Research Article

Reproductive performance of *Trichomalopsis uziae* as influenced by density of its female and host (*Exorista bombycis*) with a note on host exposure duration for parasitism

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ABSTRACT: *Trichomalopsis uziae* Sureshan and Narendra Kumar (Hymenoptera: Pteromalidae) is a new addition to the already reported parasitoid complex of the tachinid uzi fly, *Exorista bombycis* (Diptera: Tachinidae), which causes 10-20% reduction to the silkworm (*Bombyx mori* L.) cocoon production in the states of Karnataka, Andhra Pradesh, and Tamil Nadu. Due to the non-availability of information on its biological characteristics, an attempt has been made in the present investigation to document the parasitism impact of *T. uziae* female at various densities of its host and reproductive performance of parasitoid at ratios of 1 to 5:5 (Parasitoid: Host) and 1:1 to 50 (P: H). The reproductive performance of the parasitoid was also assessed based on the durations of host exposure for 1 to10 days at a constant P:H ratio of 1:5. The results revealed that there was no perceptible change in the rate of parasitism at different parasitoid densities. However, the progeny production per female was significantly higher ($P < 0.01$) at a P:H ratio of 1:5 in comparison with 2:5 to 5:5. Further, at a variable host density (from 1 to 50), there was a linear decrease in per cent parasitism with an increase in host density and it was more drastic from a host density in exceed from 15. However, both progeny production and sex ratio increased with an increase in host density, more so from a host density upwards of 15. The host exposure duration and parasitism rate were significantly inferior at 1day exposure, while it was considerably high at other exposure periods. The progeny production was significantly higher at 2 to 5 days of exposure period without much difference in the sex-ratio.

KEY WORDS: Density, exposure duration, parasitoid, sex ratio, *Trichomalopsis uziae*

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INTRODUCTION

The tachinid fly, *Exorista bombycis* (Louis), has been a serious impediment in the production of silkworm (*Bombyx mori* L) cocoons in the states of Karnataka, Andhra Pradesh, and Tamil Nadu since three decades. The reduction in the production of cocoons in these states due to this tachinid fly is about 10-20% (Narayanaswamy and Devaiah, 1998). Current management strategies of uzi fly includes an IPM package comprising an exclusion, trapping, an ovicide, and an ecto-pupal parasitoid (*Nesolynx thymus* Girault) (Hymenoptera: Eulophidae), packing of rearing residue excluding shoot material have been advocated to combat the menace of this pest (Dandin and Giridhar, 2010; Narendra Kumar *et al.,* 2017). Although as many as 20 parasitoids have been reported to parasitise maggot and/puparia of the uzi fly, the greater dependence has been laid presently on *N. thymus* due to its immense potential to destroy sizeable populations of *E. bombycis* (Narayanaswamy and Devaiah,

1998). Dependence on a single parasitoid is not a good proposition to check the menace of any pest. Recently, a new parasitoid, *Trichomalopsis uziae* Sureshan and Narendra Kumar (Hymenoptera: Pteromalidae) has been identified and reported to parasitize uzi pupae with a range of 44.00±4.00 to 88.00±8.00 % under laboratory conditions (Narendra Kumar *et al.*, 2018). The exploitation of this pupal parasitoid as a biocontrol agent alongside *N. thymus* to render their combined effect would be more appreciable. Hence, the current effort focusses on the impact of the above parasitoid at various female densities and on its host as also the duration of host exposure to parasitoid on its reproductive efficiency.

It is well-known that age, size, and density of the host and parasitoid, in addition to host exposure duration to its parasitoid, play an important role in determining various biological attributes of the parasitoids such as progeny production, progeny fitness, and progeny sex ratio

(Baitha *et al.,* 2004; Seko and Nakasuja, 2004; Aruna, 2007; Veena, 2008, Sathe and Chougale, 2009; Venkatesan *et al.,* 2009*;* Aung *et al*., 2011; Perveen and Sultan, 2012; Kraft and Nouhuys*,* 2013; Jamil *et al.,* 2015; Kumar *et al.*, 2016;). When host availability is surplus, it is quite expected that the parasitoid would allocate its progeny after careful estimation of host resources to maximize its progeny production, with ensuring its superior fitness and higher sex ratio. In the situations of host scarcity, the parasitoid would be compelled to allocate more progeny to host than that can ensure the occurrence of superior biological attributes of the parasitoid progeny remain to be inferior (Aruna, 2007; Gonzalez *et al.,* 2007; Veena, 2008; Sathe and Chougale, 2009; Pomari *et al.,* 2013; Queiroz *et al.,* 2017). A comparable performance of the parasitoid can be expected in parasitoid female density related situations too when the host would be subjected to increased level of parasitism (Aruna, 2007; Veena, 2008; Sathe and Chougale, 2009; Pomari *et al.,* 2013; Queiroz *et al.,* 2017).

