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Impact of Host Density on the Performance of the *Bracon hebetor* (Say) (Hymenoptera: Braconidae) Parasitizing Indian Meal Moth, *Plodia interpunctella* (Hübner) (Lepidoptera: Pyralidae)

Md. Forhad Hossain[1*], Md. Mahbub Hasan[2] and Mst. Raosonara Khatun[2]

[1]Institute of Food and Radiation Biology, Atomic Energy Research Establishment, Bangladesh Atomic Energy Commission, Ashulia, Savar, Dhaka-1349, Bangladesh.
[2]Department of Zoology, University of Rajshahi, Rajshahi-6205, Bangladesh.

Authors' contributions

This work was carried out in collaboration among all authors. Author MMH planned the research and designed the Methodology. Authors MFH and MRK conducted the experiments and analyzed the data and author MFH drafted the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

The parasitoid species *Bracon hebetor* (Say) (Hymenoptera: Braconidae) is an important beneficial insect as it can be used as a biological control agent. On the other hand, the Indian meal moth, *Plodia interpunctella* (Hübner) (Lepidoptera: Pyralidae) is a serious pest of stored and processed food products. The present work was conducted to investigate the impact of host density on the performance of the parasitoid and its next progeny for its mass rearing. The investigation indicates that there is no significant difference among the percentages of parasitized host larvae due to different host densities. However, the number of parasitoid pupae (P=.05), total number of adult emerged (P<.001), F1 larval periods (P<.001), F1 pupal period (P<.001), F1 total developmental period (P<.001), longevities (P=.05) differed significantly due to different host densities. Moreover, the experiment also showed that there are significant differences among the F2 larval periods (P<.001), total developmental period (P<.001), longevity (P=.05) but not among the number of F2

**Corresponding author: E-mail: mfhbgd@gmail.com;*

adult progeny, number of parasitized host larvae by F1 and number of F2 pupae. The results also showed no significant difference among the sex ratios of the F1 generation, F2 generation and size of parasitoid due to different host densities.

Keywords: Biological control; Indian meal moth; parasitoid; host density; adult longevity

1. INTRODUCTION

Stored products protection is awfully essential to ensure the food security. Indian meal moth (IMM) *Plodia interpunctella* (Lepidoptera: Pyralidae) is a serious pest of stored products and processed food commodities which causes direct product loss and indirect economic costs through quality losses and consumer complaints. Traditional chemical control methods cause environmental pollution, health hazards, affect non target organisms even the pests are being resistant.

So nowadays, it is very much appreciated to apply biological control method which is eco-friendly. In this endeavor, *Bracon hebetor* is considered one of the most important biological control agents of several pyralid moths including IMM [1]. Mass rearing is the pre-requisite of biological control.

The parasitoid *B. hebetor* has been vastly used as a biological control agent against the moths because it can be easily reared in the laboratory [2,3,4,5,6]. The effective feedback of the parasitoid ascertains the efficiency of a species for being a biological control agent and helps to know about host–parasitoid interaction [7].

The fruition of a parasitoid relies on its fitness or quality parameters over generations [8]. Host density affects the pattern and distribution of parasitoid egg-laying and females probably play a role to fix the sex ratio based on egg number and the size of the infested host clutch. The total progeny sex ratio was found about 0.5 regardless of host density, probably due to the egg allocation was related to the host density [9].

As the host is the entire larval food source, the host size, species, or developmental stages or if there is another species with which the host shared can affect different parameters of the parasitoid [5].

Many researchers have investigated the effects of host quality and or quantity on biology and ecology of *B. hebetor* [9,10]. Eliopoulos and Stathas [11] studied the parameters regarding the life table of *B. hebetor* infesting *Anagasta kuehniella* (Lepidoptera: Pyralidae) and *P. interpunctella*. The effect of host density on different life table parameters of the parasitoid was carried by Gündüz et al. [5].

The knowledge about fecundity and longevity of parasitoid are essential for the implementation of pilot-scale biological control programs [12].

By accomplishing the immune system of *Galleria mellonella* and dissimilar clutch size and sex ratio about host density, the parasitoid optimizes their potentiality of reproduction. There is a positive effect of host density on the parasitoid egg density. The maximum number of the egg was recorded (134.7 eggs) at the highest (16 larvae) host density and a minimum number was at one host larva. The egg hatching and percentage of adult emergence were negatively influenced concerning the crowding of eggs [13].

