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Effect of host species and host age on the reproductive performance and morphometrics of progenies of parasitoid, *Tetrastichus howardi* (Olliff)

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ABSTRACT: Laboratory investigations were undertaken at the Department of Studies in Sericulture Science, University of Mysore, Manasagangotri, Mysuru, to understand the effects of host species and host age on the reproductive performance and morphometric characteristics of progenies of an indigenous endo-pupal parasitoid, *Tetrastichus howardi* (Olliff) (Hymenoptera: Eulophidae). The parasitoid developmental durations were significantly longer in younger pupae of *S. litura* and older pupae of *S. frugiperda.* The mean values for progeny production were superior when the parasitoid developed in younger host when compared with older host of both the species. The longevity values for the progeny females did not differ when developed in pupae of both the ages of the hosts. Regarding morphometric parameters of the progeny males and females resulted from either age of hosts of both the species, the values were significantly superior fora greater number of parameters with younger hosts of *S. frugiperda* when compared with those with younger hosts of *S. litura* where the parameters have been shared by either category of hosts in terms of their superiority.

Keywords: Endo-pupal parasitoid, developmental duration, progeny female longevity, progeny production, progeny sex ratio.

INTRODUCTION

Parasitic hymenopterans are known for employing reproductive strategies that are invariably oriented towards maximizing progeny production with the progeny individuals being female-biased accompanied with superior fitness. Progeny production by a parasitoid female is accompanied by certain *trade-off* mechanisms, as developmental strategies, concerning certain progeny-related aspects such as adult number, adult size, and adult sex ratio *vis-à-vis* host-related factors like age, size, density, and quality where a decrease in the expression of one trait is compensated by an increase in the other. In explicit terms, for example, where progeny adult size needs to be bigger its number would be lesser and where the male number needs to be greater the female number would be lesser (reduced sex ratio) and *vice versa*. It is, therefore, appropriate to perceive that the above-mentioned parasitoid-related aspects (number, size, and sex ratio) are correlated with host-related aspects (age, size, density, and quality) that regulate the parasitoid larval foraging efficiency.

Parasitoid fitness (quality) is chiefly considered for its females with their body size being biggerby which they acquire enhanced longevity, higher temperature tolerance, superior host searching ability, and elevated parasitism level with concomitant effective suppression in pest populations after their release in the field. When the idea for mass production of parasitoids is contemplated, as a pre-requisite for field release, the focus obviously falls on the female fitness which is the outcome of combined influences of 1) host-related factors (age, size, density, quality, multi-parasitism, etc.), 2) parasitoid-related factors (female age, size, density, diet, con-specific and inter-specific competition, mated condition, etc.), and 3) environment-related (chiefly temperature and relative humidity)factors (Gordh *et al*., 1999; Aruna, 2007; Veena, 2008; Narendra Kumar,2019). Keeping these factors in view, concerted efforts have been made by specialists in biological control of crop pests so that the desired level of pest suppression can be ensured.

Confronting the hosts of different species for breeding is not uncommon among parasitoids in nature as they mostly have a broad host spectrum. Obviously, the hosts would differ in quality as well as consistency (palatability) and abundance of resources. The consistency and abundance also would change according to host age, thereby have implications on progeny production, progeny sex ratio, and progeny fitness (Sandlan, 1982). When hosts of two or more species are parasitized by a parasitoid female, her progenies are expected to differ in terms of number, fitness, and sex ratioin relation to host age (King, 1887; Aruna, 2007; Veena, 2008; Narendra Kumar, 2019), host size(Charnov *et al*., 1981; Jenner and Kuhlmann, 2006; Aruna, 2007, Narendra Kumar, 2019), host density (Bai and Smith, 1993; Aruna, 2007; Kraft and Nouhuys, 2013), host quality (Charnov and Skinner, 1984), etc. in addition to the ones associated

Table 1. Impact of host age on the progeny production of *Tetrastichus howardi* when *Spodoptera litura* was parasitized

