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AGroclimatic distribution and seasonal dynamics of predatory wasps attacking honeybee colonies in Himachal Pradesh

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Abstract
Vespa species are the largest of the social wasps and as such are physically capable of preying on honeybees with ease and impose heavy loss to the pollination economy. So the efforts were made to study the diversity, distribution and seasonal variations of *Vespa auraria* and *Vespa mandarina* with their abiotc factors at four major agroclimatic zones of Himachal Pradesh. Seasonal study present data revealed that, *Vespa auraria* showed the highest recorded activity in September in both years, while *Vespa mandarinia* was recorded mainly during the monsoon and post-monsoon period at apple valley of Shimla at Himachal Pradesh. The other species account indicates that reported peak attack periods generally fall between August and November. The efforts were also made to understand the correlation of Vespa spp. with temperature and relative humidity. These patterns can help to guide seasonal apiary surveillance; and to prevent honeybee industry loss.

Keywords: *Apis mellifera, Apis cerana, Vespa species*, diversity, morphological characteristics, seasonal activity, agroclimatic zones, Himachal Pradesh

Introduction
Presently beekeeping industry is facing many challenges throughout the world and one of the major constraints in beekeeping developmental programms in India is the damage caused to honeybee colonies by various pests, predators and pathogens. This may be due to the diversity in ecological conditions as well as in number of species of honeybees in this sub-continent (De Jong *et al*., 1982; Nagaraja and Rajagopal, 2003) [13]. Amongst the predators, wasps and hornets pose by far the most serious threat to beekeeping industry. Wasps are either semi-social or social insects which build their nests in cavities of trees, walls, cracks in the ground or hang them down from the trees. They are predacious by nature and catch bees from blossoms or at the entrances of the hives (Spradbery, 1991) [21]. Wasps are not only fatal to bees, but also rob their eggs, brood and honey stores. A serious attack sometimes results in absconding of bee colonies leaving behind a lot of honey and brood (Akre and Davis, 1978). Honeybee pests, predators and pathogens thus can create serious problems, which must be met not only by the beekeepers, but also by the bees themselves (Gochnauer *et al*., 1992; Morse and Flottum, 1997). Laterally Mattu and Sharma 2017, Brar *et al*., 2018 [2, 5, 8, 9] also reported that weather conditions like temperature and relative humidity are the environmental variables to be considered when monitoring wasp pressure around apiaries that can influence activity, foraging, colony development and the seasonal availability of prey in different parts of Himalayan region. So, the efforts were made to analyses the distribution of Vespa spp. in four agroclimatic zones of Himachal Pradesh and study was also conducted to see the seasonal dynamics of *Vespa spp*, with their abiotic factors from Apple valley (Shimla) of Himachal Pradesh.

Materials and Methods
Himachal Pradesh is mainly a hilly state lying between 30 º.22' to 33 º.12' North latitude and 75 º.47' to 79 º.04' East longitude in the lap of the northwest Himalayas. The topography of Himachal Pradesh is almost mountainous with elevations ranging from 350 to 6500 metres above mean sea level and total Average rainfall in the state stands at 1523 mm, although it varies from the minimum of 300 mm at Lahaul-Spiti to a maximum of 4400 mm at Dharamsala. The temperature in the state varies according to elevation. From the end of February, mercury rises gradually till June, which is generally the hottest month in this region. With the onset of monsoons, there is a gradual fall in temperature. When the monsoon ends by middle of September, temperature falls gradually at first and fairly rapidly after November (Rana *et al*., 2012) [14].
There are four major agroclimatic zones in Himachal Pradesh which can broadly be classified as sub-tropical (low lying hills), subtemperate (mid hills), temperate (high hills and interior valleys) and cold and dry zones. Beekeeping is widespread with several potential honey producing areas in the first three zones and also some in a few warmer pockets of cold and dry zones

