoibai* when reared on their natural host, *Erinnyis ello* were 10 and 10.3 days, respectively. Dileep (2012) noted that the total life cycle of *T. chilonis* was 11.17 days on eggs of *S. litura* while it was 9.33 days in *C. cephalonica* which is also not in favour of the present findings. The findings of past workers disagree with the present investigation on the total life cycle. The discrepancy in total life cycle might be due to different test insect species, change in factitious host and ambient temperature and relative humidity during there might be due to different test insect species, change in factitious host and ambient temperature and relative humidity during their investigation.

Morphometrics. Various morphometric observations on *T. japonicum* are presented and discussed hereunder with the following points.

Table 2: Morphometric of *T. japonicum* when reared on *C. cephalonica* under laboratory condition.

Sr. No.	Morphometric Character	Parameter	Female			Male		
			Max.	Min.	Avg.	Max.	Min.	Avg.
1.	Body	Length (mm)	0.46	0.34	0.40 ± 0.04	0.40	0.32	0.37 ± 0.02
		Breadth (mm)	0.23	0.15	0.19 ± 0.02	0.20	0.14	0.17 ± 0.02
2.	Head Capsule (Frontal view)	Length (mm)	0.18	0.15	0.16 ± 0.01	0.18	0.13	0.15 ± 0.01
		Breadth (mm)	0.21	0.16	0.19 ± 0.01	0.22	0.16	0.19 ± 0.02
4.	Antenna	Scape + Pedicel (mm)	0.07	0.05	0.05 ± 0.01	0.08	0.05	0.07 ± 0.01
		Club length (mm)	0.09	0.06	0.07 ± 0.01	0.16	0.13	0.15 ± 0.01
		Antennal length (mm)	0.16	0.11	0.13 ± 0.01	0.24	0.19	0.21 ± 0.01
5.	Forewing	Length (mm)	0.56	0.45	0.50 ± 0.04	0.54	0.42	0.49 ± 0.03
		Width (mm)	0.24	0.18	0.21 ± 0.02	0.23	0.18	0.21 ± 0.01
6.	Hindwing	Length (mm)	0.40	0.33	0.37 ± 0.02	0.40	0.31	0.37 ± 0.03
		Width (mm)	0.04	0.01	0.02 ± 0.01	0.03	0.01	0.02 ± 0.01
7.	Hind tibia (HTL)	Length (mm)	0.18	0.14	0.16 ± 0.01	0.18	0.12	0.14 ± 0.02
8.	Ovipositor	Length (mm)	0.24	0.18	0.22 ± 0.02	--	--	--

Colour and shape of adult. The female head capsule of *T. japonicum* was light yellowish in colour and triangular in shape *viz.*, wider than long in facial view. The compound eyes were dark red and covered a large area of the wasp head. Further, the antennae were short, curved, and yellowish and the flagella were modified into a club-like structure. Thorax was yellowish with light yellow ambulatories legs. Fore wings were hyaline with strongly depleted venation which was marked by dotted lines and three veins *viz.*, submarginal, marginal, and stigmas fused into one arch near the anterior margin of fore wings and was visible. The forewings were covered with numerous fringes. Hind wings were narrower than fore wings by bearing fringes along the posterior margin. The abdomen was usually yellowish but, sometimes blackish, slightly longer and wider than the thorax. Moreover, the ovipositor was blackish and arising from basal one-third of the abdominal sterna.

However, the male head capsule of *T. japonicum* was the same as that of the female except for the dull yellow colour. Antennae were curved with long flagella which consisted of many black colour tapering hairs. Thorax was yellowish with black anterior terga and its legs were the same as the female wasp. The fore and hind wings were similar in appearance to that of female *T. japonicum*. The abdomen was as wider as the thorax with black terga.

A more or less similar finding was made by Yousuf *et al.* (2016) who noticed that female *T. chilonis* was yellow with a dark red compound eye and antenna with single-segmented club whereas male antenna had long and tapering 35-44 flagellar hairs. The results also revealed that the forewings of *T. japonicum* were hyaline except for the area beneath venation was lightly infuscated. Thus, supports the present findings.

