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ECOLOGY OF *OTINOTUS ONERATUS* WALKER (HEMIPTERA: MEMBRACIDAE) ON ITS HOST PLANT *TAMARINDUS INDICA*

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ABSTRACT

This study is on the ecology and population dynamics of the membracid *Otinotus oneratus* Walker on its host plant *Tamarindus indica* L. The daily activity of *O. oneratus* when analysed revealed that it was active during 11:00 and 16:00 hr, and on extremely warmer days. Adults preferred woody internodal parts, while the early nymphal stages fed on the axil of the leaves, and the later nymphs fed on the internodal parts along with the adults. The resting posture of the adults were found to be in position with its head directed upwards on its host plant. The mean number of nymphs resting in a posture facing towards and away from node was 79.7 and 17.1 respectively; with adults, for males and females it was 3.0 and 4.6 upwards facing, and for downwards it was 2.4 and 3.6, respectively. The individuals were sluggish, and when disturbed, moved in a spiral manner around the twig, and stopped after moving some distance. Mating occurred for 5 min, followed by a female preoviposition period of 3 days. Eggs were elongate and white and laid in 'V' shaped manner, arranged in two rows with 12-19 eggs in each row. Parental care was exhibited with the females guarding 71.4 to 83.3% of egg masses. The incubation period varied from 8-12 days. Hatching occurred during the morning hours, and the nymphs were slow moving, showing a strong myrmecophilous mutualism, regularly attended by the large black ant *Camponotus compressus* F. (56.5- 92.9%). Predation by *Gonatocerus brevifuniculatus* Subba Rao and *Mirufens afrangiata* Viggiani and Hayat of eggs wqas observed. *O. oneratus* nymphs mimicked the thorns of the host plant, but they were brightly coloured (in contrast to the twigs). The occurrence of nymphs and adults reached a peak in December and January. The present study also assessed the population dynamics in relation to weather factors.

Key words: *Otinotus oneratus*, *Tamarindus indica*, bioecology, behavioure, parental care, ant attendance, predation, mimicry, colouration, population dynamics, weather factors

The family Membracidae comprises small to medium sized phytophagous insects popularly known as 'cow bugs', 'horn bugs', and 'tree hoppers'. The existence of intraspecific variations among the membracids was established through the contributions of Ananthasubramanian and Ananthakrishnan (1975a) on Indian species. In India, these insects are represented by three subfamilies, viz., Oxyrhachinae, Centrotinae and Darthulinae and have not received an adequate attention except for the habitual aspects (Behura and Panda, 1951), behavioural and bioecological studies (Ananthasubramanian and Ananthakrishnan, 1975a,b), and biosystematics (Ananthasubramanian, 1987). Misra et al. (2003) and Sharma and Pati (2011) recorded the presence of *Oxyrhachis tarandus* F. on mulberry tree and *Withania somnifera* (L.) Dunal, respectively. Nettimi and Iyer (2015) and Radha and Susheela (2016) reported on the myrmecophilous mutualism between treehoppers and ants. Recently Rajkumar et al. (2021) reported on the behavioural aspects of *Leptocentrus taurus* Fabricius, *O. oneratus* and *O. taranda* on their host plants. Remarkably, the population dynamics of membracids have been investigated in relation to weather parameters. Funkhouser (1917) studied ecological factors like temperature and humidity on the membracid species, while Ananthasubramanian and Ananthakrishnan (1975b) and Devarajan (1984) made preliminary studies on the population dynamics in relation to weather factors of common membracids, viz., *O. oneratus* and *Oxyrhachis rufescens* Walker, respectively. Mitchell and Newsome (1984) reported that the seasonal changes in temperature influenced the nymphal duration, egg incubation period and oviposition behaviour of the three cornered alfalfa hopper *Spissistilus festinus* Say. Nixon and Thompson (1987) stated the effect of temperature on hatching and nymphal development of membracids. Rajkumar et al. (2001, 2011a,b,c) evaluated the population dynamics of

three membracids, viz., *L. taurus*, *O. oneratus*, and *O. taranda*. The association between the membracid and the host plant is so characteristic that the knowledge of the one is sufficient to recognise the other. Though this statement holds well for several species of Indian membracids, the species in the present study is polyphagous. Consequently, the present research has documented its report on the behavioural, bioecological and population dynamics aspects of *O. oneratus* on its host plant *T. indica*.