Diversity and Distribution of Pests and Predators of Honeybees
A survey of different *Vespa spp.* infesting colonies of Indian hive bee, *Apis cerana* F. and European bee, *Apis mellifera* L. was made in 41 apiaries of Himachal Pradesh having different altitudes, latitudes and climatic conditions. Some efforts were also made on seasonal variation in the population of different predatory wasp attacking honeybee colonies was made from May, 2024 to April, 2026 in local apiary at Apple valley of Shimla Hills (Altitude, 2200 m, latitude 31º26' N and longitude 77º37' E). Monthly fluctuations were recorded in the activity of *Vespa auraria* and *Vespa mandarina* wasps attacking *A. mellifera* and *A. cerana* colonies. These counts were made on all the experimental colonies at regular fortnightly intervals from morning to evening. According to this method, wasp attack

was taken as 100 percent and from this data, monthly variations were calculated. Such observations were taken twice a month and repeated during the whole season of the year of wasp attack. Temperature and humidity data were also recorded at the time of taking observations regarding wasp attack. Results were expressed as a percentage of wasps attacking the honeybee colonies (Mattu and Verma, 1985).

For these studies, annual cycle of Apple valley Shimla area was divided into spring (March-April), summer (May-June), rainy (July-August), autumn (September-October), early winter (November-December) and late winter (January-February) seasons. Data were analyzed statistically by using IBM SPSS Statistics (version 31.0) calculating Mean, Standard deviation, Coefficient of Variation, test and Correlation coefficients (r) between Vespa Population with their Abio; tic factors.

Results

Among insects, wasps were the most serious and abundant predators attacking the colonies of both *A. mellifera* and *A.cerana* in Himachal Pradesh. A detailed survey of different apiaries revealed following 6 species of wasps which can pose serious threat to *Apis mellifera* and *Apis cerana* colonies in different agroclimatic zones of Himachal Pradesh. Body size ranged from 1.60–1.75 cm in the tiny wasp, V. flaviceps, to 3.25–3.35 cm in the giant wasp, V. *mandarina Smith*. Abdominal colour patterns varied among species, from the completely black abdomen of V. basalis to the banded patterns described for the other species. The source table classified V. auraria, V. tropica and V. flaviceps as gregarious, whereas V. *mandarina Smith*, V. orientalis and V. basalis were classified as solitary. Reported peak attack periods extended from August to November, with V. auraria and V. mandarinia showing peaks in August–September, V. orientalis in September–October, V. tropica in September–November, and V. basalis and V. flaviceps in November. Present studies also revealed that different species of wasps *viz*., *V. auraria*, *V. mandarina*, *V. tropica*, *V. basalis* and *V. flaviceps* were present in almost all the agroclimatic zones of Himachal Pradesh. Attack of wasps was more frequent on *A. mellifera* than *A. cerana* colonies. Out of *Vespa spp*., *V. orientalis* and *V. tropica* were the most predominant species at elevations < 950 metres amsl, whereas, attack of *V. auraria* was very low in this agroclimatic zone. In mid-hills (between 1000-1550 metres), *V. auraria*, *V. orientalis* and *V. tropica* were the most abundant predators. At higher elevations (>1550 metres), *V. auraria* and *V. mandarina* were the most predominant species with lateral being more destructive. In these areas, attack of *V. tropica*, *V. basalis* and *V. flaviceps* was almost negligible. Besides *Vespa* spp., two species of *Polistes* wasps were also seen predating upon *A. cerana* and *A. mellifera* colonies in different agro-climatic zones of Himachal Pradesh (Tables 1).

Seasonal Variations of Wasps

Studies on seasonal variations in population dynamics of predatory wasps, *Vespa auraria* and *Vespa mandarina* infesting *A. mellifera* colonies were carried out at local apiary Shimla, in Shimla district of Himachal Pradesh from March, 2024 to February, 2026. Results are summarized as follows:

1. Seasonal fluctuation of Vespa auraria

The population of V. auraria showed a pronounced seasonal increase during the warmer part of the year. In 2024–2025, the recorded mean rose from low values during March and April to 3.10 ± 0.38 in May, 14.60 ± 0.73 in June and 25.10 ± 0.52 in July. It increased further during August and reached the highest tabulated value of 83.80 ± 2.48 in September. Thereafter, the population declined to 73.80 ± 0.46 in October, 57.90 ± 0.74 in November and 27.70 ± 0.85 in December, followed by very low activity in January and no recorded activity in February.

A similar seasonal pattern is apparent in 2025–2026 [15]. The population increased through the warmer and wetter months, attained its highest recorded value in September (81.61 ± 1.01), and remained relatively high in October and November before declining during December and January. Thus, September was the peak month for V. auraria in both annual records, indicating a consistent late-monsoon/early-autumn period of elevated predatory pressure.