Male and female body. Looking at the data presented in Table-02, it can be seen that the body length of female *T. japonicum* varied from 0.34 to 0.46 mm with an average of 0.40 ± 0.04 mm. Similarly, the body length of male wasps ranged from 0.32 to 0.40 mm with an average of 0.37 ± 0.02 mm. Further, the breadth of female body varied from 0.15 to 0.23 mm with an average of 0.19 ± 0.02 mm while that of male breadth varied from 0.14 to 0.20 mm with an average of 0.17 ± 0.02 mm. Moreover, it can be seen that the overall size of the female body was larger than that of the male of *T. japonicum.*

A similar finding is reported by Khan *et al.* (2019) who revealed that the body length of male *T. chilonis* and *T. japonicum* were 0.36 and 0.37 mm, respectively. He also reported that the female of both species had the same body length (0.40 mm) whereas Yousuf *et al.* (2016) noticed that the body length of female *T. chilonis* was 0.42 mm while that of male was 0.37 mm. Khan and Yousuf (2017) showed that female of *T. achaea* was longer (0.543 mm) as compared to male (0.478 mm) of the same species, which is again in favour of the present investigation. The present findings are slightly deviated from the work of Hirai and Fursov (1998) who showed that the body length of male and female *T. japonicum* were 0.42 and 0.64 mm, respectively. Further, the work of Dahlan and Gorth (1998) noted that the female *T. australicum* was 0.489 mm long and 0.177 mm wide and larger as compared to male which was 0.454 mm long and 0.165 wider; the body length of female and male of *Trichogramma* strain TNV from Egypt were 0.539 and 0.518 mm, respectively (Abdel-Galil *et al.,* 2018); the body length of female and male of *N. japonicum* ranged from 0.67 to 0.91 mm and 0.55 to 0.75 mm, respectively (Chan and Chou, 2000) deviate from the present findings. Furthermore, Sumer *et al.* (2010) revealed that male of *T. brassicae* and *T. turkestanica* was 0.342 and 0.344 mm long; males and females of *T. rabindrai* were 0.52 and 0.59 mm long (Nagaraja and Mohanraj 2010) which are again not akin with the present findings. The findings of Hasan and Yousuf (2007) was concurrence with the present investigation which registered that the body length of male and female *T. plasseyensis* were 0.378 and 0.396 mm, respectively. Moreover, the slight difference in measurements might be due to changes in the host nutritional values and different species of *Trichogramma* during the period of investigation.

Male and female head capsule (frontal view). The perusal of data presented in Table 2 revealed that the breadth of the head capsule was more than that of its length due to its wider. Further, the length of head capsule of female wasp varied from 0.15 to 0.18 mm with an average length of 0.16 ± 0.01 mm whereas in male it ranged from 0.13 to 0.18 mm with a mean of 0.15 ± 0.01 mm. Furthermore, the breadth of head capsule of female ranged from 0.16 to 0.21 mm with a mean of 0.19 ± 0.01 mm and that of male ranged from 0.16 to 0.22 mm with an average of 0.19 ± 0.02 mm. It can be seen from the above data, the length of head capsule of female wasp was greater than that of male while the breadth of the head capsule of both sexes was almost similar in size.

A more or less similar description on measurement of head capsule was narrated by Khan *et al*. (2019) who revealed that the length and breadth of head capsule for both the sex of *T. japonicum* was similar in size with 16 and 0.19 mm, respectively; the length and breadth of head capsule of female *T. chilonis* was 0.172 and 0.207 mm and while that of male was 0.150 and 0.205 mm, respectively (Yousuf *et al.,* 2016); the length of female and male head capsule of *T. plasseyensis* were 0.159 and 0.144 mm whereas breadth of female and male of wasp were 0.190 and 0.186 mm, respectively (Hasan and Yousuf, 2007); the male and female head capsule of *T. australicum* were 0.205 and 0.213 mm wider (Dahlan and Gorth 1998); the female head capsule of *T. achaea* was 0.185 mm long and 0.223 mm wide while that of male was 0.197 mm long and 0.231 mm wide, respectively (Khan and Yousuf 2017); the female and male head width of *T. rabindrai* were 0.22 and 0.21 mm, respectively (Nagaraja and Mohanraj 2010); the female head capsule of *T. dendrolimi* was 0.19 mm wide (Liu *et al.,* 1998). The present findings slightly deviate from the results of Sumer *et al.* (2010) who noticed that male head capsule of *T. brassicae* and *T. turkestanica* were 0.169 and 0.158 mm wide, respectively. Thus, the findings of the above workers are more or less in conformity with the present investigation.

