

Journal of Biological Control, 39(3): 289–295, 2025, DOI: 10.18311/jbc/2025/49722

Research Article

Influence of parasitoid density on the reproductive behaviour of *Lipolexis oregmae* (Hymenoptera: Aphidiidae) against *Aphis gossypii* (Hemiptera: Aphididae) reared on different host plants

NIDHI SINHA and MD. EQUBAL AHMAD*

Aphid Systematics and Bio-Control Laboratory, University Department of Zoology, T. M. Bhagalpur University, Bhagalpur – 812007, Bihar, India

**Corresponding author E-mail*: equbal.tmbu@yahoo.com

ABSTRACT: Life-table statistics deal with birth and death rates, which are useful in assessing the performance of parasitoids. The numerical relationship between parasitoids and their host populations provides insights into the number of parasitoids required to regulate pest populations. Studying how parasitoid density affects performance helps to evaluate the efficiency of aphid parasitoids and highlights traits desirable in potential biocontrol agents. The study examined the performance of the parasitoid, *Lipolexis oregmae* (Gahan) (Aphidiinae: Braconidae: Hymenoptera) at varying densities on the aphid, *Aphis gossypii* Glover infesting three host plants: *Luffa aegyptiaca* Mill. (Sponge gourd), *Lagenaria siceraria* (Molina) Standl. (Bottle gourd) and *Momordica charantia* L. (bitter gourd). Results showed that the highest total fecundity of *L. oregmae* occurred on *L. siceraria* (70.1±0.73), while the lowest was on *L. aegyptiaca* (45±0.41) at six parasitoid densities. Similarly, the maximum net fecundity at six parasitoid densities was observed on *L. siceraria* (44.2±0.54), and the lowest on *L. aegyptiaca* (31±0.81). The shortest generation times at six parasitoid densities were recorded across the three host plants: *L. aegyptiaca* (9.3 days), *L. siceraria* (9.6 days), and *M. charantia* (9.5 days). Doubling time was longest at one parasitoid density and shortest at six densities across all host plants.

KEYWORDS: *Aphis gossypii*, biological control, life-table statistics, *Lipolexis oregmae*, parasitoid density

(Article chronicle: Received: 07-05-2025; Revised:12-08-2025; Accepted: 14-08-2025)

INTRODUCTION

Aphids, commonly referred to as plant lice, are among the most significant groups of plant-feeding insects. They infest all parts of plants, causing direct damage to crops, and also have a remarkable ability to transmit plant viral diseases (Singh & Singh, 2016). Most aphids are host-specific, feeding only on a limited number of closely related plant species. Even at low population levels, these aphids can cause significant damage to vegetable crops. Their management often relies on natural enemies such as parasitoids, predators, and pathogens. For the biological control of aphids, the biology, ecology, and control efficiency of the aphid parasitoids should be completely known (Singh & Agarwala, 1992). In India, a total of 167 species of aphidiine parasitoids are known parasitising about 200 species of aphids (Singh, 2025a, b, c, d). Aphid parasitoids are attracted by volatile compounds which was released by food plants of their aphid hosts (Singh & Sinha, 1982; Guerrieri *et al.*, 2002; Singh, 2003; Turlings & Erb, 2018). *Lipolexis oregmae* Gahan is widely distributed in most states of India and recorded on 21 species of aphids (Ahmad & Sinha, 2023). Parasitoids can react to higher host densities in two main ways: by increasing their population size (a numerical response) or by raising the number of hosts each individual attacks (a functional response) (Solomon, 1949). The numerical response is generally considered more significant, as it is often the main factor in reducing pest populations (Huffaker *et al.*, 1971). In fact, the ability to rapidly and strongly increase in number is regarded as the most critical trait of an effective pest-control agent (Coppel & Mertins, 1977). Although the numerical response plays an important role in host regulation, it has received comparatively little attention (Huffaker *et al.,* 1970; Takafuji & Chant, 1976). Host regulation is considered a central feature of parasitoidism, since the host is often profoundly modified after oviposition by the parasitoid—mainly due to substances introduced by the laying female (Vinson & Iwantsch, 1980). Furthermore, shifts in plant communities influence the life-history traits of higher trophic-level insects by altering plant abundance and quality (de Sassi *et al.*, 2006; Harri *et al.*, 2008; Soler *et al.*, 2005). Construction of a life-table of aphid parasitoids shows parasitoid fitness indices (Biswas & Singh, 1995; Singh *et al.*, 1996, 1997, 2000; Tripathi &