In the current investigation, an attempt has been made to document the impact of densities of *T. uziae* female and its host as also host exposure duration to parasitoid on its reproductive performance as no information is available on these aspects. Results of the investigation are expected to help planning the large-scale production of the parasitoid that would ensure fulfillment of its requirement for inundative release of *T. uziae* for the biological suppression of *E. bombycis.*

MATERIALS AND METHODS

Culture of the host

The host (uzi) pupae were obtained after allowing the post-parasitic maggots of the host collected from nearby silkworm cocoon markets to pupate at 23-28°C and 60-80% RH in the Pest Management Laboratory (PML) of the Central Sericultural Research and Training Institute (CSR & TI), Mysuru.

Culture of the parasitoid

The stock cultures of *T. uziae* were maintained on the pupae of uzi fly by allowing them to parasitize the pupae at 23-28°C and 60-80% RH in the PML. The adults of the parasitoid were fed with honey 30% as diet.

Influence of *Trichomalopsis uziae* female density on its reproductive efficiency

The reproductive performance of the parasitoid as influenced by its female density was scored by subjecting 3-day-old uzi pupae to parasitism by the gravid parasitoid females at host-parasitoid ratios of 5:1 to 5:5 for 5 days with ten replications. Observations were made on per cent

parasitism, developmental duration, progeny production, and sex ratio.

Influence of host density on the reproductive performance of *Trichomalopsis uziae*

For experimentation on the impact of host density on the reproductive efficiency of *T. uziae,* a 3-day-old uzi pupae were exposed to gravid females of the parasitoid by maintaining host-parasitoid ratios of 1:1 to 10:1, 15:1, 20:1, 25:1 and 50:1 for 5 days with ten replications. Data on per cent parasitism, developmental duration, progeny production, and sex ratio were recorded.

Impact of host exposure duration on parasitism by *Trichomalopsis uziae*

In this experiment, mated females of the parasitoid were allowed to parasitize constant number of 3-day-old uzi fly pupae (@ 1P: 5H) for 1 to 10 days by maintaining 10 replications in each. After exposure of the host pupae for a specific duration (days), the parasitoid females were removed from the exposure container. Data on the developmental duration, progeny production, and sex ratio were recorded.

The data obtained on per cent parasitism, developmental duration and progeny production were analyzed using one-way ANOVA. All the statistical analysis was performed by using SPSS package (Version 21). When ANOVA was significant, the comparison of means was made by using DMRT post hoc significance test.

RESULTS AND DISCUSSION

Influence of *Trichomalopsis uziae* female density on its re-productive performance

The influence of *T. uziae* at various densities on its host showed a significant difference ($P < 0.05$) in the per cent parasitism among the treatments, which ranged from 82.00±3.59 (5P:5H) and 82.00±4.67 (4P:5H) to 54.00±9.91 (3P: 5H) (Table 1). The rate of parasitism was almost similar at treatments 2P: 5H (74.00±6.70) and 1P: 5H (70.00±8.03). Comparison of mean values for the parameter revealed that rate of parasitism was significantly inferior ($P < 0.05$) at 3P:5H when compared with rest of the treatments where the mean results were comparable. Developmental duration of the parasitoid remained almost similar at different densities of parasitoid and host with the mean results fluctuating between 12.50±0.17 (1P:5H) and 12.10±0.28 (2P:5H) days. The progeny production per female was female-biased in all the treatments and the highest progeny production was noticed with 1P:5H (30.18±2.28) and least with the 5P: 5H (8.09±0.55). There was a drastic decline in the progeny production with 2P:5H (15.14±1.83) which further reduced considerably with 3P: 5H (9.52±1.09) and remaining almost

identical with the treatments thereafter. In case of brood allocation per host, the higher brood allocation was noticed in the treatment 4P: 5H (39.90±2.37) and 5P: 5H (40.43±2.74) and was significantly (*P* < 0.01) greater than rest of the treatments. With regard to the parasitoid progeny sex ratio, the treatment with 1P: 5H (5.50±0.56) and 2P: 5H (4.91±0.37) showed significantly (*P* < 0.05) higher progeny sex ratio in comparison to rest of the treatments.