In the experiments of parasitoid density, a higher number of progenies were produced from ten pairs of *B. hebetor* infesting 50 last instar of greater wax moth (GWM) larvae while in case of host density, a higher number of progenies emerged from the host density of 60 GWM mature larvae followed by 50 larvae using a couple of pairs of *B. hebetor* [14].

This study was planned to know the impact of host density on the performance of *B. hebetor* such as the number of progenies, sex ratio, the effectiveness of the progeny and developmental period for improving the mass the rearing technique of this parasitoid.

2. MATERIALS AND METHODS

The larvae of *P. interpunctella* were obtained from a laboratory culture (Post Harvest Entomology laboratory, Department of Zoology, University of Rahshahi) that was reared on a standardized diet [15]. 1,2,3,4,5,6,7,8,9 and 10 mature larvae of *P. interpunctella* (the host) were released in 10 separate containers (the plastic containers were transparent, and the height and diameter of the containers were 7 cm and 6 cm, respectively. The lid of the containers was perforated or cut roundly, and very small mesh sized net was attached for the aeration in the containers) containing folded paper strips. 1 pair of fresh adult *B. hebetor* (Collected from Bangladesh Agricultural Research Institute) were released into each container. Then the containers were covered with black cloths and let the *B. hebetor* to infest the host. The temperature and relative humidity of the laboratory were recorded twice in a day regularly by using thermo-hygrometer.

After 2/3 days the number of killed host larvae (paralyzed) was counted and the number and date of formation of pupae was also recorded regularly. Thus, the total number of pupae in each container was counted. Besides these, the body size (Total length, head length, thorax length, abdominal length, and wingspan in mm) of the dead parents were measured with the help of a microscope using a 1/10 mm scale. After emergence, the sex ratio, developmental period, and longevity (without food) were recorded. When F1 generation emerged then they were counted and one pair of *B. hebetor* (from F1 generation) of each container/replication was released into a separate container containing 10 mature host larvae. Finally, the same parameters as the parents were considered. The number of replications was three and the experiment was repeated thrice. The whole experiment was carried out in the Post Harvest Entomology laboratory, Department of Zoology, University of Rahshahi. The average temperature and relative humidity of the laboratory were 30.38±0.18^{0}C and 78±1.33% respectively which was controlled by using room heater and humidifier.

3. RESULTS AND DISCUSSION

3.1 Effect of Host Density on Parasitoid's Parasitism Rate

The result shows that the percentage of parasitized host larvae by *B. hebetor* was maximum (100%) in 2,3,4,5,8,9 and 10 host density and minimum (66.67%) in 6 and 7 host density showing no significant difference among the percentage of parasitized host larvae due to different host densities (F =0.78, F Crit= 2.46) (See Fig. 2).

The percentage of parasitized host larvae by F_1 *B. hebetor* in 1,2,3,4,5,6, and 7 host density was highest (100%) and in 9 host density was lowest (66.67%) (See Fig. 5). There is no significant difference among the percentage of parasitized host larvae due to different host densities (F =0.91, F Crit= 2.46).

3.2 Effect of Host Density on Parasitoid's Pupae Formation

The highest number of F_1 parasitoid pupae formed was found in 10 host density (19.33±1.20) and the lowest number of parasitoid pupae formed was found in 1 and 6 host density (4.67±2.40 and 4.67±2.91) showing significant difference among the number of parasitoid pupae formed due to different host densities (F = 4.97, F Crit=2.46).

In case of parasitoid progeny, the highest number of F_2 parasitoid pupae was found in 5 host density (15±4) and the lowest number of parasitoid pupae was found in 9 host density (5.67±2.85). There is no significant difference among the number of F_2 parasitoid pupae formed due to different host densities (F= 0.40, F crit= 2.46).

3.3 Effect of Host Density on Parasitoid's Adult Emergence

The highest total number of adults (F_1) was recorded in 10 host density (17.33±0.33) and the lowest number of adults was found in 1 host density (3.67±2.03) (See Fig. 1). There is a significant difference among the total number of adult emerged due to different host densities (F= 6.76, F crit= 2.46).