MATERIALS AND METHODS

The membracid, *O. oneratus* was studied by regular field observations, and collection was done by hand picking every fortnight by choosing ten twigs of *T. indica* in and around Binny Quarters at Pattalam near Perambur Barracks road, Chennai, Tamil Nadu, India (13.1180566°N, 80.2404789°E) for a period of eight months from September 2018 to April 2019. The glass tube enclosure method was used to study the bioecological and behavioural aspects, viz., feeding, resting, locomotion, mating, oviposition, parental care, and the honeydew secretion by nymphs when ants were introduced, besides mimicry and colouration. Live branches of its host plant containing adults were enclosed in a specially designed glass tube open at both ends. One end of the tube was closed by a cork, made up of two halves, which was grooved in the middle in such a way that the nymphs will not escape. The host plant twig was inserted through the tube so as to enclose the eggs, nymphs and the adults. The other end of the glass tube was plugged with cotton wool which prevented escape from the tube. Egg clusters were collected and reared in test tube enclosure to study the incubation period, hatching, and the duration of immature stages of this insect. Laboratory cultures were maintained for supplementing and confirming the field observations. Fresh twigs of its host plant containing egg clusters or nymphs of different stages were cut at the basal end and dipped in Knop's solution kept in a conical flask covered with a rubber cork. The twigs were enclosed in a mesh chamber kept over the conical flask. The twigs were replaced by fresh ones, once in four days. Nylon nets with medium sized meshes were tied on to the host plant for close observation of predation by natural enemies. The population dynamics of this bug was assessed in relation to the weather parameters, viz., temperature, relative humidity, rainfall, and wind speed, and their data were obtained from Meteorological Research Station, Nungambakkam, Chennai, Tamil Nadu, India. Statistical analysis was performed using SPSS software (SPSS, 2010) to work out the correlation coefficients of incidence of nymphs and adults of *O. oneratus* with weather factors.

RESULTS AND DISCUSSION

Field observations in the present study documented that *O. oneratus* was found on the young tender twigs of *T. indica*. The nymphs led a gregarious life during their early stages, while the later nymphal and adults were solitary. The daily activity observed with reference to their behavioural aspects was found to be more active during 11:00 and 16:00 hr, and on extremely warmer days. This diurnal rhythm may be due to the fact that many predators of this bug are less in numbers during the heat of the day, however, this may be only an assumption and it requires more intensive studies to confirm or disprove it. Feeding was observed at almost any hour of the day, however, the most favoured time was in the mid afternoon. Adults preferred woody internodal parts, while the early nymphal stages fed on the axil of the leaves, and the later nymphs fed on the internodal parts along with the adults. The feeding behaviour of *O. oneratus* is a leisurely one (Funkhouser, 1951). During this study, the nymphs and adults remained in one spot for a long time, and showed little disposition to seek new feeding places. Most adults rested on horizontal branches with their head directed upward, and away from the main trunk. The mean number of males and females facing upward and downward was 3.0 and 4.6, and 2.4 and 3.6, respectively. The mean number of nymphs facing towards and away from node was 79.7 and 17.1, respectively (Fig. 1). Conversely, the downward posture may be an adaptation to jump down to the ground at the sign of danger as reported by Devarajan (1984) in *O. rufescens* adults whose head faced downwards.