The impact of *T. uziae* density indicated that the female parasitoid exploited significantly more number of host pupae, indicating greater degree of parasitism, when the parasitoid-host ratios were narrower, which was quite evident in treatments with 4P:5H and 5P:5H. This observation showed that narrowing the parasitoid-host ratio has enhanced the level of competition among the female parasitoids to exploit the fixed number of host pupae as against relatively wider parasitoid-host ratios in the remaining treatments with considerably reduced levels of per cent parasitism of host. Irrespective of per cent parasitism, the parasitoid developmental duration remained almost unchanged among the treatments. Moreover, the density of developing parasitoid progeny had no impact on the developmental duration as evidenced by the data on progeny allocation per host pupa which varied between 40.43±2.74 (5P:5H) and 28.57±3.26 (3P:5H) among the treatments. It is quite unlikely that the developmental duration would alter considerably up to an optimum level of progeny allocation per host that has resource level to fulfill the foraging needs of parasitoid progenies. Nonetheless, it is a well-established fact that the female parasitoid would allocate the progeny per host based on prior careful estimation of host resources (Liu *et al.,* 2011). Further, the female parasitoid would also be careful enough to the extent that whether it should allocate female-biased progeny or male-biased one to the host depending on the availability of resources (Werren, 1984). To be precise, the parent female would allocate relatively more of female progeny under resource-rich situation, while the opposite of it happens under resource-deficient situation (Kant *et al.,* 2012). This could be seen in the current investigation with *T. uziae* where the parent female parasitoids allocated more of female progenies relative to male progenies when the parasitoid-host ratios were wider. Obviously, this impacted the sex ratio of the parasitoid progenies, being significantly higher when host density was more relative to parasitoid density. Even production of progenies by each of the female parasitoids *vis-à-vis* the host density supported the view that significantly more progenies would be produced under the situation with wider parasitoid-host ratio (more resource-rich) when compared to the condition with narrower parasitoid-host ratio (less resource-rich).

Sathe (1985, 1986) reported a decrease in parasitism with an increase in the density of parasitoids, *Cotesia durani* and *Diadegma trichoptilus*, when *Exorista atomosa* was parasitized. On the contrary, Perveen and Sultan (2012) working with *Trichogramma chilonis* Ishii observed that increase in parasitoid density resulted in significant increase in rate of parasitism with concomitant significant rise in the adult emergence without much variation among the treatments. Further, there was no significant change in the parasitoid developmental duration at various densities of the parasitoid. Mann *et al*. (1990) observed a low percentage of pupal mortality and parasitoid progeny emergence with low parasitoid densities than with high densities in four species of the pteromalids *Muscidifurax raptor* Girault and Sanders, *M. zaraptor* Kogan and Legner, *Spalangia cameroni* Perkins and *S. endius* Walker. Aruna (2007) observed with the eulophid parasitoid, *Nesolynx thymus* that the density of female parasitoid had no significant impact on the parasitoid developmental duration but had a significant positive correlation with progeny allocation per host pupa and significant negative correlation with progeny production per female and progeny sex ratio. Similar observations too were evident with the diapriid parasitoid, *Trichopria* sp., parasitizing the pupae of *E. bombycis* (Veena, 2008) and with the eulophid pupal parasitoid, *Tetrastichus howardi*, attacking *E. bombycis* (Gangadhar, 2009).

Effect of host density on the reproductive efficiency of *Trichomalopsis uziae*

The results on the effect of host (*E. bombycis*) density on the reproductive efficiency of *T. uziae* (1P:1H to 1P:50H) are given in Table 2.

The per cent parasitism of the host pupae by the parasitoid, *T. uziae* varied between 100.00±0.00 (1P:1H) and 24.60±1.58 (1P:50H) among the treatments. It declined with increase in the host density from 1 to 50. The per cent parasitism decreased drastically from a host density of 3 (60.00±2.59) onwards and remained more or less constant to a host density of 5 (68±2.17).

