

Parasites and predators of *Pauropsylla Depressa*, A gallinaceous insect of *Ficus Glomerata*

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Abstract

Ficus glomerata, commonly known as the cluster fig tree, is a key component of tropical ecosystems, providing essential ecological services and serving as a crucial habitat for various fauna. This review focuses on the diverse array of parasites associated with *Ficus glomerata*, exploring the intricate host-parasite interactions that shape the ecological dynamics of this plant species.

The study encompasses a thorough examination of the different types of parasites affecting *Ficus glomerata*, including insects, fungi, nematodes, and other pathogens. Special attention is given to the life cycles, modes of transmission, and the impact of these parasites on the health and reproductive success of the host tree. Additionally, the role of environmental factors and climate conditions in influencing parasite prevalence and distribution is discussed. Understanding the complex relationships between *Ficus glomerata* and its parasites has broader implications for ecosystem management, conservation, and agricultural practices. The review emphasizes the importance of considering these interactions in the context of biodiversity conservation and sustainable land use. Furthermore, potential strategies for mitigating the negative effects of parasites on *Ficus glomerata*, such as integrated pest management and ecological restoration, are explored.

A pair of parasites There are records of seven predators and one pathogen on it. In addition to this one, hyperparasites are also discovered, which lowers the parasite's ability to regulate its own biocontrol efficacy. Using a tube, the larva of *Bracon* sp. attaches itself to the abdomen of the fifth instar nymph, feeding on its abdominal contents and ultimately causing its death. The recorded parasitization rate ranged from 4 to 45%. The *bracon* species is hyperparasitized by a black eulophid wasp and parasitization rate between 2 and 15% of the time. Furthermore, a third instar nymph of *P. depressa* is parasitized by an unidentified endoparasitic encyrtid wasp. It lays its eggs inside the host's body, and once it has eaten through the host's bodily tissue, its larva mummifies the host and pupates inside of it. By making a hole in the mummy and hiding behind the meconium and empty shell, the adult emerges. The percentage of parasitization ranged from 5 to 92%. *P. depressa*'s predators include common mynah (*Acridotherus tristis*), red bunted bulbul (*Pycnonotus cafer*), thrip (*Cercothrip tibialis*), spider (*Aranarus tristis*), and an unidentified red mite. Additionally, *Formicid* ants of *Camponotus* sp. and *Enictus* sp. prey mantis (*Hierodula* sp. It has also been noted that the pathogen *Aspergillus flavipus* infests nymphs and galls. Some of these biocontrol agents, such as *bracon* species and *encyrtid* wasps, may be mass-produced in the lab and released into the field to monitor *P. depressa* populations. These agents are crucial in managing the *P. depressa* population.

Keywords: *Puropsylla depressa*, parasites, predators, pathogen, *Bracon* sp

Introduction

Ficus glomerata Roxburgi is severely harmed by *Pauropsylla depressa* Crawford (Homoptera: Psyllidae), which infests the plant and causes galls on its leaves. When there are severe infestations, the leaves become completely glomerated with many galls. On various sections of their host plants, *Pauropsylla depressa* produce galls. On it, records of two parasites, seven predators, and one pathogen exist. In addition to this one, hyperparasites are also identified, which lowers the parasite's ability to regulate its own biocontrol efficacy. It has also been observed that the pathogen *Aspergillus flavipus* (Table 1) infests nymphs and galls.

Ficus glomerata Roxb. is a member of the Moraceae family. *Ficus glomerata* is referred to as Gular in India. It is referred to as Umbhar in Marathi. The plant is widely found throughout India, especially in the states of Maharashtra, Karnataka, Punjab, Bihar, and Rajasthan. Since ancient times, plants have been utilized for a variety of purposes, such as the creation of diabetes treatments Beeson, (1941) [1].

Reportedly beneficial for gynecological disorders, the plant's bark has a strong taste. There is a healing claim made

about the Gular tree's bark. In countries such as India, bark is ground into a paste by rubbing it against a stone and adding water. The resulting paste is then applied to the skin affected by boils or mosquito bites, drying on the skin for a few hours before being reapplied. This is a very easy do-at-home remedy for people whose skin is particularly sensitive to bug bites. Its fruits are eaten as an expectorant, emollient, stomachic, and carminative, and are thought to be tonic and beneficial in the treatment of intestinal worms, leucorrhea, blood disorders, burning sensations, and urine discharge Chen, (2005), Czczuga (1977) [2, 3].

Moreover, it is utilized in dental preparations, piles, asthma, and skin conditions Dhiman, & Arora (2002), Inbar *et. al.*, (2010) [4, 5]. It has been reported that chemical components including flavonoids, carbohydrates, alkaloids, tannins, glycosides, saponin, and steroids are present in plant extracts from *Ficus glomerata*.

In one way or another, the host plant of this psyllid is extremely important to humans. Cattle and elephants eat the leaves of this plant. Fruits are used as a laxative and to make cold jelly; waterproof bonded papers and ground sheets are made of latex. Wood is used to make toys, agricultural tools, matchboxes, and furniture. It is one of the Indian lac insect's

known hosts. Roots can help with dysentery. The dried powder of the leaves, when combined with honey, is too useful to be wasted.

A few of these biocontrol agents, such as *bracon species* and encyrtid wasps, may be mass-produced in the lab and then released into the field to monitor *P. depressa* populations. These agents are crucial in managing *P. depressa* populations.

Furthermore, it is widely known that throughout the past century, parasitoids have played a significant role in traditional biological control programs in agroecosystems (Heimpel and Mills 2017, Wang *et. al.*, 2019) [6, 7].