2. Seasonal fluctuation of Vespa mandarina

V. mandarina was not recorded in the early months of the annual cycle in the supplied table. Its appearance was mainly confined to the monsoon and post-monsoon months. During 2024–2025, the recorded population increased from 2.40 ± 0.27 in July and 3.40 ± 0.40 in August to a maximum of 11.50 ± 0.75 in September. It then declined to 8.60 ± 0.70 in October, 4.70 ± 0.42 in November and 0.90 ± 0.23 in December. In 2025–2026, the studies indicate that activity concentrated from the monsoon period to early winter, with the peak period occurring in September (15.50 ± 0.51), followed by a decline in subsequent months.

3. Weather conditions and seasonal wasp activity

Temperature and relative humidity varied considerably over the observation period. The rise in wasp activity from summer into the monsoon and autumn months coincided with the seasonal transition in these weather parameters. The highest wasp counts occurred around September, when the recorded temperature and humidity were within the comparatively warm and humid part of the annual cycle. Wasp abundance subsequently decreased as the season advanced towards winter. This temporal coincidence suggests that weather may contribute to the seasonal activity pattern

4. Pearson's coefficient of correlation

Pearson correlation analysis of the monthly mean values indicated positive associations between wasp population and both weather parameters in the two study years. For V. auraria, the correlation with temperature was r = 0.432 in 2024–2025 (p = 0.161) and r = 0.592 in 2025–2026 (p = 0.043). Its correlation with relative humidity was stronger: r = 0.979 ($p < 0.001$) and r = 0.977 ($p < 0.001$), respectively. For V. mandarina, the correlation with temperature was r = 0.380 (p = 0.224) in 2024–2025 and r = 0.587 (p = 0.045) in 2025–2026. Correlations with relative humidity were r = 0.936 ($p < 0.001$) and r = 0.856 ($p < 0.001$), respectively.

Species / parameter	2024–2025 (r)	2025–20026 (r)	Interpretation
V. auraria – Temperature	+0.432	+0.592	Moderate positive
V. auraria – Relative humidity	+0.979	+0.977	Very strong positive
V. mandarina – Temperature	+0.380	+0.587	Weak-to-moderate / moderate positive
V. mandarina – Relative humidity	+0.936	+0.856	Very strong / strong positive

Note: Two-tailed p-values were 0.161, <0.001, 0.224 and <0.001, respectively, for the four 2024–2025 comparisons; and 0.043, <0.001, 0.045 and <0.001, respectively, for 2025–2026. The p-values are based on only 12 monthly summary observations per year and should be treated as exploratory. Seasonal co-variation may inflate correlations, particularly with humidity.

Table 1: Different behavioural traits and body size of *Vespa spp.* attacking *Apis mellifera* and *Apis cerana* colonies in different agroclimatic zones of Himachal Pradesh

Sr.No.	Common Name	Scientific Name	Body Size (cm)	Colour of Abdomen	Nature	Distribution	Peak Period of Attack
1	Golden Wasp	*Vespa auraria* S.	2.68 – 2.83	Brown with yellow bands	Gregarious	Sub-tropical Temperate	August-September September-October
2	Giant Wasp	*Vespa mandarina* S.	3.25 – 3.35	Dark brown alternating with yellow bands and interspersed with light yellow bands	Solitary	Sub-tropical Sub-temperate Temperate	August-September
3	Yellow Wasp	*Vespa orientalis* L.	2.25 – 2.55	Yellow bands alternating with brown bands	Solitary	Sub-temperate	September-October
4	Yellow Wasp	*Vespa tropica* V.	2.90 – 3.10	Yellow bands alternating with black bands	Gregarious	Sub-tropical Sub-temperate	September-November
5	Black Wasp	*Vespa basalis* S.	2.25 – 2.50	Completely black in colour	Solitary	Sub-temperate	November
6	Tiny Wasp	*Vespa flaviceps* S.	1.60 – 1.75	Yellow alternate with brown bands	Gregarious	Sub-temperate Temperate	November

Subtropical = 350- 1000 metre Sub-temperate = 1000-1500metres Temperate1550-3000 metres
cm = centimetre

Table 2: Seasonal Fluctuations in Population population of *Vespa auraria* and *Vespa mandarina* attacking honeybee colonies at Apple Valley Shimla, Himachal Pradesh