Male and female antenna. The present investigation on morphometrics of antenna (Table 2) of *T. japonicum* revealed that the male antenna was longer than the female wasp. The scape + pedicel length of female parasitic wasp varied from 0.05 to 0.07 mm with a mean of 0.05 ± 0.01 mm while male had 0.07 ± 0.01 mm long scape + pedicle which varied from 0.05 to 0.08 mm. Furthermore, the length of flagellum of male varied from 0.13 to 0.16 with an average of 0.15 ± 0.01 mm whereas club length of female wasp varied from 0.06 to 0.09 with a mean of 0.07 ± 0.01 mm. Likewise, the length of male antenna ranged from 0.19 to 0.24 mm with an average of 0.21 ± 0.01 mm. In contrast, the length of female antennae was 0.13 ± 0.01 mm (Range 0.11 to 0.16 mm).

Earlier, Khan *et al*. (2019) noted that the flagellar length of male *T. japonicum* antenna was 0.15 mm whereas antennal club of female was 0.08 mm long; the flagellar length of male antenna and club length of female antenna of *T. plasseyensis* were 0.153 and 0.077 mm, respectively (Hasan and Yousuf 2007); the antennal club of female *T. achaea* was 0.084 mm long and flagellar length of male antenna was 0.183 mm (Khan and Yousuf, 2017); the club length of female *T. bactrae* was 0.101 mm (Hutchison *et al.,* 1990); the flagella of male antenna and club of female antenna of *T. chilonis* were 0.162 and 0.083 mm long, respectively (Yousuf *et al.,* 2016). The work of the above workers are in line with the present investigation. Furthermore, Sumer *et al.* (2010) noted that flagellar length of male *T. brassicae* and *T. turkestanica* were 0.189 and 0.180 mm, respectively and Abdel-Galil *et al*. (2018) observed that antenna of male *Trichogramma* strain TNV from Egypt had 0.082 mm long scape length and 0.162 mm flagella length, which are more or less in accordance with the present findings.

Male and female wing. The data about the female wings and male wings are summarized in Table-02. The results clearly pointed out that the length of fore wings of female *T. japonicum* varied from 0.45 to 0.56 mm with a mean of 0.50 ± 0.04 mm while the length of fore wings in case male varied from 0.42 to 0.54 mm with an average of 0.49 ± 0.03 mm. Further, the average width of fore wings in female and male were 0.21 ± 0.02 mm (Range 0.18 to 0.24 mm) and 0.21 ± 0.01 mm (Range 0.18 to 0.23 mm), respectively. Moreover, the length of fore wings of female wasp was found slightly greater than male while the width of the fore wings was almost similar in both the sexes of *T. japonicum*.

The data on length and width of hind wings showed that the length of hind wings of female wasp ranged from 0.33 to 0.40 mm with an average of 0.37 ± 0.02 mm while that of male ranged from 0.31 to 0.40 mm with a mean of 0.37 ± 0.03 mm. Further, mean width of hind wings were 0.02 ± 0.01 mm in both sexes of *T. japonicum*. It can be observed that the length and width of hind wings in male and female of *T. japonicum* were almost similar in size.

The results about the measurement of fore wings are in close agreement with Khan *et al*. (2019) who reported that the length and width of fore wings of male and female of *T. japonicum* was more or less similar in size that was 0.50 mm long and 0.22 mm wide; the fore wings of male (0.480) of *T. achaea* was somewhat longer than that of female (0.465) whereas the width of fore wings of male and female wasp were 0.226 and 0.216 mm, respectively (Khan and Yousuf, 2017) ; the length of fore wings in both male and female of *T. chilonis* was found similar (0.503 mm) while the width of fore wings in male and female were 0.256 and 0.244 mm, respectively (Yousuf *et al.,* 2016); the fore wings of male (0.466 mm) of *T. plasseyensisi* was longer than that of female (0.457 mm) while fore wings of female (0.228 mm) was found wider than that of male (0.219 mm) (Hasan and Yousuf, 2007); the fore wings of *T. bactrae* was 0.459 mm long and 0.199 mm wide (Hutchison *et al.,* 1990). Thus, the findings of all the above workers are more or less similar to the present investigation.

The present findings pertaining to morphometrics on hind wings of *T. japonicum* are in tally with the findings of past workers. Furthermore, Khan and Yousuf (2017) who reported that the hind wings of male *T. achaea* was 0.371 mm long and 0.041 mm wide whereas female had 0.361 mm long and 0.038 mm wide hind wings; the length and width of hind wings of both male and female were found similar in case of *T. japonicum* which were 0.38 and 0.03 mm, respectively (Khan *et al*., 2019); the male of *T. chilonis* had larger (0.389 mm long and 0.042 mm wide) hind wings than that of its female wasp (0.369 mm long and 0.039 mm wide) (Yousuf *et al.,* 2016); the hind wings of male and female *T. plasseyensisi* were 0.393 and 0.380 mm in length, respectively whereas width of hind wings of both the sexes were similar (0.038 mm); the hind wings of male *T. brassicae* and *T. turkestanica* were 0.305 and 0.304 mm in length, respectively (Sumer *et al*., 2010). Thus, the present findings are in concurrence with the above workers.