Materials and Methods

Ficus glomerata, sometimes referred to as *Ficus racemosa* or Gular, is a host plant in the Moraceae family that is mainly impacted by the Psyllidae family gall-forming insect *Pauropsylla depressa*.

Sample Collection

In the month of November 2023, a sample of insects was collected from the host plant, *Ficus glomerata* (*F. racemosa*), located on the campus of Shaheed Mangal Pandey Govt. Girls P.G. College, Madhavpuram, in the Meerut District, where the principal host plant of *Ficus glomerata* is located. As a result, the sample is selected by hand and put in polythene bags with the galled leaves of the *F. glomerata* plant.

Mature *Ficus glomerata* leaves, both galled and ungalled, were collected from plants that were infected and those that were not. Additionally, some samples are taken from the *F. glomerata*'s bark and roots. The collected gall insects are grown in the Institute's laboratory using hurricane lantern chimneys with fire muslin cloth covering the top and wooden wire gauge cages. Stale food is replenished and fresh food is regularly provided.

The ectoparasite (outside) insects of *P. depressa* were gathered using tweezers; the endoparasite (inside) insects of both sexes were trapped using a dragnet trap; and flying

insects were caught using an insect dragnet. The insect samples were then sorted, separated into glass bottles, and put inside a plastic box (15 x 15 x 30 cm³) with screen ventilation to preserve the samples' viability.

A. Identification

The Basic Entomological key was used to identify and record the samples contained in the bottle. Under a microscope, small-size samples were identified and documented. Samples that belong to the families of predators and parasites are identified down to the species level.

3. Results

The current study's results confirm that the parasitoid's longevity and the length of its immature stages were significantly influenced by the type of host. Based on our observations, we discovered that within a few days of oviposition, *Pauropsylla depressa* decomposed and turned rotten or dry.

Two parasites, seven predators, and one pathogen have all been identified in this study. In addition, hyperparasites are also discovered, which lessens the parasite's ability to regulate its own biosynthesis. There were two types of parasites: endoparasitic encyrtid wasp and ectoparasite bracon sp. larvae (Fig. 1). Seven predators of *P. depressa* were also identified in addition to the parasites: *formicid* ants of *Camponotus* and *Enictus sp.*, preying mantis of *Hierodula sp.*, common mynah of *Acrotherus tristis*, red bunted bulbul of *Pycnonotus cafer*, thrip of *Cercothrips tibialis*, spider of *Aranarus tristis*, and an unidentified red mite. Additionally, it was noted that the pathogen *Aspergillus flavipus* was infesting nymphs and galls (Table 1).

In this manner, pathogens, parasites, and predators were recognized. In addition to this single hyperparasite, a black eulophid wasp was also discovered, which lessens the parasite's ability to regulate its own biocontrol.

Table 1: List of Predators, Parasites, Parasitoid, Pathogen and Major and Minor Natural enemies of *Pauropsylla depressa*.

Type of Parasites and Predators	Name of species	Insect	Parasitism Stage	Host Plant
Parasitoid	Eulophid wasp	<i>Bracon sp.</i>	Hyperparasite of <i>Bracon sp.</i>	<i>Ficus glomerata</i> leaves gall
ectoparasite	Bracon sp.	<i>Pauropsylla depressa</i>	5th instar nymph bracon sp. larva attached to the abdomen	<i>Ficus glomerata</i> leaves gall
endoparasite	Encyrtid wasp	<i>Pauropsylla depressa</i>	3rd instar nymphs of <i>Pauropsylla depressa</i>	<i>Ficus glomerata</i> leaves gall
Predator	Small Ants <i>Camponotus sp.</i> and <i>Myrmica sp.</i> ,	<i>Pauropsylla depressa</i>	All stages	<i>Ficus glomerata</i> [<i>Ficus racemosa</i>] leaves
Predator	Preying mantis (<i>Hierodula sp.</i>),	<i>Pauropsylla depressa</i>	All stages	<i>Ficus glomerata</i> leaves gall
Predator	Small red-coloured mite,	<i>Pauropsylla depressa</i>	All stages	<i>Ficus glomerata</i> leaves gall
Predator	Spider (<i>Araneus sp.</i>)	<i>Pauropsylla depressa</i>	All stages	<i>Ficus glomerata</i>] leaves gall
Predator	Common mynah (<i>Acridotheres tristis</i>),	<i>Pauropsylla depressa</i>	All stages	<i>Ficus glomerata</i> leaves gall
Predator	Red-bunted bulbul (<i>Pycnonotus cafer</i>),	<i>Pauropsylla depressa</i>	All stages	<i>Ficus glomerata</i> leaves
Predator	Thrip (<i>Cercothrips tibialis</i> [<i>Gigantothrips tibialis</i>])	<i>Pauropsylla depressa</i>	All stages	<i>Ficus glomerata</i> leaves gall
Pathogen	Fungus (<i>Aspergillus flavipes</i>),	<i>Pauropsylla depressa</i>	All stages	<i>Ficus glomerata</i>] leaves gall

Life cycle of *Pauropsylla depressa*

Study was done on the life cycle of the psyllid *Pauropsylla depressa*, which produces galls on *Ficus glomerata* leaves. After the adult females laid eggs, five nymphal instars appeared. In every way, the female *P. depressa* was larger

than the male. In terms of color, the male was darker than the female. There were five nymphal instars that completed the life cycle. It was observed that the 5th instar from the gall emerges more frequently at night, when it moults into imago on the leaf surface (Plate 1).

