Original Research Article

Prevalence of Brood Diseases in Indian Honey Bee (*Apis cerana indica*) Colonies: A Kerala Study

ABSTRACT

Aim: The study aimed to assess brood disease incidence in *Apis cerana indica* colonies across Kerala, analyze seasonal variation, and evaluate the effect of weather and hive conditions on disease prevalence for the management of brood diseases in Indian bee colonies.

Study design: Purposive survey, Correlation (regression) analysis, Temporal/seasonal assessment.

Place and Duration of Study: "The survey was conducted in apiaries across Kerala, India, with fieldwork carried out at sites managed by local beekeepers under the academic guidance of the Department of Agricultural Entomology, Kerala Agricultural University, College of Agriculture Vellayani. The study was carried out over a period from February 2024 to March 2025.

Methodology: The study involved a purposive one-year survey (Feb 2024-Mar 2025) across Kerala based on the disease incidence information from beekeepers. Geographical data and weather parameters such as temperature (℃) and relative humidity (%), brood disease incidence, symptoms, & prophylactic management practices followed by the beekeepers were recorded. Observations on the number of infected colonies, its colony strength and infected brood cells were recorded and was correlated with weather parameters of apiary.

Results: Of the 1143 colonies surveyed in Kerala, brood diseases were found in 329 colonies (28.78%) with the highest incidence in Kondazhy (90%) of Thrissur and lowest in Muthalamada (4.0%) of Palakkad. Brood disease incidence peaked during the dearth season, followed by brood-rearing and honey flow season. Regression analysis showed a weak negative correlation with temperature (-0.507) and a weak positive correlation with relative humidity (0.191) in the apiaries. Hive temperature showed a strong negative correlation (-12.482), while relative humidity had positive correlation (0.612) with percentage brood disease incidence (%BDI). The symptoms recorded were unsealed brood pattern, young larvae (4–5 days) lying flat in melted condition with degraded tissue, and pre-pupal stages ceasing development with their heads upright in position

Conclusion: The study reveals significant brood disease incidence in *Apis cerana indica* colonies, influenced by environmental factors and colony strength. Hygienic behavior and diverse management practices helps to avoid spread and support recovery from the diseases. These findings highlight the need for integrated, climate-adapted disease management to sustain colony health and optimize honey production in Kerala. Further research is needed to validate and refine these approaches for sustainable apiculture.

Keywords: *Purposive survey; brood disease incidence; Apis cerana indica; seasonal variation; weather correlation*

1. INTRODUCTION

Honey bees (*Apis* spp.) are vital pollinators in natural and agricultural ecosystems that, significantly supporting biodiversity and food security (Johannesmeier and Mostert, 2001). They can be managed in hives and deployed in required numbers (Goderham, 1950). In India, *Apis mellifera* and *Apis cerana indica* are the primary domesticated species, with the latter being preferred for commercial beekeeping in Kerala, a state rich in floral resources such as like rubber and coconuts that offer ample foraging opportunities. The state's favorable climate further enhances beekeeping and contributes to nearly 70% of India's honey production as being a hub for high-quality organic honey (Jacob et al., 1992). Pollination with by *A. cerana indica* improves cucumber yield by 25% and enhances crop quality (Premila et al., 2014).

Bee health is crucial because due oft to the social behavior of worker bees involved in colony maintenance, brood care, and queen selection, all of which are vital for colony productivity. However, colony vigor is compromised by pests and diseases at various life stages, causing up to 30% annual losses in India with a severe economic impact on to apiculture (Chen et al., 2006). Diseases affect the adult and brood stages, with broods being particularly vulnerable to bacterial and viral infections. Major bacterial diseases include American foulbrood (AFB) caused by *Paenibacillus larvae and* European foulbrood (EFB) caused by *Melissococcus plutonius*; viral diseases include Sacbrood virus (SBV) and Thai sacbrood virus (TSBV) (Houiston and Sons, 1882; Arbia and Babbay, 2011). These diseases cause significant challenges globally and in India, with 48-50% of the annual colony losses attributed to such infections (Hasan, 2021). AFB was first reported in Uttar Pradesh (1961), with EFB recorded in Maharashtra's Karad in 1970, causing 25-30% losses in Maharashtra and Punjab (Singh, 1961; Diwan et al., 1971; Gatoria et al., 2003). SBV was documented in Himachal Pradesh in 1998, causing 2.52–2.92% brood mortality in *Apis mellifera* (Chandel et al., 1999), and is closely related to TSBV, which was first reported in Meghalaya in 1978. The TSBV later spread north and south, causing pupal death in *A. cerana* colonies (Kshirsagar et al., 1982; Aruna et al., 2016). In 1991–1992, Kerala suffered a severe outbreak of TSBV disease, destroying of nearly 90% of honey bee colonies (Thomas et al., 2002) while Amritha et al., (2014) reported an incidence of approximately about 45% incidence in Indian bee colonies with brood disease symptoms.

