Indian Journal of Entomology Online published Ref. No. e24903 DoI. No.: 10.55446/IJE.2024.1903

EFFECT OF ELEVATED TEMPERATURE ON THE BIONOMICS OF *AENASIUS ARIZONENSIS* GIRAULT

THIMMEGOWDA M N[1], SACHIN S SUROSHE[1]* AND KIRAN KUMAR G N[1]

[1]Division of Entomology, ICAR-Indian Agricultural Research Institute, New Delhi 110012, India
*Email: sachinsuroshe@gmail.com (corresponding author): ORCID ID 0000-0003-2866-5672

ABSTRACT

An experiment was conducted to know the effect of thermal stress on the biological attributes of the parasitoid *Aenasius arizonensis* Girault of the cotton mealybug *Phenacoccus solenopsis* Tinsley. The results revealed that temperature showed a significant effect on the biological fitness traits of the *A. arizonensis*; when exposed to 32°C, parasitisation, fecundity, female sex ratio and adult longevity. At 32°C these viz., parasitisation (77%), sex ratio (63.46) and days taken from oviposition to mummy formation (6.4) were found to be the highest. Other fitness traits like fecundity (142.8) and developmental duration (11.2 - males, 12.6 - females) were found to be the highest at 27°C. These parameters gradually decreased with increasing temperature, indicating a negative relationship. Morphometrics of adults revealed that mean length and breadth of mummies, total length and breadth of adult male and females, total width of head, total length of antenna and total hind tibial length were maximum at 27°C as compared to those observed with high temperature treatments. Thus high temperature was observed to have an adverse effect on the growth and development of the parasitoid.

Key words: *Phenacoccus solenopsis*, *Aenasius arizonensis*, elevated temperature, bionomics, cotton, parasitoid, mummies, biological control, morphometrics, length, breadth, head, antenna, hind tibial, parasitisation, fecundity, longevity, sex ratio

After the introduction of Bt cotton in 2002, the sucking pest problem is the main reason for the dwindling production of cotton in India. One among them is the solenopsis mealybug *Phenacoccus solenopsis* Tinsley (Pseudococcidae: Hemiptera) which has invaded and colonized in more than 23 countries (Ahmed et al., 2015). The pest is reported to feed on 202 host plant species that encompasses field crops, ornamentals, trees, and vegetables (CABI, 2015). Biological control agents are the ecofriendly options for sustainable IPM in agri-horticultural crops. Biological control has been demonstrated by the recent success of fortuitous biological control of *P. solenopsis* (Gautam et al., 2009). The cotton mealy bug parasitoid *Aenasius arizonensis* Girault is an endophagous nymphal parasitoid causing 80% parasitization under field conditions. However, its sustainability largely depends on the abiotic factors and the temperature is one of the most important (Huffaker et al., 1999). Several studies suggest that the host insect and temperature may affect the rate of development and longevity of parasitoids (Deng and Tsai, 1998). Temperature is a key abiotic factor that regulates insect population dynamics, developmental rates, and seasonal occurrence (Campbell et al., 1974; Logan et al., 1976). The ability of an insect to tolerate the temperature stress without compromising its growth and development is an important adoption (Mizell and Nebeker, 1978). Insects require a certain amount of heat units (degree-days) to develop from one life stage to the next (Gordan, 1999). Extreme temperatures adversely affect the survival and abundance of mealybug and its parasitoids (Amarasekare et al., 2008; Vennila and Agarwal, 2013). The present study explores the influence of temperature regimes on *A. arizonenesis*.