Singh, 1990, 1997). The parasitoid density increases mutual interference, which causes a reduction in an individual's searching efficiency (Sinha & Singh, 1980b; Hassell *et al.*, 1982; Kumar & Tripathi, 1985; Abidi *et al.*, 1987; Kumar *et al.*, 1988). Due to this interference, the effect on the stability of host-parasitoid interactions has been explained theoretically (Hassell & May, 1973; Rogers & Hassell, 1974; Beddington & Hammond, 1975). The objective of this study is to evaluate the performance of the aphid parasitoid, *L. oregmae,* at different densities on the aphid *Aphis gossypii* reared on three different host plants.

MATERIALS AND METHODS

Rearing of the aphids

Aphis gossypii were reared in the fields as well as in the laboratory on the seedlings of three host plants of family Cucurbitaceae, *viz*., *Luffa aegyptiaca, Lagenaria siceraria* and *Momordica charantia*. Host plants were placed in rectangular cages made from an iron frame fitted with netting made from fine mesh nylon, whereas in the laboratory, they were reared in large insectaries. From the field, alatae forms of aphids were collected and were placed on the seedlings of the host plants, with at least 4-6 leaves.

Rearing of parasitoid

The culture of *L. oregmae* was maintained under laboratory conditions. *A. gossypii* was reared on selected host plants grown in clay or plastic pots to sustain the parasitoid culture. These pots, filled with a soil-compost mixture, were placed inside large wooden cages (1.5 × 1.5 × 1.5 m), watered daily, and illuminated for 14 h using two 40 W fluorescent lamps. Aphids collected from the field were transferred onto seedlings of the host plants, each with at least four leaves and approximately 20 cm in height. Once aphid populations had increased, field-collected female parasitoids were paired with males for copulation after feeding, and then introduced into the cages containing 100 aphids. Females were provided with a diet of honey, honeydew, and water in the ratio 30:30:40. To maintain humidity, the cages were misted with water daily using an atomizer. To prevent superparasitism, females were removed after 24 hours. The resulting mummies, along with parts of the infested leaves, were collected and placed in clear glass vials (3 × 10 cm) covered with muslin cloth until parasitoid emergence, which placed at room temperature (20-25°C) with 60-80% relative humidity.

Calculation of life-table statistics

The growth rate of the population can be calculated directly from the vital statistics of the age-specific survival and net fecundity rates, which is called as "intrinsic rate of increase (r_o)". A close approximation of the intrinsic rate of natural increase (r_m) was calculated following (Andrewartha & Birch, 1954) using a trial and error substitute of r_m in the Lotka-Euler equation:

$$\Sigma\, l_x m_x \exp(-r_m x) = 1$$

where X is the pivotal age (the median developmental time from egg to adult and the age of the adult at oviposition. Age-specific survival rate, l_x (l_x = proportion of surviving females of the cohort) and net fecundity m_x (m_x = number of female progenies per female of age X) were calculated for the adult female parasitoids using data which was obtained from the experiments described above. The net productivity rate (R_o), defined as the mean number of female progenies produced by the female during its life span, was calculated by the equation:

$$R_o = \Sigma l_x m_x$$

In the present study, the number of adults was considered as an index of the total fecundity of *L. oregame.* The total fecundity (R_t) was calculated as:

$$R_t = \Sigma l_x t_x$$

where, t_x = mean number of progeny/females at age X. This computation is essential for viewing a female's total killing activity weighted equally with her intrinsic rate of natural increase. Formulae for Generation Time (GT) and Doubling Time (DT) are as follows.

$$GT = \text{In } R_o / r_m$$

$$DT = 1n\ 2/ r_m$$

RESULTS AND DISCUSSION

The numerical response of aphid parasitoids is crucial because it determines their capacity to track and regulate host density, making it one of the most important traits for effective sustainable pest management. The study of numerical response helps to regulate pest populations for calculating the number of parasitoids needed in a biological control programme. The effect of parasitoid density influences the life-table statistics, *i.e.*, total fecundity, net fecundity, and other parameters.