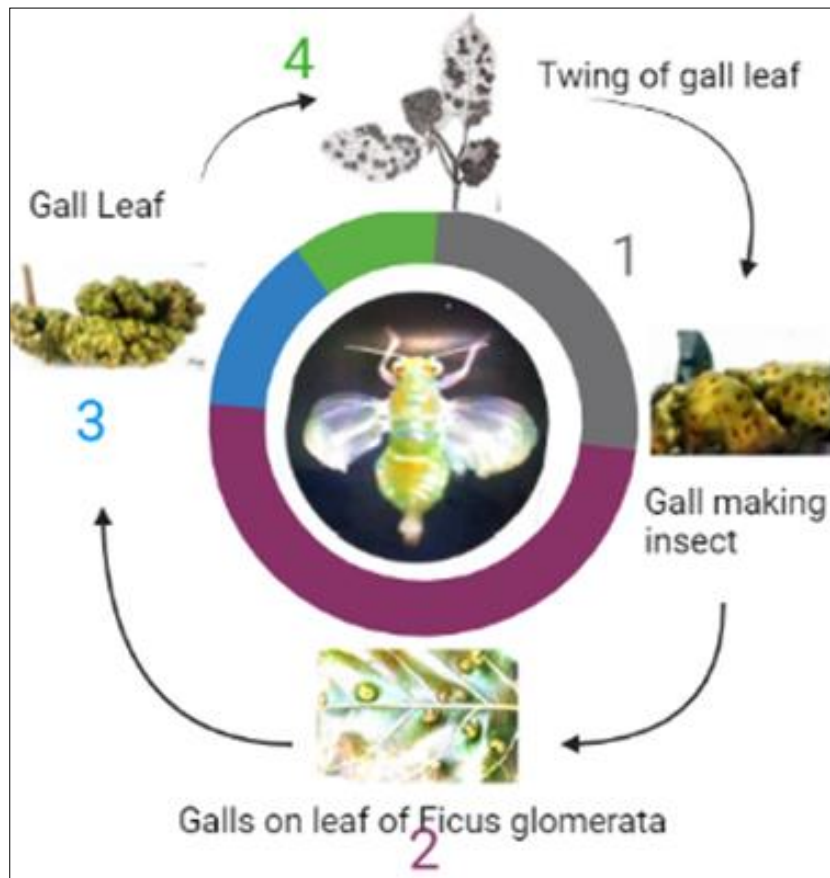
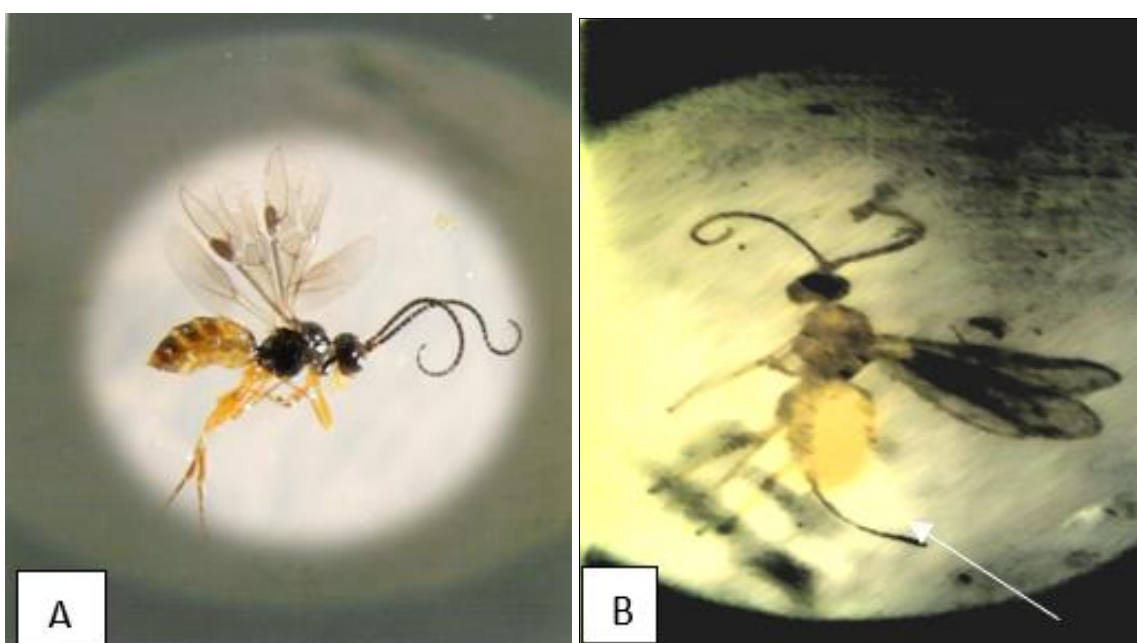


Plate 1: Life cycle of *Pauropsylla depressa*

Ectoparasite of *Bracon sp.*

Bracon sp. (Hymenoptera: Braconidae) was an ectoparasite. Within the family of parasitoid wasps, the Braconidae, is

home to the genus *Bracon*. In the (figure -1) showing adult of male and female ectoparasite of *Bracon sp.*



Graph 2: Percentage of infestation by endoparasite of *encyrtid wasp* within the body of third instar nymph of *P. depressa* on month November 2023.