Host age	Developmental duration (days)	Progeny production (No.)		Total Progeny production (No.)	Sex ratio (No. of females/ male)	Progeny Female longevity (days)
		Male	Female			
Young (2 days)	23.60 ± 0.40	7.80 ± 0.80	46.00 ± 1.70	53.80 ± 2.47	6.10 ± 0.50	20.40 ± 0.24
Old (7 days)	20.20 ± 0.80	3.60 ± 0.24	29.0 ± 1.04	32.60 ± 0.87	8.28 ± 0.86	20.80 ± 0.58
T- test	*	*	*	*	*	NS
Value	5.01	6.33	6.57	6.59	4.29	1.00

Data are the means of 5 replications (Mean ± SE) each with one host pupa

*- Significant *(P≤ 0.05)*; NS- Significant

with environmentto which the parent female as well as her developing progenies are exposed while breeding (Lysyk, 1998; Gordh *et al*., 1999; Ahmed *et al*., 2013). The information thus generated by studying the impact of these factors would create an opportunity to precisely work out as to how the mass production of parasitoids can be undertaken by ensuring superiority of their fitness.

Tetrastichus howardi (Olliff) is an indigenous gregarious endo-pupal parasitoid with immense potential to suppress the field populations of a host of lepidopteran pests in the fields of Sericulture (Sathyaprasad *et al.*, 2006), Agriculture (Pereira *et al*., 2015; Sankar and Rao, 2016), and Horticulture (Favoreto *et al*., 2021). In the field of Sericulture, small-scale field trials have demonstrated the potential of this parasitoid to keep the field populations of the leaf roller pest, *Diaphania pulverulentalis* Hampson, in check. *T. howardi* has been included as a biological control component of an IPM package that also comprises chemical and cultural measures (Sathyaprasad*et al.*, 2006). Under laboratory conditions, the parasitoid successfully parasitizes another leaf eating pest, the cut worm, *Spodoptera litura* Fabricius. However, for mass production and large-scale field trials employing this parasitoid, identification of a couple of suitable hosts is required based on screening of a few lepidopteran hosts for parasitism and progeny production. This apart, colonization of the identified host (s) itself is a matter of great importance to ensure the availability of the parasitoid required for field release.

MATERIALS AND METHODS

For experimentation, younger (2-day-old) and older (7-day-old) pupae of *S. litura* and *S. frugiperda* (as hosts) and 2-day-old gravid females of *T. howardi* were used. The values for fresh weight (g) of younger and older pupae, based on 5 pupae, for *S. litura* ranged from 0.207 to 0.224 (av.0.214 ± 0.006) and from 0.160 to 0.190 (av.0.178 ± 0.01), respectively. The corresponding values for *S. frugiperda* varied from 0.179 to 0.186 (av. 0.184 ± 0.002) and from 0.132 to 0.140 (av. 0.136±0.003). The host pupae of each category were exposed for parasitism (oviposition) by *T. howardi* in glass test tubes (15 x 1.5 cm) plugged with cotton for 2 days at a host-parasitoid ratio of 1:1. During this period, honey (30%) served as the parasitoid female diet. After2 days, the host pupae were separated from the parasitoid females and maintained at 23-28°C and 60-80% RH for the parasitoid development. After eclosion of the parasitoid progenies (1st generation), data were recorded on the reproductive parameters *viz*. developmental duration, progeny production, sex ratio, progeny female longevity as well as morphometric parameters of the progenies. The measurements regarding morphometric parameters such as body length, wingspan, and head width of male and female progeny individuals as well as abdominal length and width of male and females were recorded using a stage micrometer under a light microscope (40 X). Each of the treatments consisted of 5 replications. The accrued data were subjected to t-test at 1 and 5% levels of significance by SPSS package (version 21.0).

RESULTS

Impact of host age on the progeny production of *Tetrastichus howardi* when *Spodoptera litura* was parasitized

The results are presented in Table1. There was a significant increase (P<0.05) in the parasitoid developmental duration when it developed in younger host (23.60 ± 0.40 days) as against older host (20.20 ± 0.80 days). Regarding progeny production (number), it was significantly more when the parasitoid oviposited in younger pupae (53.80 ± 2.47) as against older pupae (32.60 ± 0.87) with the progenies being significantly female biased irrespective of host age. The parasitoid progeny sex ratio, however, was significantly lesser when the parent female exploited the older host with the values being 6.10 ± 0.50 for younger host in contrast to 8.28 ± 0.86 for older host. Further, the survival durations of the progeny females, when maintained on 30% honey, remained almost identical regardless of age categories of the host.