	2024-2025				2025-2026			
Month	***V. auraria***	***V. magnifica***	**Temp (ºc)**	**Humidity (%)**	***V. auraria***	***V. magnifica***	**Temp(ºc)**	**Humidity (%)**
March	0.40±0.16* (0.115) **	–	12.50±0.85	36.50±1.04	–	–	11.25±0.48	26.25±1.25
April	0.60±0.16 (0.172)	–	14.75±0.11	40.50±1.71	–	–	13.75±0.85	31.25±1.11
May	3.10±0.38 (0.990)	–	18.25±1.30	43.25±1.37	3.90±0.31 (0.989)	–	17.50±1.04	36.25±1.93
June	14.60±0.73 (4.189)	–	20.75±1.37	49.25±1.37	17.1±0.60 (4.338)	–	21.75±1.11	45.00±1.96
July	25.10±0.52 (7.202)	2.40±0.27 (7.619)	22.25±1.37	58.25±2.56	31.1±0.97 (7.890)	5.20±0.49 (11.135)	21.00±1.11	56.00±2.48
August	58.70±0.57 (16.844)	3.40±0.40 (10.793)	21.25±1.49	63.75±1.49	60.9±0.84 (15.450)	10.60±0.51 (22.698)	21.25±0.95	61.00±1.29
September	83.80±2.48 (24..046)	11.50±0.75 (36.508)	20.25±0.85	81.75±1.37	81.6±1.01 (20.702)	15.50±0.51 (33.191)	20.25±1.49	78.00±1.83
October	73.8±0.46 (21.176)	8.60±0.70	16.25±0.85	74.25±1.88	79.00±0.71 (18.337)	11.60±0.51 (24.839)	18.50±0.96	74.25±1.49
November	57.90±0.74 (16.614)	4.70±0.42 (14.921)	13.50±0.65	65.00±12.90	71.11±0.74 (18.041)	2.60±0.40 (5.568)	17.75±1.11	68.00±1.47
December	27.70±0.85 (7.948)	0.90±0.23 (2.857)	10.25±0.85	51.75±1.38	41.30±0.52 (10.477)	1.20±0.20 (2.570)	15.25±1.03	49.00±1.29
January	2.80±0.35 (0.803)	–	8.25±0.25	38.25±1.25	12.90±0.67 (3.273)	–	13.50±0.65	37.75±1.38
February		–	7.50±0.65	36.75±1.65	–	–	12.50±1.04	32.00±1.41

*x+S.E Mean ± Standard error about mean
**: Figures in parenthesis indicate per cent population
Population expressed in term of number of Vespa sp./hive/day

Discussion

Among insects, wasps and hornets were the most abundant and serious predators of Indian hive bee, *A. cerana* and European bee, *A. mellifera* in different localities of Himachal Pradesh. Diversity studies revealed 6 species of *Vespa viz*., *Vespa auraria* S., *Vespa mandarina* S., *Vespa*

orientalis L., *Vespa tropica* V., *Vespa basalis* S., and *Vespa flaviceps L* in different apiaries of Himachal Pradesh. Similarly, Sharma and Raj (1988) observed *Vespa orientalis*, *Vespa tropica* and *Vespa velutina auraria* attacking *Apis mellifera* colonies in Kangra Shivaliks of Himachal Pradesh. Abrol and Kakroo (1994) reported six species of wasps *viz*., *Vespa velutina, Vespa orientalis, Vespa cincta, Vespa magnifica*, *Vespa mandarina* and an unidentified species, predating upon *Apis cerana* and *Apis mellifera* colonies in Jammu and Kashmir. Among these, *Vespa orientalis* was the most abundant and serious predator. Gattoria and Jhajj (1994) also found *Vespa orientalis* and *Polistes spp.* attacking *Apis mellifera* colonies in Punjab, similarly Sharma (2002), Nagaraja and Rajagopal (2003) and Sharma and Mattu 2014, 2017 [8, 13, 19] also gave similar finding in different parts of the Indian subcontinent. Laterally many researchers also reported that Predatory wasps and hornets have also caused devastation to *Apis mellifera* colonies not only in Asia, but in many parts of world (Sauvard *et al*., 2018 [17], Sabreen G. *et al*., 2026.,)