In the case of the F_2 generation, the highest total number of adult (F_2) was found in 6 host density (9±0) and the lowest number of adults was found in 10 host density (4±2) (See Fig. 4). There is no significant difference among the total number of adults emerged from F2 produced from different host densities (F=0.56, F crit = 2.46).

3.4 Effect of Host Density on Parasitoid's Sex Ratio

The differences among the sex ratio of F_1 were insignificant ($\sum\chi^2$=11.62, df=9) (See Fig. 3). The differences among the sex ratio of F_2 were insignificant ($\sum\chi^2$=16.14, df=9) (See Fig. 6).

3.5 Effect of Host Density on Parasitoid's Developmental Period

In the case of developmental period, the highest larval period of F_1 was found in 1 host density (5.5±0.5 days) and the lowest larval period was found in 7 host density (3±0 days) (See Fig. 7). There is a significant difference among the larval periods due to different host densities (F= 13.36, F crit = 2.46).

The highest larval period of F_2 was found in 1 and 10 host density (5±0 days) and the lowest larval period was found in 3 host density (4.33±0.33 days) (See Fig. 8). There is a significant difference among the F2 larval period due to different host densities (F= 8.5, F crit = 2.46).

The highest pupal period of F_1 was found in 3 host density (8.67±0.33 days) and the lowest pupal period was found in 8 host density (5.33±0.33 days). There is a significant difference among the pupal period due to different host densities (F= 8.5, F crit = 2.46).

The highest pupal period of F_2 was found in 1, 2 and 4 host density (7±0 days) and the lowest pupal period was found in 10 host density (6±0 days). The results showed a significant difference among the pupal period of F2 generation (F= 4.87, F crit = 2.46).

The highest total developmental period of the male in F_1 was found in 3 host density (14.31±0.18 days) and the lowest total developmental period of the male was found in 8 host density (11.04±0.15 days).

The highest total developmental period of females in F_1 was recorded in 3 and 4 host density (14.4±0.25 days) and the lowest total developmental period of females was recorded in 10 host density (11.37±0.27 days).

There is a significant difference among the total developmental period due to different host densities (F= 43.59, F crit = 3.18).

The highest total developmental period of the male of F_2 was found in 1 host density (12.22±0.15 days) and the lowest total developmental period of the male of F_2 was found in 8 host density (9.58±0.23 days).

The highest total developmental period of the female of F_2 was found in 2 host density (14±0 days) and the lowest total developmental period of the female of F_2 was found in 8 host density (9.67±0.33 days). There is a significant difference among the total developmental period of F2 due to different host densities (F= 12.23, F crit = 2.46).

3.6 Effect of Host Density on the Longevity of Parasitoid

The highest longevity of male parents was recorded in 4 host density (4.67±0.33 days) and female parents in 3 host density (7.67±0.33 days) and the lowest longevity of male parents was recorded in 1 host density (3±0.56 days) and female parents in 3 host density (4.33±0.33 days) (See Fig. 9). There is a significant difference among the longevities due to different host densities (F= 5.13, F crit = 3.18).

The highest longevity of male F_1 was found in 10 host density (4.67±0.80 days) and female F_1 in 3 host density (8.33±0.67 days) and the lowest longevity of male F_1 was found in 9 host density (2.67±0.33 days) and female F_1 in 6 host density (5±0) (See Fig. 10). There is a significant difference among the longevities due to different host densities (F= 3.71, F crit = 3.18).

3.7 Effect of Host Density on Parasitoid's Size

The highest total length of male F1 parasitoid was in 3 host density (2.53±0.03 mm) and the lowest total length of the male parasitoid was in 5 host densities (2.35±0.05mm) (See Fig. 11). There is no significant difference among the sizes of parasitoids due to different host densities.

Findings of the experiment of host density on mass production of the parasitoid (*B. hebetor*) revealed that the population of the number of progenies increased linearly with the increased level of host density. Moreover, the present study indicates that more parasitoid progeny was emerged as host density increased. The results were not in agreement with the finding of Taylor [10] who reported the total numbers of eggs laid by the female *B. hebetor* was independent of the host density. However, the difference between these findings and Taylor's results could be due to a difference in the parasitoid populations or experimental conditions. On the contrary, this finding agreed with the work of Yu et al. [9] which indicates the ability of females to allocate eggs concerning host density and Alam et al. [14] according to which the adult progeny is also increased with the host density.