MATERIALS AND METHODS

The *P. solenopsis* culture was maintained in the laboratory by rearing them on sprouted potato tubers following Geethu et al. (2020) and Sweetee Kumari et al. (2021). The parasitoid (*A. arizonensis*) mummies were collected from the mealybug infested cotton and *Hibiscus rosa-sinensis* plants and placed in glass cylinder (10x4 cm) for emergence (Suroshe et al., 2013). From these adults of *A. arizonensis* were transferred to plastic jars (22.5 x 14 cm) having mealybug culture. The pure mealybug and parasitoid culture was further used. Studies on the effect of temperature were conducted at four temperatures viz*.,* 27, 32, 35 and 38± 1°C in BOD incubators. For this purpose, thirty III instar nymphs were taken from the main culture jars and released on the fresh sprouted potatoes in the small plastic jar (10 x 7 cm) using the camel hair brush. Then the mated one day old female of *A. arizonensis* was released. After 24 hr the nymphs were transferred on the cotton leaves placed in the petri dish (200 x 20 mm) having its petiole inserted in the solidified agar solution (2%) for maintaining the leaves fresh and tender (Venkanna et al., 2020). After every 24 hr the new batch of III instar mealybug was released in the plastic jar having sprouted potatoes till the released female parasitoid dies. Petri dish having cotton leaves and agar solution was replaced as and when required and the parasitized mealybugs were transferred on it as per the need. Mealybugs which turned to mummies were individually reared in the homeopathy vials (7 x 1.5 cm) for adult parasitoid emergence (Suroshe et al., 2013). The observation on parasitism %, days to mummy formation, fecundity, longevity, developmental time and sex ratio was recorded. Parasitisation % was recorded at 24 hr after parasitisation, whereas, the fecundity was recorded based on the number of mealybugs parasitized till the death of female. The stages of mealubugs and its mummies were critically observed before and after emergence under Nikon stereozoom microscope with camera attachment using software "Vimage-2016" for morphometrics analysis. Observation on the morphological characters was taken following Aga et al. (2016).

RESULTS AND DISCUSSION

The results revealed that temperature had a significant effect on the parasitism by *A. arizonensis*- highest (77) and the lowest (55) parasitism were observed at 32 and 38°C, respectively; it significantly increased with temperatures from 27(63.2 %) to 32°C (77 %), however it dropped when the temperature exceeded from 32 to 38°C. Parasitism at 35°C was found to be at par with the parasitism at 27 and 38°C (Table 1). The parasitoid, *A. arizonensis* is basically solitary endoparasitoid. Therefore a parasitized host has been considered as criteria for its fecundity. Effect of temperature on fecundity and mummy formation was found statistically significant; increasing temperature decreased the fecundity; maximum (148.8± 10.52) was at 27°C followed by 32°C (113.6± 8.64), 35°C (77.2± 7.66) and 38°C (39.2± 9.52). Temperature had significant effect on the developmental duration of both male and female; male progeny lasted less compared to female at all temperature regimes. The highest (11.2± 0.836 days) developmental period was observed at 27°C and the lowest (0.8± 0.707 days) at 38°C in male; with female the highest duration was observed at 27°C

Table 1. Effect of temperature regimes on biological fitness traits, developmental duration, longevity and sex ratio (females) of *A. arizonensis*

Temperature	Fecundity (Mean± SE)* (Numbers)	Egg to mummy formation (Mean± SE)* (Days)	Parasitisation % (Mean± SE)*	Devt. duration Male (Mean± SE)* (Days)	Devt. duration Female (Mean± SE)* (Days)	Longevity Male (Mean± SE)* (Days)	Longevity Female (Mean± SE)* (Days)	Sex ratio (Mean± SE)*
27°C	148.8± 10.521[a]	6.2± 0.836[a]	63.2± 9.03 (52.78)[b]	11.2± 0.836[a]	12.6± 0.547[a]	9± 0.707[a]	16± 1.22[a]	55.33 (48.075)[b]
32°C	113.6± 8.648[b]	6.4± 0.547[a]	77± 5.58 (61.55)[a]	9.2± 0.836[b]	10.6± 0.894[b]	7.4 0.547[b]	12.8± 0.447[b]	63.46 (52.769)[a]
35°C	77.2± 7.661[c]	3.8± 0.836[b]	60.2± 5.23 (50.94)[b]	8.4± 0.547[bc]	9.2± 0.836[c]	6.8± 1.643[b]	9.4± 0.547[c]	55.65 (48.075)[b]
38°C	39.2± 9.523[d]	3.2± 0.836[b]	55± 5.96 (47.93)[b]	8.0± 0.7[c]	8.8± 0.836[c]	5± 1[c]	7.2± 1.095[d]	44.66 (41.927)[c]
S.Em. ±	4.09	0.34	1.93	0.33	0.35	0.47	0.4	1.223
C D ($p \leq 0.05$)	12.26	1.03	5.79	0.99	1.06	1.42	1.19	3.66

*Mean of five replications; Data in parentheses arc sine transformed values.