Male and female hind tibia. The data on measurement of hind tibia of *T, japonicum* presented in Table-02 demonstrated that the female wasp had recorded hind tibia of 0.14 to 0.18 mm in length with a mean of 0.16 ± 0.01 mm. Further, the hind tibial length of male parasitic wasp varied from 0.12 to 0.18 mm with an average of 0.14 ± 0.02 mm.

The present findings are in conformity with Khan *et al*. (2019) who registered that the female hind tibia of *T. japonicum* was 0.16 mm and it was longer than that of male (0.15 mm); the female and male of *T. japonicum* had 0.165 and 0.139 mm long hind tibia (Khan *et al.*, 2018); the female and male hind tibial length of *T. chilonis* were 0.175 and 0.170 mm, respectively (Yousuf *et al.,* 2016); the female and male of *T. achaea* had 0.159 and 0.158 mm long hind tibia, respectively (Khan and Yousuf, 2017); the length of male hind tibia of *T. plasseyensisi* was 0.154 mm and it was shorter than the female of *T. plasseyensisi* (Hasan and Yousuf, 2007); the female and male of *T. australicum* had 0.163 and 0.150 mm long hind tibia (Dahlan and Gorth, 1998). Moreover, length of female hind tibia of *T. chilonis* was 0.172 and 0.216 mm when emerged from *E. kuehniella* and *P. xylostella,* respectively (Miura and Kobayashi, 1995) and it is partly in agreement with the present investigation. The work of Hutchison *et al.* (1990) who noticed that the length of male hind tibia of *T. brassicae* (0.305 mm) was longer than that of male *T. turkestanica* (0.304 mm) strongly deviates from the present investigation. The disparity seen might be due to change in species of *Trichogramma*, factitious host used and prevailing weather conditions.

Female ovipositor. A close perusal of data on measurement of ovipositor presented in Table 2 indicated that the length of female ovipositor of *T. japonicum* varied from 0.18 to 0.24 mm with a mean of 0.22 ± 0.02 mm. It was found that the length of ovipositor was 1.375 times of length of hind tibia of female *T. japonicum*. In past, more or less similar results are made by Khan *et al*. (2019) who stated that the female ovipositor of *T. japonicum* was 0.23 mm long; length of female ovipositor of *T. japonicum* was 0.246 mm (Khan *et al.,* 2018); the ratio of female ovipositor length to female hind tibial length of *T. japonicum* was found 1.37 times (Hirai and Fursov, 1998) whereas Chan and Chou (2000) reported that ovipositor to hind tibial length of *N. japonicum* ratio varied from 1.35 to 1.5 times. Furthermore, Yousuf *et* *al.* (2016) noted that female *T. chilonis* had 0.178 mm long ovipositor; the length of ovipositor was found 0.164 mm in *T. achaea* (Khan and Yousuf 2017); the ovipositor length was 0.181 mm in case of *T. australicum* (Dahlan and Gorth 1998); the ovipositor length was 0.147 mm in *T. bactrae* (Hutchison *et al.*, 1990); the ovipositor length was 0.159 mm in *T. plasseyensisi* (Hasan and Yousuf 2007). The findings of above workers strongly disagree with the present investigation. The disagreement in length of female ovipositor might be due to change in test insect species, different host eggs used for mass production and prevailing weather condition during the investigation.

CONCLUSIONS

From the above experiment, it can be concluded that the parasitoid had a few good attributes *viz.*, short developmental period, high adult emergence, comparatively longer adult longevity as well a high percentage of female progeny which ensures its suitability for integration in integrated pest management programme. Furthermore, the morphological description, as well as morphometrical measurements of various body parts presented herewith, would be helpful in the identification of *T. japonicum* from other species of *Trichogramma* and also to differentiate the opposite sex of *T. japonicum.*

FUTURE SCOPE

Trichogramma is treated as a living insecticidal weapon against many notorious lepidopteran pests and the future of biological control programme. Other laboratory hosts can also be tested to accelerate the mass production of *T. japonicum* except for *Corcyra*, which will enhance the mass production and use of *Trichogramma* in various parts of the Country.

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