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Research Article

Morphology and nesting behavior of *Ropalidia variegata variegata* Smith 1852 (Hymenoptera: Vespidae) from District Mohmand, Khyber Pakhtunkhwa, Pakistan

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ABSTRACT

This study was carried out in Mohmand District (Khyber Pakhtunkhwa, Pakistan) to investigate morphological identification and nest activities of a wasp species (*Ropalidia variegata variegata*). Wasp colonies were observed on mango tree foliage and monitored over a four-month period. Nest-building activity began at the center of the leaf and expanded along the midrib and lateral edges as the colony size increased. The numbers of nest cells, larvae, and total cells were recorded. Specimens were identified as *R. variegata variegata* using standard entomological keys. Distinct coloration patterns were noted on different body parts, including yellow, reddish-brown, and black hues. Morphometric measurements showed that the head measured 2.24 ± 0.2 mm in length and 1.96 ± 0.2 mm in breadth. The pronotum was rectangular, brown in color, and bordered by a distinct yellow margin. The thorax measured 3.51 ± 0.14 mm in length and 2.0 ± 0.42 mm in breadth. The second abdominal segment was bell-shaped. The legs measured 4.6 ± 0.56 mm in length and 0.1 ± 0.07 mm in width, while the wings measured 5.1 ± 0.8 mm in length.

Keywords: *Ropalidia variegata variegate*; behaviour; morphology; nesting; reproduction.

INTRODUCTION

Ropalidia variegata variegata (Hymenoptera: Vespidae) is a paper wasp species that belongs to the Vespidae family (Varghese and Kumar, 2023). The intricate relationships between *R. variegata variegata* and its ecosystem are crucial for promoting sustainable conservation practices and boosting measures to preserve biodiversity (Naheed et al., 2023). *R. variegata variegata* exhibits a predilection for using wood as a nesting substrate. While they do not have a distinct preference for nesting materials based on taxonomy, they tend to choose substrates based on their availability and specific characteristics (Akre, 1982, Saito and Kojima, 2005). Literature enlightens how climate change affects population dynamics and nesting patterns to develop flexible conservation strategies for the species. The species tends to prefer regions with appropriate nesting materials, demonstrating a preference for sites where they can effectively build and upkeep their nests (McGlynn, 2012, Wilson et al., 2009, Reed and Landolt, 2019, Antoine and Forrest, 2021, Unterweger et al., 2018, Walter and Winterton, 2007). The habitat selection of *R. variegata variegata* is determined by the availability of wood and other necessary resources needed for constructing nests (Shaily et al., 2021, Smith, 1852). These wasps have an aggregated distribution of nests, suggesting a predilection for specific spatial arrangements within their surroundings (McGlynn, 2012, Reed and Landolt, 2019, Varghese and Kumar, 2023). The nesting activities of *R. variegata variegata*

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correspond to their adaptation to specific environmental conditions and the resources present in their habitat (Smith, 1852, Rafi et al., 2017). The complex interrelationships between *R. variegata variegata* and its surrounding ecosystem are essential for advancing sustainable conservation practices and preserving the areas biodiversity.

Ropalidia variegata variegata possess cutting mandibles that are adept at capturing, subduing, and processing prey. They also have big eyes that enable them to locate possible prey and a well-known defense system (Stetsun and Matushkina, 2020, Kojima et al., 2007, van der Vecht, 1962). From a morphological perspective, insects can be categorized into distinct body parts: the head, thorax, legs, and wings. The head consists of the mesosoma and metasoma, which have an exoskeleton (Naz et al., 2020, Peeters et al., 2020, Qasim et al., 2022, Inayatullah, 2012). The first and second segments of the abdomen are connected by a stalk or peduncle known as the petiole (Blommers, 2012, Tan et al., 2014, Polašek et al., 2022). Males in the genus *Vespula* have shorter mandibles and fewer teeth than females (Baranek et al., 2018); labium is responsible for a maxilla-like structure through which liquid food is taken readily, in certain species, there has been a transition from chewing to cutting to facilitate adaptations (van de Kamp et al., 2022). Moreover, they possess a set of antennae consisting of 10 or more segments (Kojima et al., 2007, Shan et al., 2019), and winged which are flexible with a limited number of veins (Perrard et al., 2014); certain small species of wasps lack veins in their wings (Eraghi et al., 2021).

Certain species of wasps exhibit an aesthetically pleasing appearance in their adult stage, characterized by prominent black, brown, yellow, or white markings on their bodies (Huber, 2009). Frequently, they fulfill a significant purpose in global ecosystem processes, such as controlling pest populations, safeguarding prey as a food source for their offspring, and acting as scavengers (Brock et al., 2021). Furthermore, sex pheromones are essential in the mating behaviour of Hymenoptera, as they significantly impact wooing rituals and the attraction of mates. Studies on different species, such as wasp *Nasonia vitripennis* male produces these pheromones to attract females, and the specific composition of these pheromones affects mate selection and reproductive results (Ruther et al., 2011). Comprehending the development and purpose of these sexual pheromones illuminates the complex mating behaviours within the Hymenoptera order (Wang et al., 2021), demonstrating the significance of chemical communication in achieving reproductive success and ensuring the survival of the species.

Understanding the morphology and nesting behavior of *R. variegata variegata* is crucial for effective pollinator management strategies in resting areas, aiding in the conservation and enhancement in the region. Before this study, very limited research has been conducted on wasps or other insects in the district. Studying the morphology and nesting behavior provides insights into the ecological role of *R. variegata variegata* within its habitat, including its interactions with plant species and contributing to broader ecosystem understanding. Knowledge of the nesting habits and morphology of *R. variegata variegata* is essential for developing conservation plans aimed at protecting this species and its nesting sites, ensuring the preservation of biodiversity in the northwestern part (Prang Ghar, District Mohmand) of Pakistan. Providing and studying the morphology and nesting behavior, researchers can gain valuable information for managing and conserving *R. variegata variegata* populations, helping maintain healthy bee populations and ecosystem balance.

MATERIALS AND METHODS

District Mohmand having total area of 2,296 km2 surrounded by Bajaur (North), Khyber (South), Malakand (East) and to the southeast by Peshawar. The precipitation is minimal, with most of it occurring during winter. The fauna and flora Mohmand district, hold significant importance due to the presence of the Hindukush mountain range, which originates from Prang Ghar and extends into Dir and Chitral (Figure 1). The location of R. variegata was recorded at 34.37778° N, 71.64395° E, with an altitude of 386 m.

Collection and Preservation of Samples

R. variegata variegata were collected with the help of collecting nets, forceps and from mango trees between March and December 2022. Specimens and their nests were collected in plastic bags along with foliage. The nest construction of this particular type of wasp is distinctive and notably different from the nests of other wasp species found in Pakistan and other Asian countries. According to (Kojima, 1982), the nest structure of R. variegata varies based on the structure of the leaf, and it plays a crucial role in specimen identification. This variation is necessary to ensure stability and support, prompting the nest to adapt its shape. However, the reported nests on the (upper surface of) leaves appeared intriguing due to their design, location, planning, and arrangement (Kojima, 2000). They were organized in three lines, with one nest positioned along the midrib and two nests along the margins of the leaves.

Ethanol Preservation of Samples

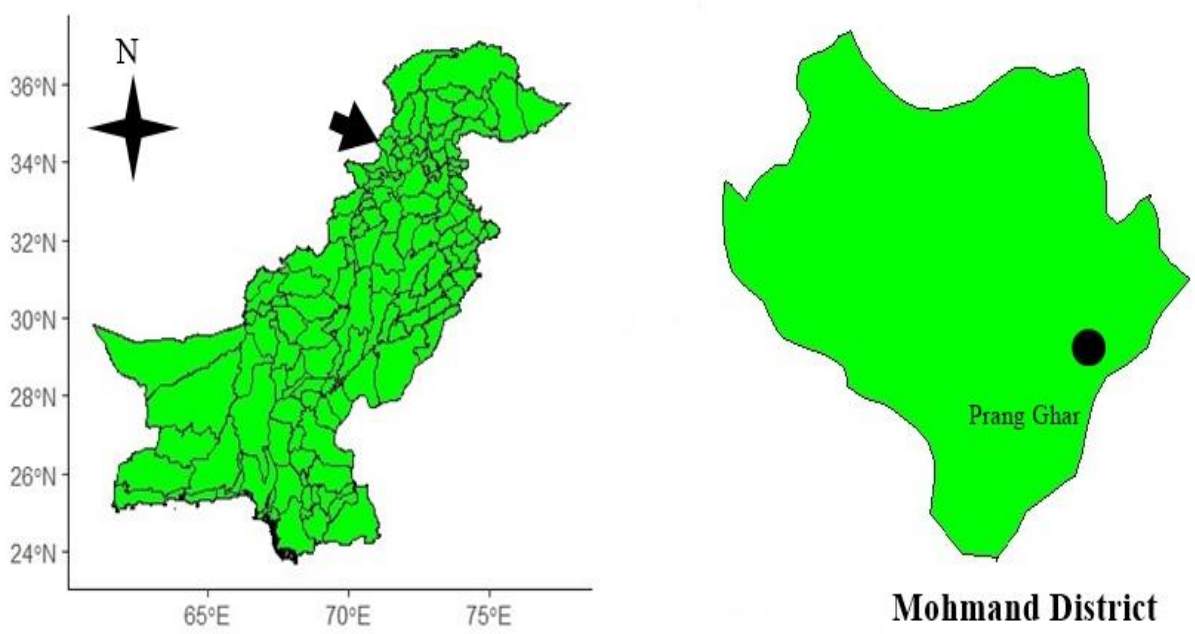

Figure 1. Map of Prang Ghar that reports *R. variegata variegata*, Mohmand District.