There was a further slump in the per cent parasitism from a host density of 6 (41.66±3.46) and again increased to a host density of 10 (53.00±3.73) but without any significant difference. A further decrease in per cent parasitism was noticed as host density increase from 15 (30.66±2.55) and to 50 (24.60±1.58). Comparison of mean results was significant (*P* < 0.01) statistically among the treatments. There was significant difference in the developmental duration of parasitoid among the treatments which ranged from 13.60±0.22 (host density of 20) to 12.50±0.17 days

Table 1. Impact of density of parasitoid on the reproductive performance of *Trichomalopsis uziae* when host density is constant

Para-sitoid: host density	Per cent parasitism	Develop. Duration	Brood allocation per pupa			Progeny production per female			Sex ratio (females per male)
			Male	Female	Total	Male	Female	Total	
1: 5	70.00±8.03 [ab]	12.50±0.17	4.64±0.62 [b]	25.54±1.79 [ab]	30.18±2.28 [b]	4.64±0.62 [a]	25.54±1.79 [a]	30.18±2.28 [a]	5.50±0.56 [a]
2: 5	74.00±6.70 [ab]	12.10±0.28	5.12±0.66 [b]	25.16±3.14 [ab]	30.28±3.65 [b]	2.56±0.33 [ab]	12.58±1.57 [ab]	15.14±1.83 [ab]	4.91±0.37 [ab]
3: 5	54.00±9.91 [b]	12.30±0.15	5.59±0.71 [ab]	22.65±2.78 [b]	28.57±3.26 [b]	1.87±0.24 [b]	7.55±0.93 [b]	9.52±1.09 [b]	4.04±0.56 [b]
4: 5	82.00±4.67 [a]	12.30±0.15	8.27±0.79 [a]	31.63±1.90 [a]	39.90±2.37 [a]	2.07±0.19 [b]	7.91±0.48 [b]	9.98±0.59 [b]	3.82±0.31 [b]
5: 5	82.00±3.59 [a]	12.40±0.16	7.84±0.65 [a]	32.59±2.35 [a]	40.43±2.74 [a]	1.57±0.13 [b]	6.17±0.48 [b]	8.09±0.55 [b]	3.93±0.35 [b]
F-value	2.741*	0.619 NS	5.774**	3.172 *	3.960**	4.364**	3.257**	4.224**	3.559**

Values given in the Table are the mean of 10 replications (Mean ± SE); Mean values followed by the same superscript in columns are statistically not significant; ** - Significant at 1 %; * - Significant at 5 %; NS – Non-significant

Table 2. Influence of host density on the reproductive performance of *Trichomalopsis uziae*