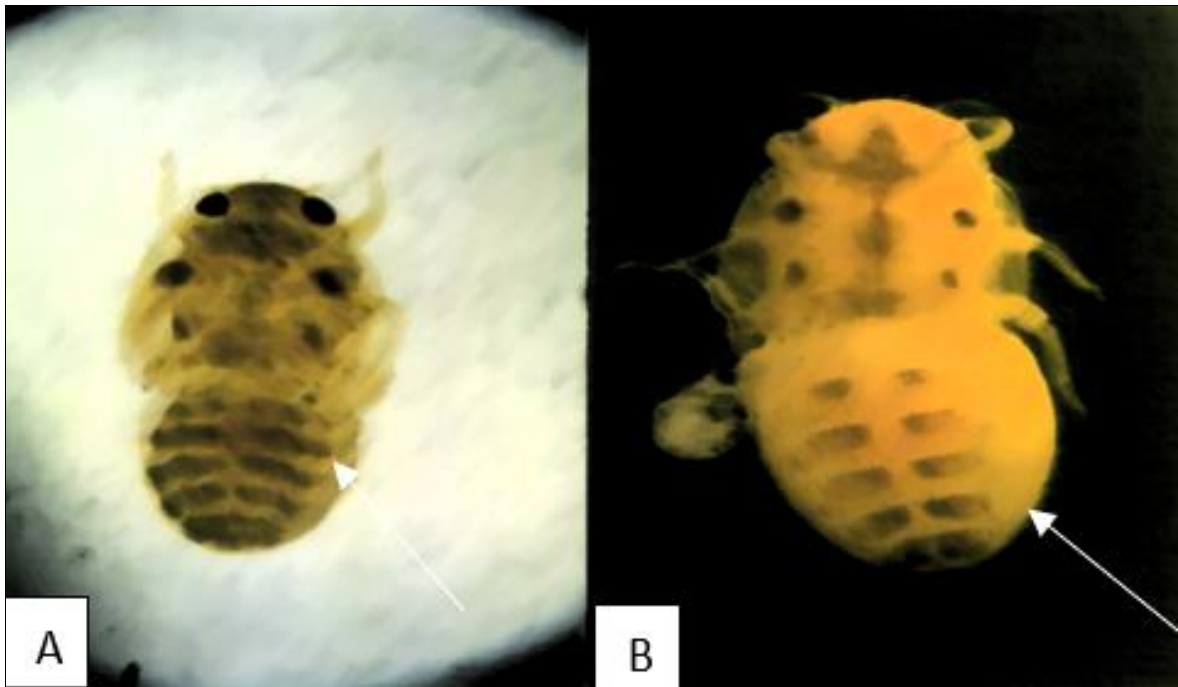


Plate 3: A & B Fifth instar nymphs of *P. depressa*

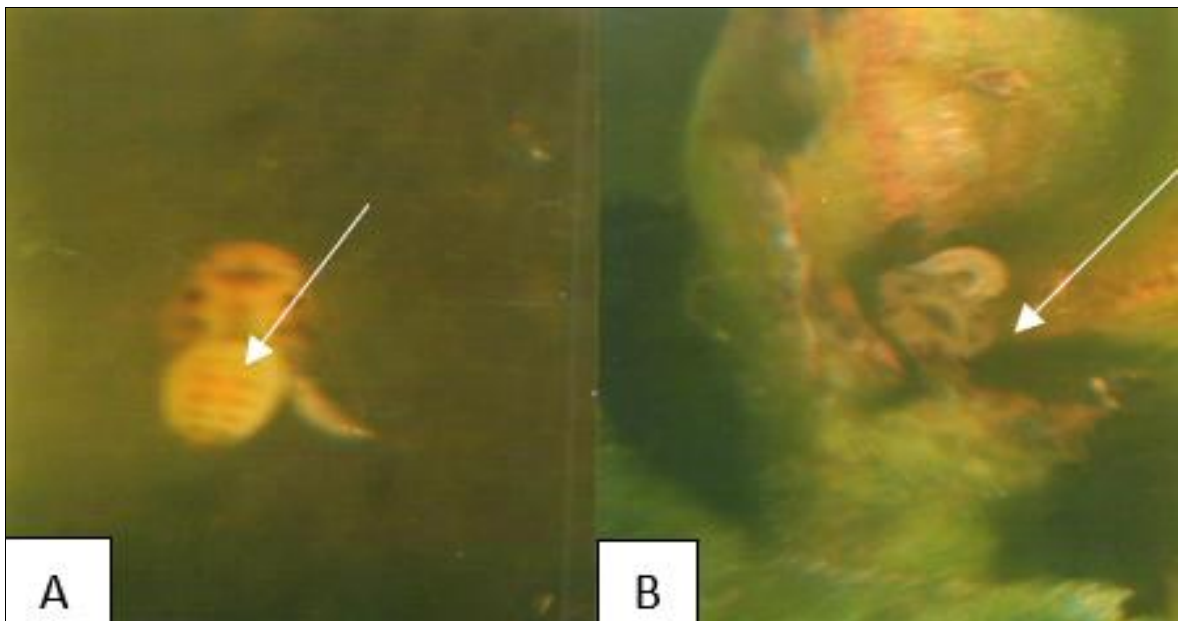


Plate 4: Larva of *Bracon sp.* attached to the fifth instar nymphs of *P. depressa*.