Effect of host age on the progeny morphometric parameters of *Tetrastichus howardi* when it developed in *Spodoptera litura*

The results are furnished in Table 2.Of8 morphometric parameters of the progeny individuals, only 2 of them *viz*. wingspan of male (1.24 ± 0.02 mm) and head widths of male and female (0.75 ± 0.05 and 0.79 ± 0.01 mm) were significantly superior when developed in older host, while body length of male (1.41 ± 0.06 mm) was significantly so when developed in younger host.

Influence of host age on the progeny production of *Tetrastichus howardi* when *Spodoptera frugiperda* was parasitized

The results are depicted in Table 3. The parasitoid developmental duration was significantly longer when it developed in older host (15.00 ± 0.00 days) as against younger host (14.00 ± 0.31 days). With progeny production (number), it was significantly greater (P≤0.01) when the parent female parasitized younger hosts (137.80 ± 2.45) in sharp contrast to older host (56.60 ± 2.54) with the values for males and females with younger pupae being significantly more when compared with older hosts. The parasitoid progeny sex ratio too was far superior when the progenies developed in younger host (7.99 ± 0.53) as against older host (4.34 ± 0.37). Further, the longevity of 30% honey-fed parasitoid progeny females remained almost similar irrespective of the category of host the parent female parasitized.

Impact of host age on the progeny morphometric parameters of *Tetrastichus howardi* when it developed in *Spodoptera frugiperda*

The results are presented in Table 4. Body length was significantly higher for males when they developed in younger host pupae (1.55 ± 0.01 mm), while it was so

Table 2. Effect of host age on the progeny morphometric parameters of *Tetrastichus howardi* when it developed in *Spodoptera litura*

Host Age	Body length (mm)		Body width (mm)		Wing span (mm)		Head width (mm)		Female abdomen (mm)		Male abdomen (mm)	
	Male	Female	Male	Female	Male	Female	Male	Female	Length	Width	Length	Width
Young (2 days)	1.41 ± 0.06	2.10 ± 0.02	0.36 ± 0.01	0.90 ± 0.02	1.15 ± 0.01	1.50 ± 0.04	0.57 ± 0.06	0.70 ± 0.01	0.97 ± 0.05	0.82 ± 0.02	0.74 ± 0.13	0.36 ± 0.01
Old (7 days)	0.75 ± 0.01	2.17 ± 0.07	0.68 ± 0.02	0.84 ± 0.31	1.24 ± 0.02	1.59 ± 0.05	0.75 ± 0.05	0.79 ± 0.01	1.12 ± 0.09	0.84 ± 0.03	0.75 ± 0.33	0.70 ± 0.02
T- test	**	NS	*	NS	*	NS	*	*	NS	NS	NS	**
Value	10.89	1.81	9.69	1.04	4.75	1.08	3.60	4.00	2.46	0.52	0.17	13.70

Data are the means of 5 replications (Mean ± SE) at one host pupa

** - Highly Significant *(P≤ 0.01)*; * - Significant *(P≤ 0.05)*; NS - Non significant

Table 3. Influence of host age on the progeny production of *Tetrastichus howardi* when *Spodoptera frugiperda* was parasitized

Host age	Developmental duration (days)	Progeny production (No.)		Total Progeny production (No.)	Sex ratio (No. of females/ males)	Female longevity (days)
		Male	Female			Progeny
Young (2 days)	14.00 ± 0.00	15.60 ± 1.20	122.20 ± 1.82	137.80 ± 2.45	7.99 ± 0.53	18.80 ± 0.37
Old (7 days)	15.00 ± 0.31	10.80 ± 0.80	45.80 ± 2.28	56.60 ± 2.54	4.34 ± 0.37	20.80 ± 0.58
T- test	*	*	**	**	*	NS
Value	3.16	4.31	23.40	22.06	7.59	2.39

Data are the means of 5 replications (Mean ± SE) at one host pupa.

** - Highly Significant *(P≤ 0.01)*; * - Significant *(P≤ 0.05)*; NS - Non significant.

for females when they developed in older host pupae (1.96 ± 0.01 mm). The values for wingspan of both males (0.92 ± 0.01 mm) and females (0.97 ± 0.02 mm) were significantly greater when older host pupae were parasitized. Head width of males remained almost similar irrespective of host age, while their female counterparts had significantly higher values when the parent females oviposited in younger host (0.54 ± 0.00 mm).Looking at the female abdomen length and width of progenies, there was a similarity in the measurements for the progenies obtained from host pupae of either category.