Seasonal variation in brood disease incidence has been is documented; SBV and TSBV peak during spring and brood-rearing seasons, with incidences of up to 47% in some regions (Joshi and Verma, 1985; Naveen & Yadav, 2021). The EFB and AFB peaks in warmer months were correlating positively correlated with brood area and colony strength (Rathod et al., 2025). Correlation studies have shown that brood disease incidence is positively associated with humidity and rainfall but negatively associated with higher temperatures. Colony hygieneic behavior significantly affects disease resistance, with more hygienic colonies exhibiting lower brood disease rates (Joshi and Verma, 1985; Haran et al., 2024).

Despite the economic importance of *Apis cerana indica* in agriculture and& honey production, there is a limited region-specific data on the incidence and seasonal dynamics of brood diseases in Indian bee colonies across Kerala. This knowledge gap restricts the development of effective disease monitoring and management strategies required for healthy and productive bee colonies in thise region. Therefore, the current investigation was undertaken to conduct a purposive survey of brood disease incidence across multiple districts of Kerala, aiming to document spatial and temporal variations in brood disease incidence and to analyze correlations with environmental and hive parameters. The findings will provide valuable insights to support targeted disease control measures, promoteing sustainable beekeeping practices that enhance pollination services and, biodiversity conservation, and simultaneously represent the state's role in quality and organic honey production.

2. MATERIAL AND METHODS

2.1. Purposive survey on the brood disease incidence in Kerala

A sSurvey on the disease incidence inof Indian bee colonies was conducted in different locations from Kerala during the period of one year, *i.e.* February, 2024 to March 2025. A pProper survey schedule was prepared, and data on apiary locations, such as GPS, Altitude, Temperature and Relative humidity, were recorded. Around 2-3 apiaries from each location and ~90-100 infected colonies per ~~each~~ district surveyed based on the beekeeper's information, were selected tofor recording the brood disease incidence. Information on different brood diseases, their symptoms, and the management strategies followed by ~~the~~ beekeepers were collected. Colony parameters, such as the total number of colonies, number of diseased colonies, and colony strength, were recorded. Brood ~~parameters~~ and ~~the~~ hive parameters, such as temperature and relative humidity, were also recorded during the three seasons of beekeeping in Kerala.

2.1.1. Brood disease symptoms and management methods

The symptoms were recorded based on the change in the colour and, position of the brood in the cells, odour emitted by the brood, and their capping pattern. Along with the brood conditions, the activity of workers in the colony was ~~also~~ monitored to identify any changes in their behaviour. Information on the management methods followed by ~~the~~ beekeepers against ~~the~~ diseases in Indian bee colonies waswere recorded.

2.1.2. Colony parameters and percentage brood disease incidence

Colony parameters, such as the number of diseased and& healthy colonies from each apiary were recorded, and the percentage of brood disease incidence was calculated ~~by~~ using the following formula:

$$\text{Percentage of infection} = \frac{Number\ of\ diseased\ colonies}{Total\ number\ of\ colonies} \times 100$$

2.1.3. Colony strength

Bee colony strength iIn the infected colonies~~, bee colony strength~~ was also documented based on the number of bees present in a colony. It was assessed using the visual scoring method (Delaplane et al., 2013) *i.e.* by observing the number of bees covering ~~in~~ each colony. A sScore was assignedgiven to a colony as a numbers. The colony was scored '6' as the strength, if all the 6 combs are fully covered by the bees.

2.1.3. Brood parameters and Infected brood area

Brood conditions andwell as ~~the~~ number of infected larvae/pupal cells were recorded from the infected colonies. ~~Then~~ Tthe infected brood area was then calculated ~~by~~ using the formula:~~.~~

Infected brood area = No. of infected larvae or pupae (cells) × aArea of a single cell (A)

where, Area of a single cell of a comb is measured by the equation

$$\text{Area of a hexagon} = \frac{3\sqrt{3}}{2} \times a^2$$

'a' is the side of a hexagon which is 0.30. The area of a single cell was calculated and found to be 0.47 cm^2 (Shah & Shah, 1973). Therefore, the area was multiplied bywith no. of infected larvae or pupae to obtainget anthe infected brood area.