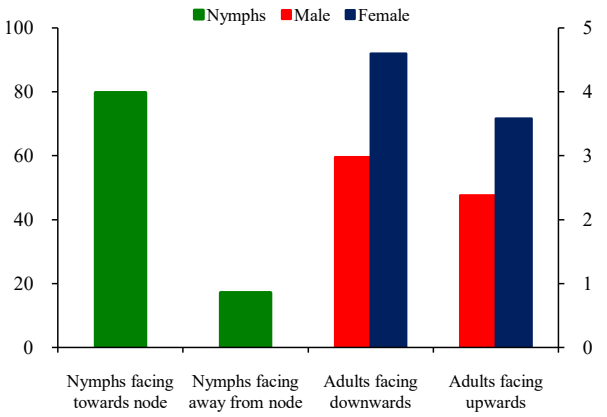

Fig. 1. Resting posture of *O. oneratus*

Oxyrhachis oneratus movement was sluggish, and when disturbed, moved in a spiral manner around the twig of the host plant, and stopped their movement after moving to some distance. Adult males were more easily disturbed than the females and they exhibited a tendency to take to their wings on continued disturbance. Nymphs were incapable of flight when disturbed, and crawled around the twig in a spiral fashion, and settled down on a node far away from the point of disturbance as reported by Funkhouser (1951). A single female was surrounded by four to seven males, and for unknown reasons, all but one moved away in the present study. The pair remained for several hours in copula with their heads facing opposite directions. Mating occurred for 5 min, and thereafter, the male disengaged and moved away, and the female passed into the preoviposition period, and invariably oviposited on the young twigs of the host plant. Observation made on the mating behaviour of *Platycotis vittata* F. by Wood et al. (1984) showed that females mate up to five times, and the present study also revealed similar sequences.

Preoviposition period of 5-10 days was observed after mating (Funkhouser, 1951), while in the present study, it occurred for 3 days. Females possessed strong and powerful ovipositors, and searched for a suitable ovipositing site on the host plant, before making the puncture. In the act of oviposition, the ovipositor was held at right angles to her abdomen, and numerous eggs were laid in 'V' shaped manner, arranged in two rows wherein each row converged at one end and diverged at the other, and each row contained 12-19 eggs. The eggs were shiny white, elongate, with a slight curvature, while its basal part was round and its tip appeared club-like as in *L. leucaspis* Walker (Ananthasubramanian and Ananthakrishnan, 1975b). Membracids exhibit maternal care to the nymphs (Urquizo et al., 2020). In the present study, of *O. oneratus* guarded 71.4 to 83.3% of egg masses (Fig. 2), and in case a female was dislocated, another female took over the duty of guarding the eggs. Further, they showed aggressive behaviour to the enemies, by repelling them, thereby increasing the survival value of the eggs.

The incubation period was for a minimum of eight days and a maximum of 12 days, and extended to more than nine days in October and November (Fig. 3). This difference in the incubation period appear might be due to the effects of temperature, moisture, and humidity as extreme temperature and low humidity may retard embryonic development (Ananthasubramanian and Ananthakrishnan, 1975a,b). Hatching occurs during the