Preserving Hymenoptera species in a solution of 80% ethanol offers numerous benefits. Optimal preservation concentrations differ depending on the objective (Pérez-Benavides et al., 2023). Ethanol effectively preserves Hymenoptera specimens, enabling their use in museum collections and taxonomic studies (Mawalagedera et al., 2022). Ethanol with higher concentrations (95–100%) is most efficient in maintaining DNA. It quickly enters cell membranes and turns off the activity of DNase, guaranteeing improved preservation of DNA (Mueller et al., 2021). In the current study, we utilized 80% ethanol while collecting mature Hymenoptera specimens, as recommended by Marquina et al. (Marquina et al., 2022).

Naphthalene Balls for the for the Preservation of Samples

Specimens were killed using pesticides, pinned to a stretching board, and labeled with location data including the name, date, Tehsil Prang Ghar coordinates, and District. Identified specimens were pinned (2 cm entomological pins) in a naphthalene-filled insect box and placed in the University of Swabi, Zoology Department, Insect museum (Gibb, 2014, Panhwar et al., 2025). Wasps were collected using nets and forceps and then transferred to plastic containers. The shoppers habitually adorned their nests with the leaves that covered them. where they were observed for almost a month without being provided any sustenance. They survived for over a month in the cold, but eventually, one by one, they began to die.

Microscopic Work

The stereoscope Labomet CZM4 - 4X was used to identify specimens. The colour of distinct patches and strips were carefully investigated using stereoscope. In addition, a Labomet CE 920 camera was installed to capture photos and facilitate further analysis.

Identification of Specimen

The specimens were classified taxonomically at the species level using several identification tools, such as the keys provided by (Tan et al., 2014) in China and Pictorial keys to the wasps by (Walter and Winterton, 2007). In addition, the specimens were directly compared to previously reported specimens in the National Insects Museum (NIM) at the National Agriculture Research Centre (NARC) in Islamabad, Pakistan.

Nest Observation of Specimen

The mango tree served as the source of specimens for observation. The nest construction on the ventral side of the leaves made them appear more remarkable. The wasps were observed for a duration exceeding 6 months (June-December.

Statistical Analysis

The data of collected specimens and nests were analyzed statistically using ANOVA in GraphPad Prism 8.

RESULTS AND DISCUSSION

This study used the colour and size of body parts of *R. variegata* from district Mohmand, Pakistan, to analyze its morphology. Each nest has 7–12 specimens. Wasps are medium to vast and yellow to brown with black markings or black. Both genders are winged. Torulus has a straight dorsal rim, a deep, emarginated eye margin, a V-shaped pronotum edge, and an abrupt, highly developed posterolateral apex above the anterior tegula margin. The pronotum reaches the tegulae. It is frequently folded longitudinally but not always. *R. variegata vareigata* (Smith, 1852) is the only species represented.

Length of Body

We recorded measurements from back of the head to front of the lower abdominal segment, with individual body lengths ranging from 7.5 ± 0.89 mm to 10.94 ± 1.89 mm. The hind wing measured about 4.0 ± 0.83 mm, while the forewing measured approximately 6.25 ± 0.3 mm in length. While the breadth of the head is smaller than that of the mesoscutum, the size of the head is around 2.2±0.22 mm. An average distance of 0.70±0.20 mm is observed between two posterior ocelli, but the distance between the anterior and posterior ocelli is 0.5±0.3 mm. Small structures that resemble hair cover the entirety of the body as in Figure (2).

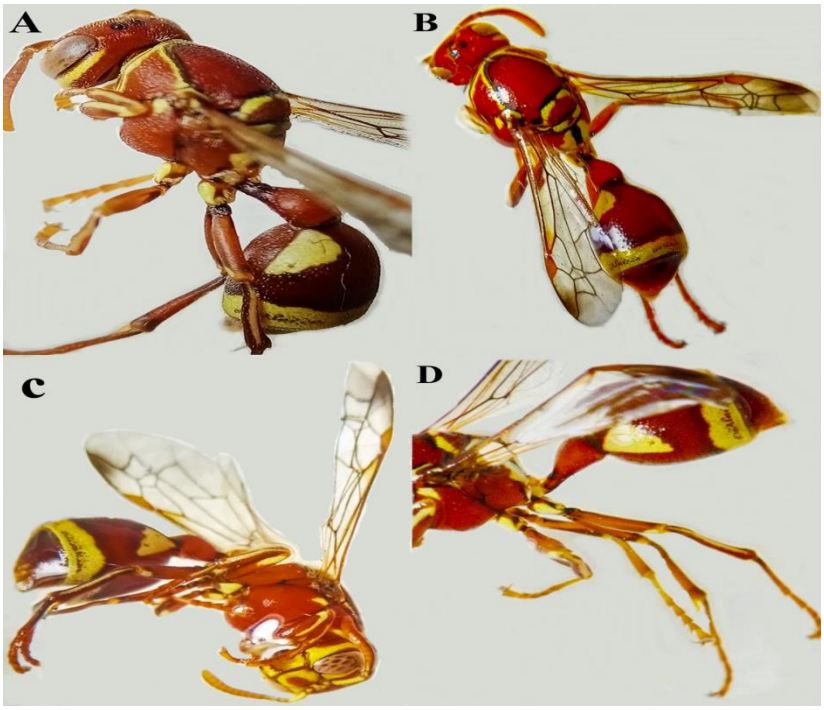

Figure 2. *Ropalidia variegata variegata*. a side view of lateral body; B dorsal body view, C; ventral and front view, D; lateral side thorax, abdomen and legs.

Description of the head

The clypeus is the central hard part of the head located just above the labrum. It is usually defined by the groove on the upper and side parts of the head, and it has a heptagonal shape. It is composed of 2 distinct colours: the centre is brown, while the sides, connected to the eyes and mandible, are yellowish. Head has a length of 2.2±0.2 mm. Distance separating the posterior ocelli and compound eye is longer than the distance separating the two ocelli. The antenna of male has 11 segments, with a slight curvature at the final segment. The female partner possesses 10 segments in their antennae, which are linear in shape, in contrast to the male partner, whose last segment is curled. Additionally, the space between the antennae and the antennae is brown. The mandibles are predominantly yellow, with the exception of the teeth, which have a dark brownish hue. The anterior colour is brown, although the apex is also yellow in hue. The eyes have a pronounced inward curvature on their inner sides (Figure 3a).

Description of Thorax

The pronotum is rectangular in shape and has a brown colour. Most Hymenoptera also extend to the dorsolateral or lateral half of prothorax. It is distinguished by a yellow margin that divides it from the mesoscutum, mesopleuron, and propleuron. The mesoscutum, which refers to the front section of the mesonotum excluding the scutellum, exhibits a golden brown colouration. It is distinguished from other parts by a surrounding black colouration. The propodial groove is wider in middle, and central furrow is indistinct. A patch between the median and the lateral ocelli is occasionally faint; a vertex has an interrupted line following the ocelli pronotal with a line; apical and basal width range: scutellum,

postscutellum, mesopleuron. The meso-pluron and meta-pleuron are red-brown, except for a little yellow patch near the pronotum. A smooth structure called a propodium is located at the centre of the groove on the propodeum. The propodeum groove is not well-defined and is wider in the middle. The propodium has a subsemessile shape (Figure 3b).

Description of the Abdomen

This species abdomen comprises 5 segments, with the first tergum completely reddish-brown. The length of the first segment is 2.25±0.3mm, and its breadth is 1.9±0.14mm. The second segment is bell-shaped and broader than the previous segments, as are the third, fourth, and fifth segments. They are gradually decreasing in size, each in their way. A profound constriction creates a clear separation between Sternum II and Sternum I. The propodeum exhibits a paired, longitudinal basal carina, which is a slightly elevated ridge on the integument. This ridge displays distinct striations between the basal and lateral carinae. The second segment of the metasoma is completely reddish-brown and features yellow patches at the tip, which are seen only in a limited number of Ropaldian species. The lateral sides of tergum and dorsal sclerite of the body segment, are not enlarged anteriorly and have a narrow shape. Compared to the first metasomal tergum, the second tergum is slender, measuring approximately 0.4 times the width of the first tergum at its widest point when viewed from above (Figure 3c, 3d).

Description of Legs

In most cases, the coxa, appears yellowish. However, a tiny area of red-brown colour is also observed on the upper side. Likewise, the trochanter and trochantalius exhibit a golden hue on their underside, while their upper side is tinged with a brownish shade. The distal portion of the femurs hind limb exhibits a yellow patch, while the remainder is brown. The middle-leg femurs have black pigmentation on both the upper and lower surfaces. The tibia is the fourth segment having brownish color. The tarsus also has a brownish appearance, and the tibia and tarsus have black spots on the upper and bottom sides. Each leg is composed of five segments in the tarsus. Each legs tarsus is equipped with two claws on its lower side. Each leg possesses tibial spurs, which are spine-like extensions of the cuticle that consist of several cells. These spurs are attached to an appendage via a socket and are often located at the apex of the tibiae. Additionally, planter lobes are also found on each leg as in Figure 4a. The leg has a length of 4.6 ± 0.56 mm, while the

Table. 1. Morphometry of different body parts along with mean and standard deviation.

