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HYMENOPTERA ATTRIBUTES ON MORPHOMETRIC AND PARASITISM AS NATURAL ENEMIES OF *PIERIS BRASSICAE* IN KUMAUN DIVISION, UTTARAKHAND, INDIA

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ABSTRACT

Around the world, *Pieris brassicae* (Linnaeus) is a proactive cruciferous agricultural pest. An unpredictable pool of parasitoids, primarily belonging to the order Hymenoptera, routinely transmit natural control. The spectrum of species and central physical traits of the hymenopteran parasitoid complex affiliated with *P. brassicae* are covered in this paper. Meanwhile, it examines the pattern of parasitism frequencies over time for five Hymenoptera species, *viz*. *Brachymeria lasus* (Walker), *Cotesia glomerate* (Linnaeus), *Pteromalus puparum* (Linnaeus), *Oomyzus sokolowskii* (Kurdjumov), and *Vespa orientalis* Linnaeus in the Kumaun division over two years in a row (2022 and 2023). Between these two years, all species saw higher parasitism rates, according to a statistical comparison, with *O. sokolowskii* showing the most dramatic increase in proportion. With the mean rate accelerating from 6.96% in 2022 to 8.46% in 2023, statistical testing verified that the overall increase in parasitism rates was significant. Our primary findings disclose that *O. sokolowskii* is the smallest and *V. orientalis* is the largest. In addition to having the greatest parasitism rates, *C. glomerata* is special for its phenomenal morphological kind. Interestingly, no relationship involving parasitism susceptibility and body size was detected. As a result, there are apparent shifts each year, and fluctuating factors may have a ripple effect on parasitism.

Keywords: *Pieris brassicae*, natural enemies, Hymenoptera, parasitism, morphometric

INTRODUCTION

Pieris brassicae (Linnaeus), commonly known as the large white butterfly (LWB) or cabbage butterfly, is a significant pest of brassicaceous crops. Its larvae cause extensive damage, leading to substantial yield losses (Abbas et al. 2021). Biological control methods, particularly the use of parasitoids, offer a sustainable approach to managing LWB populations (Harvey et al. 2010). LWB is a *Brassica* specialist and is considered a destructive pest of cruciferous crops. It causes significant damage (around 40%) to crops like cabbage and cauliflower, which are important vegetables (Mehrkhou and Sarhozaki 2013). From eggs to larvae to pupae, a variety of parasitoid species target LWB at various phases of development (Razmi et al. 2011).

All the hymenopterous parasitoids and predators reared were identified and redescribed with emphasis on morphometrics. The taxonomic synonymies are also mentioned. The pest is naturally regulated by a complex of parasitoids, primarily belonging to Hymenoptera (Van et al. 2022). These parasitoids exhibit various levels of host specificity and parasitism strategies (e.g. koinobiont vs. idiobiont), making their identification and classification essential for biological control programs. The parasitoid percentage on LWB varies depending on the geographic location and environmental factors (Razmi et al. 2011). It's essential to fully grasp such distinctions to employ biocontrol regulation strategies that work. Meanwhile, warming temperatures and altered precipitation patterns may affect the efficacy of parasitoids (Lin et al. 2018). It can be positive in optimizing biocontrol methods by comprehending the organic ecology (Huigens et al. 2011). The Kumaun region's temperate climate, characterized by moderate temperatures and diverse vegetation, provides an ideal environment for the development of LWB. Studies have indicated that the species thrives in areas with temperatures ranging from 15.2°C to 30°C, which aligns with the climatic conditions prevalent in Kumaun during certain periods of the year (Tomar et al., 2022).

Understanding the chemical ecology of parasitoid-host-plant interactions can help optimize biological control strategies (Fatouros et al. 2007), and landscape features that affect parasitoid populations can inform habitat management practices (Gueratto et al., 2019). Releasing multiple parasitoid species could lead to more effective and sustainable pest management (Yuan et al., 2024). Moreover, factors that influence parasitoid percentage are crucial for developing effective biological control strategies against LWB conservation, which involves enhancing the natural enemies already present in the environment, and can be a sustainable approach (Silvie et al. 2024). A potential avenue for biological control, offering an alternative to synthetic insecticides, which pose environmental risks. With the spotlight on the communication between LWB and its parasitoid complex, the current work will examine the parameters driving parasitism patterns in various communities. Therefore, selected hymenopteran insect species are explored with a focal point on taxonomic traits and intriguing high parasitism dimensions. A more thorough version is discussed below to overcome biocontrol shortfalls while delivering a solid foundation of taxonomy to achieve better results.