Influence of host species of identical age (young vs young and old vs old) on the progeny production of *Tetrastichus howardi*

The results are presented in Tables 5 and 6. When a comparison was brought out on the reproductive performance of *T. howardi* parasitizing the young hosts of *S. litura and S. frugiperda*, the parasitoid has shown significantly superior performance in the production of progenies in the latter host (137.80± 2.45), as opposed to the former host (53.80 ± 2.47), while significantly (P≤0.01) reducing its developmental duration. Considering the individual sexes of the progenies too, the parasitoid reproductive performance, including the parasitoid sex ratio, was far superior for both the sexes when *S. frugiperda* was exploited. In respect of longevity of the parasitoid progeny females, they lived significantly longer when the progenies were developed in *S. litura* (Table 5). Production of the parasitoid progenies in older hosts too was significantly higher when the parasitoid oviposited in *S. frugiperda* (56.60 ± 2.54), against 32.60 ± 0.87 in *S. litura*, with the individuals of both the sexes being significantly more in number but with significantly reduced sex ratio (4.34 ± 0.37 in *S. frugiperda* and 8.28 ± 0.86 in *S. litura*). Further, the results for longevity of the parasitoid female progenies emerging from both the hosts were comparable (Table 6).

DISCUSSION

Developmental duration of *T. howardi* was substantially longer in both younger and older pupae of *S. litura* when compared with *S. frugiperda*. An appreciable increase in production of progenies of the parasitoid was noticed when it developed in younger pupae of both *S. litura* and *S. frugiperda*. The increase was of the order of 1.65, 1.58, and 2.17 times for total, female, and male populations, respectively with *S. litura* when compared with its older counterparts; the corresponding values with *S. frugiperda* were 2.43, 2.67, and 1.44, thus demonstrating the suitability of younger hosts for enhanced production of both male and female progenies. Though production of progenies in the pupae of both the age categories was female biased, the sex ratio (number of females/male) among the progenies generated in older pupae was significantly higher with *S. litura*, which was due to relative decrease in male numbers in relation to those of females. This was not the case with younger host for the parasitoid progeny production where the number of males being relatively morein relation to those of females.

Though the parasitoid female produced relatively greater number of males when the older pupae were parasitized, it doesn't hold much significance as even a few males would be adequate to mate with several females owing to their polygamous nature. As opposed to *S. litura*, the sex ratio for the parasitoid progenies developing in *S. frugiperda* was significantly higher with younger pupae, which was in excess by1.84 times. Knowing fully well that female being the performing sex in terms of host mortality, greater the number of female productions per host would have distinct advantage in terms of host suppression under field conditions when released under biological control program. An examination of the overall reproductive performance of *T. howardi* indicated that *T. frugiperda* could serve as relatively a better host regardless of whether it is younger or older as evidenced by substantially greater number of progenies being produced, more so of females. Interestingly, it may be noted that the reproductive performance of the parasitoid in the older host of *S. frugiperda*, despite being significantly low when compared with its younger counterpart, is comparable with that of younger host of *S. litura*. The longevity of the progeny females generated from both younger and older pupae of both the hosts was comparable, thus indicating similarity in one of their quality parameters.

The superiority/suitability of *S. frugiperda* for progeny production by *T. howardi* could be attributed to its nutritional aspects that seem to be more suited to nourish the foraging larvae of the parasitoid. The fact that the younger host pupae were found more suitable for the parasitoid breeding when compared with older pupae of both the species could be explained based on the following: a)relative abundance of resources that the parasitoid female estimates as an important pre-oviposition behavior so that she can allocate progenies in accordance with that estimate and b) better palatability (suitable consistency) of host resources for the foraging larvae that would facilitate effective development of the progenies. The reason indicated under the point (a) above is quite evident from the fresh weights of younger pupae that were substantially higher in comparison to their older counterparts that had relatively lesser amounts of resources as these appear to have been utilized by the hosts for their own development as the age advanced, thus compelling the parasitoid female to limit (reduce) her progeny allocation to some extent as to facilitate effective development of progenies. Moreover, it's quite possible that the resources in the older host pupae have been transformed into structural forms, thus proving to be relatively less palatable to the foraging larvae. If that is being the case, then the adults emerging from the younger pupae should have been bigger than their counterparts emerging from smaller pupae. But this hasn't been clearly reflected in the morphometric parameters of the progeny individuals. To make it more explicit, some of the morphometric parameters are inferior when the parasitoid developed in younger host and *vice versa*. As such the trend observed for progeny production with younger hosts proving to be more suitable than older ones in both the host species used in the present investigations cannot be discerned when the morphometric parameters were considered.