Ind.No	Head		Thorax		Abdomen		Legs		Wings
	Length	Width	Length	Width	Length	Width	Length	Width	Length
1	2.2	2	3	2	5.8	2.25	5.4	0.15	4.0
2	2.0	1.9	2.9	2	6	3	5	0.2	4.5
3	2.1	1.9	2.9	2.1	5.5	2.8	4	0.1	3.9
4	2.2	2	3.1	2.2	5.9	2.9	4.1	0.1	5.1
5	2.0	1.6	2.7	2	6	2.2	4	0.12	6.0
6	2.5	2	3.1	2.3	6	2.5	5	0.3	5.3
7	2.3	1.8	3	2	5.7	3	4	0.2	6.5
8	2	2	2.9	2.5	5.5	2.9	5.2	0.1	4.6
9	2.5	2.1	2.7	0.9	6.1	3	4.5	0.3	5.1
10	2.6	2.3	3	2.1	5.6	2.5	5.1	0.12	6.0
M±SD	2.240± 0.2	1.96±0.18	3.51± 0.14	2.0± 0.42	5.8 ±0.2	2.7±0.31	4.6±0.56	0.1±0.078	5.1±0.8

Ind.No mean Individual number.

width is 0.1 ± 0.07 mm. The length of the wings is 5.1 ± 0.8 mm. The length of the fore-wing is 6.25 ± 0.3 mm, while the hind-wing is 4.0 ± 0.83 mm, as shown in Figure 4b.

Behavior observation

Each nest included polymorphic wasps, including drones, queens, and workers. The wasp exhibited lower hostility when interfering with nest activities than other hymenopterans such as honey bees, paper wasps, and hornets. Upon agitating their nest through shaking, approaching, touching, and seizing, all of them promptly abandoned their whole colony, which contained nests, larvae, and eggs. Suddenly, they disappeared for a duration ranging from 30 to 48 minutes. Subsequently, all the individuals reconvened and resumed the identical activities. However, they exhibited no signs of hostility, such as stinging, attacking, buzzing of wings, or gathering on the edge of the leaf. Each species of wasp has specific responsibilities, including egg-laying for queens, nest construction for workers, food foraging, and mating readiness for drones. Following mating, the female bees perish, while the population of male bees declines.

Although they bring cellulose particles for nest construction, they primarily feed on larvae and defend the colony against other insects. However, the drones die after mating with the queen. The social activities of wasps were reported to include coexistence, mutual participation in nest construction, and vigorous foraging. Therefore, several protective behaviours, such as unpredictable flight, rapid wing movement, pecking with the mandibles, pumping the abdomen, and twisting the abdomen, were not classified as pseudo-attacks when the individuals approached the wasp colony. However, certain workers have noted that they ensure the safety of their colony by protecting their nest members from prospective insect adversaries. The queen deposits eggs within a compact structure known as a comb, which is safeguarded by multiple layers of thin, papery substances. Queen sought wood fibres combined with chewed wood and saliva, which she then used to construct additional layers for her nest as in displayed in Figure (5A).

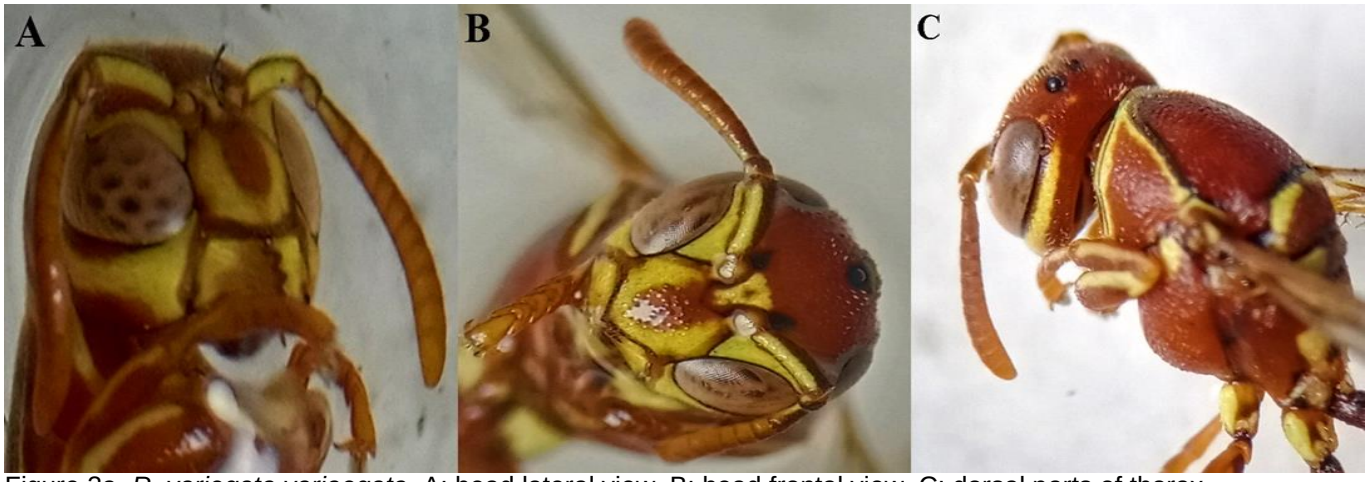

Figure 3a. *R. variegata variaegata*. A; head lateral view, B; head frontal view, C; dorsal parts of thorax.

Figure 3b. *R. variegata variaegata*. A; lateral side view of head and thorax, B; head and thorax side view, C; dorsal view of thorax.

The Architectural Pattern of the Nest

The social wasp nest exhibited distinct characteristics, including constant engagement in nest-related tasks. Their conduct exhibited a diminished level of aggression. The queen engaged in her fair share of oviposition. A colony of R. variegata variegata was discovered on the upper side of mango leaves. The nests are located on leaves that are situated amidst clusters of other branches. The nest was connected to leaves by means of a little yet sturdy stem. The nest is composed of a polygonal framework. Although, the form of the nest remains unchanging. Their nests consist of a single layer, where cells are directly exposed to the external environment. The structure of nest discovered in several leaves were indistinguishable. Initially, these wasps were seen while constructing their nests on the underside of the mango leaf. They showed no fear of rain or other predators when occupying these lower-shaded branches. As the population of wasps grows, they construct additional nests on the same leaf. Approximately 20 nest cells are found on a single leaf when the process of laying eggs is complete (Figure 5B, 5C).

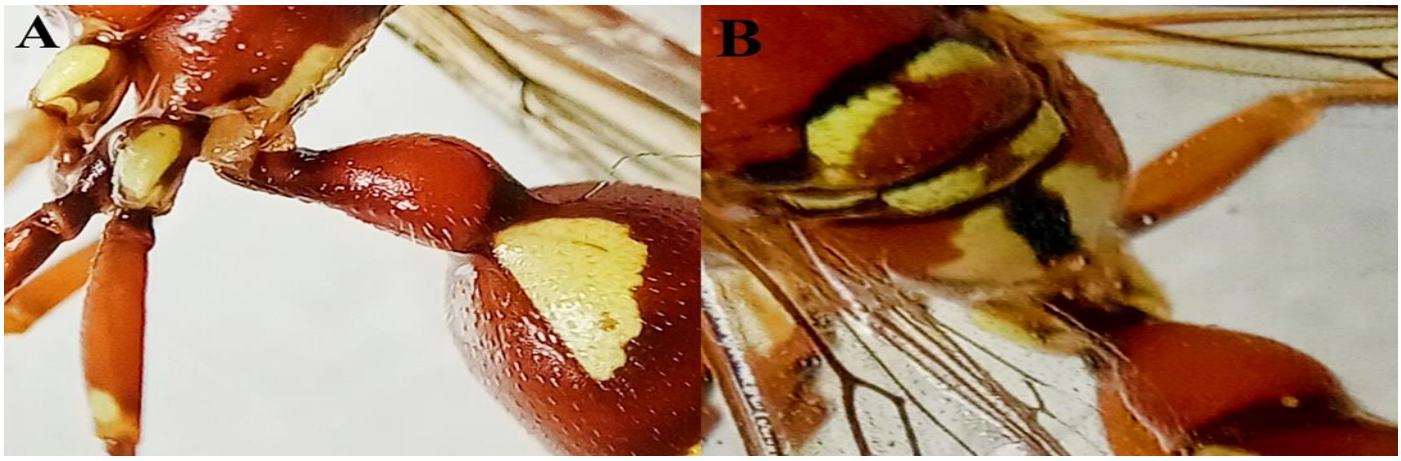

Figure 3c. *R. variegata variaegata*. A; mid and hind legs, petiole and abdomen side view, B; dorsal view of thorax and petiole.

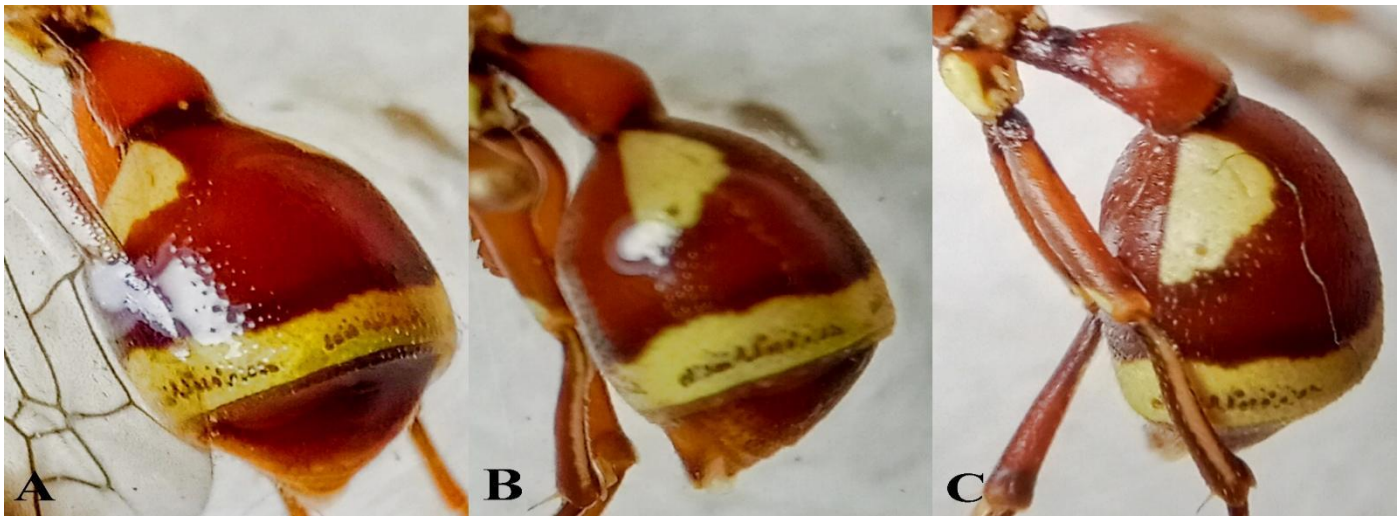

Figure 3d. *R. variegata variaegata*. A; dorsal view of petiole and abdomen, B; petiole and abdomen side view, legs, C; side view of petiole, abdomen and hind legs

Figure 4a. *R. variegata variaegata*. A; middle and hind leg pairs, B; frontal leg and pair claws; C; middle leg, D; hind legs and claws.