(12.6± 0.547 days) and at 38°C was and the lowest 8.8± 0.83 days. Temperature had a significant effect on the adult longevity and it decreased with increase in temperature. Usually, male longevity remains shorter than the female. Male lived longest at 27°C (9± 0.707 days) and shortest at 38°C (5± 1days) whereas female lived longest at 27°C (16± 1.22) and shortest at 38°C (7.2± 1.095 days). Observed sex ratio at all temperature treatments were found to be statistically significant with a female of 55.3, 63.46, 55.65 and 44.6% at 27°C, 32°C, 35°C and 38°C, respectively (Table 1).

Natural enemies get exposed to different environmental stresses, such as temperature, might affect their biological traits (Fand and Suroshe, 2015). The successful mass rearing and release of parasitoids depends on the suitable temperature condition (Dhillon and Sharma, 2009). Thus, it is necessary to ascertain the effect of temperature on the biology of parasitoids. Optimum range of temperature is required for development of parasitoids to promote parasitisation and survival (Tunca et al., 2010; Qiu et al., 2012). In the present study the highest parasitism % was at 32°C and increased from 27 to 32°C, but dropped when temperature exceeds 32°C. Similar results were observed by He et al. (2018) but in contrast to Kahya et al. (2021) where they reported highest parasitization rate at 25°C. Fecundity of female parasitoid during its longevity was the highest at 27°C and it decreased with temperature. These, results are in line with Hira et al. (2023). Iqbal et al. (2016), studied the effect of parasitoid age on fecundity of *A. bambawalei* at 27± 2°C and 65± 5% RH. The results revealed that the fecundity did not change significantly during the first five days of age; thereafter it declined significantly under laboratory condition. Sex ratio of female was the highest at 32°C, and as the temperature increased further, it decreased significantly under laboratory condition. This implies that, females prefer not to parasitize their hosts at higher temperatures. These results are partially corroborate with Zhang et al., 2016, on *A. bambawalei*. The developmental duration of male and female decreased with temperature; lower temperature, may reduce the physiological and metabolic rates of insects by prolonging the hatching of eggs, larval development and pupal periods and delaying adult emergence. Similar results were obtained in *A. arizonensis* when exposed to temperature stresses (H et al., 2018; Kahya et al., 2021; Hira et al., 2023). The survival rates of the insects have already been shown to be often affected by temperature (Huffaker et al., 1999). Results revealed that the longevity of adult female and male parasitoids had an inverse relationship with temperature; maximum longevity of both adult female and male was at 27°C and it decreased with temperature. Soumia et al. (2011) also reported that the longevity of female and male adults of *A. bambawalei* decreases with increases in temperature. The parasitoids *Microplitis manila, Eretmocerus hayati* and the predaceous pentatomid *Arma chinensis* (Fallou) survival rates also decreased with temperature (Qiu et al., 2012; Zhang et al., 2019; Xia et al., 2022)

Both adult male and females are blackish with female conspicuously larger; apex of antennae clubbed like and pale black. The mummies barrel shaped and dark brown measuring length and breadth as 2.81± 0.36 mm and 1.61± 0.44 mm, respectively at 27°C; these became shorter (2.39± 0.35 and 1.52± 0.37) at 38°C (Table 2). Adults emerged out through circular hole made on the mummies after completion of pupal period. The maximum total length and breadth of female varied from 1.29 to 2.97 mm and 0.36 to 0.98 mm, respectively. In male it varied from 0.7 to 1.78 mm and 0.37 to 0.72 mm, respectively at 27°C; at 38° C these became from 0.72 to 2.1 mm and 0.3 to 1.2 mm (female) and 0.52 to 1.51 mm and 0.27 to 0.72 mm (male), respectively. Head size varied between male and female was larger (0.85± 0.22) at 27°C and the lowest at 38°C (0.37± 0.08 mm); in male it was found to be 0.50± 0.11 mm at 27°C and 0.40± 0.11 mm at 38°C. Antenna is used for differentiating the male and female and it was measured 0.85± 0.19 and 0.82± 0.10 mm, respectively at 27°C; and 0.67± 0.21 and 0.61± 0.09 mm, respectively at 38°C. The maximum hind tibial length of the female and male parasitoid was observed as 0.51±0.06mm and 0.33±0.5mm, respectively at 27°C. The minimum hind tibial length of the female and male parasitoid was noticed as 0.35± 0.034 mm and 0.26± 0.05 mm, respectively at 38°C (Table 2).