The present results shows that the development time of parasitoids varies significantly with host densities which was not in agreement with the results of Taylor [10] who found that host species had a small but significant effect on mean development time of *B. hebetor* but host density had no significant effect on it and Alam et al. [14] who also found that host species had a small but significant effect on mean development time of *B. hebetor* but host density had no significant effect on it. This may be the effect of host species, environmental factors and rearing without food.

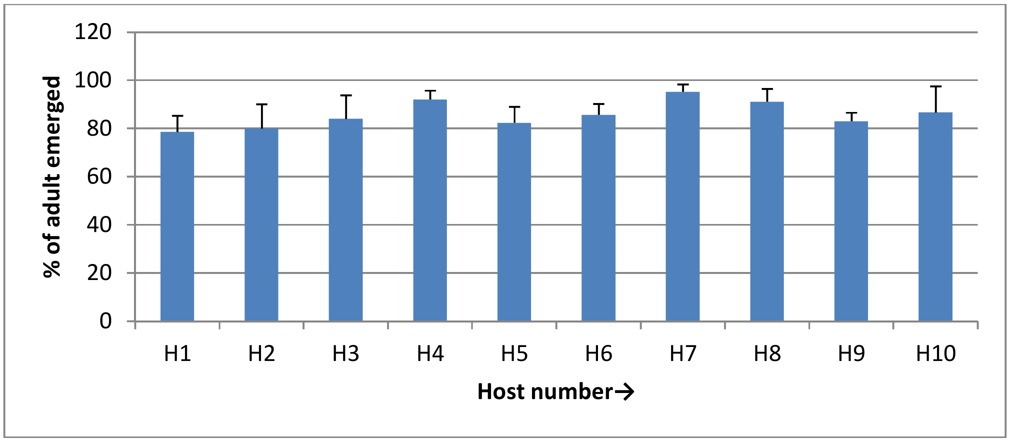

Fig. 1. Effect of host densities on the % of adult emerged in *B. hebetor* (F_1 generation)

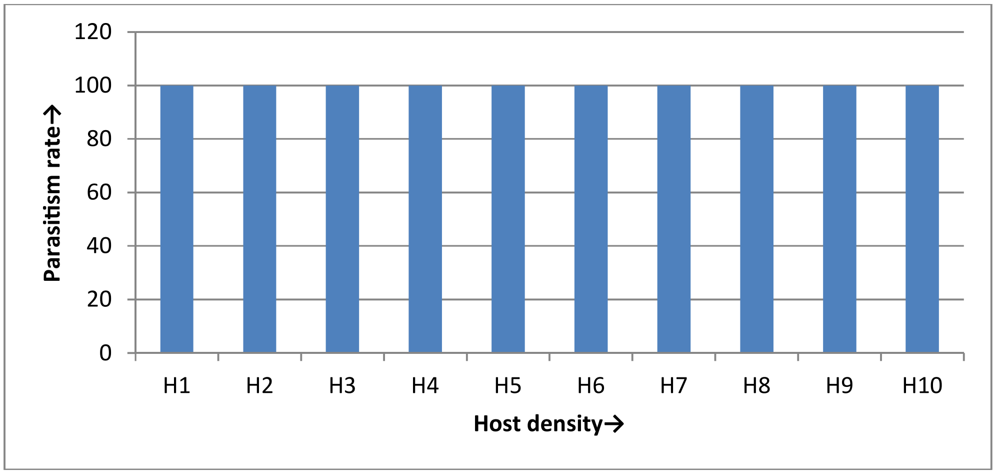

Fig. 2. Percentage of parasitism rate of *B. hebetor* in different host densities