Figure 4b. *R. variegata variaegata*. A; frontal and open wings, B; frontal and hind wings view at shrinkage.

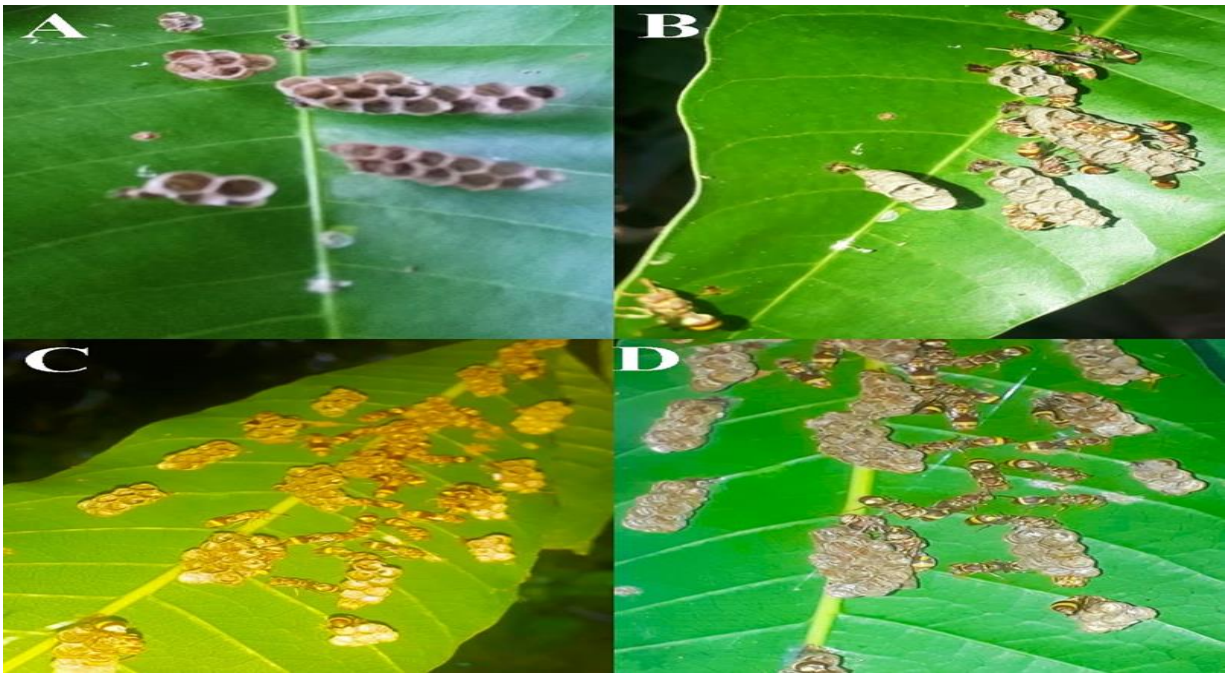

Figure 5. A; nest building, B; new cells formation in nests and left the nest by disturbance, C; building of nests in at both margins and middle of lives special on midrib as well as D; egg laying in cells, development of larvae and hatching in June.

Observations in June

During the initial stage, the wasps were observed collecting chewed wood and constructing their first nest on these leaves. As they grew up for population, they began laying eggs in these cells after completing the nest. However, there were more nests along the leaf central line than the edges. The number of nests seen ranged from 0.0 to 1.5 ± 0.7 on the first leaf, 0.1±0.4 to 1.5±0.4 on the second leaf, and 0.08±0.4 to 3.0±0.4 on the third leaf in the month of June. Similarly, the cell count varied from 0.0 to 1.5±0.7 at the first leaf, 0.1±0.4 at the second leaf, and 0.0 to 1.8±0.2 at the third leaf. The larvae on the first leaf ranged from 0.0 to 3.8±0.7; on the second leaf it was 0.6±0.1; on the third leaf, it was 0.0±3.8 (Table 2, Figure 5, Figure 6).

Observations in Jul

Table 2. Positions and activities of nests formation in different leaves in the month of June.

Sn	Leaf 1st									Leaf 2nd										Leaf 3rd							
	NNLC	NCLC	NLL	NNCC	NCCC	NLC	NNR C	NCR C	NLR	NNL C	NCL C	NL L	NNC C	NCC C	NL C	NNR C	NCR C	NLR C	NNL C	NCL C	NL L	NNC C	NCC C	NL C	NNRC	NCR C	NLR C
1	0	0	0	0	0	0	0	0	0	0	0	0	1	5	4	0	0	0	0	0	1	7	0	0	0	0	0
2	0	0	0	2	5	2	0	0	0	0	0	0	1	9	6	0	0	0	0	0	1	6	4	0	0	0	0
3	0	0	0	2	13	8	0	0	0	0	0	0	1	0	8	0	0	0	0	0	1	10	6	0	0	0	0
4	0	0	0	1	4	2	0	0	0	1	3	3	1	15	3	1	10	10	1	3	1	11	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	1	8	7	1	6	2	1	5	3	1	8	1	7	0	0	0	0	0
6	0	0	0	1	6	3	0	0	0	1	7	6	1	11	1	1	7	1	1	7	1	4	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	1	12	2	1	9	3	0	0	1	0	1	8	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	1	7	6	1	5	5	0	0	0	1	7	6	1	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
M ± SD	0.0± 0.0	0.0 ± 0.0	0.0 ± 0.0	1.5± 0.7	0.5± 4.0	3.8 ± 2.3	0.0± 0.0	1.1± 0.0	0.0 ± 0.0	0.1± 0.4	0.1 ± 2.9	0.2 ± 2.5	1.5± 0.4	1.3± 5.4	0.6 ± 2.7	5.5± 0.5	2.6± ± 3.9	0.4 ± 3.0	3.0± 0.4	1.8 ± 2.9	0.2 ± 0.5	1.5± 4.2	0.5± 2.6	3.8 ± 2.7	0.08±0 .2	0.0± 0.0	0.0 ± 0.0

Positions and nests formation in July: NNLC, Number of nests in left column; NCLC, Number of cells in the left column; NLLC, Number of larvae in the left column; NNCC, Number of the nest in the central column; NCCC, Number of cells in the central column; NLCC, Number of larvae in the central column; NNRC, Number of the nest in the right column; NCRC, Number of cells in the right column; NLRC, Number of larvae in the right column.

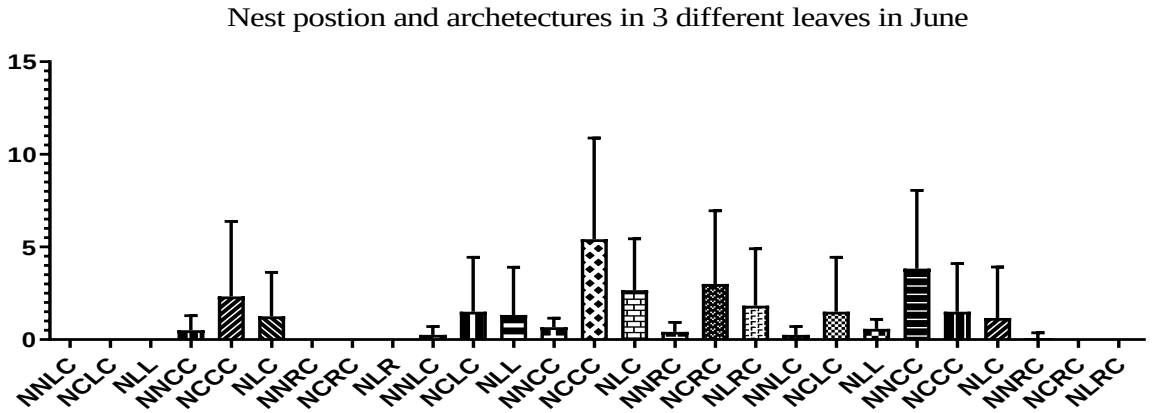

Figure 6. Positions and nests formation in the June.
NNLC, Number of nests in left column; NCLC, Number of cells in the left column; NLLC, Number of larvae in left column NNCC, Number of nest in central column, NCCC, Number of cell in central column, NLCC, Number of larvae in central column NNRC, Number of nest in right column, NCRC, Number of cell in right column, NLRC, Number of larvae in right column.