MATERIALS AND METHODS

Research was conducted in the Brassicaceae agroecosystem in the Kumaun division, specifically in Nainital, Almora, Udham Singh Nagar, Champawat, and Bageshwar. Natural enemies are expected to emerge from the host species relatively quickly. Within this ecosystem, LWB larvae and pupae coexist, often alongside various insects, either underground or on plant surfaces. To facilitate the emergence of natural enemies, LWB eggs, larvae, and pupae were isolated in covered Petri dishes. Under these conditions, adult insects typically emerged within 1 or 2 weeks. Throughout the experiment, the food plants remained consistent and monitored daily for the emergence of natural enemies. And meticulously examined under a stereo zoom binocular microscope.

Identification & Morphometric Measurements

Standard identification keys are primarily defined by morphological attributes such as colour and shape, particularly focusing on features like the head and antennae. These characteristics are discernible either to the naked eye or with the aid of a magnifying glass, allowing for a clear understanding of the specimens being studied.

Parasitism Percentage

The data collected after identifying the natural enemy species were utilized to calculate the parasitism percentage attributed to each species. The emerged were identified with the assistance of experts, who also helped estimate the parasitism rates for each species.

Statistical Analysis

The collected data will undergo a t-test, with comparisons conducted for parasitism percentage.

RESULTS AND DISCUSSION

Identification

1. ***Brachymeria lasus* (Walker, 1841)**
Family- Chalcididae
Subfamily- Chalcidinae
Prototype examined: Nainital, 8. IV.2022. In pupae of LWB near a cabbage field.
Distinctive characters
Colour

Head, face, antennae	Black
Eyes	Black with white inner margin
Ocelli	Brown to yellow
Abdomen	Matte black
Pronotum, mesonotal, and scutellum	Black
Tegulae	Yellow
Wing veneation	Brown
Tibia and tarsus	Yellow
Base of the hind tibiae	Black
Forefemur	Yellow
Mid and hind femur	Yellow spot on the dorsal distal end
Metasoma	Black

Head

Transverse and covered densely with minute white hairs and punctuated, being wider than the pronotum, almost equal in width to the mesonotum. Frontal

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scrobe is deep with carinated margins somewhat irregularly, and lateral ridges are produced rather prominently in front of antennal toruli. Large oval eyes are present, and preorbital carina is altogether absent, while postorbital carina is completely formed without branches reaching the margin of the genotemporal region. Ocelli are fairly large and sit quite close together, forming a triangle that appears somewhat acute in shape. Antennae comprising 12 segments are inserted rather low down at the inner side of the compound eyes, and flagellomeres are subequal in length.

Mesosoma

Punctuation appears as concave round dots coarser compared with the head and is covered densely with minute hairs, rather evenly. Tegulae are relatively large and slightly longer than broad. Prepectus is triangular and small, almost equal to the tegula in length. Scutellum is not emarginated at the apex. Forewing appears rather hyaline and extremely shiny. The propodeum has coarser punctuation dorsally and irregularly. Metasoma appears glabrous with 8 visible punctate segments. Its length nearly equals the mesosoma and the first segment is disproportionately larger than the other.

Leg

Hind coxae hold an inner ventral tooth or protuberance. The hind tibia is arch-shaped and rests in a femoral groove. A distal spur is present on the hind tibia. Large, swollen hind trochanter has a small trochantellus and is significantly longer than the mid and fore trochanter. Tarsi are 5-segmented, terminating into the pretarsus. Basitarsus on the hind leg is remarkably long.

Propodeum with punctuation coarser and irregular dorsally.

Metasoma tergite I almost glabrous, almost equal to mesosoma in length, with 8 visible segments, punctated, first segment discriminately larger than other segments.

2. ***Cotesia glomerate*** **(Linnaeus, 1758)**
Family-Braconidae
Prototype examined: Ramnagar, 11.IV.2022. In mustard field.
Distinctive characters
Colour

Head, antenna	Black or brown
Mouthparts	Clypeus and labrum are brown, while other parts are orange colour
Ocelli	Brown
Abdomen	Matte black
Pronotum, mesonotal, and scutellum	Black
Tegula & stigma	Brown
Wing venation	Dark brown at distal, light brown at proximal
Legs	Light brown except coxa and tarsal segments
Metasoma	Brown
Mesosoma	Brown to black

Head
Clypeus appears transverse and is densely covered with minute transparent hairs. The width is roughly equivalent to the mesosoma at the tegula. Eyes are medium-sized and nearly oval. Ocelli form an acute triangle overall. Antennae are filiform with 18 segments.
Mesosoma
The pronotum is tightly infused with small, translucent follicles extending near perpendicular without concealing on the other side.
Leg
Typically, tarsi are composed of exactly five parts. Hind and mid trochanters are almost equal. The hind leg is significantly longer than the midleg and forelegs.
Metasoma length is slightly closer to the mesosoma.