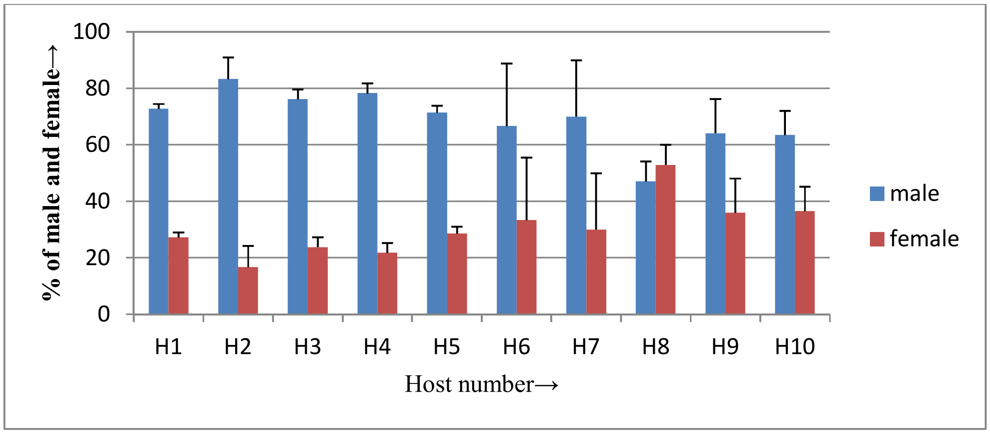

Fig. 3. Sex ratio of *Bracon hebetor* reared on different host densities

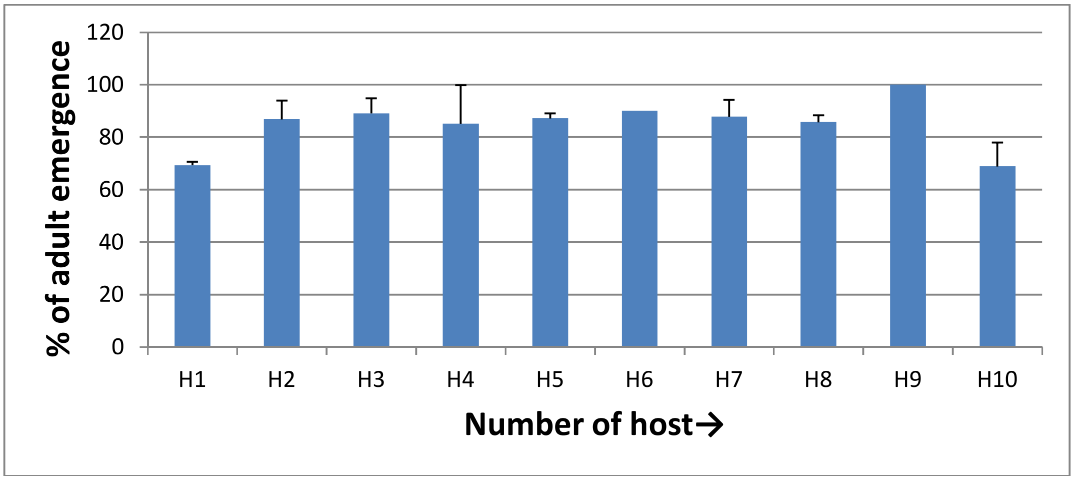

Fig. 4. Effects of host densities on the percentage of adult (F_2) emerged