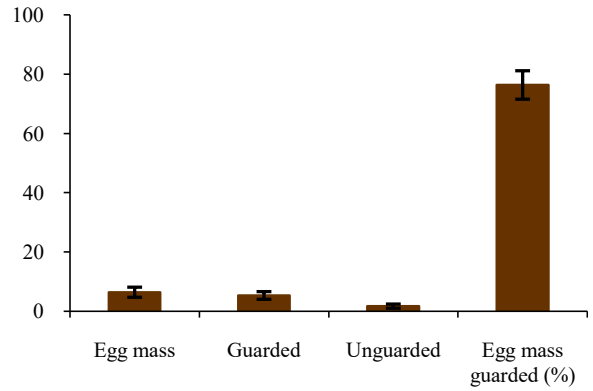

Fig. 2. Parental care of *O. oneratus*

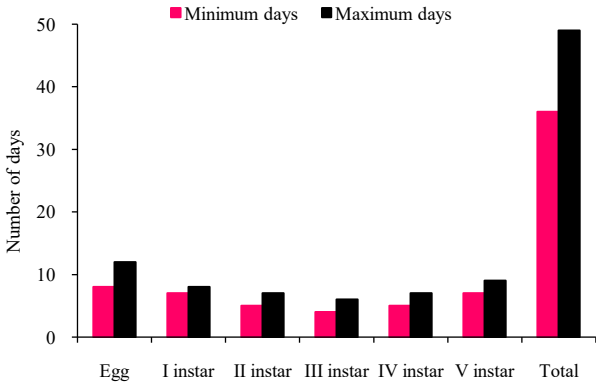

Fig. 3. Incubation period of *O. oneratus*

morning, and the whole process of hatching takes about 15 to 30 min, prior to which, the eggs increase in size, turns yellow, and the duration of egg stage differs, with a minimum of 5 days, and to a maximum of 16 days (Ananthasubramanian and Ananthakrishnan, 1975b). The same was observed in the present study too. During hatching, the hatching membrane which enclosed the embryo ruptured, the egg cap was forced upwards, and the head of the nymph projected out. The nymphs then pulled the terminal part of their abdomen out of the shell and rested for a while. Nymphal stages of membracids are caressed by ants for their anal secretion which are consumed by ants, and they in turn afford protection against predators and natural enemies (Nettimi and Iyer, 2015; Radha and Susheela, 2016). In the present study, *O. oneratus* nymphs were attended by the large black ant *C. compressus*, and the ant attendance was between 56.5 and 92.9% (Fig. 4). Similar observations were made by Sharma and Sundarraj (2011) on *Leptocentrus longispinus* Distant, *O. oneratus* and *O. tarandus*; and by Seni (2021) on *O. oneratus* and *L. taurus* which also demonstrated the value of ant attendance in increasing the survival value of nymphs. The nymphs behaviour ensured easy honey dew collection by ants, thereby

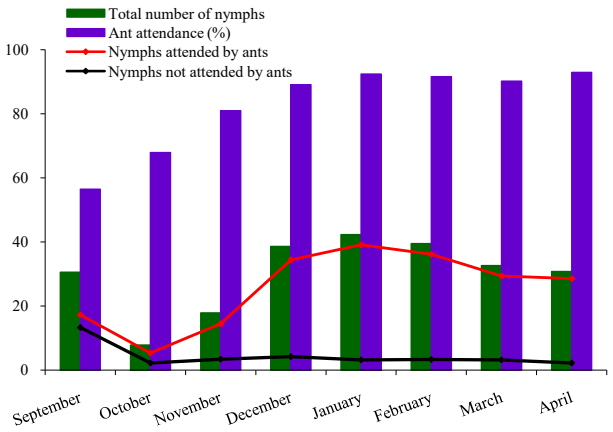

Fig. 4. Ant attendance to *O. oneratus*

making trophobiosis a success as reported by Gjonov and Lapeva-Gjonova (2013).

In the present study, *G. brevifuniculatus* and *M. afrangiata* attacked the eggs of *O. oneratus*. No nymphal parasitoids was observed. Similar predation was reported by Ananthasubramanian and Ananthakrishnan (1975b) on membracid eggs by chalcidoid hymenopterans. Ananthasubramnian and Ananthakrishnan (1975a) proved the value of mimetic behaviour and cryptic colouration in the survival rate of membracids wherein they reported the mimetic nature of membracids body form and colour patterns that blend remarkably with the bark, flowers, buds, stipules, spines, and fruits of their host plants. In the present study, *O. oneratus* nymphs mimicked the thorns of the host plant, but with regard to their colouration, they were brightly coloured in contrast to the colour of the twigs on which they inhabited, and therefore were easily attacked by predators.