3. ***Pteromalus puparum*** **(Linnaeus 1758)**

Family- Pteromalidae
Prototype examined: Sitarganj, 18.VI.2022. Near a cauliflower field.

Distinctive characters **Colour**

Body, head, face, clypeus, mesosoma, and metasoma	Shiny blackish green
Mouthparts	Brown
Eyes	Black
Abdomen	Matte black
Pronotum, mesonotal, and scutellum	Black
Tegula & stigma	Brown
Wing venation	Brown
Legs	Yellowish brown

Head

The transverse surface is substantially broader than the mesosoma. Because of their moderate size, the eyes don't converge towards the clypeus. Moderately large ocelli form an acute triangle. The 13 segments of the antennae.

Mesosoma

When viewed from the side, the hairy mesoscutum is almost always uncovered and descends nearly vertically onto the pronotum.

Metasoma is noticeably shorter than it looks from most dorsal angles.

4. ***Oomyzus sokolowskii*** **(Kurdjumov 1912)**

Family-Eulophidae

Prototype examined: Betalghat, 21.V.2022. In coriander, cabbage, radish field.

Distinctive characters

Colour

Head, antenna	Black or blue
Mouthparts	Brown
Antennae	Brown
Tibia	Creamy yellow
Femur	Distal end is creamy yellow
Tegula & stigma	Brown

Head

At the tegula, it's narrower than the mesosoma. The eyes are large, almost oval. They are virtually hairless. 9 segments make up the antenna's clubbed tip. Ocelli are small and arranged in a sharp triangle.

Leg

The tibia has 4-segmented tarsi, and the hind basitarsus is the longest. The metasoma is narrowly joined at the propodeum, and the tarsi on the mesosoma are longer than those on the tibia.

5. ***Vespa orientalis*** Linnaeus

Family-Vespidae

Prototype examined: Ranikhet, 27.IV.2022. Near a coriander area.

Distinctive characters & Colour

Head, antenna	Brown
Eyes	Dark brown
Ocelli	Yellow
Abdomen	Matte black
Clypeus	Yellow
Wings	Dark brown at distal, light brown at proximal
Legs	Brown

Head

The head has scant, short, stiff hairs that resemble bristles. Ocelli are tiny and positioned on the vertex of a triangle.

Mesosoma

The elongated radial cell in the forewing is the longest cubital cell, followed by the second cell that constricts towards the radial cell, which receives both recurrent nerves.

Legs

The lengths of the hind tibia and hind femur are identical. With 5 segments, the hind tarsal segment is as the other segments combined. The hind leg is longer than the mid and forelegs combined.

Metasoma

The abdomen is sharply pointed at the apex, and typically has sparse or dense.

Morphometric measurements

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The species with the most variation overall is *C. glomerata*, followed closely by *V. orientalis*. This means that *C. glomerata* has the greatest relative variability in its body and antenna measurements among the species analysed.

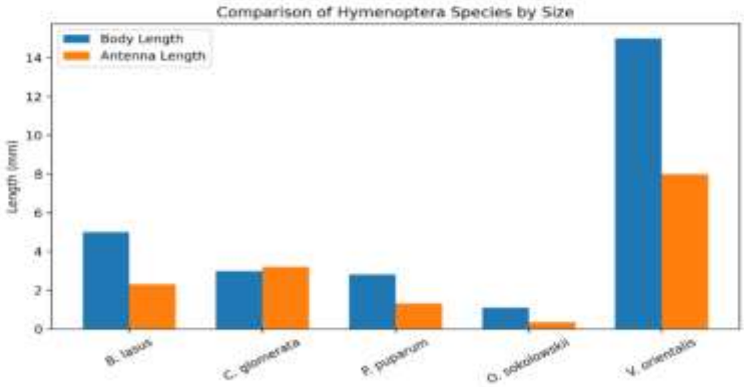

Fig 1. The bar chart compares the average body length and antenna length for each species.

V. orientalis is much larger than the other species in both body and antenna length, while *O. sokolowskii* is the smallest. The other species fall in between, with *B. lasus* and *C. glomerata* having moderate sizes, and *P. puparum* being relatively small as well.