2.1.4. Hive temperature and Relative humidity of the infected colonies

The tTemperature and rRelative humidity of the diseased colonies were recorded by placing the two sensor wires of a Digital Data logger inside the hive for 5 minutes. A cCorrelation analysis was performeddone to determineknow the effect of hive parameters on brood disease incidence.

3. RESULTS AND DISCUSSION

3.1. Survey on brood disease incidence

Out of 1143 colonies surveyed for brood disease incidence from 14 different locations inof nine districts of Kerala, 329 infected colonies were found. Apiaries surveyed for brood disease incidence from different regions of Kerala are geographically represented (Fig.1).

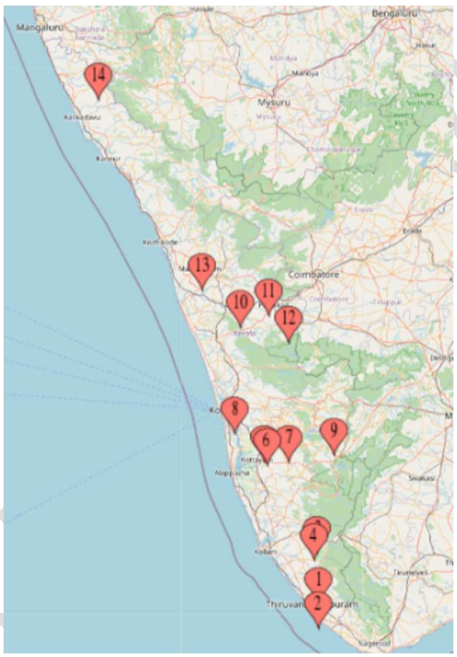


Fig. 1. Locations surveyed for brood disease incidence from different districts of Kerala during 2024-25

Data on the GPS, altitude, temperature, and relative humidity (%RH) of apiaries purposively selected for recording brood disease incidence in Kerala during 2024-25 areis presented in Table.1.

Table 1. Details of the apiaries surveyed for per cent brood disease incidence

District	Season	Location of apiary	GPS Coordinates	Altitude (m)	Temperature (℃)	RH (%)	Apiaries visited	Total colonies	Diseased colonies

			(Latitude & Longitude)						
Trivandrum	Honeyflow season	Kollamkavu	8.62°N, 77.00°E	65	31.80	51	3.00	105.00	17.00
	Dearth season	Kalliyoor	8.43°N, 76.99°E	10	30.38	78	1.00	45.00	12.00
Kollam	Dearth season	Edamon	9.00°N, 76.99°E	92	25.70	90	3.00	45.00	19.00
	Dearth season	Ayilara	8.95°N, 76.97°E	96	25.30	92	2.00	50.00	19.00
Kottayam	Honeyflow season	Puvanthurathu	9.68°N, 76.59°E	22	36.70	32	2.00	70.00	14.00
	Dearth season	Kattachira	9.68°N, 76.59°E	600	35.40	35	1.00	100.00	50.00
	Brood rearing season	Panackapalam	9.70°N, 76.76°E	34	29.80	74	2.00	100.00	35.00
Ernakulam	Brood rearing season	Arakkunnam	9.90°N, 76.43°E	34	36.80	60	3.00	90.00	55.00
Idukki	Brood rearing season	Kanjar	9.81°N, 76.82°E	57	27.80	83	1.00	92.00	5.00
Thrissur	Honey flow season	Kondazhy	10.71°N, 76.38°E	96	29.90	70	3.00	30.00	27.00
	Honey flow	Akathethara	10.83°N,	89	30.00	71	3.00	102.00	17.00

	season		76.62°E						
Palakkad	Dearth season	Muthalamada	10.58°N, 76.83°E	217	35.50	41	2.00	99.00	4.00
Malappuram	Honey flow season	Chattipparamba	11.00°N, 76.10°E	60	33.90	54	5.00	125.00	42.00
Kasargod	Brood rearing season	Kolichal	12.45°N, 75.30°E	141	36.10	50	2.00	90.00	13.00
Total= 9		14					33	1143	329.00