Total fecundity

The maximum total fecundity at one parasitoid was observed on *A. gossypii* when reared on *L. siceraria* (55.3± 3.49) (Table 1) and lowest on *L. aegyptiaca* (28.8±0.87) (Table 2). At varying parasitoid densities, similar results were observed. The maximum fecundity on six parasitoids was recorded again on *L. siceraria* (70.1±0.73) (Table 1) and lowest on *L. aegyptiaca* (45±0.40) (Table 2). However, the total fecundity per female decreases when parasitoid density

Table 1. Effect of parasitoid density on the total fecundity (R_t) and net fecundity (R_o) of *L. oregmae* on plant *L. siceraria*

Parasitoid density	Total progeny	Progeny/ female	Total female progeny	Female progeny/ female
1	55.3±3.497	55.3±3.497	34.8±1.712	34.8±1.712
2	60±0.447	30±0.223	36.9±0.278	18.4±0.139
4	68±0.730	17±0.182	41.2±0.365	10.3±0.091
6	70.1±0.730	11.6±0.182	44.2±0.547	7.3±0.091

Table 2. Effect of parasitoid density on the total fecundity (R_t) and net fecundity (R_o) of *L. oregmae* on plant *L. aegyptiaca*

Parasitoid density	Total progeny	Progeny/ female	Total female progeny	Female progeny/ female
1	28.8±0.875	28.8±0.875	20.7±0.483	20.7±0.483
2	32.5±0.816	16.3±0.408	22.4±0.557	11.2±0.278
4	40.5±0.365	10.1±0.091	27±0.408	6.75±0.102
6	45±0.408	7.5±0.068	31±0.816	5.16±0.136

Table 3. Effect of parasitoid density on the total fecundity (R_t) and net fecundity (R_o) of *L. oregmae* on plant *M. charantia*

Parasitoid density	Total progeny	Progeny/ female	Total female progeny	Female progeny/ female
1	41.7±0.875	41.7±0.875	28.9±2.415	28.9±2.415
2	45.2±0.408	22.6±0.204	29.6±0.649	14.8±0.324
4	53±0.505	13.2±0.126	34±0.408	8.5±0.102
6	56±1.115	9.3±0.185	36±0.471	6±0.078

increases at 100 aphids on each host plant (Tables 1-3). The Analysis of Variance test (ANOVA) of data reveals that there is a significant difference between host plants (F_1 = 870.92, $p<0.05$) and varying parasitoid density (F_2 = 188.46, $p<0.05$). The relationship between total fecundity and parasitoid density yielded a positive linear correlation (Figure 1).

Net fecundity

The maximum net fecundity at one parasitoid was recorded on *L. siceraria* (34.8±1.7) (Table 1) and lowest on *L. aegyptiaca* (20.7±0.48) (Table 2). Similarly, the maximum net fecundity on six parasitoids was recorded on *L. siceraria* (44.2±0.54) (Table 1) and minimum on *L. aegyptiaca* (31±0.81) (Table 2). The net fecundity also decreases with an increase in parasitoid density at 100 aphids when reared on these host plants (Tables 1-3). The analysis of variance test of data reveals that there is a significant difference between host plants (F_1 = 2.705, $p<0.05$) but an insignificant difference at varying parasitoid density (F_2 = 0.651, $p<0.05$). The relationship between net fecundity and parasitoid density was observed to be linear (Figure 2).

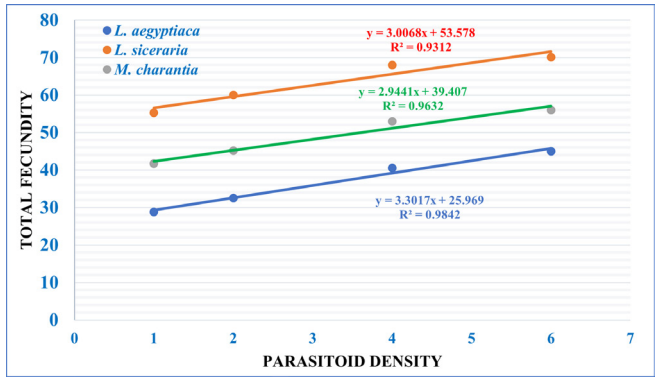


Figure 1. Relationship between parasitoid density and total fecundity.