Host density	Per cent parasitism	Develop-mental Duration	Progeny production			Brood allocation per pupa			Sex Ratio (females per male)
			Male	Female	Total	Male	Female	Total	
1	100 ±0.00[a]	12.6±0.163[cd]	13.2±0.061[bcd]	33.3±0.024[d]	46.5±0.030[cd]	13.2±0.061[a]	33.3±0.024[a]	46.5±0.030[a]	2.52±0.044[de]
2	90.00±5.99[a]	12.7±0.213[cd]	20.6±0.078[ab]	49.8±0.070[cd]	70.4±0.073[bcd]	12.5±0.070[a]	29.0±0.077[ab]	42.5±0.064[a]	2.32±0.025[e]
3	60.00±2.59[b]	12.5±0.167[d]	9.7±0.1010[d]	33.8±0.071[d]	43.5±0.079[d]	5.2±0.079[bc]	18.65±0.053[cd]	23.85±0.060[bc]	3.59±0.054[bc]
4	57.50±5.56[b]	12.7±0.153[cd]	15.1±0.097[abcd]	44.4±0.098[d]	59.5±0.095[cd]	7.42±0.088[b]	19.05±0.059[cd]	26.47±0.065[bc]	2.57±0.070[cde]
5	68.00±2.17[b]	12.8±0.249[cd]	9.9±0.073[cd]	42.7±0.084[d]	52.6±0.084[cd]	5.23±0.054[bc]	22.45±0.060[b]	27.68±0.061[b]	4.29±0.020[bc]
6	41.66±3.46[cd]	12.8±0.249[cd]	10.4±0.080[cd]	40.5±0.072[d]	50.9±0.072[cd]	4.14±0.042[bc]	16.59±0.047[cd]	20.74±0.043[bc]	4.01±0.043[bcd]
7	51.42±1.84[bc]	13.3±0.396[abc]	14.3±0.032[abcd]	50.4±0.049[cd]	64.7±0.044[bcd]	4.02±0.025[bc]	14.19±0.045[de]	18.21±0.040[cd]	3.52±0.026[cde]
8	51.25±4.29[bc]	13.1±0.314[abcd]	13.7±0.085[bcd]	39.3±0.096[d]	53.0±0.092[cd]	3.53±0.045[cd]	9.31±0.030[f]	12.84±0.030[de]	2.64±0.042[de]
9	41.11±4.55[cd]	13.8±0.389[a]	11.8±0.092[cd]	40.3±0.109[d]	52.1±0.10[d]	3.22±0.039[cde]	10.99±0.015[ef]	13.70±0.047[de]	3.41±0.034[cde]
10	53.00±3.73[bc]	12.9±0.233[bcd]	17.0±0.080[abc]	56.0±0.101[cd]	73.0±0.09[bcd]	3.23±0.043[cde]	9.99±0.048[ef]	13.22±0.047[de]	3.09±0.034[cde]
15	30.66±2.55[d]	13.0±0.000[bcd]	10.7±0.084[cd]	44.3±0.064[cd]	55.0±0.06[cd]	2.29±0.032[def]	9.97±0.026[ef]	12.26±0.024[e]	4.35±0.046[bc]
20	32.50±2.18[d]	13.6±0.221[ab]	12.9±0.060[bcd]	72.6±0.058[bc]	85.5±0.057[bc]	2.05±0.035[ef]	11.26±0.032[ef]	13.31±0.032[de]	5.49±0.038[b]
25	26.80±1.39[d]	13.4±0.163[abc]	9.8±0.066[cd]	90.8±0.059[b]	99.8.6±0.060[b]	1.38±0.026[f]	13.08±0.026[def]	14.46±0.026[de]	9.49±0.028[a]
50	24.60±1.58[d]	13.4±0.163[abc]	22.7±0.028[a]	253.4±0.018[a]	276.1±0.015[a]	1.92±0.0154[ef]	21.01±0.045[bc]	23.38±0.037[bc]	10.94±0.033[a]
f-value	27.37**	2.76**	3.58**	10.18**	8.60**	18.15**	11.69**	15.01**	15.84**

Values given in the Table are the mean of 10 replications (Mean ± SE); Mean values followed by the same superscript in columns are statistically not significant; ** - Significant at 1 %; * - Significant at 5 %; NS – Non-significant

(host density of 3). The brood allocation per host varied between 46.50±0.03 to 12.26±0.02 at a host density of 1 to 15, While there was no difference in the brood allocation at the host density of 3 (23.85±0.06) up to 7 (18.21±0.04). At a host density of 8, the brood allocation stood at 12.84±0.03 and these remained almost similar up to a host density of 25 (14.46±0.03). At a host density of 50, the brood allocation was 23.38±0.04. In all the treatments, the allocation of progenies by the female parasitoid was highly female biased. The maximum progeny production was noticed at a host

density of 50 (276.10±0.02) and minimum at 3 (43.5±0.08). There was no consistency in the production of progenies *vis-à-vis* host density, which varied considerably among the treatments. However, it showed a spurt in the progeny production at host densities from 20 onwards. The production of male and female progenies exhibited the trend observed for total progenies which was greatly in favor of females. The parasitoid progeny sex ratio was distinctly superior ($P < 0.01$) at host densities of 25 (1:9.49±0.03) and 50 (10.94±0.03). At other treatments, it varied from 5.49±0.04 (host density of 20) to 2.32±0.03 (host density of 2). In the present study the per cent parasitism of *T. uziae* decreased with increase in density of host. The parasitoid developmental duration significantly increased with increase in host density, possibly due to reduced allocation of brood to each of the hosts so as to facilitate the effective development of the parasitoid under resource-rich situation. With regard to progeny production and progeny sex ratio, the results were comparable for the respective parameters up to a host density of 15 pupae; thereafter, the progeny production greatly increased with sex ratio being female-biased.