The above morphometrics observed are in accordance with previous studies (Aga et al., 2016; Poorani, 2009; Hayat, 2009). Mummies of the parasitoids were barrel shaped and dark brown; size varied with temperature and the maximum length (2.81± 0.36 mm) and breadth (1.61± 0.44 mm) of mummies were observed at 27°C and the minimum length (2.39± 0.35mm) and breadth (1.52± 0.37 mm) was observed at 38°C. Total length and breadth, head breadth and length of antenna were found to vary with the increasing temperature and the highest mean value was recorded at 27°C and the lowest value at 38°C. This suggests that, the temperatures ranging between 27 to 32°C is the best suited for the growth and development of parasitoids under laboratory

Table 2. Morphometrics of *A. arizonensis* at different temperatures

Sl. No.	Morphological characters*	27°C Male Mean± SE	27°C Male Range	27°C Female Mean± SE	27°C Female Range	32°C Male Mean± SE	32°C Male Range	32°C Female Mean± SE	32°C Female Range	35°C Male Mean± SE	35°C Male Range	35°C Female Mean± SE	35°C Female Range	38°C Male Mean± SE	38°C Male Range	38°C Female Mean± SE	38°C Female Range
1	Total length	1.27± 0.34	0.7- 1.78	1.73± 0.30	1.29- 2.97	0.96± 0.32	0.92- 0.96	1.39± 0.45	0.92- 2.01	0.86± 0.36	0.59- 1.51	1.3± 0.48	0.79- 2	0.84± 0.38	0.52- 1.51	1.27± 0.55	0.72- 2.1
2	Total breadth	0.52± 0.11	0.37- 0.72	0.72± 0.26	0.36- 0.98	0.43± 0.09	0.27- 0.52	0.47± 0.18	0.28- 0.68	0.4± 0.08	0.27- 0.5	0.58± 0.37	0.31- 1.2	0.53± 0.19	0.27- 0.72	0.60± 0.38	0.3- 1.2
3	Head breadth	0.50± 0.11	0.38- 0.69	0.85± 0.22	0.56- 1.2	0.48± 0.17	0.35- 0.68	0.47- 0.18	0.28- 0.68	0.44± 0.15	0.32- 0.62	0.38± 0.11	0.27- 0.56	0.40± 0.11	0.31- 0.61	0.37± 0.08	0.27- 0.5
4	Length of antenna	0.82± 0.10	0.68- 0.97	0.85± 0.19	0.59- 1.14	0.78± 0.07	0.68- 0.86	0.83 ±0.25	0.54- 1.09	0.70± 0.08	0.58- 0.79	0.76± 0.24	0.49- 1.01	0.61± 0.09	0.48- 0.72	0.67± 0.21	0.42- 0.9
5	Length of hind tibia	0.33± 0.5	0.26- 0.39	0.51± 0.06	0.45- 0.59	0.30± 0.013	0.29- 0.32	0.4± 0.015	0.38- 0.42	0.30± 0.032	0.28- 0.41	0.38± 0.021	0.36- 0.41	0.26± 0.055	0.2- 0.32	0.35± 0.034	0.32- 0.4
	Mummies* (Mean±SE)																
6	Length	2.81±0.36				2.55±0.65				2.49 ±0.40				2.39± 0.35			
7	Breadth	1.61±0.44				1.37±0.40				1.56± 0.38				1.52± 0.37			

*Mean of ten replications. All observations in mm.

condition. Aga et al. (2016) observed the mean length and breadth of mummies of *A. arizonensis* as 3.74± 0.13 mm and 2.05± 0.13 mm, respectively at 27°C; and externally it appeared barrel shaped and dull brown. The adult female length was 1.83± 0.08 mm and male was 1.38± 0.06 mm. The mean length and breadth of adult female fore, middle and hind legs were 1.35± 0.04, 1.55± 0.04 and 1.89± 0.05 mm, respectively. The mean length of adult female antennae was 0.93± 0.05 mm. Sangle et al. (2013) with *A. bambawalei* observed the same trend. Present observations revealed that the optimum parasitization, longevity, sex ratio and developmental durations of *A. arizonensis* could be achieved between 27 to 32°C without compromising its growth and development. Thus, 27 to 32°C is the optimum temperature for mass rearing of parasitoid in laboratory condition.