It's matter of great interest to record that progeny production by *T. howardi* female was 2.56 times greater

Table 4. Impact of host age on the progeny morphometric parameters of *Tetrastichus howardi* when it developed in *Spodoptera frugiperda*

Host Age	Body length (mm)		Body width (mm)		Wing span (mm)		Head width (mm)		Female abdomen (mm)		Male abdomen (mm)	
	Male	Female	Male	Female	Male	Female	Male	Female	Length	Width	Length	Width
Young (2 days	1.55 ± 0.01	1.69 ± 0.01	0.45 ± 0.08	0.45 ± 0.01	0.79 ± 0.01	0.86 ± 0.02	0.53 ± 0.06	0.54 ± 0.00	0.79 ± 0.06	0.81 ± 0.00	0.81 ± 0.01	0.56 ± 0.31
Old (7 days	1.31 ± 0.08	1.96 ± 0.01	0.36 ± 0.00	0.51 ± 0.15	0.92 ± 0.01	0.97 ± 0.02	0.42 ± 0.05	0.48 ± 0.00	0.81 ± 0.03	0.70 ± 0.05	0.54 ± 0.01	0.46 ± 0.10
T- test	**	**	*	NS	**	*	NS	*	NS	NS	**	*
Value	20.92	10.53	6.39	2.58	16.74	0.29	1.01	6.12	0.99	2.16	13.90	4.25

Data are the means of 5 replications (Mean ± SE) at one host pupa.
** - Highly Significant *(P≤ 0.01)*; * - Significant *(P≤ 0.05)*; NS - Non significant.

Table 5. Influence of host species of identical age (young vs young) on the progeny production of *Tetrastichus howardi*

Host age	Developmental duration (days)	Progeny production (No.)		Total Progeny production (No.)	Sex ratio (No. of females/ males)	Female longevity (days)
		Male	Female			Progeny
Young (SL)	23.60 ± 0.40	7.80 ± 0.86	46.00 ± 1.70	53.80 ± 2.47	6.10 ± 0.50	20.40 ± 0.24
Young (SF)	14.00 ± 0.00	15.6 ± 1.20	122.20 ± 1.82	137.80 ± 2.45	7.99 ± 0.53	18.80 ± 0.37
t- test	**	*	**	**	*	*
t-value	24.00	7.64	33.61	29.88	3.22	3.13

Data are the means of 5 replications (Mean ± SE) at one host pupa.
** - Highly Significant *(P≤ 0.01)*;* - Significant *(P≤ 0.05)*; NS - Non significant.

in younger and 1.74 times higher in older pupae of *S. frugiperda* than that generated in *S. litura* despite the pupae of the former host being smaller by 1.16 times with younger pupae and 1.31 times with older pupae when compared with the latter host. Suitability of *S. frugiperda* is justifiable when the progenies (males, females, and total) produced in the older pupae were comparable with those generated in the younger pupae of *S. litura*. In fact, *S. frugiperda* produced progenies of 10.80 ± 0.80 males and 45.80 ± 2.28 females (total 56.60 ± 2.54) in older pupae as opposed to 7.80 ± 0.86 males and 46.00 ± 1.70 females (total 53.80 ± 2.47) in younger pupae of *S. litura*. From the foregoing account, it becomes amply clear that host age matters from the viewpoint of progeny production in each host species but the importance of host species from the viewpoint of quality of resources for parasitoid progeny production cannot be underestimated. However, it is important to understand whether a parasitoid female restricts her progeny allocation when the host resource quality is inferior, or the survival of progenies would be reduced under such circumstances where the *fittest of the progenies* only would survive.