On the influence of host density *vis-à-vis* the reproductive performance, a host of studies have been conducted in many parasitoids. They adjust their clutch size/brood allocation depending on the host density. In many cases, it was found that they lay more eggs on a host that was scarcely available and allocation of eggs or clutch size decreases as the host density increases (Aruna, 2007; Veena, 2008). By contrast, Gangadhar (2009) noticed that there was no influence of host density on the brood allocation in *T. howardi* while Veena (2008) and Gangadhar (2009), in their studies with *Trichopria* sp. and *T. howardi*, respectively, found a significant positive correlation between host density and parasitoid developmental duration, Jamil *et al.* (2015) recorded maximum number of egg laying in *Bracon hebetor* (Say.) at high host density compared to a single host. Also, egg deposition increased with increase in density of host. However, the parasitoid optimized its clutch size to avoid overcrowding of eggs on host's body. They also observed maximum egg hatching at highest host density as compared to a single host which may be due to less crowding of eggs on host larvae. Consequently, percentage adult emergence was also greater at highest host density, due to less larval competition for foraging during the course of development. With regard to sex ratio, they recorded that it increased as the host density increased.

Perveen and sultan (2012) reported that developmental duration and adult longevity were not significantly different at all host egg densities tested in *T. chilonis*. In addition, adult emergence was highest at minimum and lowest at maximum host egg densities. Kraft and Nouhuys (2013) studied the gregarious parasitoid, *Pteromalus apum* Retzius preying on two co-occurring butterfly species, *Melitaea cinxia* and *M. athalia*. It was found that host density affected life-history and population traits of the parasitoid. Low host density resulted in high superparasitism and with larger brood size. Also, a positive correlation was observed between brood size and sex ratio among broods at low host density because of superparasitism, while negligible correlation was found among broods at high host density. In the present investigation, high host density resulted in the production of more progenies as well as female biased sex ratio. Similarly, Perveen and Sultan (2012) studied the impact of host density on the biological parameters of *T. chilonis* and observed that at different densities of host eggs, the rate of parasitism was significantly different depending on the host species tested. With the host, *Sitotroga cerealella*, the rate of parasitism increased significantly with an increase in host egg number up to certain extent and then started declining. However, adult emergence gradually decreased with increase in host density. With the host species of *Corcyra cephalonica*, there was not much relationship between host density and parasitism, though adult emergence significantly reduced with increase in host density. Mann *et al.* (1990) found that when the varying number of hosts was exposed to a constant number of parasitoids, it resulted in gradual increase in the average parasitism as well as average progeny production, while increasing the number of host pupae killed per parasitoid as well as progeny production per parasitoid.

Impact of host exposure duration on the reproductive effectiveness of *Trichomalopsis uziae*

The data on the influence of host exposure duration on the reproductive effectiveness of *T. uziae*, are furnished in Table 3.

The results of per cent parasitism by *T. uziae* ranged from 96.00±2.67 (3-days exposure) to 56.00±5.81 (1-day exposure) among the treatments. The rate of parasitism was significantly inferior ($P < 0.01$) in treatment with 1-day exposure in comparison to the most treatments, while it was somewhat comparable with a few other treatments (7, 9, and 10-day exposure). The minimum parasitoid developmental duration was noticed at 1-day (11.70±0.15 days) and maximum at 8-day (13.60±0.16 days) of exposure period. The results of exposure duration from 1 to 5-days were similar, while significant difference ($P < 0.01$) was observed once the exposure period was increased from 6 to 10-days. The brood allocation by *T. uziae* female fluctuated between 39.42±3.27 (4-day) and 20.57±1.40 (1-day). Barring the allocation at 1-day, the allocation up to 5-days was significantly higher ($P < 0.01$) in comparison to rest of the treatments without any significant difference. The similar trend was observed

Table 3. Duration of exposure of host pupa (*Exorista bombycis*) and its impact on the reproductive performance of *Trichomalopsis uziae*