ACKNOWLEDGEMENTS

The first author acknowledges the Junior Research Fellowship received from Indian Council of Agricultural Research, New Delhi.

FINANCIAL SUPPORT

Authors acknowledge the financial help received from the Director, ICAR-IARI, Pusa, New Delhi and DST-SERB, Govt. of India.

AUTHOR CONTRIBUTION STATEMENT

SSS designed the experiments and reviewed the manuscript; TMN performed the experiment and wrote the manuscript; KGN reviewed and incorporated the corrections in the manuscript.

CONFLICT OF INTEREST

No conflict of interest.

REFERENCES

Aga T M, TambeV J, Nagrare V S, Naikwadi B. 2016. Parasitoid, *Aenasius arizonensis* (Girault) (Hymenoptera: Encyrtidae): Its biology, morphometrics, host stage preference and use in biological control. Journal of Biological Control 30(2): 91-98.

Ahmed M Z, Ma J, Qiu B L, He R R, Wu M T, Liang F, Zhao J P, Lin L, Hu X N, Lv L H, Breinholt J W, Lu YY. 2015. Genetic record for a recent invasion of *Phenacoccus solenopsis* (Hemiptera: Pseudococcidae) in Asia. Environmental Entomology 44(3): 907-918.

Amarasekare K G, Mannion C M, Osborne L S, Epsky N D. 2008. Life history of *Paracoccus marginatus* (Hemiptera: Pseudococcidae) on four host plant species under laboratory conditions. Environmental Entomology 37(3): 630-635.

CABI. 2015. Invasive species compendium datasheets, maps, images, abstracts. http://www.cabi.org/isc/datasheet/109097(15/9/2016).

Campbell A B, Frazer D, Gilbert N, Gutierrez A P, Mackauer M. 1974. Temperature requirements of some aphids and their parasites. Journal of Applied Ecology 11(2): 431-438.

Deng Y X, Tsai J H. 1998. Development of *Lysiphlebia japonica* (Hymenoptera: Aphidiidae), a parasitoid of *Toxoptera citricida* (Homoptera: Aphididae) at five temperatures. Florida Entomologist 81: 415-423.

Dhillon M K, Sharma H C. 2009. Temperature influences the performance and effectiveness of field and laboratory strains of the ichneumonid parasitoid, *Campoletis chlorideae*. Biocontrol 54(6): 743-750.

Fand B B, Suroshe S S. 2015. The invasive mealybug *Phenacoccus solenopsis* Tinsley: A threat to tropical and subtropical agricultural and horticultural production systems. Crop protection 69: 34-43

Gautam R D, Suroshe S S, Gautam S, Saxena U, Fand B B, Gupta T. 2009. Fortuitous biological control of exotic mealybug *Phenococcus solenopsis*- A boon for Indian growers. Annals of Plant Protection Sciences 17(2): 473-473.

Geethu S, Suroshe S S. 2020. Feeding potential and biology of six spotted ladybird beetle *Cheilomenes sexmaculata* on cotton mealybug *Phenacoccus solenopsis*. Indian Journal of Entomology 82(2): 302-305

Gordan H T. 1999. Growth and development of insects. pp. 55-82.

Hayat M. 2009. Description of a new species of *Aenasius* Walker (Hymenoptera: Eneyrtidae), parasitoid of the mealybug, *Phenacoccus solenopsis* Tinsley in India. Biosystematica 3(1): 21-26.

He L F, Li P, Zhou Z S, Xu Z F. 2018. Temperature-dependent parasitism and development in *Aenasius arizonensis* Girault (Hymenoptera: Encyrtidae), a solitary endoparasitoid of *Phenacoccus solenopsis* (Hemiptera: Pseudococcidae). International Journal of Pest Management 64(1): 45-50.

Hira H, ul Abdin Z, Tayyib M, Arshad M, Hussain F, Abbas S K. 2023. Effects of varying temperature on the reproduction and survival of mealybug parasitoid, *Aenasius arizonensis* (hymenoptera: encyrtidae). Journal of Animal and Plant Sciences 33(3): 553-61.

Huffaker A C, Berryman A, Turchin P. 1999. Dynamics and regulation of insect populations. pp. 269-312.