The population of *O. oneratus* gradually increased from December 2018 to April 2019, and its density showed the highest peak in the months of December, January and February. Decrease in their population was observed in the months of October and November (Fig. 5). Among the nymphs, the population of I instar was more when compared to other nymphal instars, and V instar was the least (Fig. 6). The adult population showed more number of females when compared to males. The average male: female sex ratio was 1:4.1, and was maximum in October (1: 5.4) and February (1:5.7) (Fig. 7). Student 't' test performed between the nymphs and adults was found to have a high level of significance between them, and the calculated 't' test value between males and females was found to be greater than the table value at 95% level of significance which indicated a significant difference between them

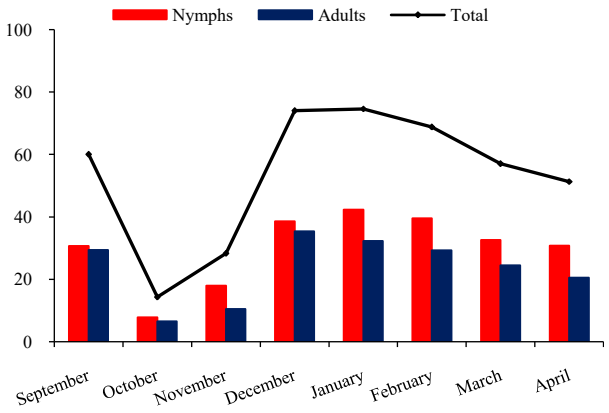

Fig. 5. Population dynamics of *O. oneratus* -adults

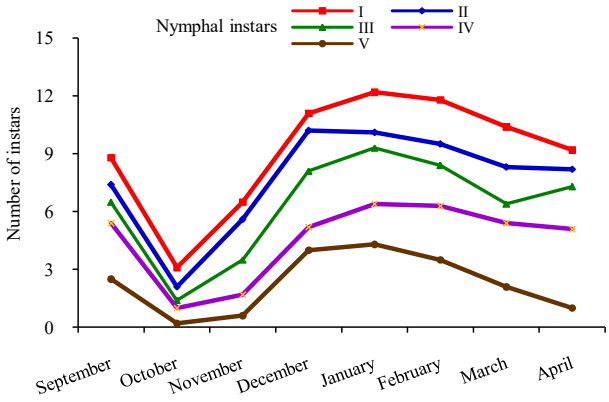

Fig. 6. Population dynamcis of *O. oneratus*- nymphs

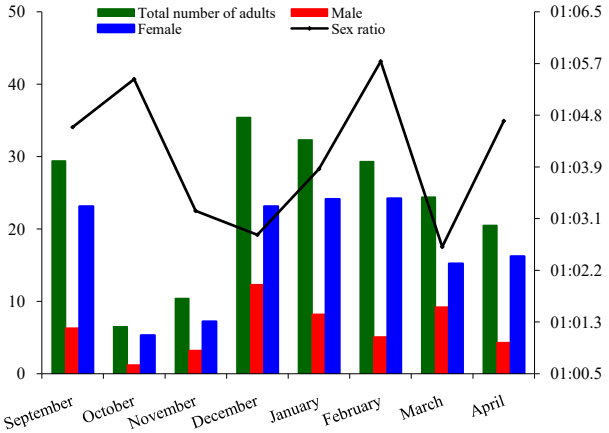

Fig. 7. Sex ratio of *O. oneratus*

(Table 1). The weather parameters, viz., temperature, relative humidity, rainfall, and wind speed played a vital role in changing the population structure (Fig. 8), and the fluctuations were statistically correlated (Table 2).

The present study brought to light that the weather parameters played a significant role on the population fluctuation of *O. oneratus* and their peak period based on the seasonal periods. Temperature played a vital role