Days of exp	Per cent parasitism	No. of pupa parasitised@	Develop. Duration	Total Progeny production			Progeny production per pupa			Sex Ratio (females per male)
				Male	Female	Total	Male	Female	Total	
1	56.00±5.81 [c]	2.80±0.29 [c]	11.70±0.15 [c]	14.25±1.91 [cd]	43.34±2.76 [d]	57.59±3.78 [c]	5.09±0.63 [c]	15.48±1.30 [d]	20.57±1.40 [d]	3.04±0.52
2	88.00±3.27 [ab]	4.40±0.16 [ab]	12.00±0.00 [c]	27.00±2.67 [bc]	132.90±8.30 [ab]	159.90±10.38 [a]	6.10±0.51 [c]	30.19±1.63 [a]	36.29±1.98 [ab]	4.95±0.32
3	96.00±2.67 [a]	4.80±0.13 [a]	12.10±0.23 [c]	33.00±3.09 [ab]	144.80±5.20 [a]	178.80±7.75 [a]	6.90±0.67 [ab]	30.34±1.36 [a]	37.24±1.92 [a]	4.39±0.35
4	84.00±5.81 [ab]	4.20±0.29 [ab]	12.00±0.00 [c]	38.80±4.91 [a]	124.40±10.60 [ab]	163.20±14.56 [a]	9.39±1.10 [a]	30.03±2.37 [a]	39.42±3.27 [a]	3.19±2.72
5	88.00±3.27 [ab]	4.40±0.16 [ab]	12.10±0.23 [c]	37.20±3.13 [a]	118.20±6.78 [b]	155.40±8.16 [a]	8.62±0.81 [ab]	26.81±1.11 [ab]	35.43±1.54 [ab]	3.25±0.27
6	78.00±6.29 [ab]	3.90±0.31 [ab]	13.30±0.21 [ab]	18.50±1.14 [cd]	75.20±4.53 [c]	93.70±5.36 [b]	4.98±0.42 [c]	19.89±1.15 [cd]	24.87±1.51 [cd]	3.99±0.23
7	68.00±8.00 [bc]	3.40±0.40 [bc]	13.10±0.18 [ab]	21.90±3.38 [cd]	67.70±7.66 [c]	90.60±10.16 [b]	6.70±0.97 [ab]	22.10±3.19 [ab]	28.80±4.03 [bc]	3.29±0.95
8	76.00±7.18 [ab]	3.80±0.36 [ab]	13.60±0.16 [a]	17.40±1.72 [cd]	66.50±6.15 [c]	83.90±7.76 [b]	4.77±0.42 [bc]	17.94±1.19 [cd]	22.70±1.59 [cd]	3.80±0.19
9	72.00±9.04 [bc]	3.60±0.45 [bc]	12.90±0.18 [b]	19.50±3.03 [cd]	66.90±8.05 [c]	86.70±10.64 [b]	5.51±0.87 [c]	21.48±3.51 [ab]	26.99±4.12 [cd]	3.90±0.93
10	70.00±8.03 [bc]	3.50±0.40 [bc]	13.00±0.21 [b]	18.40±2.71 [cd]	69.20±7.49 [c]	87.60±9.87 [b]	5.45±0.68 [c]	21.63±3.05 [ab]	27.08±3.63 [cd]	3.97±0.30
f-value	3.485**	3.485**	14.241**	8.995**	26.192**	22.565**	4.417**	6.633**	6.286**	0.843NS

Values given in the Table are the mean of 10 replications (Mean ± SE); Mean values followed by the same superscript in columns are statistically not significant; @ - Out of 5 pupae provided for parasitization; ** - Significant at 1 %; NS – Non-significant

in the progeny production per female, as observed for brood allocation. With reference to progeny sex ratio, the results were not differing significantly among the treatments.

The reproductive potential of parasitic hymenoptera is reported to be affected by many factors, including optimum exposure period of the host to the parasitoid. Kumar *et al.* (2016) studied the impact of exposure of *T. howardii* female to the host pupa of sugarcane stalk borer, *Chilo auricilius* (Dudgeon), and observed significantly more number of adults emerging from the host which was exposed for 24h compared to 48, 72, 96, and 120h. The percentage female production was maximum at 24h exposure duration followed by 48, 72, and 4h. There was no significant difference in the developmental period in the treatments. Further, when the parasitoid was exposed to *C. partellus* for varying durations, Baitha *et al.* (2004) recorded no parasitism at 1h exposure and maximum and minimum of progenies at 12 and 2h exposure, respectively. As the exposure duration prolonged (>12 h), the number of adults emerging per pupa did not increase significantly. However, upon dissection, such pupae were observed to contain a number of partially developed parasitoids. The female progeny production was greatest in 12 h exposure and it declined significantly with increase in exposure period.

From the foregoing account, it can be concluded that density of *T. uziae* female and its host, *E. bombycis*, as also the duration of the host exposure to the parasitoid have significant influence on the parasitoid reproductive parameters such as per cent parasitism, brood allocation per host, progeny production per female, and progeny sex ratio. The information thus generated would throw light on mass production of the parasitoid in question when such an attempt is contemplated in future for its field release either singly or in association with other parasitoids, especially *N. thymus* which is currently exploited under biological control program of *E. bombycis*.

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