3.2. Percentage brood disease incidence and colony strength

Colony parameters recorded on percentage brood disease incidence resulted in a 28.78% incidence during the period, 2024-25 (Table.2.). The highest incidence ofpercentage brood disease incidence was recorded infrom Kondazhy (Thrissur) (90.00%) and the lowest infrom Muthalamada (Palakkad) (4.04%). The cColony strength of the infected colonies was comparatively lowerless in the location thatwhich reported maximum incidence (Kondazhy) (1.30), and wthichs was in similarity towith the findings ofaddressed by Haran et al., (2024) and Devi et al. (2024) in infected colonies of *Apis cerana indica*. Moreover, the findings in the studies regarding the colony strength by Budge et al. (2015) reported that the reduction in the strength as an indicator for pathogen exposure in the colonies.

Table.2. Percentage brood disease incidence, brood parameters and hive parameters of surveyed apiaries

District	Location	Colony strength*	Percentage brood disease incidence*	Mean number of brood cells with infected larva / pupa	Hive Temperature (℃)	Hive Relative humidity (%)
Trivandrum	Kollamkavu	2.25	16.19	53.67	34.50	54.10
	Kalliyoor	3.50	26.67	40.00	34.50	53.00
Kollam	Edamon	3.00	42.22	43.50	32.50	65.20

	Ayilara	5.00	38.00	109.00	34.50	66.00
Kottayam	Puvanthurathu	1.75	20.00	76.33	32.30	66.10
	Kattachira	4.80	50.00	60.34	35.10	62.80
	Panackapalam	2.80	35.00	96.00	33.50	82.30
Ernakulam	Arakkunnam	4.00	61.10	115.33	32.30	81.90
Idukki	Kanjar	4.30	5.43	44.83	35.00	70.00
Thrissur	Kondazhy	1.30	90.00	38.67	31.00	69.00
	Akathethara	3.80	16.67	45.00	35.00	70.00
Palakkad	Muthalamada	5.00	4.04	10.67	34.50	68.00
Malappuram	Chattipparamba	2.75	33.60	99.50	34.50	58.00
Kasargod	Kolichal	4.50	14.44	60.00	35.00	69.00
9	14		28.78±0.88			

**Values are mean of four infected colonies*

District-wise brood disease incidence was computed, and the maximum incidence was reported from the Ernakulam district (61.1%), while the minimum was from the Palakkad district (4.04%) (Fig.2).). Variation in the incidence ofpercentage brood disease incidence was observed owingdue to the spatial and temporal attributes of different agroclimatic regions (Rao, 2009) which was also evident in the present findings. The brood disease incidence of 28.78% recorded infrom the surveillance studies in the state, was higher than that of previous reports from Kashmir (with 8–18%) (Suresh et al., (2018). Comparable or higher incidences have also been reported infrom China, with 28.90% incidence in *Apis cerana* colonies (Gong et al., 2016) and American foulbrood affecting 37.30% of colonies in northwest Pakistan (Khan et al., 2018). The elevated incidence observed in this studyhere may be due to local climatic conditions, nutritional stress during dearth periods, and colony management practices.

Season-wise incidence resulted in the highest percentage of brood disease incidence during thehoney honeyflow season (Fig.3). This pattern aligns with the findings offrom the previous reports in Kerala, wherein some of the regions surveyed for bacterial disease incidence were found to be more infected during the dearth period (Joesph & Amritha, 2020). In Himachal Pradesh, the studies on the influence ofbetween brood disease incidence and forage scarcityе period (dearth) have also reported a negative correlation (Sharma *et al*., 2025) suggesting that pollen substitutes and supplements during dearth periods improve colony

strength, brood area, and disease resistance. This supports our present findings by highlighting the direct link between nutrition and disease dynamics in Indian bee colonies under Indian climatic conditions.