Literature is replete with the information related to impact of host age and host species (quality) on the reproductive performance, including fitness returns of progenies, of parasitoids. Progeny production by a parasitoid differs according to whether the parasitoid is an *idiobiont* (parasitizing a host with fixed resources like egg and pupa) or a *koinobiont* (parasitizing a host that continues to feed and grow even after parasitism like larva). In both the kind of parasitoids, the progeny allocation per host, be it a natural one or a factitious one, is based on precise estimation of host resources by the parasitoid female at the time of oviposition. Efforts to record the impact of host age on the reproductive performance of parasitoids included egg, larval, larvi-pupal, and pupal parasitoids of solitary as well as gregarious nature. King (1998) working with *Spalangia cameroni*, Husni *et al*. (2001) with *Brachymeri alasus* (Walker), Nakamura and Noda (2002) with *Oomyzus sokolowskii* Kurdjumov, Aruna with *Nesolynx thymus* Girault, Veena with *Trichopria* sp., and Narendra Kumar (2019) with *Trichomalopsis uziae* Sureshan & Narendra Kumarhave observed that the parasitoids preferred to parasitize the younger hosts with concomitant significant increase in progeny production and sex ratio. Regarding host quality (species), which relates to nutritional status of host, King (1998) found that *S. cameroni* allocated more female progenies to the pupae of stable fly (*Stomoxy scalcitrans* L.) when compared with pupae of house fly (*Musca domestica*L.) with associated increase in their survival when developed on the former host where their developmental duration was shorter by about 2%. In a recent study, Simanato *et al*. (2020) working with *T. howardi* using *Helicoverpa armigera* (Hubner) and *Diatraea saccharalis* (Fabricius) as hosts have presented an explicit account as to the impact of host age/stage and host quality where the importance of these host-related factors on the rate of parasitism, progeny developmental duration, progeny production, sex ratio, and longevity of progeny individuals has become evident. From the foregoing account regarding impact of host species and hostage on the reproductive performance of *T. howardi*, what could be understood/ concluded is that both these

Table 6. Influence of host species of identical age (old vs. old) on the progeny production of *Tetrastichus howardi*

Host age	Developmental duration (days)	Progeny production (No.)		Total Progeny production (No.)	Sex ratio (No. of females/ males)	Female longevity (days)
		Male	Female			
Old (SL)	20.20 ± 0.80	3.60 ± 0.24	29.0 ± 1.04	32.60 ± 0.87	8.28 ± 0.86	20.80 ± 0.58
Old (SF)	15.00 ± 0.31	10.80 ± 0.80	45.8 ± 2.28	56.60 ± 2.54	4.34 ± 0.37	20.80 ± 0.58
t- test	*	**	*	*	*	NS
t-value	6.04	10.85	5.88	7.40	6.79	1.08

Data are the means of 5 replications (Mean ± SE) at one pupa / replication.
** - Highly Significant *(P≤ 0.01)*;* - Significant *(P≤ 0.05)*; NS - Non significant.

host-related factors assume importance. However, it is even more important to identify a couple of suitable hosts, as also their age, based on screening of many potential hosts so that large-scale production of the parasitoid could be undertaken while keeping the fitness qualities of the progenies intact. Further, it is also important to develop a suitable technology for colonization of the identified host(s) as a prerequisite for undertaking mass production of the parasitoid in question.

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REFERENCES

Ahmed, K. N., Hasan, M. R., Ahmed, H., Hannan, M. A. and Ghose, S. K. 2013. Effects of temperature, relative humidity and host on the biology of *Anisopteromalus calandrae* (Hymenoptera: Pteromalidae). *Bangladesh Journal of Zoology*, **41**(1): 87-96.

Ana Laura Favoreto., Rafaela Freitas Pavani., Murilo Fonseca Ribeiro., Antonio Jose Vinha Zanuncio., Marcus Alvarenga Soares., Jose Cola Zanuncio and Carlos Frederico Wilcken (2020). *Tetrastichus howardi* (Hymenoptera: Eulophidae): first report of parasitism in Oxydia vesulia (Lepidoptera: Geometridae). *Brazilian Journal of Biology,* **81**(2): 406-410.