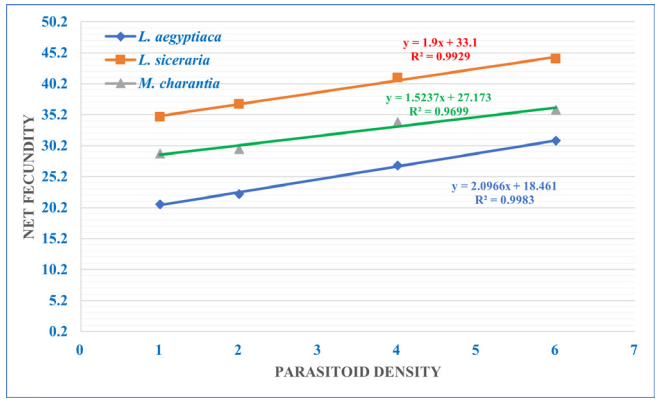


Figure 2. Relationship between parasitoid density and net fecundity.

Generation Time (GT)

The maximum generation time was observed on one parasitoid density in *L. aegyptiaca* (10.5 days), *L. siceraria* (9.8 days) and *M. charantia* (10.1 days). The generation time was decreased with an increase in parasitoid density on three plants: *L. aegyptiaca* (9.3 days), *L. siceraria* (9.6 days) and *M. charantia* (9.5 days) (Table 4). The relationship between generation time and parasitoid density yielded a negative linear correlation (Figure 3).

Doubling Time (DT)

The doubling time also decreased with the increase in parasitoid density. The maximum doubling time was reported on one parasitoid density on *L. aegyptiaca* (2.41 days), *L. siceraria* (1.92 days) and *M. charantia* (2.09 days). The minimum doubling time was reported on six parasitoids on *L. aegyptiaca* and *L. siceraria* (Table 4). The linear correlation was observed between parasitoid density and doubling time (Figure 4).

Intrinsic rate of natural increase (r_m)

The value of the intrinsic rate of natural increase (r_m) increased when parasitoid density increased. It was observed

Table 4. Life-table parameters of *L. oregmae* at varying parasitoid density

One parasitoid			
Host plants	***L. aegyptiaca***	***L. siceraria***	***M. charantia***
r_m	0.287	0.360	0.331
GT	10.558	9.844	10.105
DT	2.415	1.925	2.090
Two parasitoids			
Host plants	***L. aegyptiaca***	***L. siceraria***	***M. charantia***
r_m	0.333	0.373	0.357
GT	9.448	9.600	9.423
DT	2.100	1.858	1.941
Four parasitoids			
Host plants	***L. aegyptiaca***	***L. siceraria***	***M. charantia***
r_m	0.341	0.384	0.375
GT	9.643	9.645	9.388
DT	2.032	1.805	1.848
Six parasitoids			
Host plants	***L. aegyptiaca***	***L. siceraria***	***M. charantia***
r_m	0.368	0.392	0.372
GT	9.366	9.659	9.503
DT	1.883	1.768	1.863

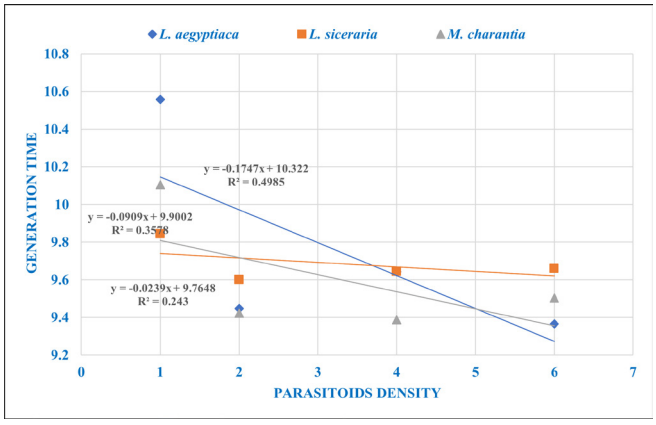


Figure 3. Relationship between parasitoid density and generation time.

to be highest at six parasitoids on the following host plants, *L. aegyptiaca* (0.368), *L. siceraria* (0.392) and *M. charantia* (0.372) and minimum on one parasitoid on all three plants, *L. aegyptiaca* (0.287), *L. siceraria* (0.360) and *M. charantia* (0.331) (Table 4). The linear positive correlation observed between intrinsic rate of natural increase and parasitoid density (Figure 5).