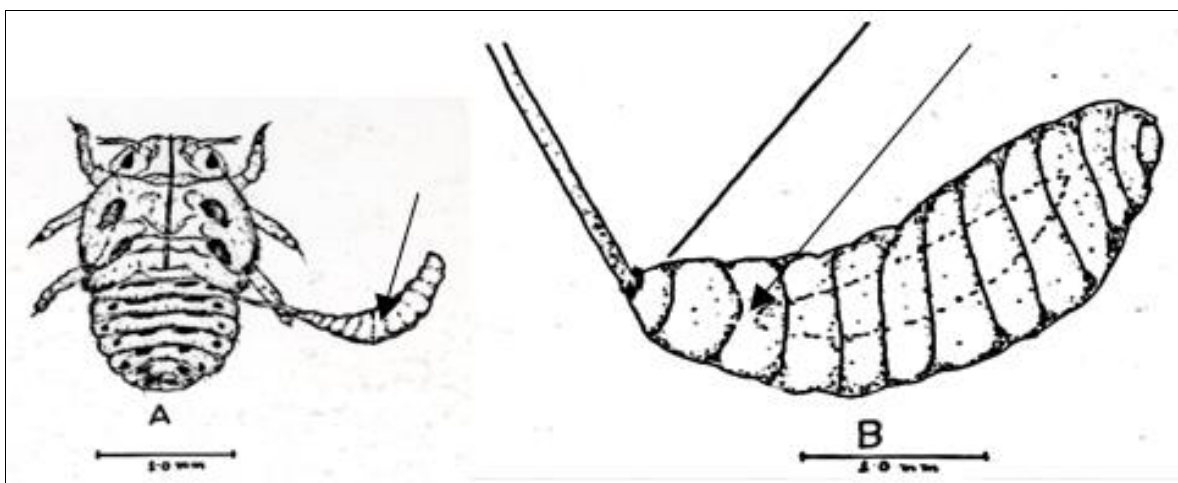


Fig 1: Larva of *Bracon sp.* attached to the fifth instar nymphs of *P. depressa*.

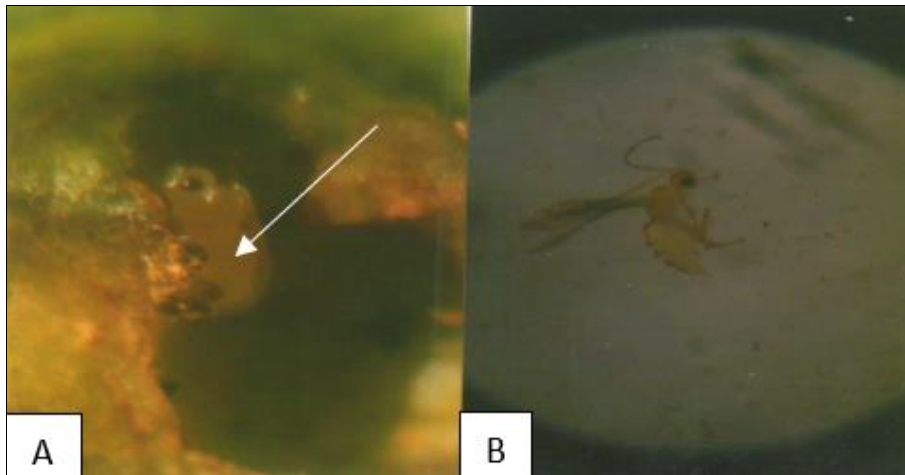
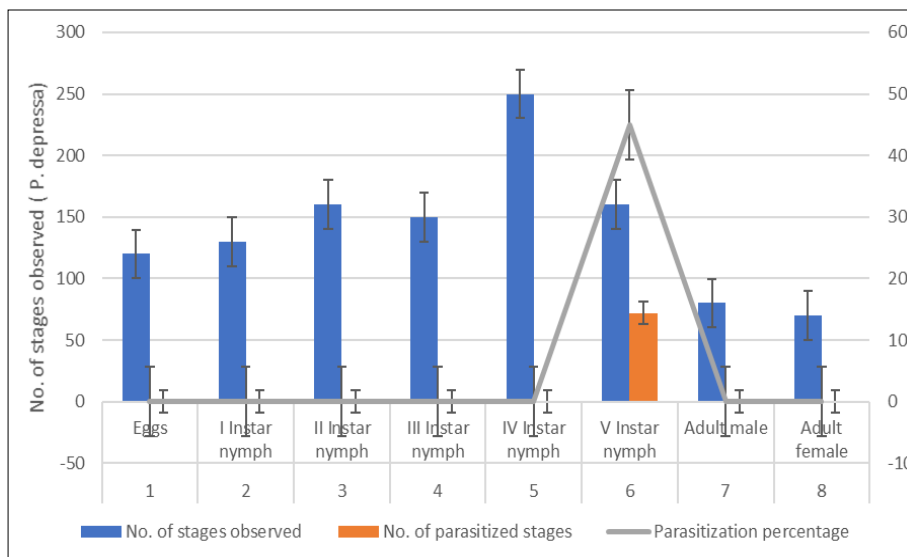


Plate 5: (A) Pupa of *Bracon sp.* (B) Adult of *Bracon sp.*



Graph 1: Infestation percentage of *bracon sp.* of various stages of Nymph *P. depressa* on month November 2023.

One parasite was the larva of *bracon sp* attaches to the abdomen of the fifth instar nymph of *P. depressa* with the help of a tube and feeds on its abdominal content finally causing its mortality. Parasitization recorded was 4 to 45% (Graph-1). A black eulophid wasp causes 3.9 - 17% hyper

parasitization of the *bracon species*.

Hyperparasite of Eulophidae family

The bracon species is hyperparasitized by a black eulophid wasp and parasitization rate between 3.9 - 17% of the time.