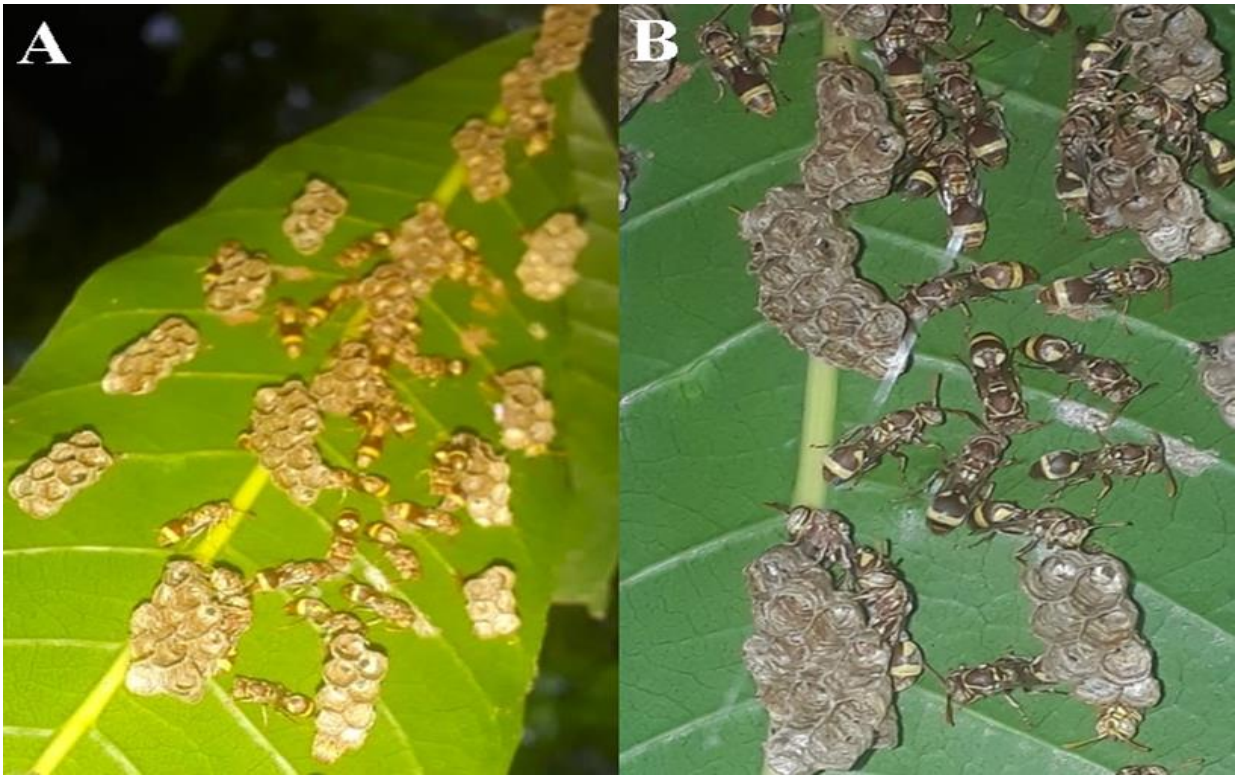

Figure 7. A; Nest, nest cell formation, B; larvae development and hatching in July.

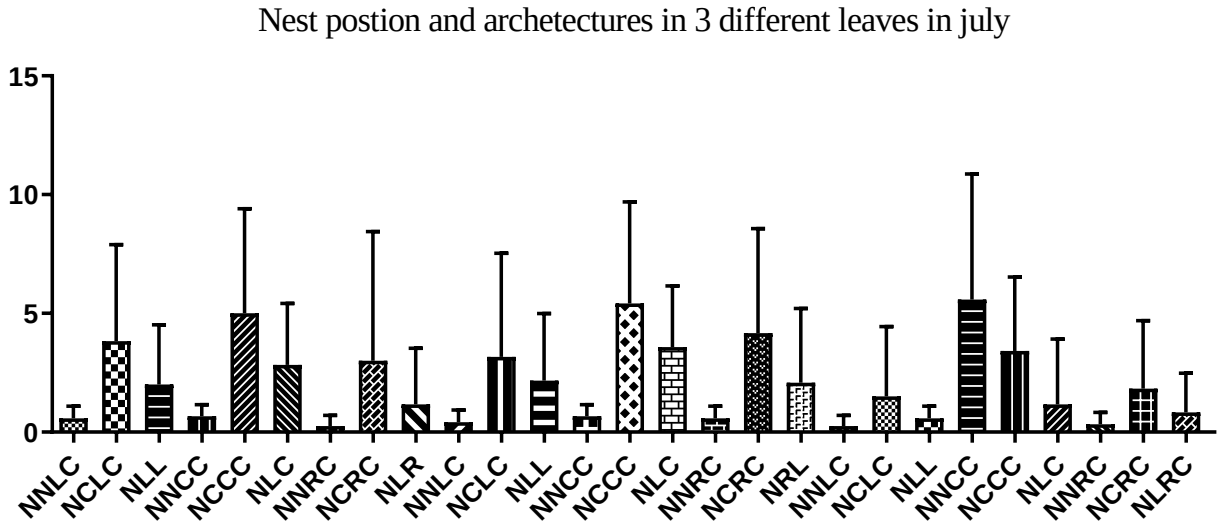

Figure 8. Positions and nests formation in July: NNLC, Number of nests in left column; NCLC, Number of cells in the left column; NLLC, Number of larvae in the left column. NNCC, Number of the nest in the central column, NCCC, Number of cells in the central column, NLCC, Number of larvae in the central column. NNRC, Number of the nest in the right column, NCRC, Number of cells in the right column, NLRC, Number of larvae in the right column.

The frequency of nest construction rose as the juveniles matured on each leaf. Starting from the center, the numerals gradually grew on the remaining sides while maintaining a consistent gap at the edges. There was a rise in the number of nests on this leaf. On the first leaf, the number of nests varied from 0.2±0.4 to 0.6±0.4. On the second leaf, it ranged from 0.4±0.5 to 0.6±0.4. On the third leaf, the number of nests varied from 0.2±0.4 to 5.5±0.4. The number of cells at the first leaf ranged from 3.0±0.2 to 5.0±0.2. At the second leaf, it ranged from 3.1±4.3 to 5.4±4.2. At the third leaf, it ranged from 0.3±0.1 to 03.4±0.5. The larvae count for this month varied from 1.1±0.1 to 2.8±0.5 on the first leaf, 2.0±0.2 to 3.5±0.4 on the second leaf, and 0.5±0.1 to 1.8±0.4 on the third leaf. Upon the establishment of nests, the laying of eggs commence, and the creation of larvae takes place during a span of 3 days, as depicted in Table 3 and Figure 7

Table 3. Positions and activities of nests formation in different leaves in the month of July.

Sn	Leaf 1st									Leaf 2nd									Leaf 3rd								
	NNLC	CNLC	NLL	NNCC	NCCC	NLC	NNRC	NCRC	NLR	NNLC	NCLC	NLL	NNCC	NCCC	NLC	NNRC	NCRC	NRL	NNLC	NCLC	NLL	NNCC	NCCC	NLC	NNRC	NCRC	NLRC
1	0	0	0	0	0	0	0	0	0	0	0	0	1	6	4	0	0	0	0	0	1	7	5	0	0	0	0
2	1	2	0	1	5	2	0	0	0	0	0	0	1	10	6	0	0	0	0	0	1	6	3	0	0	0	0
3	1	6	3	1	13	8	1	12	7	0	0	0	1	8	4	1	8	5	0	0	1	10	7	0	0	0	0
4	0	0	0	1	10	4	1	13	2	1	3	3	1	5	3	1	10	10	1	3	1	14	7	0	1	4	2
5	1	6	4	1	7	4	1	11	5	1	8	7	1	7	2	1	5	3	1	8	1	7	4	0	0	0	0
6	1	11	4	1	7	4	0	0	0	1	7	6	1	11	6	1	12	4	1	7	1	13	7	0	1	7	3
7	1	6	2	1	9	6	0	0	0	0	0	0	1	12	7	1	8	3	0	0	1	9	1	8	0	0	0
8	1	10	8	1	5	3	0	0	0	1	8	5	1	7	6	1	3	0	0	0	0	1	7	6	1	4	0
9	1	5	3	1	4	3	0	0	0	0	0	0	0	8	5	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	1	12	5	0	0	0	0	0	0	0	0	0	0	0	0	1	7	5
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	4	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
M±SD	0.5±0.5	3.8±4.0	2.0±2.5	0.6±0.4	5.0±4.4	2.8±2.5	0.2±0.4	3.0±5.4	1.1±2.3	0.4±0.5	3.1±4.3	2.1±2.8	0.6±0.4	5.4±4.2	3.5±2.5	0.5±0.5	4.1±4.5	2.0±3.1	0.2±0.4	1.5±2.9	0.5±0.5	5.5±5.2	3.4±3.1	1.4±2.7	1.6±0.4	0.3±2.8	1.8±1.6

NNLC, Number of nests in left column; NCLC, Number of cells in the left column; NLLC, Number of larvae in the left column; NNCC, Number of the nest in the central column; NCCC, Number of cells in the central column; NLCC, Number of larvae in the central column; NNRC, Number of the nest in the right column; NCRC, Number of cells in the right column; NLRC, Number of larvae in the right column.