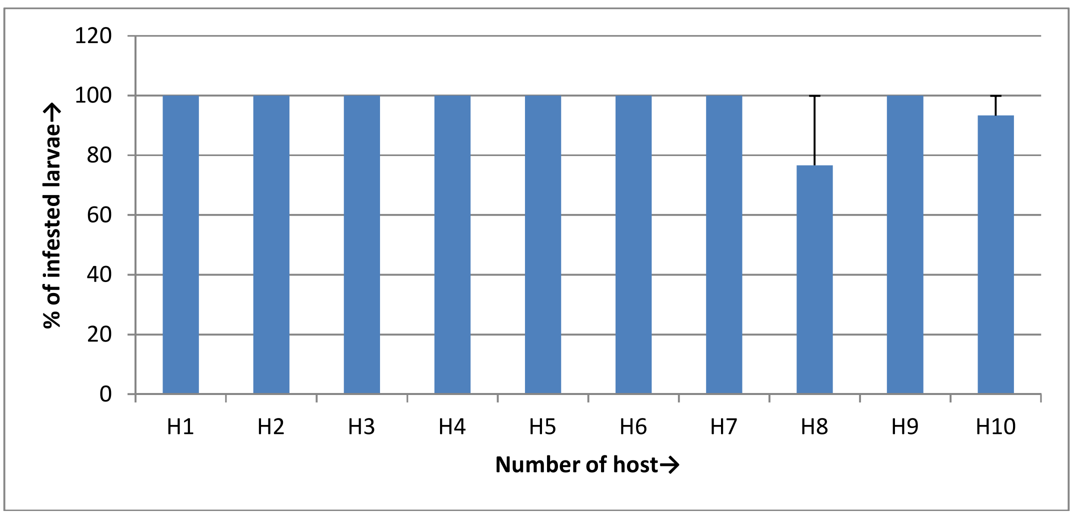

Fig. 5. Percentage of parasitism rate of F_1 progeny of *B. hebetor* in different host densities

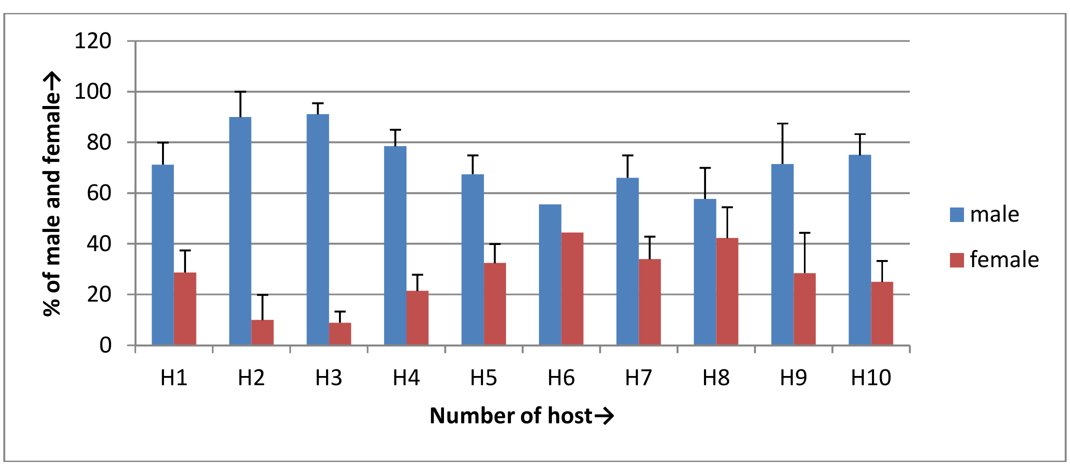

Fig. 6. Sex ratio of F_2 genetations of *Bracon hebetor* reared on different host densities