Aruna, A. S. 2007. Developmental dynamics of an Eulophid ecto-pupal parasitoid (*Nesolynx* thymus) on some Dipteran hosts. *Ph. D. Thesis*, University of Mysore, Mysuru, Karnataka, India. 291.

Bai, B. and Smith, S. M. 1993. Effect of host availability on reproduction and survival of the parasitoid wasp, *Trichogramma minutum. Ecological Entomology,* **18:** 279-286.

Charnov, E. L. and Skinner, S. W. 1984. Complementary approaches to the understanding of parasitoid oviposition decision. *Environmental Entomology*, **14**: 383 – 391.

Charnov, E. L., Los-den Hartog, R. L., Jones, W. T. and Van den Assem, J. 1981. Sex ratio evaluation in a variable environment. *Nature,* **289**: 27 - 33.

Gordh, G., Legner, E. F. and Caltagirone, L. E. 1999. Biology of Parasitic Hymenoptera. In: *Handbook of Biological Control* (Eds. T.S. Bellows and T.W. Fisher), Academic Press, San Diego, California, USA, 355-381.

Husni, Kainoh, Y. and Honda, H. 2001. Effect of host pupal age on host preference and suitability in *Brachymeria lasus* (Walker) (Hymenoptera: Chalcididae). *Applied Entomology and Zoology*, **36**(1): 92-102.

Jenner, W. and Kuhlmann, U. 2006. Significance of host size for a solitary endo-parasitoid: a trade-off between fitness parameters. *Basic and Applied Ecology,* **7:** 461-471.

King, B. H. 1987. Offspring sex ratios in parasitoid wasps. *Quarterly Review of Biology*, **62:** 367-396.

King, B. H. 1998. Host age response in the parasitoid wasp *Spalangia cameroni* (Hymenoptera: Pteromalidae). *Journal of Insect Behavior,* **11**: 103-117.

Kraft, T. and Nouhuys, S.V. 2013. The effect of multi-species host density on superparasitism and sex ratio in a gregarious parasitoid. *Ecological Entomology,* **38:** 138-146.

Lysyk, T. J. 1998. Relationships between Temperature and Life History Parameters of *Trichomalopsis sarcophagae* (Hymenoptera: Pteromalidae). *Environmental Entomology*, **27**(2): 488 - 498.

Nakamura, A. and Noda, T. 2002. Effects of host age and size on clutch and sex ratio of *Oomyzus sokolowskii* (Hymenoptera: Eulophidae), a larval-pupal parasitoid of *Plutella xylostella* (Lepidoptera: Yponomeutidae). *Applied Entomology and Zoology*, **37**(2): 319- 322.

Narendra Kumar, J. B. 2019. Biology and behavior of *Trichomalopsis uziae* Sureshan & Narendra Kumar, an ecto-pupal parasitoid, with reference to the uzi fly, *Exorista bombycis* (Louis). *Ph. D. Thesis*, University of Mysore, 266.

Pereira, F. F. 2015. Parasitism and emergence of *Tetrastichus howardi* (Hymenoptera: sand adults. *Florida Entomologist*, **98**(1): 377-380.

Sandlan, K. P. 1982. Host Suitability and Its Effects on Parasitoid Biology in *Coccygomimus turionellae* (Hymenoptera: Ichneumonidae). *Annals of the Entomoogical Society of America***, 75:** 217-221.

Sankar, M. and Manjunatha, S. Rao. 2016. A new record on mass rearing of pupal parasitoid, *Tetrastichus howardi* (Olliff) using silk worm pupae for the management of sugarcane stem borers in South India. *International Journal of Agricultural and Forestry Science,* **1**(1): 1-6.

Sathya Prasad, K., Shekar M. A., Vinod Kumar and Kariyappa, B. K. 2006. Field evaluation of IPM against leaf roller, *Diaphania pulverulentalis* (Hampson) (Lepidoptera: Pyralidae). *National Seminar on social health and water management for sustainable sericulture* held on 27-28 September, 2006 at Regional Sericultural Research Station, Kodathi, Bangalore, India p.100 (Abstract).

Veena, N. 2008. Investigations on the biology and development of an endo-pupal parasitoid, *Trichopria* sp. (Hymenoptera: Diapriidae), in the tachinid fly, *Exorista bombycis* (Louis). *Ph.D. Thesis,* University of Mysore, Mysuru, 161.

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