Consistent with the present findings, Parween & Ahmad (2015) reported that both the total and net fecundity of *L. oregmae* increased with parasitoid density on *Aphis craccivora* reared on different host plants. They further noted that *Vicia*

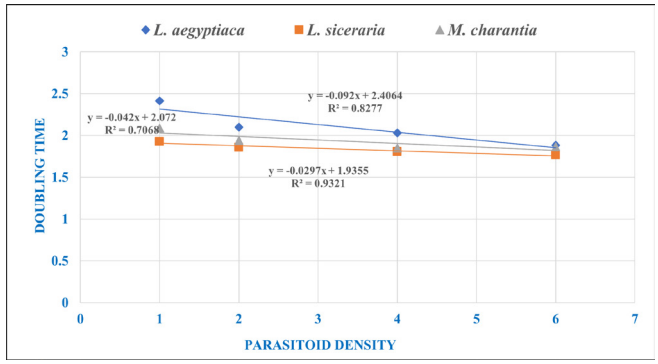


Figure 4. Relationship between parasitoid density and doubling time.

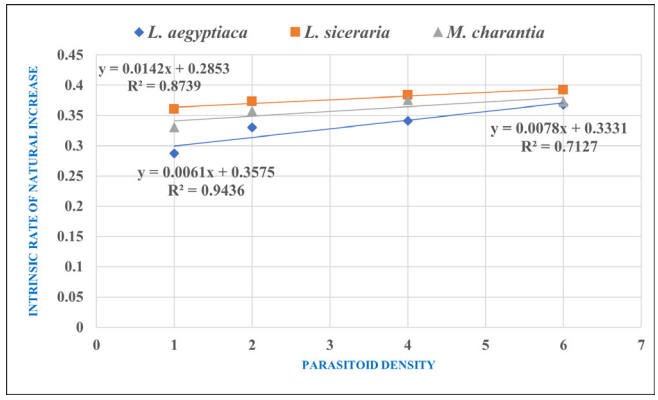


Figure 5. Relationship between parasitoid density and intrinsic rate of natural increase (r_m).

faba was a more suitable host plant than *Phaseolus vulgaris*. In the current study, maximum fecundity was observed on *A. gossypii* when reared on *L. siceraria*. Similarly, Singh *et al.* (2006) found that female density influenced the reproductive behaviour of *Diaeretiella rapae*, while Singh *et al.* (2009) reported higher total births per female (R_t) and female progeny per female (R_o) of *L. oregmae* on *A. gossypii* reared on *Cajanus cajan* at a single parasitoid density. Singh *et al.* (2006) also observed a decrease in GT and DT with rising parasitoid density, similar to the present results.

Van Alphen & Vet (1986) demonstrated that an increase in parasitoid-host ratio reduced searching efficiency, and that parasitoid fitness gain per unit time decreased as the intrinsic rate of natural increase (r_m) rose, although generation time was not influenced by parasitoid density. According to Sinha & Singh (1980a), reduced total and net fecundity at higher female densities could be attributed to superparasitism. Shukla *et al.* (1997) studied numerical interactions between *D. rapae* and its host *Lipaphis erysimi* across three brassicaceous host plants and found that higher parasitoid densities resulted in lower multiplication rates and reduced progeny per female, indicating mutual interference. Similarly, Sinha & Singh (1980b) observed that increasing parasitoid numbers did

not significantly enhance parasitoid emergence, likely due to direct interference during encounters. Hassell & Varley (1969) suggested that reduced search rates arise from mutual interference among foraging parasitoids, while Hassell (1978) attributed the decline in searching efficiency at higher parasitoid densities to parasitoid behavioural mechanisms. Mishra & Singh (1993) also reported that the presence of additional females increased the rate of superparasitism.

CONCLUSION

The present finding demonstrates that parasitoid density plays a critical role in shaping key life-table parameters of *L. oregmae* reared on different host plants. Both total and net fecundity were highest on *L. siceraria* and lowest on *L. aegyptiaca*, with fecundity per female showing a decline as parasitoid density increased. GT and DT decreased with higher parasitoid densities, indicating faster population turnover, while the intrinsic rate of natural increase (r_m) showed a clear rise under the same conditions. These findings highlight that host plant species significantly influence parasitoid reproductive performance and population dynamics, and that higher parasitoid densities enhance population growth potential despite reducing individual fecundity. Overall, the results emphasise the importance of considering both host plant suitability and parasitoid density in optimising biological control programs against aphid pests.