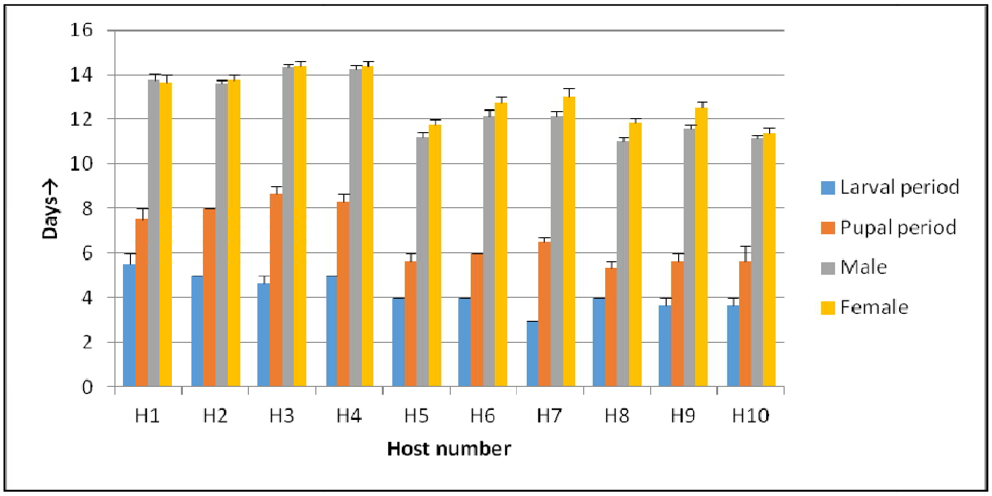

Fig. 7. Effects of host densities on the parasitoid developmental period

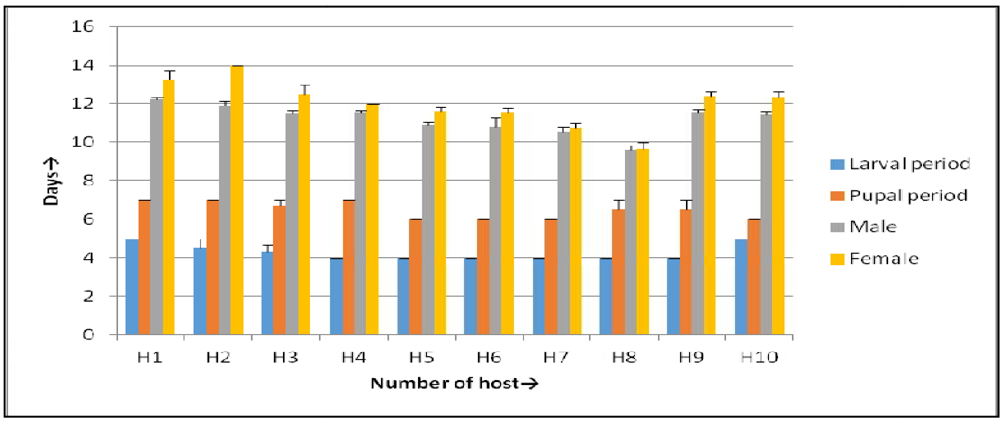

Fig. 8. Effects of host densities on the developmental period of parasitoid F_2 progeny

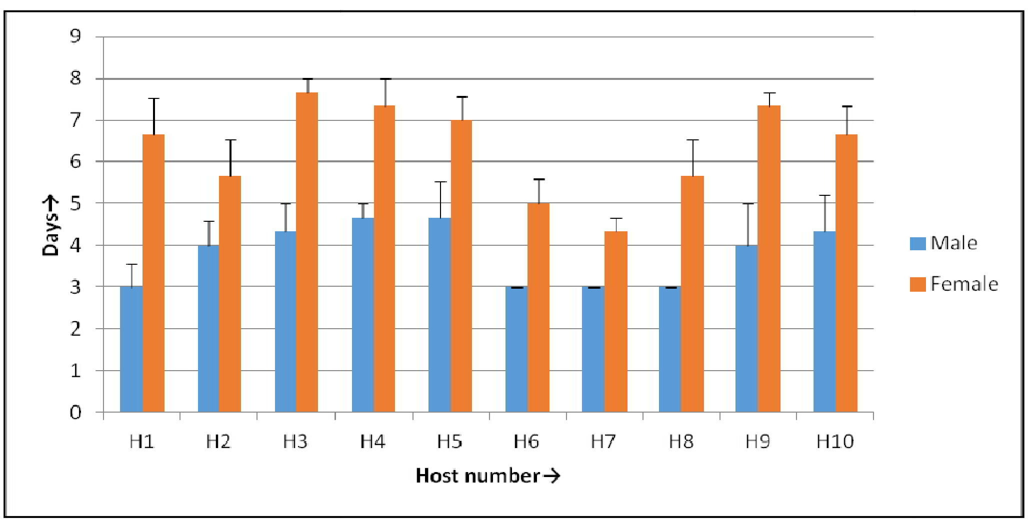

Fig. 9. Effect of host densities on the parasitoid longevity (days)