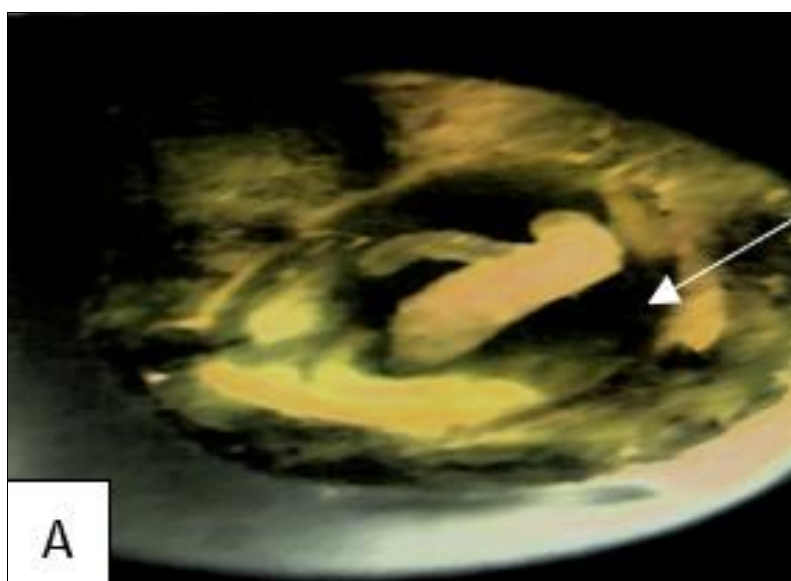


Plate 6: Larva of eulophidae family feeds on larva of *Bracon sp.* showing hyperparasitism.

Adults of *Eulophidae* family

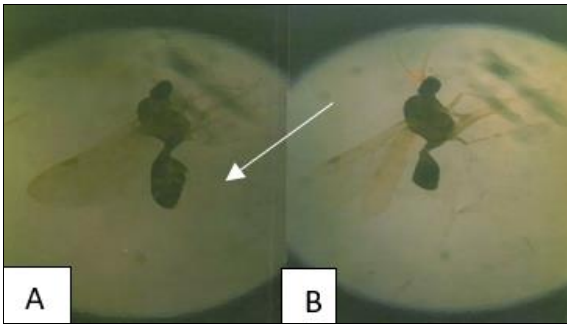


Plate 7: Male and Female of *eulophidae* family

Endoparasite

Black-coloured encyrtid wasp (Hymenoptera: Encyrtidae) was found to be an endoparasite of 3rd instar nymphs of *Pauropsylla depressa* (Plate 9).

Additionally, a third instar nymph of *P. depressa* is parasitized by an unidentified endoparasitic encyrtid wasp (Plate 8). After feeding on the host's bodily tissue, it lays eggs inside the host's body, mummifies the host, and pupates inside the mummy. By making a hole in the mummy and hiding behind the meconium and empty shell, the adult emerges. The percentage of parasitization ranged from 5 to 92% (Graph 2).

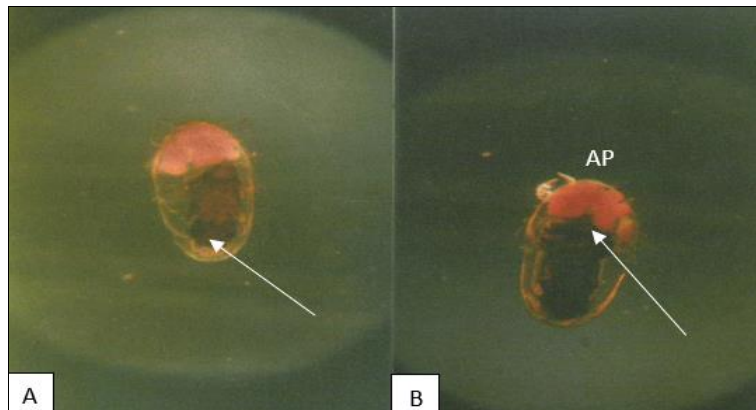
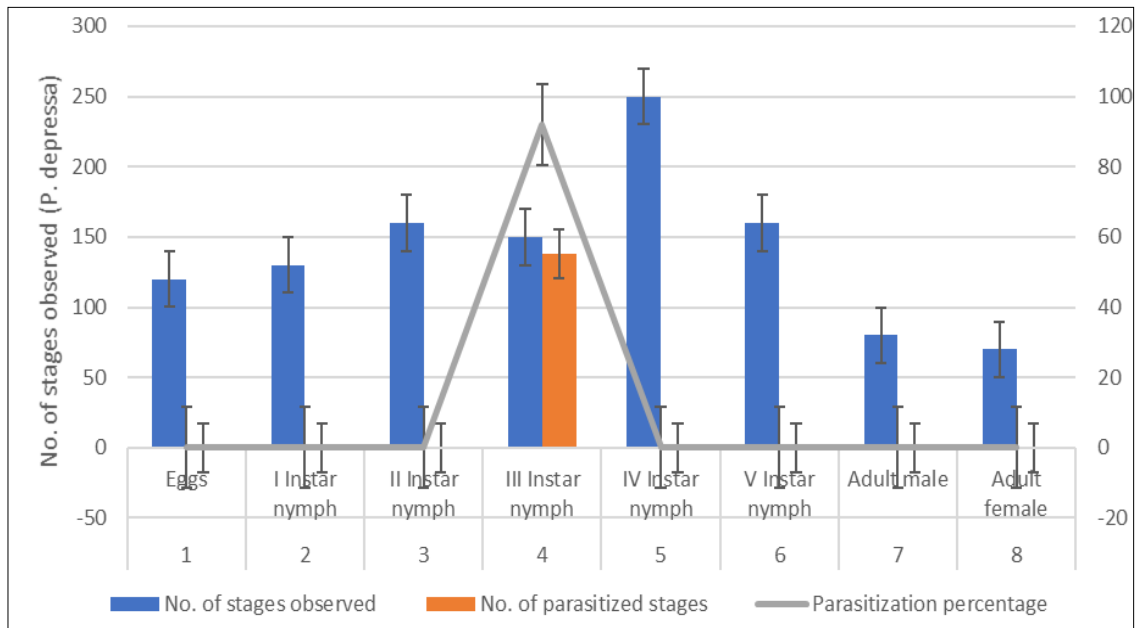


Plate 8: Adult encyrtid wasp within the body of third instar nymph of *P. depressa*.