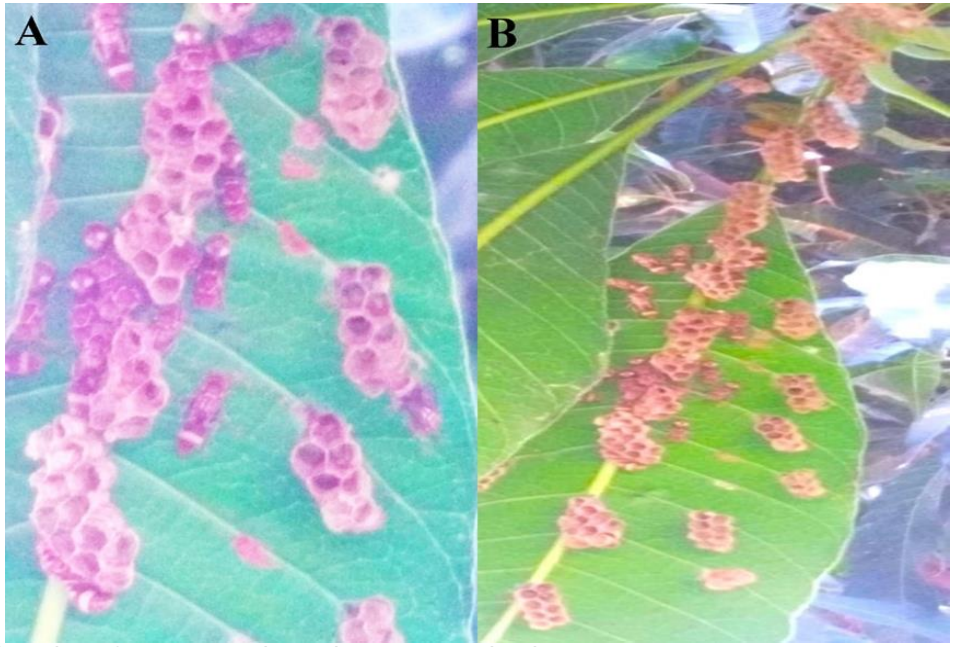

Figure 9. A; Nest cell formation and resting of wasps, B; shows larvae emerging in August.

Table 4. Wasp positions and activities on the leaves in the month of August.

SN	Leaf 1st										Leaf 2nd										Leaf 3rd							
	NNLC	NCLC	NLL	NNCC	NCCC	NLC	NNRC	NCRC	NLR	NNLC	NCLC	NLL	NNCC	NCCC	NLC	NNRC	NCRC	NLRC	NNLC	NCLC	NLL	NNCC	NCCC	NLRC	NNRC	NCRC	NLRC
1	0	0	0	0	0	0	0	0	0	0	0	0	1	5	4	0	0	0	0	0	1	7	0	0	0	0	0	
2	0	0	0	1	5	2	0	0	0	1	4	2	1	9	6	0	0	0	0	0	1	6	4	0	0	0	0	
3	0	0	0	1	13	8	1	6	3		0	0	1	0	8	0	0	0	1	7	1	10	6	1	1	8	0	
4	0	0	0	1	8	4	1	8	4	1	3	3	1	15	3	1	10	10	1	6	2	11	0	0	1	6	1	
5	0	0	0	1	8	6	0	0	0	1	8	7	1	6	2	1	5	3	1	8	3	7	0	0	0		0	
6	0	0	0	1	6	3	0	0	0	1	7	6	1	11	1	1	7	1	1	7	1	4	0	0	0	0	0	
7	0	0	0	1	6	5	1	5	3	0	0	0	1	12	2	1	9	3	1	8	3	0	1	8	0	0	0	
8	0	0	0	1	5	2	0	0	0	1	8	4	1	7	6	1	5	5	1	11	4	1	7	6	1	0	0	
9	0	0	0	1	7	3	0	0	0	1	11	5	4	5	4	0	0	0	1	11	4	0	0	0	0	0	0	
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	7	2	1	7	0	0	0	0	1	7	3	
11	0	0	0	0	0	0	0	0	0	1	13	3	0	0	0	1	1	0	1	6	0	0	0	0	0	0	0	
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	9	1	1	5	2	1	5	4	
M ± SD	0.0± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.7± 0.4	4.8± 4.1	2.8 ± 2.6	2.5± 0.4	1.6± 2.9	0.8 ± 1.5	0.6± 0.5	4.5 ± 4.7	2.5 ± 2.5	1.0± 3.0	5.8± 0.3	3.0 ± 3.5	0.6± 1.4	3.7± 4.1	2.0± 2.7	0.8± 2.7	6.7 ± 0.5	1.7 ± 3.3	0.4± 1.3	2.3± 2.7	0.6± 1.6	0.6± 1.6	0.4± 3.7	0.5± 2.4	

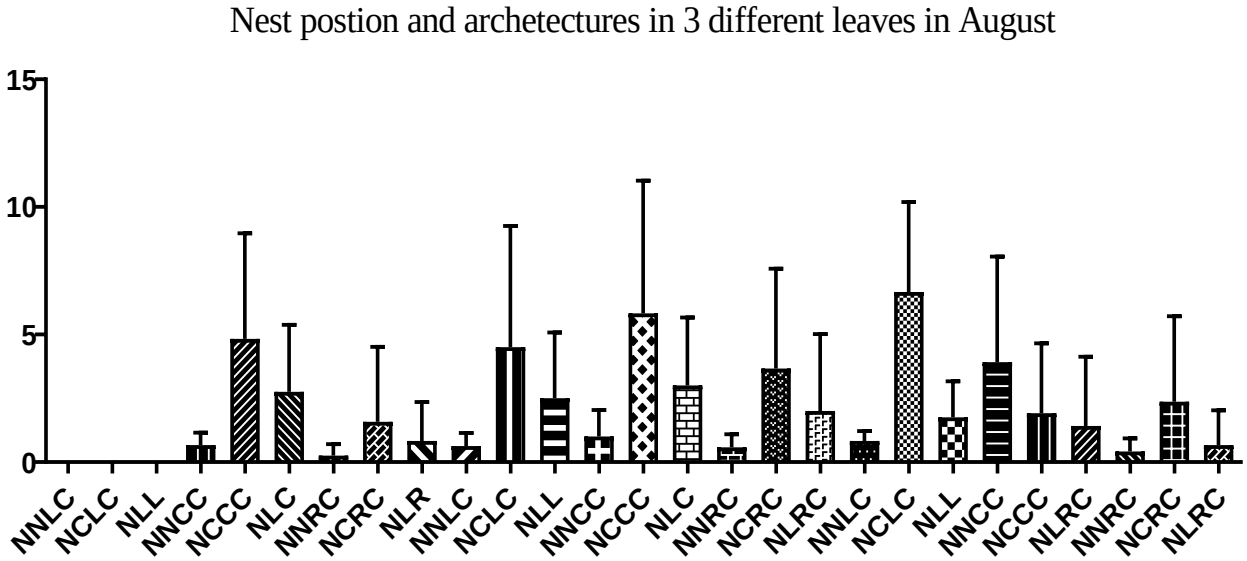

Figure 10. Nest formation in the month of August.

NNLC Number of nests in left column; NCLC Number of cells in the left column; NLLC Number of larvae in left column NNCC Number of nest in central column; NCCC Number of cell in central column; NLCC Number of larvae in central column. NNRC Number of nest in right column; NCRC Number of cell in right column; NLRC Number of larvae in right column

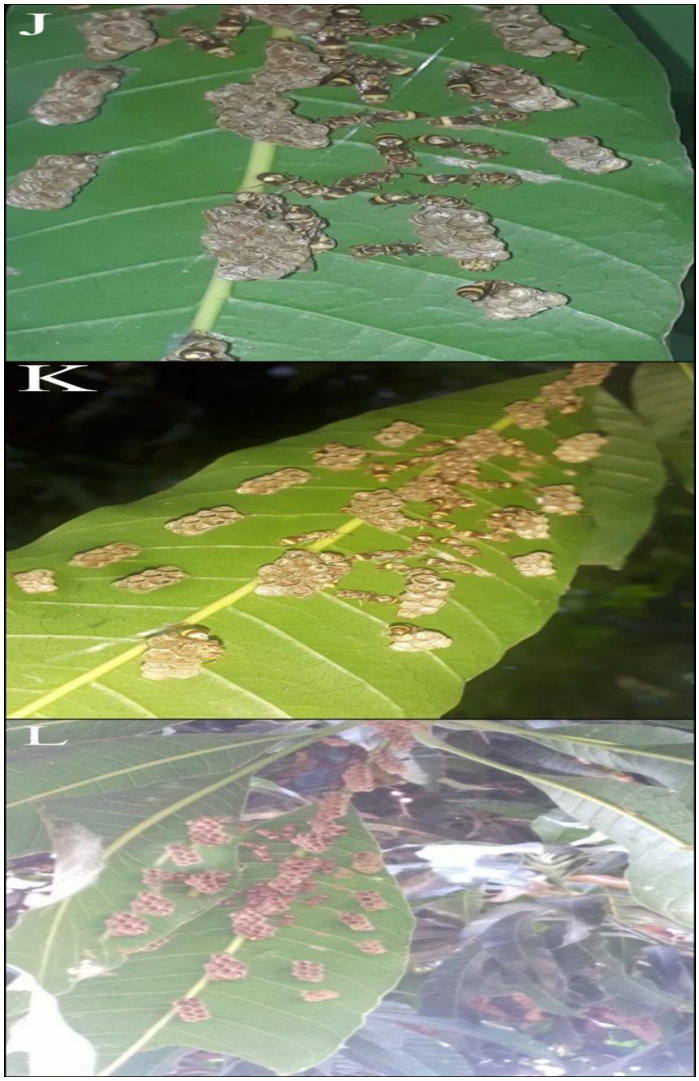

Figure 11. J shows nest cell formation and larvae in covered cells; K shows cells with larvae; L shows larvae left the nest in September.