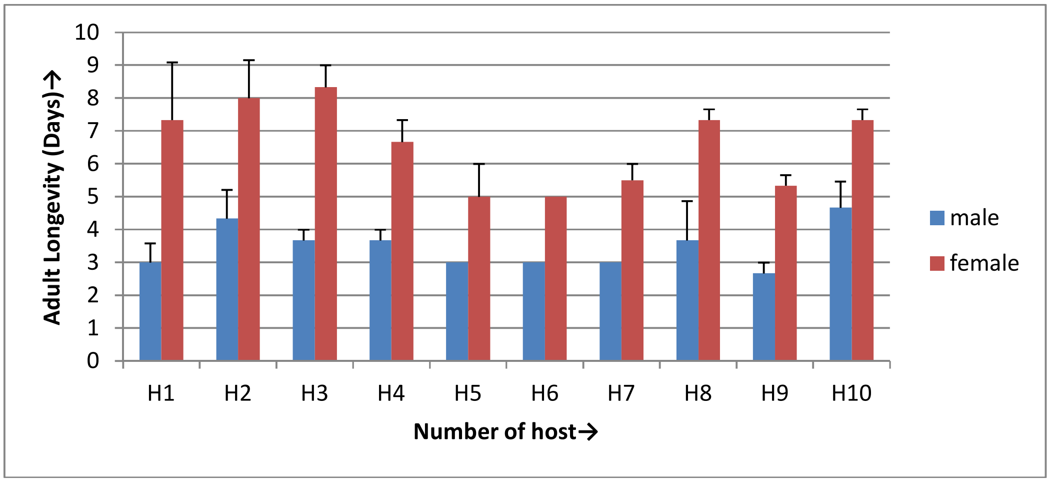

Fig. 10. Effect of host densities on the longevity of parasitoid's progeny (days)

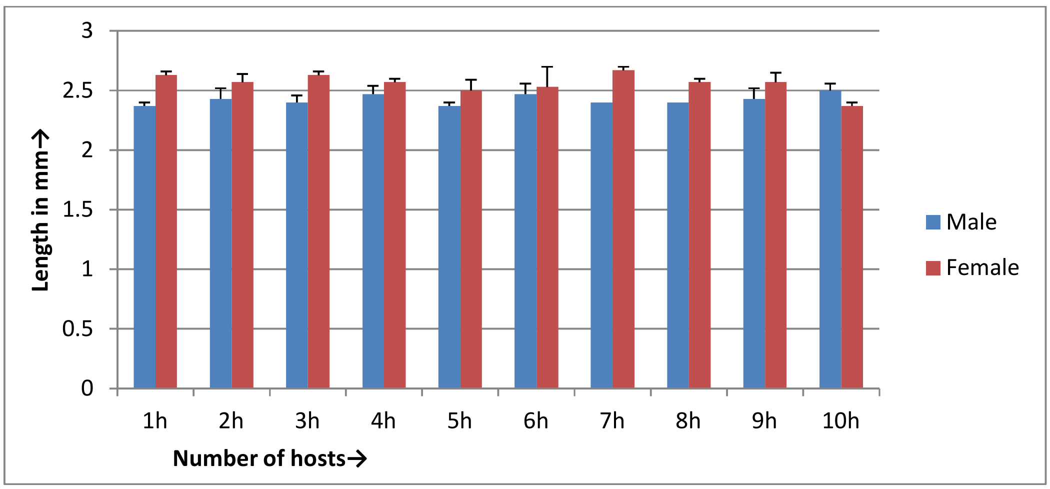

Fig. 11. Effect of host densities on the body size (total length) of parasitoid

The sex ratio was not significantly different among host densities ($\sum\chi^2$=11.62, df=9). This is in agreement with Yu et al. [9] who, after working on *B. hebetor*, reported that overall progeny sex ratio (male/total) was not affected by host density. Sagarra et al. [16] obtained similar results with the Hymenopterous parasitoid, *Anagyrus kamali* Moursi (Hymenoptera: Encyrtidae) parasitizing *Maconellicoccus hirsutus* Green (Homoptera: Pseudococcidae).

However, the present results are not in agreement with Rotary and Gerling [17] who reported that the progeny sex ratio (male/total) increased as the host/parasitoid ratio decreased in *B. hebetor.* Differences in the strains of *B. hebetor* or experimental condition could be involved in this contradictory result.

4. CONCLUSION

The above findings collectively suggest that all host densities, used in this study are all suitable for the development and survival of *B. hebetor*. When wasps had access to more than one host, however, produce more progeny to the next generation. This is an important consideration in the utilization of biological control agents.

These results will help to culture *B. hebetor* and *P. interpunctella* in a mass form in the laboratory for fruitful research and understanding the biology of this particular pest and could help in its management and control. Therefore, future studies should also be focused on its practical applications in the field level.

CONSENT

It is not applicable

ETHICAL APPROVAL

It is not applicable

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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