ACKNOWLEDGEMENT

The authors are grateful to the Head, University Department of Zoology, T. M. Bhagalpur University, Bhagalpur, for providing facilities.

REFERENCES

Abidi, A. Z., Kumar, A., and Tripathi, C. P. M. 1987. Impact of male on the functional response of *Diaeretiella rapae* (McIntosh) (Hym: Aphidiidae), a parasitoid of *Lipaphis erysimi* Kalt. (Homoptera: Aphididae). *Appl Entomol,* **103**: 304-312. https://doi.org/10.1111/j.1439-0418.1987.tb00989.x

Ahmad, M. E., and Sinha, N. 2023. Host records of *Lipolexis oregmae* Gahan (Hymenoptera: Braconidae: Aphidiinae) with food plants in India (A Review Article). *J Adv Zool*, **44:** 2240-2249. https://doi.org/10.53555/jaz.v44i5.3108

Andrewartha, H. G., and Birch, L. C. 1954. The distribution and abundance of animals. University of Chicago Press, Chicago and London, pp. 782.

Beddington, J. R., and Hammond, P. S. 1975. On the dynamics of host parasite, hyperparasite interactions. *J Anim Ecol*, **46**: 811-821. https://doi.org/10.2307/3642

Birch, L. C. 1948. The intrinsic rate of natural increase of an insect population. *Anim Ecol*, **17:** 15-26. https://doi.org/10.2307/1605

Biswas, S., and Singh, R. 1995. Frequency of constrained sex allocation in field population of aphid parasitoids (Aphidiidae: Hymenoptera). *J Adv Zool,***16:** 16-20.

Coppel, H. C., and Mertins, J. M. 1977. Biological insects pest suppression, Springer Verlag, Berlin, Heidelberg, New York, pp. 314. https://doi.org/10.1007/978-3-642-66487-8

de Sassi, C., Miller, C. B., and Krauss, J. 2006. Fungal plant endosymbionts alter life history and reproductive success of aphid predators. *Proc R Soc B*, **273:** 1301-1306. https://doi.org/10.1098/rspb.2005.3442 PMid:16720406 PMCid:PMC1560287

Guerrieri, E., Poppy, G. M., Powell, W., Rao, R., and Pennacchio, F. 2002. Plant to plant communication mediating in flight orientation of *Aphidius ervi, J Chem Ecol,* **28**(9). https://doi.org/10.1023/A:1020553531658 PMid:12449500

Harri, S. A., Krauss, J., and Muller, C. B. 2008. Trophic cascades initiated by fungal plant endosymbionts impair reproductive performance of parasitoids in the second generation. *Oecologia*, **157**: 399-407. https://doi.org/10.1007/s00442-008-1094-y PMid:18636277

Hassell, M. P. 1978. The dynamics of arthropod predator - Prey systems. Princeton University Press, Princeton.

Hassell, M. P., and May, R. M. 1973. Stability in insect host - parasite models. *J Anim Ecol*, **42**(3): 693-726. https://doi.org/10.2307/3133

Hassell, M. P., and Varley, G. C. 1969. New inductive population model for insect parasites and its bearing on biological control. *Nature* (London), **223**: 1133-1137. https://doi.org/10.1038/2231133a0 PMid:5810684

Hassell, M. P., Waage, J. K., and May, R. M. 1982. Variable parasitoid sex ratios and their effect on host - parasitoid dynamics. *J Anim Ecol*, **52**(3): 889-904. https://doi.org/10.2307/4462

Huffaker C. B, Simmonds, F. J., and Laing, J. E. 1970. The theoretical and empirical basis of biological control. In: C. B. Huffaker, P. S. Messenger (Eds), Theory and practice of biological control, Academic Press, New York, pp. 41-78. https://doi.org/10.1016/B978-0-12-360350-0.50009-X

Huffaker C. B., Messenger, P. S., and De Bach, P. 1971. The natural enemy component in natural control and theory of biological control, In C. B. Huffaker (Ed), Biological control, Plenum Press., New York. pp. 16-67. https://doi.org/10.1007/978-1-4615-6528-4_2