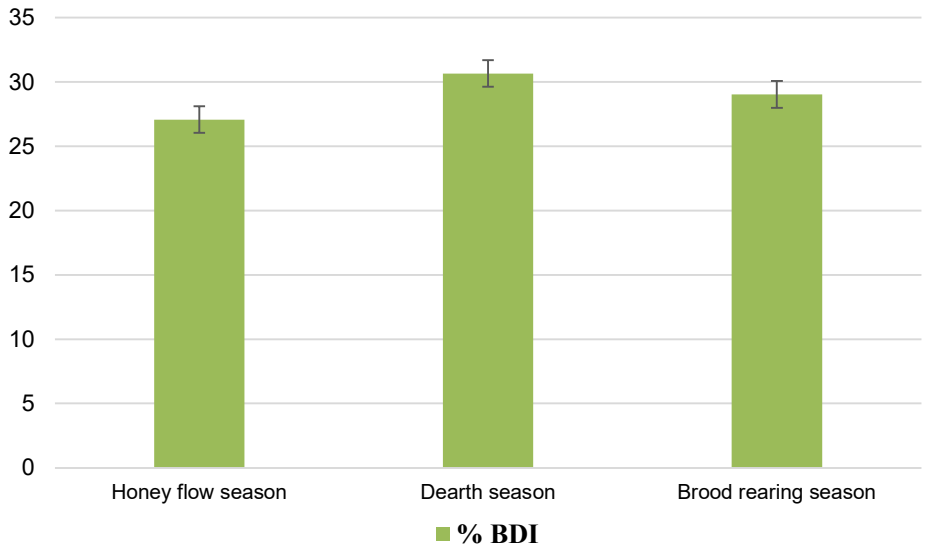


Fig.2. District wise brood disease incidence (%) from different locations of Kerala

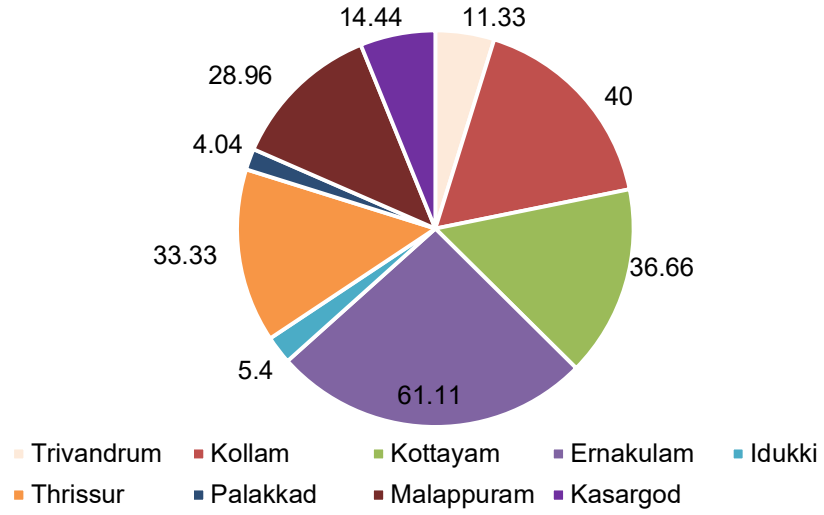


Fig.3. Season wise brood disease incidence (%) from different locations of Kerala

In other countries, ~~the~~ research emphasizes that ~~the~~ nutrient deficiency during the dearth period ~~impacts~~ increase~~d~~ susceptibility to brood pathogens (Mattila & Otis, 2006; Alaux et al., 2010). Conversely, abundant floral resources during the honey flow season enhance colony strength and hygien~~eic~~ efficiency, thereby lowering infection rates (Evans & Spivak, 2010). Similar seasonal trends have been reported in Indian apiaries, where ~~the~~ outbreak~~s~~ of foulbrood and sacbrood diseases peak~~ed~~ during these periods (Bhatia et al., 2014; Suresh et al., 2018).

3.3. Symptomatology and Management strategies

~~The~~ I~~i~~nfected colonies exhibited ~~an~~ irregular brood pattern~~s~~. Infected larvae, typically 4–5 days old, exhibited~~showed~~ a~~the~~ color change from pearly white to creamish-white. However, in~~At~~ the early stages of infection~~, however~~, distinct color changes were not observed~~always noticeable~~. Most frequently, the affected larvae were observed lying flat along the cell base in a melted or semi-fluid condition, with symptoms suggestive of bacterial infections (Fig.4~~). .~~). When ~~stretched out~~ the infected brood was stretched, ~~the~~ ropy ~~nature~~ was not observed~~noticed~~. Similar symptoms, such as irregular broods with flaccid or semi-liquid larvae, were reported by Ansari et al. (2016) from India and Forsgren (2010) from Europe, and the absence of ropey nature in the larval remains suggests the indication of EFB rather than American foulbrood (OIE, 2021). Similarly, the color change at the earlier stage of infection~~s~~ i~~wa~~s not always pronounced, as documented by Forsgren (2010) and~~&~~ Ellis (2016), indicating that subtle initial symptoms can complicate field diagnosis.