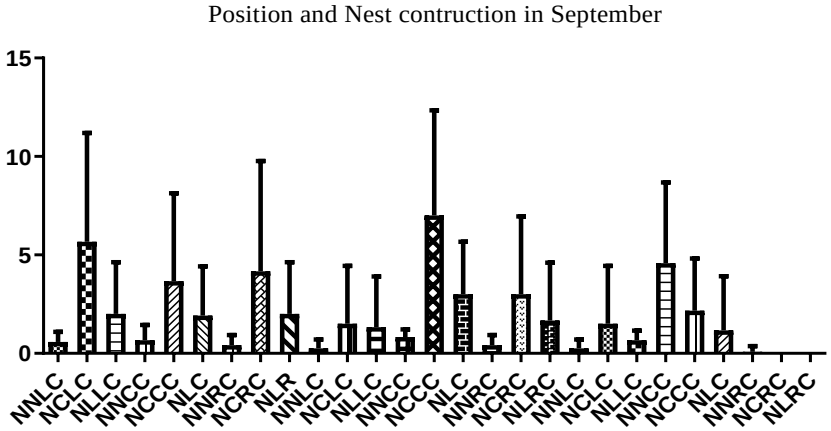

Figure 12. Nest activites in September.
NNLC Number of nests in left column; NCLC Number of cells in the left column; NLLC Number of larvae in left column NNCC Number of nest in central column, NCCC Number of cell in central column; NLCC Number of larvae in central column; NNRC Number of nest in right column: NCRC Number of cell in right column; NLRC Number of larvae in right column.

Table 5. Positions and activities of nests formation on different leaves in the month of September

SN	Leaf 1st									Leaf 2nd									Leaf 3rd								
	NNLC	NCLC	NLLC	NNCC	NCCC	NLC	NNRC	NCRC	NLR	NNLC	NCLC	NLLC	NNCC	NCCC	NLC	NNRC	NCRC	NLRC	NNLC	NCLC	NLLC	NNCC	NCCC	NLC	NNRC	NCRC	NLRC
1	0	0	0	0	0	0	0	0	0	0	0	0	1	5	4	0	0	0	0	0	1	7	4	0	0	0	0
2	1	14	5	2	5	2	0	0	0	0	0	0	1	9	6	0	0	0	0	0	1	6	4	0	0	0	0
3	1	5	0	2	13	8	1	5	3	0	0	0	1	0	8	0	0	0	0	0	1	10	6	0	0	0	0
4	1	6	3	1	9	4	1	10	4	1	3	3	1	15	3	1	10	10	1	3	1	11	0	0	0	0	0
5	0	0	0	1	5	2	1	13	5	1	8	7	1	6	2	1	5	3	1	8	1	7	0	0	0	0	0
6	1	12	4	1	8	4	1	8	5	1	7	6	1	11	1	1	7	1	1	7	1	4	0	0	0	0	0
7	1	11	5	0	0	0	1	14	7	0	0	0	1	12	2	1	9	3	0	0	1	1	1	8	0	0	0
8	1	10	7	0	0	0	0	0	0	0	0	0	1	7	6	1	5	3	0	0	0	1	7	6	1	0	0
9	1	10	0	0	0	0	0	0	0	0	0	0	1	14	0	0	0	0	0	0	1	8	4	0	0	0	0
10	0	0	0	1	4	3	0	0	0	0	0	0	1	5	4	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
M± D	0.5± 0.5	5.6± 5.5	2.0± 2.6	0.6± 0.7	3.6± 4.4	1.9± 2.5	1.9± 0.5	0.4± 5.6	4.1± 2.6	2.0± 0.4	0.2± 2.9	1.5± 2.5	1.3± 0.3	0.8± 5.3	7.0± 2.6	3.0± 0.5	0.4± 3.9	3.0± 2.9	1.6± 0.4	0.2± 2.9	1.5± 4.1	0.6± 2.6	4.5± 2.7	2.1± 0.2	1.1± 0.0	0.1± 0.0	0.1± 0.0

NNLC, Number of nests in left column; NCLC, Number of cells in the left column; NLLC, Number of larvae in the left column; NNCC, Number of the nest in the central column; NCCC, Number of cells in the central column; NLCC, Number of larvae in the central column; NNRC, Number of the nest in the right column; NCRC, Number of cells in the right column; NLRC, Number of larvae in the right column.

Figure 8.

Observation in August

In the third month of observation, we noticed a rise in the quantity of larvae. By the last week, most of them had reached maturity and formed their own nests. The population peaks during a specific month of the year, then gradually declines until the beginning of winter. The number of nests on each leaf was as follows: on the first leaf, the range was from 0.0 to 2.5±0.4; on the second leaf, it was from 0.6±0.5 to 1.0±0.3; and on the third leaf, it was from 0.6±0.3 to 0.8±0.4. Similarly, the number of cells on the first leaf ranged from around 0.0 to 4.8±0.2, on the second leaf it was 1.0±0.2, and on the third leaf it ranged from 0.4±0.1 to 6.7±0.7. Similarly, the number of larvae on these leaves was as follows: on the 1st leaf, the number of larvae ranged from 0.0 to 2.8±0.1; on the 2nd leaf, the number of larvae ranged from 2.0±0.3 to 03.0±0.5; and on the 3rd leaf, the number of larvae ranged from 0.5 to 1.77±0.3, as shown in Table 4, Figure 9, and Figure 10.

Observation in September

Approximately last month, their activities led to a fall in population numbers. As a result, one nest will be divided into many castes when the queen lays her eggs. The number of nests on this particular leaf exceeded that of other leaves due to the larvae maturation and subsequent nest construction initiation. Once the early larvae reached maturity, they ceased laying new eggs and entered a unique form of hibernation where they closed more than two neighbouring leaves. The number of nests on each leaf was 0.5 to 1.9 on the first leaf, 2.0 to 1.3 on the second leaf, and 0.6 to 1.6 on the third leaf. The cell count in each nest varied from 0.40.5 to 5.65.5 at the first leaf, from 0.22.9 to 0.80.2 at the second leaf, and from 0.10.0 to 4.52.7 at the third leaf. The larvae count varied from 1.9±0.5 to 4.1±2.6 on the first leaf, 1.5±0.5 to 7.0±0.3 on the second leaf, and 0.1±0.00 to 2.1±0.2 on the third leaf. Larvae inhabited most nests at the end of July; as seen in Table 5, Figure 11, and Figure 12, these larvae had reached maturity and begun to disperse to the adjacent leaf.

Rearing of the Specimens

During the first week of October, specimens were carefully collected and placed together in plastic jars with appropriate ventilation. They were then maintained at an optimal room temperature. The objective was to study the lifespan of wasps. It has been observed that they have the ability to survive for approximately one month without consuming any food. In mid-July, they began constructing a petiole for their nest along the midrib of the leaf. Cells were still being formed

on this stalk. We examined 2-5 nests on these leaves during the third week. During the final week of this month, there was a mutual increase in nest numbers. However, they constructed compact nests consisting of only a few cells, resulting in a count of 9 to 14 cells per nest. In November, they laid eggs in the nest cells and diligently attended to the task of caring for and incubating the eggs. New larvae emerged from these cells, while other wasps were observed diligently constructing additional nests on different leaves. The nests on the leaves were meticulously arranged in a clever pattern, with three lines running in opposite directions - one along the leaf midrib and two along the margins, as shown in Figure 11.

Closing of Leaves through Specific Fibers

It was fascinating to observe how they prepare for the upcoming winter by combining hibernation and strategies to stay warm. At the end of October, certain leaves were found to be brought closer together and wrapped in a delicate thread of silk-like fiber on the underside of a lower branch. They constructed a hive to endure the frigid winter temperatures and ensure their survival during hibernation. During the winter season, they migrated from their breeding colonies and sought refuge in a shelter resembling mango leaves. The leaves were carefully bonded using silk thread, providing them with a sense of security during the harsh winter months. This hive has been constructed on a branch strategically positioned to capture the sunlight and harness its radiant energy.

DISCUSSION

The current study was conducted in Mohmand district, Khyber Pakhtunkhwa, Pakistan, based on the morphological characterization of Ropalidia variegata variegata and their nest. The species are large yellow-brown with black markings. The maximum size is about 7.5±0.89 to 10.94±1.89 mm with little body hairs. R. variegata variegata colony consists of worker, queen, and drone wasps. When interfering with nest activity, the wasp was less aggressive than honey bees, paper wasps, and hornets. They would leave abruptly without warning after shaking, approaching, touching, or even stealing the nest, larvae, and eggs.

The Polistes genus was initially documented in Southeast Asia and subsequently spread worldwide. It has a total of 19 species that are classified under the family Vespidae (Naheed et al., 2023). In this work, we have successfully identified R. variegata variegata for the first time based on their morphological characteristics. These characteristics include a body length ranging from 7.5±0.89 to 10.94±1.89 mm, measured from the front of the head to the back of the lower segment of the belly. Khan et al. (2018) discovered that the body length of R. brevita ranged from 12 to 13 mm, while the wing length of R. variegata variegata ranged from 3.9±0 to 6.5±0.83 mm, whereas in R. brevita it measured between 9 and 11 mm. Tan et al. (2014) reported that R. parartifex has a body length similar to that of another species. They also found that the frontal view of the head is approximately 1.2 times wider than its height, and in the dorsal view, it is 2.2 times wider than its length. The head is straightly contracted behind the eye and has a posterior emargination. Additionally, the head is about 1.1 times broader than the mesonotum, including the tegulae. The cranial length of R. variegata variegata ranges from 2.0±0.22 to 2.6±0.22 mm, although its width is less than that of the mesoscutum. The distance between the two posterior ocelli is 0.70±0.20 mm, while the distance between the anterior and posterior ocelli is 0.5±0.3 mm.