Based on present bio-ecological studies on predatory wasps in Himachal Pradesh, it was observed that *Vespa orientalis* and *Vespa tropica* were the most prominent species at elevations < 950 metres, whereas, in mid hills, *Vespa auraria*, *Vespa orientalis* and *Vespa tropica* posed serious problems to *Apis mellifera* colonies. At higher elevations (> 1550 metres), *Vespa auraria* and *Vespa mandarina* were the most prominent species with latter being more destructive. These results are in conformity with the earlier observations of Sharma and Raj (1988) who also found *Vespa auraria* as the predominant species at higher elevations and *VESPA orientalis* at the lower altitudes in Kangra Shivaliks. Recently, Sharma and Mattu, 2014, Sharma *et al*., 2018 and Motmayen and Sharma 2025 [2, 10, 19] gave similar findings on *Vespa* species in Himachal Pradesh.

Behavioural data on seasonal variations in the infestation of *Vespa auraria* and *Vespa magnifica* showed that it was maximum during the month of September at Shimla apiary of Himachal Pradesh. Thus, a significant positive ($P<0.01$) correlation was found between *Vespa auraria* and *Vespa magnifica* population with temperature (r=+0.591; +0.618) and relative humidity (r=+0.977; 0.856) in honeybee colonies (Table 1,2).

In Nagaraja and Rajagopal, (2003) [13], showed the peak period of predatory wasp infestation was between September to November at Bangalore. These variations in peak period of infestation in different parts of country may be due to differences in physiographic and environmental conditions (Sauvard *et al*., 2018) [17].

During the study period observations show that V. auraria was the more abundant of the two-wasp species recorded at New Shimla. Its population increased during the warmer months, peaked in September in both years, and declined sharply during late autumn and winter. V. mandarina showed a narrower seasonal window, with most activity occurring from July to December and a peak around September. The recurrence of the peak month across years suggests that the late-monsoon and early-autumn period is a predictable high-risk period for honeybee apiaries in this locality. The preliminary correlation analysis also showed strong positive associations with relative humidity in both years, while the association with temperature was weaker and varied between years.

The pattern broadly agrees with reports from other parts of Himachal Pradesh. Mattu and Sharma (2017) [8] reported seasonal attacks by V. auraria and V. mandarina on A. mellifera colonies in Kangra, with the highest activity of V. auraria in September and V. mandarina in October. Brar *et al*. (2018) [2] also reported a September peak in V. auraria activity at Nauni, Solan, and described positive associations with temperature and relative humidity. These studies support the importance of seasonal monitoring, although differences in location, altitude, species composition and observation methods may affect the timing and magnitude of wasp activity.

The apparent coincidence between elevated wasp populations and relatively humid months is biologically plausible, but it should not be interpreted as proof that either weather variable independently drives wasp abundance. Seasonal food availability, wasp colony development, local nesting activity, apiary management, honeybee colony strength and surrounding habitat may also influence the number of wasps visiting hives

Conclusion

Present studies revealed 6 species of wasps *viz*., *Vespa auraria* Smith, *Vespa mandarina* Smith, *Vespa tropica* (Leefmansi) Vecht, *Vespa orientalis* Linnaeus, *Vespa basalis* Smith, *Vespa flaviceps* Smith, of all wasps, *V. orientalis* and *V. tropica* were the most predominant at elevations <1000 metres amsl (low lying hills and valleys), whereas, attack of *V. auraria* was very low in this agro-climatic zone. In mid-hills (between 1000-1550 metres), *V. auraria, V. orientalis* and *V. tropica* were the most abundant predators. At higher elevations (> 1550 metres), *V. auraria* and *V. mandarina* were the most destructive and predominant predators. Present biodiversity studies further revealed that attack of *Vespa* spp. was more frequent on European *A. mellifera* than native *A. cerana* colonies in all the agro-climatic zones of Himachal Pradesh.

Present data showed that Vespa Auraria was maximum during the months of September, although V. mandarina was mainly recorded from July to December and also showed its highest reported activity around September at this apiary of Himachal Pradesh. The late-monsoon and early-autumn months should therefore be considered the principal period for intensified apiary surveillance and protective management. A significant positive correlation was established of population of *Vespa auraria* and *Vespa mandarina* with temperature (r=0.592, 0.618; $P<0.01$)) and relative humidity (r= 0.997; 0.856; $P<0.01$)) in *Apis mellifera* colonies.

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