In addition, diseased colonies ~~also~~ displayed symptoms in the late larval to pupal stages, characterized by uncapped cells and a “pepperbox” brood pattern. The pupal stage within these cells showed their heads oriented upwards with retarded development, which is~~are~~ indicative of possible viral infections, such as sacbrood virus (Fig. 4). ~~The~~ T~~t~~ypical sac-like symptoms were present in some of the colonies but were~~was~~ not observed~~seen~~ in ~~the~~ asymptomatic colonies. Similarly, Wei et al. (2022) and Gong et al. (2016) also described that the symptoms in the colonies appear as “pepperbox” brood and head-up larvae in *Apis* sp. from Asia.

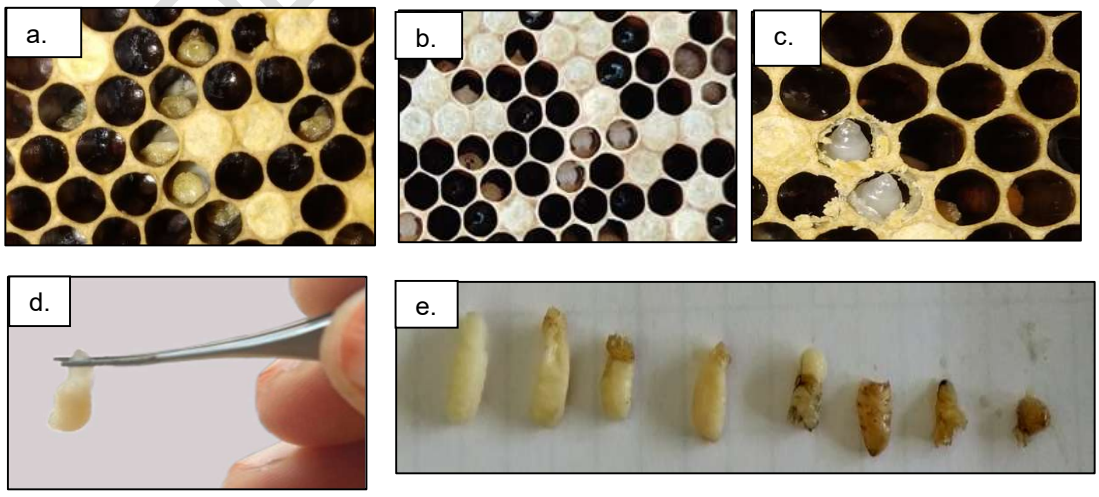
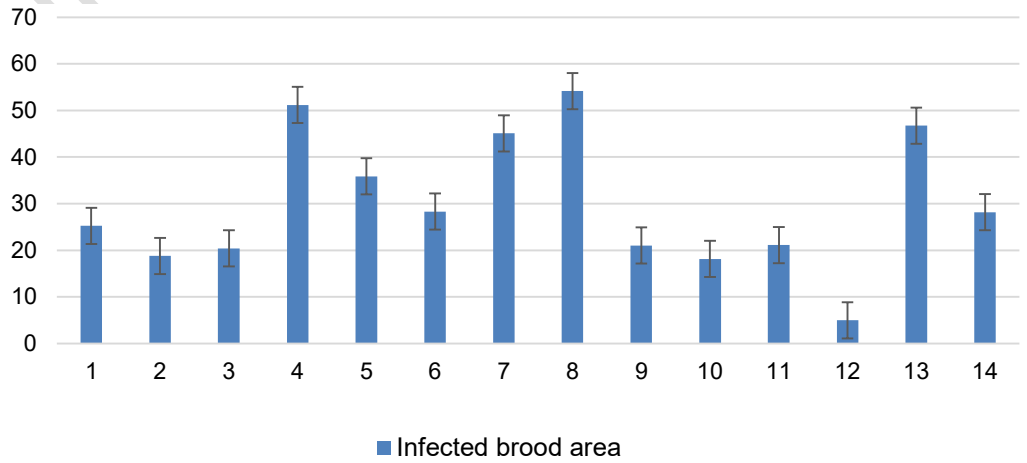


Fig. 4. Symptoms of infected colonies recorded from different locations.
a) Larvae in melted condition, b&c) Pupal stages head in upright orientation, d) Sac-like appearance of the late-larval stage & e) Brood exhibiting colour change forming into scales

Information on management strategies adopted by the beekeepers revealed that they followed different methods ~~were followed by them~~ in the apiaries. To reduce the spread of the infection, colonies showing disease symptoms were discarded from the apiary. Bacterial infected colonies were treated with~~by applying~~ turmeric (2 g) or antibiotic (~~,~~ t~~T~~erramamycin 500 mg) along with ~~the~~ artificial feed (50% sugar solution) to combat the infection. Sulfphur~~-~~based A~~a~~yurvedic medicines have~~were~~ also been used to treat~~against~~ these diseases. Old queens from ~~the~~ colonies showing viral infection were~~was~~ removed, and a new queen was provided. Combs with~~having~~ diseased broods were cut and discarded.