Kumar, A., and Tripathi, C. P. M. 1985. Parasitoid host relationship between *Trioxys (Binodoxys) indicus* Subba Rao and Sharma (Hymenoptera: Aphididae). IV. Effect of host plants on the sex ratio of the parasitoid. *Entomon*, **12**: 96-97. https://doi.org/10.1111/j.1439-0418.1984.tb03721.x

Kumar, A., Shanker, S., Pandey, K. P., Sinha, T. B., and Tripathi, C. P. M. 1988. Parasitoid host relationship between *Trioxys (Binodoxys) indicus* Subba Rao and Sharma (Hymenoptera: Aphididae) and *Aphis craccivora* Koch, (Hemiptera: Aphidiidae) VI. Impact of male on the number of progenies of the parasitoid reared on certain host plant. *J Appl Entomol*, **105**: 476-482 https://doi.org/10.1111/j.1439-0418.1988.tb00213.x

Mishra, S., and Singh, R. 1993. Mating behaviour of *Lysiphlebus delhiensis* (Subba Rao & Sharma), an aphidiid parasitoid of corn aphid *Rhopalosiphum maidis* (Fitch). *Z Angew Zool*, **79**: 319-328.

Parween, N., and Ahmad, M. E. 2015. Numerical response of *Lipolexis oregmae* (Hymenoptera: Aphidiinae) against *Aphis craccivora* (Hemiptera: Aphididae), *Eur Sci J,* **11**(24): 1857-7881.

Rogers, D. J., and Hassell, M. P. 1974. General models for insect parasite and predator searching behaviour: Interference. *J Anim Ecol*, **43**: 239-253. https://doi.org/10.2307/3170

Shukla, A. N., Tripathi, C., and Singh, R. 1997. Effect of food plants on the numerical response of *Diaeretiella rapae* (McIntosh) (Hymenoptera: Braconidae), a parasitoid of *Lipaphis erysimi* Kalt. (Hemiptera: Aphididae). *Biol Agricul Horticul*, **14**(1): 71-77. https://doi.org/10.1080/01448765.1997.10749919

Singh, D., Prasad, S., and Singh, R. 2006. Female density influences the reproductive behaviour of an aphid parasitoid *Diaeretiella rapae* (McIntosh) (Hymenoptera: Braconidae, Aphidiinae). *J Aphidol*, **20**(1): 61-69.

Singh, D., Prasad, S., and Singh, R. 2009. Life-table of aphid parasitoid, *Lipolexis oregmae* (Gahan), a parasitoid of *Aphis gossypii* Glover reared on pigeon pea. *Ind J Entomol*, **71**(2): 110-112.

Singh, R., and Agarwala, B. K. 1992. Biology, ecology, and control efficiency of the aphid parasitoid *Trioxys indicus*: A review and bibliography. *Biol Agricul Horticul*, **8**: 271-298. https://doi.org/10.1080/01448765.1992.9754606

Singh, G., and Singh, R. 2016. Aphids and their biocontrol. In Omkar (Ed.), Eco friendly Pest Management for Food Security, Academic Press, pp. 63-108. https://doi.org/10.1016/B978-0-12-803265-7.00003-8

Singh, R. 2003. Tritrophic interactions with reference to biological control of insect pests: A review. *Biol Mem*, **29**(2): 55-70.

Singh, R. 2025a. Distribution and tritrophic associations of aphid parasitoids of tribes Ephedrini and Praini (Aphidiinae: Braconidae: Hymenoptera) in India. *J Fauna Biodiver,* **1**(4): 162-196. https://doi.org/10.70206/jfb.v1i4.13753

Singh, R. 2025b. Distribution and tritrophic associations of aphid parasitoids of the tribe Aphidiini (Aphidiinae: Braconidae: Hymenoptera) in India. *Arthropods*, **14**(3): 94-149

Singh, R. 2025c. Tritrophic associations (parasitoids - aphids - plants) and distribution of species of *Betuloxys* Mackauer, *Lipolexis* Förster and *Monoctonus* Haliday (Hymenoptera: Braconidae: Aphidiinae: Trioxini) in India. *Mun Ent Zool,* **20**(2): 2311-2326.