Plate 9: Third instar nymph of *P. depressa*.



Graph 2: Percentage of infestation by endoparasite of encyrtid wasp within the body of third instar nymph of *P. depressa* on month November 2023.

Parasites and predators complex of *P. depressa*

Formicid ants of *Camponotus* and *Enictus* species, which feed on mantises (*Hierodula* sp.), common mynah (*Acridothrus tristis*), red bunted bulbul (*Pycnonotus cafer*), thrip (*Cercothrip tibialis*), spider (*Aranarus tristis*), and an unidentified red mite are the predators of *P. depressa*.

Pathogen: Galls and nymphs have also been observed to be infested by the fungus *Aspergillus flavipus*.

Discussion

The percentage of *Bracon* sp. infested at different stages of Nymph *P. depressa*. The percentage of parasitization ranged from 4 to 45%. The larval ectoparasitoid *Bracon* sp. (Hym.: Braconidae) was discovered near Bangalore, India, attached to the host larva's thorax. Within the tunnel that its host had constructed, it pupated in a silk cocoon and caused parasitization that ranged from 9.2% to 28.1%. As per Tewari and Sardana (1987a) [8], it was considered a promising parasitoid.

It is uncommon for several eulophid parasitoid species to parasitize ladybird eggs, and it seems to be limited to phytophagous ladybird hosts in the Epilachninae, Ceryngier and Hodek 1996 [9]. There is less selection for these interactions to evolve because newly hatched carnivorous ladybird larvae frequently engage in cannibalism, which increases the risk of predation of parasitized eggs Ceryngier and Hodek 1996. [9]. The most susceptible phases for parasitoids to attack in predatory ladybird beetles are the larval and pupal stages Ceryngier et al., 2012 [10]. *D. coccinellae*'s capacity to distinguish between hosts that are parasitized and those that are not is limited, as evidenced by the fact that superparasitism rates in their natural hosts can surpass 600% Ceryngier (2000) [11].

This outcome supported the findings of Gerling and Rotary (1973) [12], who stated that *Spodoptera littoralis* is an inappropriate host for *Bracon* sp. The genus *Bracon* belongs to the Braconidae family of parasitoid wasps. Even though Ameri et al. (2013) [13] have described several hundred species, thousands more are still undiscovered. The

Hernández et al., (2008), Žikić et al., (2012), Belshaw (2001) Papp et al., (2012) Magalhães et al., 2019 [14, 15, 16; 17, 18].

Research on the biology of parasitoids suggested that *B. brevicornis* was better suited for the laboratory host, *G. mellonella*. This was in contrast to the findings of regarding *Bracon* spp. on *C. cephalonica*, its laboratory host, and *Chilo partellus* (Swinhoe), its natural host. Temerak (1983) [19] also reported that *B. brevicornis* favored parasitizing and completing its life cycle on *Earias* spp., *H. armigera*, and *P. gossypiella* over other host insects that were possible. Furthermore, according to Thanavendan and Jeyarani (2010) [20], *B. brevicornis* was better suited for *C. cephalonica* and *E. vittella*, its natural host. According to Mohanty et al. (1998) [21], who reported that *B. brevicornis*'s biology was faster on *C. cephalonica* than on other insects, adult longevity was found to be short on *C. cephalonica* flowed by *G. mellonella*. Contrary to Dabhi's (2011) [22] report, which states that the maximum duration (44.30 days) for a female *B. hebetor* to complete her life cycle was recorded in *C. cephalonica*, followed by *S. cerealella*, Thanavendan and Jeyarani (2010) [20] found that adult longevity was more on *E. Vittella* and *C. Cephalonica*, followed by *H. Armigera*. According to our findings, *G. mellonella* was the most favorable host for oviposition when compared to other tested hosts; this could be because the larvae were rearing on rich diets in the larval bodies. However, Thanavendan and Jeyarani (2010) [20] discovered that progeny production was higher on *E. vittella* and *C. cephalonica* than on other host insects. Furthermore, the fecundities of *H. hebetor* reported by Amir-Maafi and Chi (2006) [23] were 66.3 eggs/female on *E. kuehniella* and 78.3 eggs/female on *G. mellonella*, which were lower than our findings. The variations in hosts, temperature, and even nutrition of hosts could be the cause of the discrepancies in results with other studies. The aforementioned findings indicate that the host has an impact on *B. brevicornis* biology. Compared to other hosts, where the female's lifespan was shorter and the total number of eggs deposited was higher, *G. mellonella* is thought to be a more suitable host for *B. brevicornis*.