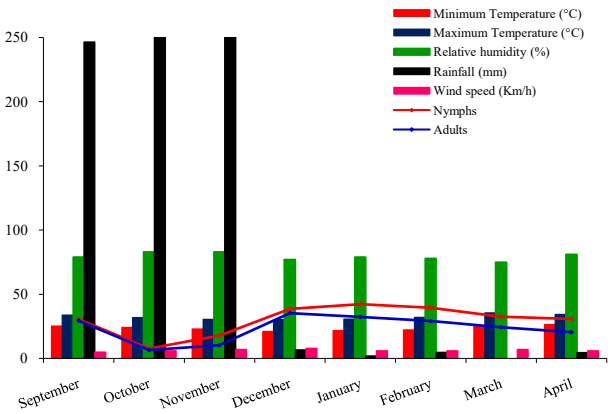

Fig. 8. Effect of weather parameters on *O. oneratus*

Table 1. Student 't' test analysis between nymphal and adult populations of *O. oneratus*

Nymphal and adult population	Mean± S.D.	't' value
Total with I instar	-20.88± 8.70	-6.785*
Total with II instar	-22.34± 9.06	-6.971*
Total with III instar	-23.65± 9.10	-7.351*
Total with IV instar	-25.45± 9.78	-7.363*
Total with V instar	1.46± 10.33	-7.594*
I with II instar	2.78± 0.61	6.815*
I with III instar	4.58± 0.78	10.188*
I with IV instar	6.86± 1.31	9.852*
I with V instar	1.31± 1.85	10.483*
II with III instar	3.11± 0.61	6.081*
II with IV instar	5.40± 1.19	7.414*
II with V instar	1.80± 1.59	9.605*
III with IV instar	4.09± 0.91	5.612*
III with V instar	2.29± 1.52	7.602*
IV with V instar	2.29± 1.18	5.471*
Total with male	-47.31± 19.07	-7.02*
Total with female	-36.24± 14.60	-7.02*
Female with male	-11.08± 5.92	-5.29*
Total with nymphs	-23.53± 10.41	-6.40*
Total with adults	-30.01± 11.73	-7.23*
Nymphs with adults	-6.49± 3.97	-4.62*

on the nymphal and adult populations. Moderate rainfall did not have any substantial influence, however, heavy rainfall did reflect on its population density in October and November. The population reached the peak in December and January due to congenial condition involving moderate temperature, relative humidity, rainfall and wind speed. Ali et al. (2008) reported that the population density of *O. tarandus* was associated with temperature, relative humidity, rainfall, and vapour pressure. Lopes (1995) reported that the abundance of membracids were high from the months of October to February, while from March to September, they showed a decrease in their numbers. Rajkumar et al. (2001) reported that the population density of *O. taranda*

Table 2. Statistical inferences between population of *O. oneratus* and weather parameters

Weather parameters	Correlation coefficient	Regression equation	't' value
Minimum temperature (°C)	-0.394	Y=25.223-7.06E-02X	-1.046
Maximum temperature (°C)	-0.030	Y=32.471-5.66E-03X	-0.073
Relative humidity (%)	-714	Y=330.998-9.076X	-2.281
Rainfall (mm)	-776**	Y=84.331-0.211X	-3.013
Wind speed (Km/h)	0.084	Y=6.200+7.422E-03X	0.207

*Significant at p=0.01; **Significant at p=0.05%

attained its peak in September, declined in October due to heavy rainfall, and was then stable from December to February, and thereafter in March, April and May, decreased due to increase in temperature. It was shown that the population fluctuation of both the nymphs and adults had a positive correlation to temperature only to a certain extent, because at very high temperature, the population was affected and the population remained quite static. The population of *L. taurus* (Rajkumar et al., 2011a), *O. oneratus* (Rajkumar et al., 2011b) and *O. taranda* (Rajkumar et al., 2011c) reported highest peaks in the months of October, November and December due to rainfall, and its decline in May due to high temperature, besides less rainfall and relative humidity. Bijewar et al. (2018) and Brahman et al. (2018) also reported that the population of *O. oneratus* was high in September and October. Henceforth, the precise role of various abiotic and biotic factors on the population fluctuation of membracids are to be determined by further studies.

Although the present findings has brought to light the salient ecological and behavioural aspects of *O. oneratus*, future line of investigations are needed, and studies on membracids exposed to different species of plants may show more ecological and biological aspects when ventured in different geographical regions of host diversity.

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