Singh, R. 2025d. Tritrophic associations and distribution of *Binodoxys* Mackauer, *Cristicaudus* Starý and Remaudière, *Fissicaudus* Starý and Schlinger and *Trioxys* Haliday (Hymenoptera: Braconidae: Aphidiinae: Tioxyni) in India. *Mun Ent Zool,* **20**(2): 2064-2094.

Singh, R., and Sinha, T. B. 1982. Bionomics of *Trioxys (Binodoxys) indicus* Subba Rao and Sharma, an aphidiid parasitoid of *Aphis craccivora* Koch. 13. Host selection by the parasitoid. *Z Angew Entomol*, **93**: 64-75. https://doi.org/10.1111/j.1439-0418.1982.tb03571.x

Singh, R., Biswas, S., and Pandey, S. 1996. Dietary role of honeydew on the life-table parameters of a cereal aphid parasitoid, *Lysiphlebia mirzai* Shuja-Uddin (Hymenoptera: Braconidae). *J Appl Zool* Res, **7**: 102-103.

Singh, R., Singh, A., and Pandey, S. 2000. Effect of host - patch size and parasitoid density on the progeny sex ratio of an aphid parasitoid *Binodoxys (Trioxys) indicus* (Subba Rao and Sharma). (Hymenoptera: Braconidae, Aphidiinae). *J Adv Zool*, **22**: 44-52.

Singh, R., Upadhyay, A. K., and Ahmad, M. E. 1997.

Thermal influence on the life-table of *Trioxys indicus* Subba Rao and Sharma (Hymenoptera: Braconidae) an aphid parasitoid of *Aphis gossypii* Glover at variable host densities. *J Aphidol*, **11**: 205-2012.

Sinha, T. B., and Singh, R.1980a. Studies on the bionomics of *Trioxys (Binodoxys) indicus* Subba Rao and Sharma, an aphidiid parasitoid of *Aphis craccivora* (Hemiptera: Aphididae)-the area of discovery of the parasitoid. *Z Angew Entomol,* **89**: 173-178. https://doi.org/10.1111/j.1439-0418.1980.tb03455.x

Sinha, T. B., and Singh, R. 1980b. Bionomics of *Trioxys(Binodoxys)indicus*, an aphidiid parasitoid of *Aphis craccivora*. III. Numerical aspects of the interaction of the parasitoid and its host. *Entomol Exp Appl,* **28**: 167-176. https://doi.org/10.1111/j.1570-7458.1980.tb03001.x

Soler, R., Bezemer, T. M., van der Putten, W. H., and Vet, L. E. M., Harvey, J. A. 2005. Root herbivore effects on above - ground herbivore, parasitoid and Hyperparasitoid performance via changes in plant quality. *J Anim Ecol*, **74**: 1121-1130. https://doi.org/10.1111/j.1365-2656.2005.01006.x

Solomon, M. E. 1949. The natural control of animal population. *J Anim Ecol*, **18**: 1-35. https://doi.org/10.2307/1578

Takafuji, A., and Chant, D. A. 1976. Comparative studies of two species of predaceous mites (*Acarina: Phytoseiidae*), with special reference to their responses to the density of their prey. Res. *Popul Ecol*, **17**: 255-310. https://doi.org/10.1007/BF02530777

Tripathi, S. K., and Singh, R. 1990. Fecundity, reproductive rate of increase of aphidiid parasitoid *Lysiphlebia mirzai* Shuja-Uddin. *Entomophaga*, **35**: 601-610. https://doi.org/10.1007/BF02375094

Tripathi, S. K., and Singh, R. 1997. Effect of host food plant transfer on the life-table of *Lysiphlebia mirzai* Shuja-Uddin, an aphid parasitoid of cereal aphids. *J Appl Biol*, **26**: 5-55.

Turlings, T. C. J., and Erb, M. 2018. Tritrophic interactions mediated by herbivore-induced plant volatiles: Mechanisms, ecological relevance, and application potential. *Annu Rev Entomol*, **63**: 433-452. https://doi.org/10.1146/annurev-ento-020117-043507 PMid:29324043

Van Alphen, J. J. M., and Vet, L. E. M. 1986. An evolutionary approach to host finding and selection. Insect parasitoid, Academic Press, London, pp. 23-61.

Vinson, S. B., and Iwantsch, G. F. 1980. Host regulation by insect parasitoids, *Chicago J,* **55**(2). https://doi.org/10.1086/411731