Iqbal M S, Abdin Z, Arshad M, Abbas S K, Tahir M, Jamil A, Manzoor A. 2016. The Role of Parasitoid Age on the Fecundity and Sex Ratio of the Parasitoid, *Aenasius bambawalei* (Hayat) (Hymenoptera: Encyrtidae). Pakistan Journal of Zoology 48(1): 67-72.

Kahya D, Keçe A F, Ulusoy M R. 2021. The determination of developmental time, parasitism rate at different temperatures and parasitism behavior at constant temperature of *Aenasius arizonensis* Girault 1915 (Hymenoptera: Encyrtidae). Plant Protection Bulletin 61(3): 36-41.

Logan J A, Wollkind D J, Hoyt S C, Tanigoshi L K. 1976. An analytical model for description of temperature dependent phenomenon in arthropods. Environmental Entomology 5(6): 1133-1140.

Mizell R F, Nebeker T E. 1978. Estimating the developmental time of the southern pine beetle *Dendroctonus frontalis* as a function of field temperatures. Environmental Entomology 7(4): 592-595.

Poorani J, Rajeshwari S K, Gupta A. 2009. Notes on diagnosis and biology of *Aenasius bambawalei* Hayat (Hymenoptera: Encyrtidae), a parasitoid of the invasive mealybug, *Phenacoccus solenopsis* Tinsley (Hemiptera: Pseudococcidae). Journal of Biological Control 23(4): 463-466.

Qiu B, Zhou Z S, Luo S P, Xu Z F. 2012. Effect of temperature on development, survival, and fecundity of *Microplitis manilae* (Hymenoptera: Braconidae). Environmental Entomology 41(3): 433-730.

Sangle P M, Korat D M, Patel B H. 2013. A note on morphometry and post larval life stages of *Aenasius bambawalei* Hayat. Karnataka Journal of Agricultural Sciences 26(1): 151-154.

Soumia P S. 2011. Influence of temperature and humidity on *Aenasius bambawalei* Hayat (Hymenoptera: Encyrtidae) – A potential parasitoid of *Phenacoccus solenopsis* Tinsley. Thesis: submitted to Post Graduate School. Indian Agricultural Research Institute, Pusa Campus, New Delhi. 31 pp.

Suroshe S S, Gautam R D, Fand B B. 2013. Natural enemy complex associated with the mealybug, *Phenacoccus solenopsis* Tinsley (Hemiptera: Pseudococcidae) infesting different host plants in India. Journal of Biological Control 27(3): 204-210.

Sweetee K, Suroshe S S, Dinesh K, Budhlakoti N, Venkanna Y. 2021. Foraging behaviour of *Scymnus coccivora* Ayyar against cotton mealybug *Phenacoccus solenopsis* Tinsley. Saudi Journal of Biological Sciences 28(7): 3799-3805.

Tunca H O C, Kilincer N. 2010. Temperature dependent development of the egg-larval parasitoid *Chelonus oculator* on the factitious host, *Ephestia cautella*. Turkish Journal of Agriculture and Forestry 34(5): 421-428.

Venkanna Y, Suroshe S S, Bhagyashree S N, Sweetee K. 2020. Biology of *Cheilomenes sexmaculata* (F.) (Coleoptera: Coccinellidae) on cotton aphid *Aphis gossypii.* Indian Journal of Entomology 82(1): 75-79.

Vennila S, Agarwal M. 2013. Spices as host crops of cotton mealybug, *Phenacoccus solenopsis.* Annual of Plant Protection Sciences 22(1): 190-239.

www.cotcorp.org.in/national_cotton.aspx (accessed on 16.08.2022)

Xia P L, Wang B, Xie X F, Feng Y, Huang Y. 2022. Effect of temperature on survival and immature development of *Arma chinensis*. Journal of Asia-Pacific Entomology 25(3): 101927.

Zhang J, Huang J, Lu Y, Xia T. 2016. Effects of temperature and host stage on the parasitization rate and offspring sex ratio of *Aenasius bambawalei* Hayat in *Phenacoccus solenopsis* Tinsley. PeerJ 4: e1586.

Zhang Y B, Zhang G F, Liu W X, Wan F H. 2019. Variable temperatures across different stages have novel effects on behavioral response and population viability in a host-feeding parasitoid. Scientific Reports 9(1): 2202.

(Manuscript Received: January, 2024; Revised: January, 2024;
Accepted: January, 2024; Online Published: February, 2024)
Online First in www.entosocindia.org and indianentomology.org Ref. No. e24903