Compared to younger or older larvae, this generalist larval parasitoid laid more eggs on *T. ni* larvae that were 2 days old. According to Boling and Pitre (1970)^[24], the minimum developmental time from oviposition to adult emergence from the host was six days. After a brief encounter with host larval frass or host-damaged cotton leaves, females exhibited a significant increase in reactivity to host odors (Turlings *et al.* 1989)^[25]. A non-occluded, filamentous, baculo-like virus was discovered to be present in the noctuid larvae of *C. marginiventris* from *T. ni* and four other species (Styer *et al.* 1987)^[26].

Percentage of infestation by endoparasite of encyrtid wasp within the body of third instar nymph of *P. depressa* was recorded 5 to 92%. The percentage of encyrtid wasp endoparasite infestation within the third instar nymph of *P. depressa* was found to range from 5 to 92%. One of the three primary parasitoids of *T. ni* on cotton (Ehler 1977a)^[27] and other crops in California is *Hyposoter exiguae* (Hym.: Ichneumonidae), a solitary endoparasitoid with a limited capacity to discriminate between hosts that are parasitized and those that are not (Beegle and Oatman 1975; Browning and Oatman 1984)^[28, 29]. All *T. ni* larvae are acceptable for ovipositing, but the female prefers to do so in the late first or second instar. When parasites started developing in hosts that were one day old, it took 13.85 days, but when they started developing in larvae that were ten days old, it only took 7.4 days (Smilowitz and Iwantsch 1975;^[30] After parasitization, *T. ni* larvae exhibit a markedly reduced rate of weight gain (Smilowitz and Iwantsch 1973; Iwantsch and Smilowitz 1975; Thompson 1982)^[31, 30, 32].

The rate of successful parasitization of *T. ni* larvae decreased with host age, reaching 27% in the middle of the fifth instar in older larvae and ranging from 83% to 88% in the first, second, and early third instars. Superparasitization decreased in later instars, with females depositing an average of 2.3 eggs in the first instar and 1.3 eggs in the second (Smilowitz and Iwantsch 1975)^[30].

Infected host larvae laid twice as many parasitoid eggs as healthy larvae. Six percent of healthy hosts that were later exposed to the infected hosts received infectious doses of the virus from the 60% of females that oviposited in infected hosts. 90% of the female parasitoids that developed in hosts infected with viruses were able to transfer infectious doses to an average of 21% of exposed healthy host larvae. According to Beegle and Oatman (1974)^[33], *T. ni* larvae parasitized by *H. exiguae* needed twice the amount of virus to infect them, and the parasitoid finished developing before the host larvae perished. Unless a virus or fluid from the parasite oviduct is added, washed *H. exiguae* eggs do not mature when injected into *T. ni* larvae (Vinson and Stoltz 1986)^[34]. Given that the effects of *H. exiguae* parasitization are visible 24 hours after oviposition and before the parasitoid hatches, it is likely that the metabolic alterations caused are caused by the *H. exiguae*-associated virus rather than the parasitoid itself (Thompson 1986)^[35].

Philippines-based *Apanteles* sp. (Hymenoptera braconidae) Navasero (1983)^[36] India only; ecto lab only; bracon greeni larva 1948; Venkatraman *et al.*^[37] Larva of *Bracon* sp.; ecto in India Sardana & Tewari (1987a)^[8]

Indonesian *Bracon* (Microbracon) phyllocnistidis (1933) Muesebeck;^[38] *Bracon* Sp. 1969 Barroga Japan's braconid Vietnam Ujiye (1988)^[39] N. van Cam (*Bracon phyllocnistidis*) pers. comm. 1994 This braconid may be the

same as the *Bracon* sp. reported from the Philippines (Barroga 1969)^[40].

Ants are ubiquitous and have a wide range of food sources, making them valuable biological control agents for agricultural pests (Way and Khoo 1992)^[41].

A black eulophid wasp hyperparalyzes the *bracon* species, with a parasitization rate ranging from 3.9 to 17%. With the exception of a few systems like the ladybird parasitoid *D. coccinellae* or the spider parasitoids *Zatypota* spp., the biocontrol effectiveness of parasitoids of arthropod predators has not gotten much attention. The majority of studies on these parasitoids have concentrated on phylogeny and taxonomy. Every predator group examined in this article has highly specialized parasitoids that are limited to particular families or genera of predatory hosts. This is especially true for ant and spider parasitoids, and it makes sense given certain peculiarities in their biology. There hasn't been much research done on the variables that influence parasitoids' foraging habits in natural settings as arthropod predators. Plant volatiles produced by herbivores serve as crucial foraging cues for parasitoids that feed on insect herbivores Turlings and Erb (2018)^[42]. As herbivorous prey, ladybird beetles, hoverflies, and lacewings may also rely on prey-induced plant volatiles as dependable cues to direct their parasitoids to their hosts. For example, Orre *et al.*, (2010)^[43] demonstrated that methyl salicylate, a common compound in volatile blends released by plants in reaction to herbivory, attracted *A. zealandica* (Figitidae), a parasitoid of lacewing larvae. As an alternative, direct cues pertaining to the predator's prey may act as a major mediator in the host's location.

Conclusions

Formicid ants of *Camponotus* and *Enictus* species, which feed on mantises (*Hierodula* sp.), common mynah (*Acridotheres tristis*), red banded bulbul (*Pycnonotus cafer*), thrip (*Cercothrip tibialis*), spider (*Aranarus tristis*), and an unidentified red mite are the predators of *P. depressa*. Galls and nymphs have also been observed to be infested by the pathogen *Aspergillus flavipus*. These biocontrol agents are crucial in regulating the *P. depressa* population. They include the bracon species and the encyrtid wasp, which can be mass-produced in the lab and released into the field to monitor *P. depressa*.

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