Khan et al. (2018) documented that the body length of R. brevita ranged from 12 to 13 mm, while the forewing length was estimated to be between 9 and 11 mm. R. cyathiformis has a body length of 7.5 mm and a forewing length of 6 mm. In P. indicus (Stolfa, 1934), the body length measured 10–12 mm and the forewing length measured 11–12.5 mm. Gawas et al. (2020) reported that the clypeus exhibited a heptagonal morphology and displayed a dichromatic coloration. Specifically, the central region seemed brown, while the portion adjacent to the eyes and mandible exhibited a yellowish hue. The precise measurement of the head overall length was determined to be approximately 2.2±0.2mm. It was observed in P. indicus that the clypeus had punctures particularly deep in the bottom half region. The vertex had a hue that was reddish-brown in tone. The body exhibited a uniform yellowish-brown coloration. The antenna articles exhibited a reddish-orange coloration, with the initial two being entirely black and the third displaying some black pigmentation on its upper surface. The latest research has revealed that the distance separating the posterior ocelli and the compound eye is larger than the distance between two ocelli. The male antenna comprises 11 segments, with a slight curvature at the final segment. The female partner has 10 segments in their antennae, which are straight. In contrast, the male antennae are bent in the last segment. Additionally, the internal gap is brown. Both antennas have a brown tone. The mandibles exhibit a golden hue, with the exception of the teeth, which display a dark brownish shade. The anterior tint is brown, but the apex is also yellow. The eyes have a pronounced inward curvature on their inner sides. Tan et al. (2014) discovered that the distance from the ocelli to the eye is less than twice the distance

between the posterior ocelli. The initial flagellomere of the female antenna is relatively short, measuring less than 2.5 times the width of its apex.

The pronotum is a brown rectangular structure with a yellowish edge that distinguishes it from the mesoscutum, mesopleuron, and propleuron. Mesoscutium is characterized by its golden brown colour and a distinct black ring that encircles it, distinguishing it from other components. The propodial groove exhibits a wider width near its midpoint, whereas its median furrow lacks distinct clarity. There is an area located between the median and lateral ocelli that is occasionally less bright. The vertex is marked by an interrupted line after the ocelli, while the pronotal has a line. The scutellum, postscutellum, and mesopleuron have a variety of widths at their apical and basal ends. The meso-pleuron and meta-pleuron are predominantly red-brown, except for a small area near the pronotum that is yellow.

A streamlined structure called the propodium is located at the centre of the groove on the propodeum, although it is not well defined. The groove is broader in the middle. The propodium has a sub-sessile shape. Naz et al. (2020) reported that V. orientalis Linnaeus exhibits a brown body colouration. In females, the clypeus and antennal shield have a little black colour, while in workers, they have a yellowish hue. The dorsal side of the scape is yellowish-brown. The apical margin of T1 is just yellow, while T3 and T4 are almost entirely yellow. T1 exhibits a yellowish mark that is notched in the middle; T3 and T4 display little blackish-brown dots. The coxa exhibits a predominantly golden hue, with a small area of red-brown color observed on the dorsal side. Likewise, the trochanter and trochantalius exhibit a golden hue on their underside, whereas their upper side has a brownish coloration. The femur of the hind leg has a yellow spot on its bottom side, whereas the rest is brown. The femurs of the middle legs have a black coloration on both the upper and lower sides.

According to Handru et al. (2020), the rear face had a coxa and a dorsal longitudinal carina. The coxae and trochanters have a few hairs, the femora are nearly hairless, and the terminal gastral sternite is covered in long and shaggy light pubescence. The tibia and tarsus display a brownish hue, with discernible black patches on their dorsal and ventral surfaces. The tarsus of each leg consists of five parts. Each legs tarsus had a pair of claws on its lower side. Each leg possesses tibial spurs and a planter lobe. Poinar (2021) examined the elongated trochanters seen in Evaniella setifera, that these trochanters had spines on their anterior and middle legs, particularly on the upper part of the protibia, opposite a swollen region.

Itô (1985) studied and observed that during the pre-emergence stage, R. fasciata typically had one foundress who consistently remained in her nest and played a significant role in defending against natural enemies, including ants and parasitoids. Female Polistes versicolor wasps, which resemble wasps, were seen to be relatively docile both before and after emerging from their nests. They witnessed a minimal or nonexistent number of attacks during the pre-emergence period. The researchers examined the occurrence in this particular species, observing that it did not include the gripping of a limb or wing nor the biting of another individual body.

An exceptional aspect of this study was the utilization of statistical analysis to examine the nest construction behavior of the wasp. No progress has been made on the nest construction, nor has there been any increase in the number of cells and larvae. Thus, this species has been observed for the first time. In this work, we closely monitored the daily activities of R. variegata while they constructed nests over a span of 4 months. The nest counts ranged from 0.0 to 1.5±0.7 on the first leaf, 0.1±0.4 to 1.5±0.4 on the second leaf, and 0.08±0.4 to 3.0±0.4 on the third leaf during the month of June. Similarly, the quantity of cells in several nests was investigated, ranging from 0.0 to 1.5±0.7 at the first leaf, 0.1±0.4 at the second leaf, and 0.0 to 1.8±0.2 at the third leaf. Similarly, the number of larvae found on the first leaf ranged from 0.0 to 3.8±0.7; on the second leaf, it was 0.6±0.1, and on the third leaf, it ranged from 0.0 to ±3.8.

In July, there was a surge in the quantity of nests found on these leaves. The number of nests at the first leaf ranged from 0.2±0.4 to 0.6±0.4. At the second leaf, it ranged from 0.4±0.5 to 0.6±0.4. Finally, the number of nests at the third leaf ranged from 0.2±0.4 to 5.5±0.4. The number of cells measured at the first leaf ranged from 3.0±0.2 to 5.0±0.2; at the second leaf, it ranged from 3.1±4.3 to 5.4±4.2, and at the third leaf, it ranged from 0.3±0.1 to 3.4±0.5. In addition, the number of larvae observed in July on the first leaf ranged from 1.1±0.1 to 2.8±0.5; on the second leaf, it ranged from 2.0±0.2 to 3.5±0.4, and on the third leaf, the number of larvae ranged from 0.5±0.1 to 1.8±0.4.

In August, there was a decline in the total number of nests observed on each leaf. On the first leaf, the number of nests checked ranged from 0.0 to 2.5, with an average of 0.6 and a standard deviation of 0.4. On the second leaf, the number of nests ranged from 0.6 to 1.0, with an average of 0.9 and a standard deviation of 0.3. On the third leaf, the number of nests ranged from 0.6 to 0.8, with an average of 0.7 and a standard deviation of 0.4. Similarly, the cell count recorded at the first leaf ranged from 0.0 to 4.8±0.2; at the second leaf, it was 1.0±0.2; and at the third leaf it ranged from 0.4±0.1 to 6.7±0.7. Furthermore, a significant quantity of larvae was discovered on these leaves. Larva counts were observed

at the 1st leaf, ranging from 0.0 to 2.8±0.1. At the 2nd leaf, the range was from 2.0±0.3 to 3.0±0.5. Alternately, at the 3rd leaf, the range was from 0.5± to 1.77±0.3. Over the past month, their activity level experienced a decline, thus leading to a fall in the population. As the larvae in the nest matured, they began to assist the senior workers in creating a new nest. This collaboration was seen during the nest creation process and lasted until October. Unterweger et al. (2018) documented the hibernation mechanism in Hymenopterans, focusing on parasitoid families such as Braconidae and Ichneumonidae. They noted that the allocation of individuals among the plant compartments indicates a preference for flower heads and leaves over stems and tufts during hibernation.

CONCLUSION

Morphological and morphometrical study of body length and body section colors identified R. variegata variegate. The head measured 2.24±0.2 mm in length and 1.96±0.2 mm in breadth. The posterior ocelli and complex eyes are farther apart than the two ocelli. Female antennae have 10 segments, while male antennae have 11. Males have bent antennae ends, whereas females have brown inter-antennal spaces. The vertex is yellow, and the fronts are brown. Various colors were found. The thorax is 3.51±0.14 mm in length and 2.0±0.42 mm in width. Mesoscutium is golden-coloured with a black line around it. The mesopleuron and metapleuron are reddish-brown, save for a yellow patch around the pronotum. The median line does not split the smooth propodium. The legs measure 4.6±0.56mm in length and 0.1±0.07mm in width. Similarly, the wings were 5.1±0.8mm long. The second main objective is to examine nest structure and count nests, cells, and larvae on each mango tree three leaves throughout four months. Few nests were on these leaves in June. Nests with few cells also existed. July saw a gradual increase in wasps. Wasp populations peaked in August and spread. After a population drop in August and September, hibernation preparations began. They behaved less aggressively than other hymenopterans.

AUTHOR'S CONTRIBUTION

Mian Sayed Khan and Zahid Khan conceived and designed the study, and wrote the main manuscript text based on observations and analysis of activities. Haroon performed the study. Zahid Khan and Muhammad Saeed collected the wasps and made photographs with microscope. All authors reviewed the manuscript.

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AVAILABILITY OF DATA AND MATERIAL

The datasets supporting this study are included in the article. Extended methodological details and raw data can be accessed by contacting the corresponding author, subject to ethical and institutional guidelines.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

This study did not involve human subjects or animal models. In accordance with institutional guidelines, ethical approval and informed consent requirements were formally waived for this research.

CONSENT FOR PUBLICATION

I, the undersigned, consent to the publication of my identifiable information.

CONFLICT OF INTERESTS

The authors have no conflict of interest.

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