3.4. Infected brood area and hive parameters

Brood parameters, *viz*., number of brood cells with infected larvae or pupae, hive temperature, and~~&~~ %relative humidity (Table.2.) revealed a significant difference in the infected brood area. The m~~M~~aximum infected brood area was documented from Arakkonam (Ernakulam) (54.2 cm^2), while the lowest area was from Muthalamada (Palakkad) (5.01 cm^2), as shown~~represented~~ in Fig. 5. This variation within the apiary of Arakkonam can be partially explained by the differences in hive types. Taric et al. (2019) reporteds ~~revealed~~ that the hive type used for bee~~-~~keeping differs due to the internal hive microclimate, which influences ~~the~~ colony health and ~~also~~ the brood area. For instance, commercial or framed hives used in some apiaries provide different ventilation and temperature regulations than~~compared to~~ traditional hives, which can affect brood susceptibility to diseases. The present study also reported a reduction in the brood area of the infected ~~colonies in~~ colonies with less incidence; similar results were obtained by~~in the studies of~~ Rana et al. (2004) and Rao (2009). Moreover, disease incidence was not always directly correlated~~directly~~ with the infected brood area of the colonies in a region, based on~~from~~ the present findings. The inverse relationship between hygienic behavior and the extent of the infected brood area shows that colonies with stronger hygienic responses tend to have fewer infected brood cells. The positive influence of colony strength on hygienic activity further indicates that stronger colonies are more effective in~~at~~ detecting and removing diseased broods. This hygienic behavior helps in controlling brood disease severity by minimizing infected broods within the cells and limiting disease spread throughout the colony.



1-Kollamkavu, 2-Kalliyoor, 3- Edamon, 4- Ayilara, 5- Puvanthurathu, 6- Kattachira, 7- Panackapalam, 8- Arakkunnam, 9- Kanjar, 10- Kondazhy, 11- Akathethara, 12- Muthalamada, 13- Chattipparamba & 14- Kolichal

Fig.5. Infected brood area of the diseased colonies from different locations in Kerala (2024-25)

3.5. Correlation between temperature and %relative humidity and percentage brood disease incidence.

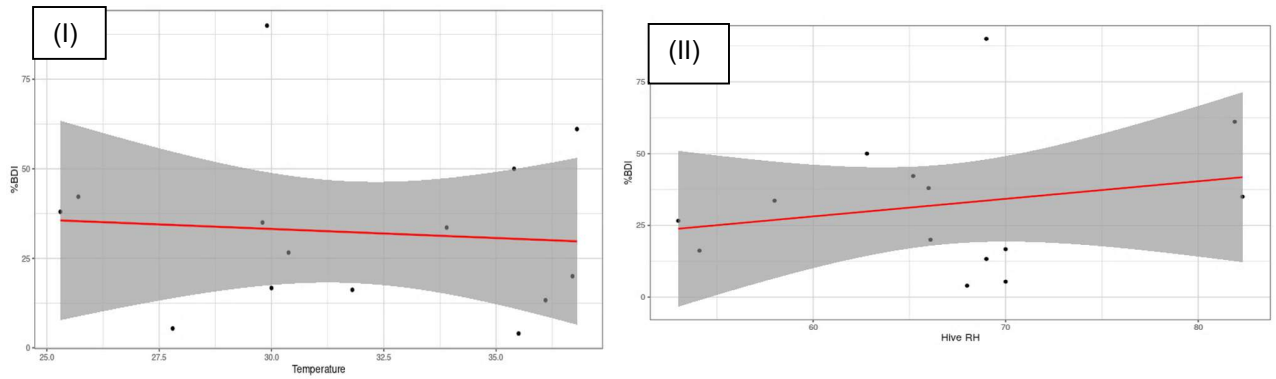
Location parameters and hive parameters ofn temperature and %RH showered significantly correlatedion with the percentage of brood disease incidence (Table.3.). Regression analysis ofn the effect of weather parameters on the%BDI of the apiary locations revealed a weak negative correlation with temperature (-0.507) and a weak positive correlation with percentage relative humidity (0.191). The Hive parameter, temperature, showed a significantly strong negative correlation (-12.482) with percentage brood disease incidence, while percentage relative humidity exhibited a positive correlation (0.612), as shown~~given~~ in ~~the~~ fig.6.