Table1. Morphometric measurements (in mm ± SD) of adult species of Hymenoptera Parasitoids of *P. brassicae*

Hymenoptera species	Body length	Antenna
B. lasus	4.8 ± 0.4	2.2 ± 0.13
C. glomerata	2.7 ± 0.8	3.2 ± 0.03
P. puparum	2.7 ± 0.2	1.3 ± 0.02
O. sokolowskii	1.1 ± 0.03	0.35 ± 0.01
V. orientalis	19 ± 1.8	7.0 ± 0.07

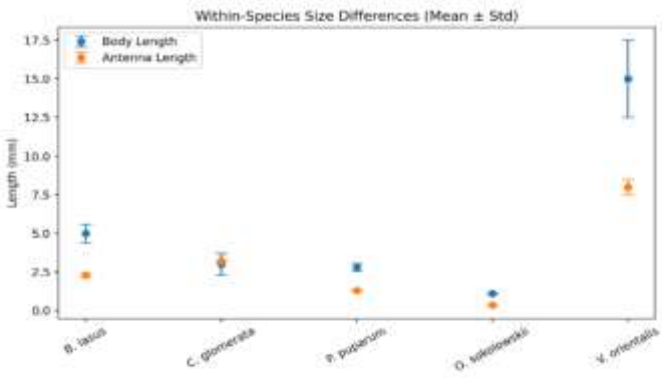

Fig. 2: Error bar plot shows means and standard deviation for body and antenna length within each species

The table above summarizes the mean and standard deviation for both body and antenna lengths within each species, giving a sense of the average size and the spread of measurements. The error bar plot visually represents these differences, showing both the average and the variability (standard deviation) for each species. By doing so, it's practicable to swiftly recognize species that differ strongly in size on average, rather than merely being larger or smaller on average, which have more or less variation in their sizes.

Parasitism percentage

The bar chart visually compares these parasitism rates across species. *C. glomerata* had the highest parasitism rate, followed by *B. lasus* and *P. puparum*, while *O. sokolowskii* had the lowest. This makes it easy to spot which species were most and least affected by parasitism during the year.

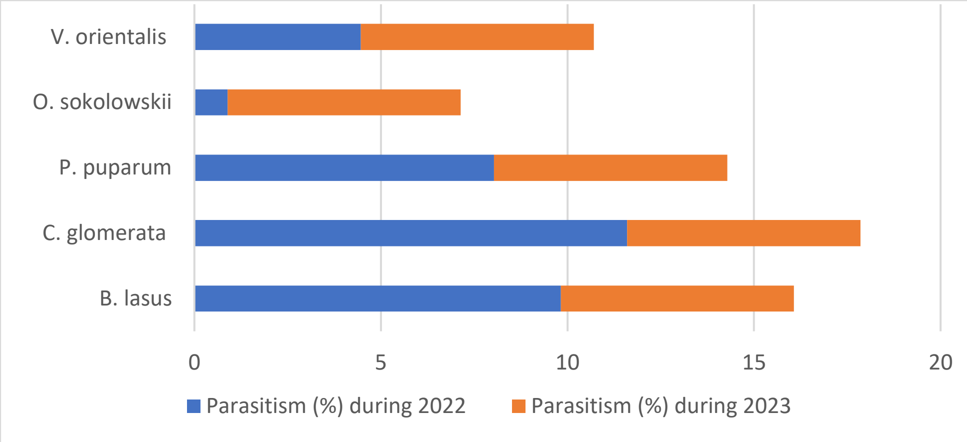

Fig 3. The grouped bar chart makes it easy to spot changes over time: for example, *C. glomerata* saw a noticeable increase in parasitism rate, while other species like *O. sokolowskii* and *V. orientalis* also experienced rises, though less dramatic. This visualization helps highlight trends and shifts in parasitism pressure across years and species.

Paired t-test Results
T-statistic: -3.73; P-value: 0.02; Significant increase (p < 0.05): True

Overall Parasitism Trends
Mean 2022 6.96%
Mean 2023 8.46%
Overall increase: 1.5%

The analysis reveals a statistically significant increase in parasitism rates from 2022 to 2023 (p=0.02). *O. sokolowskii* showed the largest relative increase, while all species experienced some level of increased parasitism pressure.

Conclusion

By tracking down multiple species that were never documented in the Kumaun division and certain areas throughout India, the current research investigation confirms a broad spectrum of Hymenoptera parasitoids and predators correlated to LWB. The existence of these natural enemies and their parasitism percentage conveys the potential benefit of combining them in pest management initiatives to deliver environmentally friendly substitutes for chemical control. The previous research has provided a comprehensive list of natural enemies (Pervez et al. 2024). This information is crucial for understanding ecological interactions and can guide future studies in the field. However, earlier research concentrated on a small part of Indian regions, primarily Kashmir, Manipur, and Himachal Pradesh. This has culminated in an alarming absence of understanding about the transmission of parasitoids. Therefore, upgrading biological techniques for controlling along with promoting ecologically ethical insect prevention can be gained by extending our familiarity with species behaviour in frontier areas. Especially around

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conjunction with the current global transition with current global transition to organic farming.

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