Table. 3. Effect of weather parameters and hive parameters on per cent brood disease incidence (%BDI)

Parameters	Estimate	Standard Error	t value	P-value
Temperature (℃) of the location	-0.507	1.695	-0.299	0.770
%RH of the location	0.191	0.339	0.564	0.583
Hive temperature (℃)	-12.482	3.689	-3.383	0.005
Hive %RH	0.612	0.774	0.791	0.444

Regression analysis with dependent variable (%BDI) & parameters as independent variables

Regression co-efficient with P-value <0.05 are significant (alpha = 0.05)



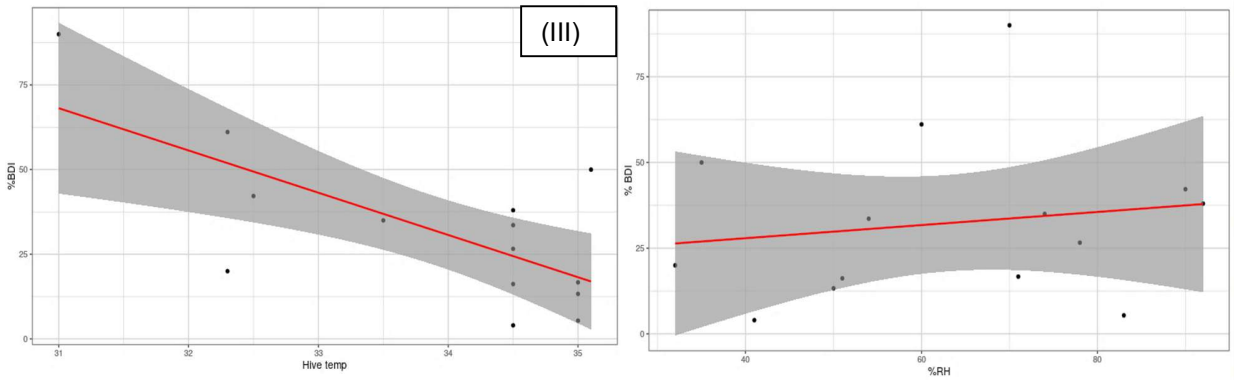


Fig. 6. Effect of weather parameters and hive parameters (Temperature (℃), %RH) on percentage brood disease incidence.

(I) Weak negative correlation between location temperature & % BDI, (II) Weak positive correlation between location %RH & % BDI, (III) Strong negative correlation between hive temperature & % BDI & (IV) Weak positive correlation between hive %RH & % BDI

4. CONCLUSION

In the present study, a survey conducted across 14 locations in Kerala revealeds a significant brood disease incidence of 28.78 % %in *Apis cerana indica* colonies, with an overall incidence of 28.78%. The spatial and seasonal variations in disease incidence underscores the influence of local environmental factors, particularly the positive correlation with relative humidity and inverse relationship with temperature, on brood disease dynamics. Low colony strength in regions of high disease incidence highlights the susceptibility of weak colonies to pathogen exposure, which is consistentaligning with previous studies linking colony vigor to disease resistance. Hygienic behavior has emergeds as a critical factor in reducing the infected brood area and controlling the further spread of the disease in the colonies. The diverse management strategies adopted by beekeepers *viz*., the removal of infected colonies, queen replacement, comb sanitation, and application of Aayurvedic-–based medicinal treatments/–antibiotics in 50% artificial feed, positively influenced colony health by limiting disease spread and promoting recovery. These findings emphasize the necessity of integrated disease management suitable forto changing climatic conditions and colony health contexts in order to sustain healthy colonies and optimize honey production. This study fills a vital gap in region-specific epidemiological data and offers a foundation for informed interventions promoting sustainable apiculture in Kerala, enhancing both pollination services and the quality of organic honey quality.

Consent to participate
Not applicable

Consent to publish
Not applicable

Ethics approval
Not applicable. No human or animal subjects, materials, or data awere included~~involved~~ in this study.

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